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# Assessment and management of the Trochus Fishery at West Nggela, Solomon Islands: an interdisciplinary approach

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## Abstract

A proper understanding of the management status of small-scale subsistence and artisanal fisheries requires not only detailed sociocultural study, but comprehensive analysis of the state of the fished population(s), using rigorous stock assessment and other fisheries biology tools. In this article I describe several approaches taken to assess the artisanal trochus fishery at West Nggela. This includes stock density and other data, that demonstrate many reefs are overfished. I discuss the social and economic factors influencing the performance of the fishery. The importance of an understanding of property tenure is dealt with in some detail. An analysis of the various categories of fishers' ecological knowledge about trochus is also presented, and discussed with respect to the categories of biological and ecological information considered by most fisheries biologists as essential to the assessment and management of a fishery. © 1998 Elsevier Science Ltd. All rights reserved.

## 1. Introduction

At West Nggela, Solomon Islands (Fig. 1), the management of sedentary invertebrate fisheries is based on Customary Marine Tenure (CMT), common throughout coastal Melanesia [1–3]. Under this system, reefs and the stocks they support are owned by lineage-based groups, and primary rights (which include rights of exclusion) to resources are typically inherited under a variety of systems [4–9]. There is now a large body of literature on CMT and its significance in the management and conservation of marine resources [2, 9–14]. However, little detailed stock assessment work has been done to support the many claims about the

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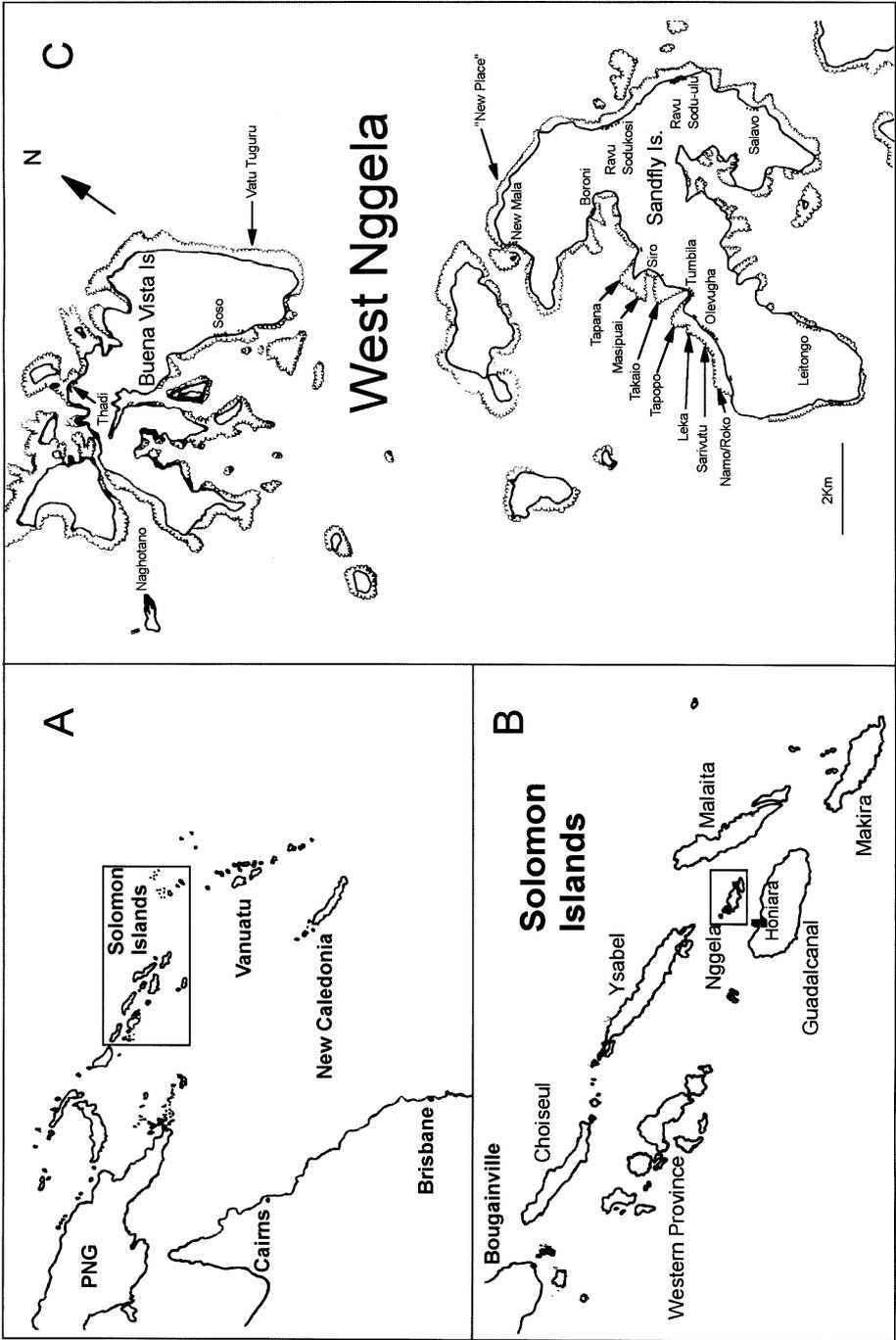


Fig. 1. Maps of (a) Australia and Melanesia, showing positions of Solomon Islands; (b) Solomon Islands, showing position of Nggela group (boxed); (c) West Nggela, showing locations of the various reefs surveyed for trochus.

potential role of CMT in modern fisheries management put forward in much of this literature.

CMT is clearly not the only factor that determines whether a fishery is managed effectively. Management decisions are influenced by economic pressures and constraints, which in turn are contingent on the price obtainable for the resource and the effort required to harvest and then market it. Management is also informed by fishers' knowledge of the biology, ecology and population dynamics of the target species. Such local knowledge may comprise several different categories of information, each of which might be relevant and useful to the management of the species [15, 16]. In this article I discuss the various categories of ecological knowledge about trochus (*Trochus niloticus*) possessed by Nggela fishers, and examine how this knowledge may be used in preventing overfishing of the stocks, and indeed in maximizing yields.

## 2. Trochus harvesting at West Nggela

Most land- and reef-owning groups at West Nggela apply a system of serial prohibitions to the trochus stocks on their reefs. These are often punctuated by harvests, which are typically annual but can be more frequent, and often occur toward the end of the calendar year. Prohibitions (*tambu*) are installed by the local Anglican priest, and take the form of a "conditional spell". (Nggela has a long history of missionization, and many aspects of the traditional culture appear to have been incorporated into Christianity.) There are two varieties of traditional or "custom" *tambu*, *sanda* and *pure*, though these are now rarely used, because most former practitioners have either died or have been forced by missionaries to abandon their practices. "Custom" *tambu* are believed to be less powerful than the more popular "Church" *tambu* installed by Anglican priests and brothers. Individual priests and brothers also have different reputations regarding the power of their *tambu*, and hence the fear and respect their *tambu* commands.

A *tambu* is almost always indicated by a stick erected on the reef, usually near the reef crest. Once the *tambu* is formally lifted, a representative of the ownership group usually conducts the trochus harvest, with some assistance from his or her family. Because most trochus habitat at Nggela is subtidal, harvesting is invariably done by breath-hold diving. A harvest usually takes three or more days of intensive diving, depending on stock density and reef size. When the representatives' harvest has been completed (presumably when catch-per-unit-effort declines below a threshold, which is likely to vary considerably among individuals), the reef is opened to fishing by the wider community. Re-installation of the *tambu* can either follow immediately, or be delayed by several months. No quota limits are set by the reef owners or community leaders. Harvested trochus are cooked, and the meat consumed locally. The shells are sold to buyers in Honiara, the national capital, and approximately 50 km by sea from West Nggela.

### 3. Approaches to assessment and management of the fishery: field methods

#### 3.1. *The study site*

Data used here were obtained during 15 months of fieldwork carried out between August 1994 and March 1996, on reefs and in communities at Sandfly (Mbokonim-beti) and Buena Vista islands, in West Nggela (Fig. 1).

#### 3.2. *Stock abundance and density*

Trochus stock assessments were attempted, using the Peterson mark-recapture technique [17], on 10 reefs in the Sandfly-Buena Vista area (Table 1). This method was trialled for trochus by Nash et al. [18] at Aitutaki, Cook Islands, and found to give greater precision than transect counts and the change-in-ratio method [17]. Trochus were marked with pencil on the nacre of the shell, just inside the aperture. (This was done so that the marks did not make the trochus more visible to divers.) These marks usually lasted about one month before they became overgrown and obscured by new nacre. The mark-recapture method was found to be particularly convenient at West Nggela, because the dates of most post-*tambu* harvests are planned with some certainty. Thus marking could be timed to precede harvests by two or three weeks. This was sufficient to give marked animals enough time to mix with the rest of the population, and brief enough to ensure that marks were not overgrown by new nacre. When the harvest was delayed to more than four weeks after marking, the animals were re-marked because of the increased risk of losing the first mark.

Up to four local divers, expert in diving for trochus, assisted in the collection and marking of trochus in each area to be harvested. The team attempted to mark 50–100 shells in the size range typically harvested ( $> 6$  cm). This number of marks ensured sufficient recaptures in the harvest to give a reasonably precise abundance estimate. The population density was presumed too low for the method to be useful if the team could find fewer than 30 animals after two days of diving. In such cases the exercise was abandoned. Marking ranged across as much as possible of the area demarcated for harvesting, to ensure that marked and unmarked individuals had the same chance of being captured in the harvest. After being marked (and measured), each trochus was usually returned to where it was found. After harvest by the reef owners, all harvested trochus were measured and inspected for marks. (Boiling of the shells and removal of the animal for domestic consumption had no effect on the mark.)

Densities of trochus were calculated using the area of trochus habitat at each site. Habitat areas were plotted on a digitizer from high-resolution black and white aerial photographs. Natural features marking ownership boundaries were easily distinguished on the photographs. Areas containing predominantly sand and seagrass were excluded from the measurements. Distances between two or more recognizable points on each reef were measured while in the field, using a handheld GPS receiver (Garmin 45) to calibrate the scale.

Although detailed data on habitat quality for trochus were obtained for only one reef (not presented here), all reefs surveyed were judged by the author and another

Table 1  
 Estimates of population sizes and densities of Trochus on ten reefs at West Nggela (numbers in parentheses are the 95% confidence limits. B = Binomial distribution, P = Poisson distribution)

Reef	Tambu length (months)	Harvest size > 8 cm/All	Abundance estimate (> 8 cm)	Abundance estimate (All)	Habitat area (Ha)	Density (> 8 cm/All) (Trochus/Ha)	Poaching?	Disputed?	Remote?
New Place	0		TFM	TFM	NA	NA	Yes	No	Yes
Takaio	8		TFM	TFM	NA	NA	Yes	Yes	No
Masipuai	9		TFM	TFM	NA	NA	Yes	Yes	No
Tapana	9		TFM	TFM	NA	NA	Maybe	No	No
Namo/Roko	9		TFM	TFM	NA	NA	Yes	No	Semi
Vatu Tuguru	9	15/52	ND	741 (278; 2214) P	18.74	ND/39.5	Maybe	No	Yes
Tapopo	11	91/160	261 (209; 313) B	ND	9.47	27.6/ND	No	No	No
Leka	11	46/88	87 (69; 104) B	175 (160; 190) B	6.42	13.5/32.3	No	No	No
Salavo	12	207/295	436 (303; 569) B	789 (487; 1254) P	10.26	42.5/76.9	No	No	No

Note: TFM = Too few marked; ND = No data; NA = Not applicable. "All" refers to fishable trochus only. Population estimates include all animals removed in the harvest and at any other time after marking.

experienced biologist to contain abundant habitat suitable for trochus. In addition, anecdotal evidence (and hoarded harvests in one case) indicated that all reefs, including those with very low densities, had proven capable of producing large harvests at some time in the past.

### 3.3. *Property tenure*

Details of the local property tenure system and boundaries on each reef were obtained by interviews and informal discussions in each village. Genealogies were constructed for several of the groups to facilitate an understanding of inheritance of primary rights over property. I discussed disputes over primary rights to properties with many fishers and reef owners, to clarify the implications for management of trochus and other reef resources. Problems with enforcement of *tambu* on disputed and remote reefs were also covered. I also attended two court hearings of property disputes. Subsequent discussions with leaders from each party, as well as with a judge from one of the hearings, helped elucidate issues relevant to reef resource management. A third case, of a low-level conflict between two related parties (by marriage, so they had different tribal affiliations) over a trochus harvest, is discussed here to illustrate apparently common mechanisms in dispute-related management problems.

### 3.4. *Economic priorities*

Fishers were routinely asked to identify their most important source of cash income for the current year. They were also asked to subjectively rank trochus harvests in terms of cash return per unit effort, compared to other cash-earning activities, such as fishing or gardening.

### 3.5. *Categories of ecological knowledge informing management decisions*

Initial interviews, with wide-ranging questions about the behavior and natural history of trochus, produced answers revealing a number of subject areas on which a large number of Nggela fishers were knowledgeable and generally in agreement. These categories of information were then explored in more detail in later interviews.

Detailed interviews were conducted on the following subjects:

- diel, lunar and seasonal patterns of trochus emergence;
- natural mortality, including loss of shells to boring polychaetes (“rotten tops”), predation by hermit crabs, and any other factors; and
- reasons for recent decreases in catches.

To validate information volunteered by fishers on lunar patterns of emergence in trochus, an experiment was carried out on a remote reef subject to little fishing pressure. The positions of approximately 8 wild trochus were marked with subtidal floats, and the location and behavior of each animal was recorded on 21 separate dives (8 during the day and 13 at night, between 18:50 [dusk] and 21:00) over a 5-week period that included two new moons and one full moon. The objective was to obtain a basic understanding of the timing of spawning, diurnal emergence and feeding

patterns, and the extent of movement over the reef. After observing the presence or absence of the marked trochus, about 45 min during each dive were spent searching for and marking the positions of new individuals.

The number of “rotten tops” was noted for all harvests inspected, and divers were asked to recall the number they had left on the reef during each harvest. The number of hermit crabs occupying trochus shells was noted for each marking dive, and fishers were asked the number of hermit crabs in trochus shells they encountered during their harvests.

## 4. Results and discussion

### 4.1. Stock assessment

Trochus abundance and density estimates from mark-recaptures are shown in Table 1. Another large reef, at Ravu Sodu'ulu, was calculated to support a density of between 90 and 135 shells ( $> 6$  cm)/ha, based on harvest size and assuming a similar exploitation rate (i.e. 1/3 to 1/2) as for other reefs [19]. The wide confidence limits obtained for Vatu Tuguru occur partly because recaptured animals from only one of two harvests were available for calculation of the estimate (see explanation in the “property tenure” section, below). Although this should not bias the estimate [17], precision is clearly reduced. The data in Table 1 show that reefs that supported harvestable quantities of trochus tend to be those that were undisputed and located in front of villages [19]. Reefs subject to an ongoing public dispute over primary rights are widely acknowledged to be overharvested. This is because it is regarded as pointless for either of the contending parties to attempt to exercise rights of exclusion, via a *tambu* over a disputed reef, if another group refused to respect those rights. Similarly, reefs at some distance from a village center are much more likely to be poached, although the level of poaching may vary depending on the vigilance of the primary rights owners.

With the possible exception of Ravu Sodu'ulu, the densities presented here are low compared with well-managed trochus fisheries elsewhere in the Pacific [18, 20]. Poaching is a widely acknowledged common problem on reefs out of sight of settlements, and where regular surveillance is therefore difficult or impossible. (This includes the reefs marked “remote” in Table 1.) Trochus are relatively easy to find, hide and sell (see “economic priorities” section below). Much of the poaching appears to be done by youths, most of whom are skilled divers with access to small dugout canoes and diving goggles. Few of them have alternative means of obtaining cash, and it seems that in the modern context they are less deterred by Church *tambu* than they once would have been by “Custom” *tambu*.

Fig. 2 shows the size-frequency distributions of the four trochus harvests for which abundance and density estimates were obtained. Despite the introduction in 1993 of minimum and maximum size limits of 8 and 12 cm, respectively, by

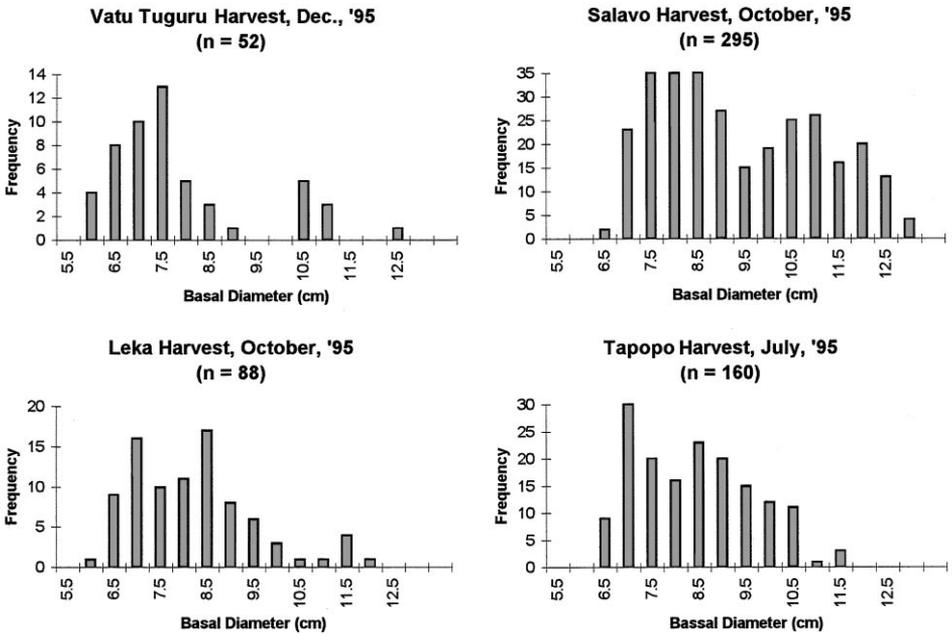


Fig. 2. Size frequencies of harvests made by reef owners for four of the reefs surveyed in the study.

Solomon Islands Fisheries Division, it is clear that smaller and larger animals are still being harvested at West Nggela. Villagers are always able to sell the entire harvest in Honiara.

The size-frequency distributions shown in Fig. 2 are all bimodal. The first mode, around 7–8 cm, reflects the annual pulse of heavy fishing that occurs at the end of a *tambu* period. Those trochus comprising the first mode in one harvest are probably just smaller than the smallest animals taken in the preceding harvest, assuming a growth rate within the range expected for Solomon Islands (which will produce an increment of approximately 2 cm for 6 cm-sized trochus in 7–12 months) [21, 22]. Growth rate slows dramatically in trochus larger than 7–8 cm, so that several year classes “bunch up” within a narrow size range, thereby producing the second mode. This bimodality is an indication of fairly heavy fishing pressure, as such a large component of the catch (i.e. the first mode) is comprised of animals that recruited subsequent to the previous harvest.

Additional evidence of high fishing pressure is that most reefs at West Nggela contained few or no trochus in the 12 cm or larger size range [19]. At Aitutaki, Nash et al. [18] described size-frequency distributions with a large proportion of shells in the range 12–14 cm for most sites. Similarly, McGowan [23] presented size-frequencies for North Palau and Jaluit that also contained a high proportion of shells larger than 12 cm, whereas harvests from South Palau and Truk, which he regarded as overharvested at the time, contained size-frequencies in a similar range to those at West Nggela.

## 5. Property tenure in West Nggela

### 5.1. *The system*

At Nggela primary rights to property, and tribal affiliation, are inherited matrilineally. Unilineal matrilineages are called *susu*. Under this system a man inherits and, with his siblings, is free to use primary rights over his mother's property. But his sisters' children will normally inherit these rights when he dies. Property may also be transferred in other ways, as described below.

There are seven named clans (*kema*; since the Nggela people translate this into English using "tribe", I use the term "tribe" here). Within each tribe are a number of named subclans (*vike*; locally translated as "subtribes"). Everyone was open about his/her tribal affiliation, but many people appeared reluctant to divulge their *vike*. Each *vike* also traditionally had a named "devil" (*keramo*), one or more sacred (and usually secret) shrines in the bush, an ancestral warrior or hero (*malagai*), and a chief (*vanagi*). Most of these details were usually kept secret and were sometimes produced as "trump cards" to substantiate claims during property disputes.

The marriage system is predominantly endogamous; marriage of second cousins is preferred and quite common. Virilocal residence (women go to live in their husband's village) predominates, but exceptions are common, and usually occur where the bride's family has a large amount of land. A substantial bride price is typical, but cases where no payment was made are not uncommon. The dominant pattern of virilocal residence means that land-owning corporations centered on the *susu* rarely remain together. The result is that primary rights to land are commonly transferred to resident non-members of the *susu* through a customary property acquisition mechanism, known as *huihui*. A significant number of people use rights to land and reef which they do not own; here these are referred to as secondary or usufructory rights. Sons routinely exercise primary rights over their fathers' property as long as the father is alive. This is frequent with trochus *tambu* and harvests.

The *huihui* is commonly used among close relatives. For example, it is widely used to obtain exclusive rights over land jointly inherited (i.e. buy out siblings) or owned by one's father. It is less commonly used to acquire land from non-relatives. Prior to about 1950, the paramount chief of the area was almost always involved in such transactions, giving final permission for the transaction, and acting as a kind of broker. Subsequently, the paramount chief's role became much reduced. In a typical *huihui*, the price of the land being acquired is usually paid in baskets of food, pigs and a small amount of money (but much less than the freehold value of the land were it sold to an outsider). Where a number of people contribute to the total price, each contribution entitles the contributor to a share of the primary rights over the property, with the largest share going to the person who makes the largest contribution. Witnesses are summoned, and these must include chiefs and "big men" (*mane sule*) from each party, as well as the paramount chief of the area. The case of Vatu Tuguru reef, described below, and others not described here, indicates that problems arise when a *huihui* took place several generations ago and where none of the witnesses remain alive to attest to the details of the transaction.

Primary rights acquired through *huihui* are heritable matrilineally. But if a matriline (*susu*) has no female heirs, then primary rights are officially supposed to revert to the tribe from which they were purchased. However, in the one such case during the period of fieldwork, an arrangement was made with the remaining resident male heir (of the matriline lacking female heirs) that included undertakings by that resident to refrain from using any rights of exclusion over such valuable resources as trochus, and to seek permission from the original owners before going ahead with any development on the property.

Within any descent corporation political power and authority over the exercising of primary rights appears to be most commonly in the hands of the senior males, which Keesing termed “Board of Directors” [4]. During court cases men usually speak and make decisions “on behalf of” wives, sisters and mothers. They also control allocation of rights to declare *tambu* and harvest trochus within the corporation. In some cases, although not all, husbands also exercise rights of exclusion over their wives’ land/reef, even though they might belong to a different tribe.

## 6. Case studies

The following two case studies of low-level conflict over rights to properties are included to illustrate the mechanisms that have led to a breakdown in management of the trochus fishery on certain reefs at West Nggela.

### 6.1. *Vatu Tuguru*

A *tambu* was imposed on Vatu Tuguru reef in March 1995 by a resident of Boroni Village, on Sandfly Is. In November 1995 I conducted a marking dive at Vatu Tuguru with this man’s son, who was planning to harvest the trochus in mid-December. When I returned with him and a team of divers in mid-December, it was immediately apparent that the reef had already been harvested. It was suggested (and I believed) that it had been poached. Two months later I received the message that the husband and son-in-law of a woman on Buena Vista, who claimed primary rights over Vatu Tuguru, had harvested trochus a week before we arrived. (The woman had apparently also kept a written list of all the numbers on the marked trochus in that harvest.)

Subsequent investigation of the genealogies of both parties showed that each party’s claim to ownership depends entirely on the interpretation of the details of a *huihui* in which Vatu Tuguru was acquired from a third tribe (Fig. 3). Interestingly, no formal dispute had arisen between these two groups, and it is most likely that this is because there is relatively little at stake besides trochus (see “economic priorities” below). Also, the reef is quite remote from the residences of both groups, which further decreases the ratio of return to effort in harvesting the resource.

### 6.2. “New Place”

A senior male resident of Boroni officially controls the trochus resource at “New Place” (Fig. 1). However, his sister’s son, who lives at Ravu Sodikosi, routinely

## History of Vatu Tuguru Acquisition

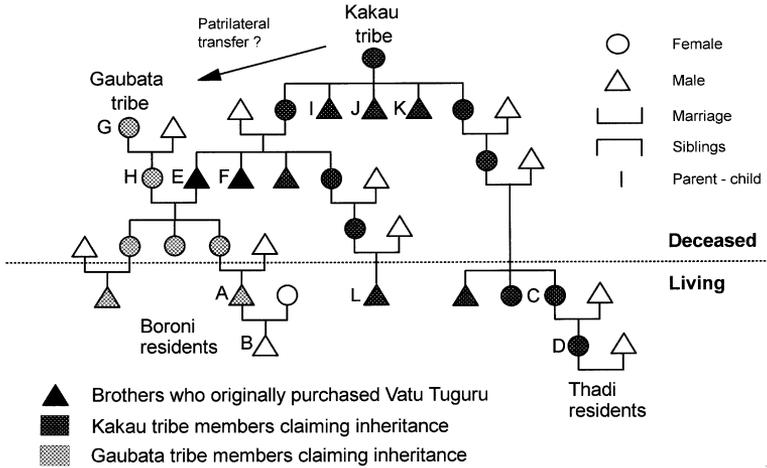


Fig. 3. Genealogies of the two parties that harvested trochus at Vatu Tuguru contemporaneously in 1995. The *tambu* in March 1995 was made by A, with no apparent protest from C and D. However, the husbands of C and D harvested trochus at Vatu Tuguru about one week before B did, on behalf of his father. A claimed primary rights to Vatu Tuguru through G and H, who he alleges contributed to the purchase price levied by E and F, the brothers who initiated the *huihui* to acquire Vatu Tuguru from another group. The brother of C, however, claimed that G and H had no part in the purchase, and instead, that E and F were assisted by I, J and K, whose sisters' children therefore inherited primary rights as a consequence. It is quite possible that A's claim may be valid for a different reason, if for example E acquired his wife cheaply, or for free, and her family demanded a share of Vatu Tuguru in lieu of the bride price ("patrilateral transfer"). These details may then have been forgotten over the years, but the fact of matrilineally heritable rights over the property was remembered [24]. L also technically had a claim over Vatu Tuguru but lived at East Nggela and was unlikely to exercise his right.

harvests it. But this son has never bothered to place a *tambu* on that reef, and has been regularly harvesting trochus there for a few years. He explained that there is no point in placing a *tambu* there because the Malaitan settlers at "New Mala" poached there regularly, and would never respect a *tambu*. So he fished it down in competition with the poachers. ("New Place" had a very low density of trochus, and is treated here as overfished.) But the story may be more complicated, given that a trochus *tambu* requires no particular effort to install, and that the Boroni resident had placed a *tambu* on it only a few years previously, which resulted in a large harvest.

Further insights can be gained by considering the details of the *huihui* through which the property was acquired. The Boroni resident, who controls the property, acquired it together with his sister. The sister contributed a relatively small share of the total price, but enough to give her son primary rights. It is highly likely that the son would not declare a *tambu* there out of deference to his uncle, who is the "boss" of

this particular corporate group. At the time of fieldwork both the uncle and his Boroni-resident sons were all too busy with other enterprises to be concerned with installing a trochus *tambu* at “New Place”.

## 7. Economic priorities

Sixty-three people (4 women and 59 men) from West Nggela were asked to name their most important source of cash income for 1995. The results are summarized in Table 2. Most were engaged in more than one of the listed activities, and often as part of a group.

Of all these activities, diving for trochus is unanimously regarded as having the highest cash return per unit effort, even though the total return per individual over the course of a year may be less than for other, regular, but more effort-intensive activities, such as artisanal fishing or marketing garden produce. Unlike fresh fish and other primary products, trochus shell needs no processing (apart from removing the meat, which is really a subsistence bonus), can be stored indefinitely at no cost, sold quickly and in any quantity, and is relatively easy and cheap to transport. For most of 1994 and 1995, villagers were receiving an approximate equivalent in local currency of USD 3.5–4.35/kg for whole trochus shell delivered to Honiara. Most villagers in Nggela regard trochus as “pure cash just sitting on the reef”. Of the 55 men who listed something other than trochus as their major cash-earner, 32 derived some income from trochus during 1995. Trochus is the most important non-fish resource in terms of export earnings in Solomon Islands [25]. Although the money derived from sales of trochus can be and often is used for individual purposes, proceeds from harvests following a *tambu* are commonly earmarked for family or communal purposes, such as cementing a grave, paying school fees or maintaining a clinic or church.

Table 2  
Primary sources of cash income for a sample of villagers at West Nggela 1995

Source of income (and market)	No. of people
Artisanal fin-fishery (Honiara)	19
Remittances/employment	12
Aquarium fish (exported via Honiara)	11
Garden produce, including betelnut	6
Trochus (exported via Honiara)	4
Bêche-de-mer (exported via Honiara)	4
Lime (Honiara) <sup>a</sup>	3
Wildlife (exported via Honiara)	2
Other	2

<sup>a</sup>Lime is sold for consumption with betelnut, and is made mainly from coral (mostly *Acropora* spp.).

## 8. Categories of ecological knowledge informing management decisions

### 8.1. Local knowledge about trochus at Nggela

The following items of local knowledge relevant to trochus were widely agreed on by West Nggela fishers:

- Trochus are easiest to find two or three days after full moon. This period is known as “*dantega*”, a compound of “*dani*” (day) and “*tega*” (to perch). It refers to a moon that is “perched” just above the horizon at daybreak at this time of the month;
- If reefs are closed to fishing for longer than a year, too many trochus are lost to shell borers (“rotten top”; *mboro vuvuha*) and hermit crabs (*komba*) (occupation of shells by hermits results in degradation of the shell, rendering it unsalable if the hermit has been resident for more than a few weeks);
- Cyclone Ida, in 1972, was the main reason trochus are relatively scarce at Nggela today;
- A greater abundance of juvenile trochus can be found on the rubble zone (inshore of the reef crest) than on the reef crest and outer platform; and
- Trochus abound on the deeper slopes of the reef (where the reef slopes away gradually, as on the North side of Sandfly and Buena Vista Islands), beyond the reach of breath-holding divers, and migrate upward to replace those removed by diving on the shallower part of the reef crest.

### 8.2. Investigations of local knowledge

The investigation of trochus behavior, described above, supports the Nggela fishers’ assertion that trochus are easier to find around *dantega*. The number of new trochus (i.e., those discovered subsequent to the individuals marked at the beginning of the trial) found during the *dantega* period (6, or 1.2 per dive) was considerably higher than the number discovered before (3, or 0.37 per dive, excluding the first dive) and after this period (0). One trochus was observed exhibiting spawning behavior on the night following the full moon. It is possible that a proportion of the trochus population, that normally resides deep in crevices and holes in the reef (out of sight and reach of fishers), may migrate to the top of the reef to spawn around full moon, and then remain close to the top of the reef for a day or two after spawning. Further work is needed to elucidate both this and a great many other aspects of the reproductive behavior and ecology of trochus [21, 26].

Borer damage was very rare, with only one trochus affected from all the harvests examined during the study. This was at Salavo, where a relatively larger proportion of the harvest exceeded 12 cm than at other sites (Fig. 2). Trochus smaller than 12 cm are rarely damaged by borers [21]. Of 11 divers interviewed, 10 reported seeing no borer damage during their harvests. However, it appears that a proportion of trochus is taken over by hermit crabs (Table 3). Given that hermit crabs select a wide range of shell sizes, it is difficult to know whether a reduction in fishing pressure, through longer prohibitions, would affect the proportion of the population lost to hermit crabs. It is also difficult to know what proportion of trochus have been killed by the

Table 3  
Number of hermit crabs occupying trochus shells found during marking dives in 1995

Reef	Day/Night	Hermits	Trochus
Tapopo	Night	11	46
Leka	Night	2	30
Leka	Day	1	81
Salavo	Day	1	55
Vatu Tuguru	Day	4	83

hermit crab and what proportion are secondarily occupied after death from other causes.

Abundant anecdotal evidence from older fishers indicates that trochus harvests prior to Cyclone Ida (1972) were considerably larger than those at the time of fieldwork, in some cases by at least an order of magnitude. If trochus abundances did drop significantly following the cyclone, it seems reasonable to assume that this resulted mainly from the massive habitat destruction caused by the cyclone. Given that trochus grow to legal size (8 cm maximum basal shell diameter) in three years, and the plate coral (*Acropora hyacinthus*) grows at up to 10 cm yr<sup>-1</sup> [27], there should have been ample scope for substantial recovery of both trochus populations and suitable shelter for trochus in the ensuing 23 years, assuming no other factor, such as high fishing mortality, was acting to keep populations depressed. These facts, and the evidence presented here of constant and heavy fishing pressure on trochus at Nggela, makes it doubtful that Cyclone Ida is the sole reason for recent low harvest sizes.

A great deal of research has demonstrated that juvenile trochus are more abundant (or at least are easier to find) on the rubble areas of reef flats than on the outer platform and reef crest [21, 28, 29].

Most trochus reside shallower than 8 m, which puts them well within reach of most breath-holding divers. Although trochus have been reported from as deep as 13 m, they are not common at such depths [23].

### 8.3. *The categories of biological information important for management*

Whether or not particular items of local ecological knowledge are judged by professional biologists to be true, partly true, untrue, or an unresolved mystery, the issue of exactly how useful this information is to the management of a population being fished has received relatively little detailed analysis in the literature. Much of local knowledge possessed by subsistence, artisanal and commercial fishers is focused on how to locate individuals of a target species in space and time, and, once located, how to capture them [16, 30]. This sometimes includes impressive, if not encyclopedic, knowledge about behaviors including migratory and aggregative behaviors, as well as other miscellaneous details pertaining to the intra- and inter-specific ecology of the quarry [15, 16, 26, 31, 32]. Fishers are also usually acutely aware of such physical

phenomena as temperature, rain, winds, currents, tides, and moon phases, that impinge on the behavior, biology and ecology of their targets.

However, these categories of knowledge do not necessarily include information essential to the assessment of stock abundance and regulation of effort to prevent overfishing (but see the works of Johannes [15, 16, 31] for some exceptions, most notably with respect to grouper spawning aggregations). In fact, in some Pacific countries, like Solomon Islands, it is highly likely that such knowledge was never needed in the past, since human populations were never large enough to seriously reduce the densities of the fish and other marine fauna used for subsistence. But the advent of export economies and exploding human populations has changed that, and many marine species are now in urgent need of careful management [25].

The types of information required for efficient management of tropical marine fisheries, such as trochus, include the following:

- life-span and natural mortality rate;
- reproductive biology, age/size at maturity, and potential fecundity;
- growth rate;
- sex ratios and fertilization ecology;
- dispersal range and settlement ecology of larvae;
- habitat (including food) requirements, for both juveniles and adults; and
- other life history features, including migrations, aggregations and habitat change.

In a broad sense the first three categories can be considered together. Short-lived species (which therefore have a high rate of natural mortality), fast-growing and highly fecund animals, such as Skipjack tuna [33] and many baitfish species [34, 35], can sustain very high levels of fishing mortality, and support high-yielding and relatively stable fisheries in the contemporary Solomon Islands. In contrast, long-lived, slower-growing species, such as groupers (*Epinephelus* spp. and *Plectropomus* spp.) and deep-water snapper (*Etelis* spp. and *Pristipomoides* spp.), can be overfished very rapidly [36].

Both male and female trochus become sexually mature at around 5.5–7 cm basal diameter [21]. Knowledge of this is important for the following reason. If the size at which trochus become fishable is smaller than, or equal to, the size at which they become sexually mature, then heavy fishing pressure will remove a large proportion of the reproductive population, possibly resulting in recruitment failure and stock collapse. Accurate data on size at maturity, as well as relative fecundity at various sizes, can be factored into egg-per-recruit (EPR) models, that allow the calculation of the potential reproductive output of a cohort of trochus throughout its lifespan under different levels of fishing pressure. Minimum size limits can also be factored into EPR models as well as yield-per-recruit (YPR) models, to determine the combination of minimum size limit and fishing mortality that will optimize yield while ensuring that sufficient reproduction occurs to prevent recruitment failure. EPR and YPR analyses of trochus populations at West Nggela [22] have shown that enforcement of the official minimum size limit of 8 cm (remembering that trochus were being fished down to around 6 cm at the time of fieldwork) would result in substantial increases in both yield and egg-production. Over time that would reverse the present situation of recruitment overfishing on many of the local reefs. In fact, an increase in minimum size

limit was long ago advocated for the Nggela trochus fishery [37] and is now widely employed throughout the Pacific [21].

That trochus have separate sexes and are broadcast spawners (females usually releasing eggs in response to the presence of sperm in the water [38]), means that when stock densities decline below a certain threshold, the increasing average distance between spawning individuals, and consequent dilution of gametes, results in a decrease in fertilization success. Thus the remaining reproductive potential of the population is essentially wasted, and few or no larvae are produced as a result. This is known as the Allee effect [39] and could be either prevented or ameliorated by the creation of multiple, small reserves, on a scale smaller than the average dispersal range (about 10 km for most trochus larvae, which remain planktonic for about three days [21]) [40, 41]. Reefs downstream (“sink” reefs) of others are likely to receive larvae from the latter (“source” reefs), and so may be capable of sustaining much higher levels of fishing pressure. A good knowledge of local currents is therefore important in considering the best places to locate reserves. This is exactly one of the areas of cooperation between some village resource managers in Vanuatu and the Vanuatu Fisheries Division; villagers are using their local knowledge of currents to assist the Fisheries Division in establishing reserves that will act as sources of larvae for neighboring depleted reefs [42].

Juvenile trochus appear to be most abundant on rubble areas of outer reef flats (as shown above), and there is some evidence that reefs lacking large areas of rubble may have lower juvenile survival and therefore reduced rates of recruitment to the adult population [21, 28, 29]. Such reefs can, however, still support dense populations of trochus, and it is clear that much remains to be examined about the behavior and ecology of juvenile trochus.

Although some of the above categories of information are known to subsistence and artisanal fishers, many are not. It would appear that considerable improvements in the management of resources could be achieved through a concerted collaborative effort between custodians of local knowledge and fisheries biologists. But collaboration is clearly not a simple matter [43], particularly given the vastly different contexts in which local ecological knowledge and fisheries biology are respectively situated. While the latter is typically a highly abstracted and explicit form of information, local knowledge is most often part of a “system of knowing” that is fluid, context-sensitive, task-oriented and predominantly implicit [42]. The challenge for fisheries biologists is to convey their information in a practical and demonstrably useful way, so that it will be embraced by rural fishers and combined synergistically with local knowledge to improve fishers’ own management strategies.

## **9. Conclusions**

The customary marine tenure system has been shown, both here and in the work of others, to be an important element in the management of marine resources. However, CMT is not by itself a guarantee of good management [45]. The poor performance of the trochus fishery on many of the reefs at West Nggela and elsewhere in Solomon

Islands [20] is adequate testament to this. The advent of a strong financial incentive (i.e., high return relative to effort) has led to high levels of fishing pressure on particular stocks that would not have occurred in a purely subsistence economy.

Despite the existence of local knowledge about trochus, the categories of information needed to underpin a sound management strategy are mostly lacking at West Nggela. Of particular concern is the apparent lack of knowledge about the planktonic dispersive larval phase of many reef fauna, including trochus, and the implications this has for recruitment failure when adult stock densities are very low over a wide area. This gap in knowledge has clearly contributed to poor management practices. Consequently, some collaboration or consultation with adequately trained fisheries extension staff would clearly benefit the custodians of high value marine resources, such as trochus, in this context.

A concerted effort must be made to present any new information in a similar cognitive framework to existing local knowledge, so that it can be readily identified with and incorporated into the local knowledge base, and so be of some practical value. The synergistic combination of the specialized expertise of both fishery biologists and rural fishers can hardly fail to bring about significant improvements to community-based management strategies. It is also clearly important for any outside expert working in Melanesia to understand the complexities of the local property tenure system, some of which are considerably more complex than that described here, and to appreciate the economic pressures on and priorities of local people.

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