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## Reef colonization and socioeconomic impacts from trochus translocations to Samoa

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## 2 Executive summary

### Background

Trochus (*Rochia nilotica*) has long been collected for the export of its shell, which has a high quality mother-of-pearl nacre, used for manufacturing buttons and handicrafts (Gillett and Tauati, 2018). The species is also consumed in some Pacific Islands. For more than 80 years, the species has been introduced or translocated to islands in the Pacific and is known to have negligible, or limited, ecological impacts (Bell et al. 2005). Trochus did not naturally occur in Samoa and it was introduced on both Upolu and Savai'i in 2003–2006 by the Ministry of Agriculture and Fisheries Samoa (MAF), through funding from ACIAR Project FIS/2001/085, to diversify seafood and income sources for local communities (Tiitii and Aiafi, 2016). Yet, that project could not show success of the introductions because colonisation of the snails on other reefs in Samoa was not yet apparent. However, several years after the introduction, MAF reported finding large numbers of trochus being sold around the islands, and trochus quickly became a popular seafood (Tiitii and Aiafi, 2016). From 2010, sales of trochus in local markets and roadside stalls soared, and MAF reported finding them on reefs on Upolu.

The Samoan trochus fishery seemed successful, yet the lack of knowledge on the extent to which wild populations have established, and the socioeconomic impacts, remained uncertain. In addition, the full economic value of the trochus in Samoa was largely underutilised, because fishers were not using the shells and were only benefiting from the flesh of the snails. Furthermore, because information about the fishery was incomplete, MAF did not allow trochus exports due to concerns that export sales would spur overfishing of the developing fishery.

The aims of this project were to assess the extent of establishment of trochus on Samoan reefs, to understand the factors that affect the trochus captures by fishers, to assess the socioeconomic impacts of the trochus fishery, to build capacity in value-adding of trochus shells in Samoa and to reveal the potential for exporting trochus sustainably.

### Methodology

The project team completed underwater visual censuses at 14 sites around Upolu and 14 sites around Savai'i. Trochus were counted and measured on transects along with native reef gastropods. An Honours student studied the habitat relationships of trochus.

Socioeconomic surveys of trochus fishers using questionnaire interviews were conducted in 34 villages. The surveys had a gender and livelihoods focus and collected data on catches, fishing modes, effort, consumption, perceptions about stocks, sale and trade of trochus in Samoa. We also examined the carbon footprint of the fishery and fishers' views on potential management regulations. We used sophisticated mixed-effects models to analyse gendered and geographic disparities in fishing responses while accounting for other variables to distinguish fishers.

Four one-week capacity-building workshops were held to train people from neighbouring villages in skills to make trochus shell jewellery and to polish trochus shells. Equipment from Australia was set up and left in Samoa for future training and use by artisans.



## Results

Our underwater surveys showed that **there are abundant exploitable trochus stocks in Samoa**. Although trochus population at some sites seem to still be developing, at a few sites we found some very high densities ( $>500$  ind  $\text{ha}^{-1}$ ). The large spatial variation implies that **benefits of future translocations will be variable across villages in a fishery**.

A majority of fishers consumed part of their catch and shared harvests within communities using informal distribution networks. Trochus was the second-most harvested resource (after fish). The fishery was largely **gender equitable**—fishing efficiency, catch diversity, fishing income and perspectives about stocks were similar between men and women fishers. However, trochus tended to be more important in the catches of fisherwomen. These findings urge for an **equal representation of women in the decision making** in small-scale fisheries; e.g., in consultation meetings and industry bodies.

The fishery has an extremely modest carbon footprint (20 tonnes  $\text{CO}_2$  annually). **The fishery nurtured positive wellbeing outcomes that were inclusive among age groups and genders**. New income from the fishery was most often spent on food, church tithing and school fees. Extrapolations of annual incomes across the fishery revealed a **rapid return on investment from the earlier ACIAR project** to introduce trochus.

Data indicate that **around 7 million trochus were harvested in Samoa in 2018**. Sales of trochus meat generated income to at least 1000 Samoan village fishers nationally of around AU\$800,000 annually. Approximately 260 tonnes of legal-sized trochus shell (90–120 mm diameter) were harvested that year, which could serve in exports to increase the value of the fishery.

We trained 42 village-based artisans in the four one-week workshops. They made necklaces, key chains and ear rings from trochus shells. Many of them were interested to take on handicraft making as an alternative livelihood activity. MAF has set up one station at the village of Asau (Savai'i island) and will set up machines at two other stations so artisans can access them to make handicrafts from trochus shells.

The project will publish four peer-reviewed journal articles, and has published a media article (SPC Fisheries Newsletter), a Policy Brief and numerous social media articles.

## Conclusions

The fishery is truly an inspiring success story of rural development through Australia's foreign aid program. The introduction of trochus has provided a significant alternative livelihood and source of food for over 1000 fishers, in an era when seafood supply in the Pacific is under threat. The fishery is gender equitable, with women and men catching similar amount of trochus per day, similar income for their catch, and reporting similar satisfaction and perceptions about the fishery. The majority of fishers believed that trochus numbers are increasing on reefs in Samoa.

The Samoan trochus fishery management needs to be implemented. The regulations include a 'slot' size limit of 90–120 mm shell diameter, collection during daytime only, the potential to set seasonal fishery closures, and export licences (if exports are allowed). The potential value of shell exports from Samoa is estimated at \$1.3 million Tala, which could almost double the present income of fishers.

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### 3 Background

Trochus is a large ‘topshell’ marine snail, economically important in the Asia-Pacific region because of its thick shell and pearly nacre. Trochus is valued locally for its flesh, and its shell can be polished and sold locally or exported for button manufacturing. Trochus fisheries are important in numerous Pacific Island countries including Cook Islands, Federated States of Micronesia, Marshall Islands, Papua New Guinea, Solomon Islands and Vanuatu, and in southeast Asian countries including Indonesia, Philippines, Vietnam and Thailand.

Trochus did not originally occur in Samoa. The geographic distribution of trochus was originally restricted to the western-central Pacific, and many countries did not have the species on their reefs (Nash 1993). The reason for this was that trochus has a particularly short phase as dispersive planktonic larvae, lasting only 3–7 days. This reduces the ability for trochus to naturally disperse to new places beyond their distribution. As a form of “assisted migration”, trochus have been translocated to new localities across the Pacific since the 1930s (Gillett 1993). In all of the many occasions, there have been few, if any, deleterious ecological impacts of trochus introductions, either to corals or to native competitor marine snails (Bell et al. 2005). In fact, trochus is a prey to numerous reef carnivores and it is known in aquaculture to serve as a grazer to regulate overgrowth of algae, which could be viewed as beneficial in times like the present when reefs have lost coral cover and have had increased cover of turfing algae.

In 2003, the Samoan Ministry of Agriculture and Fisheries, through the support of ACIAR project (FIS/2001/085), translocated trochus broodstock and initiated a mariculture program in Samoa to produce hatchery-reared juveniles to nucleus sites on the two main islands in Samoa. The aim was for the animals to breed naturally so the offspring would colonise other reefs in Samoa. The intention was that the broodstock would spawn naturally on the stocked reefs, and the lecithotrophic<sup>1</sup> larvae would disperse in currents to nearby reefs where they would settle and create new (F<sub>1</sub>) populations. However, the project was unable to show that any new populations were created, although the timeframe was probably too short to evaluate ecological success.

The broodstock eventually bred successfully on the Samoan reefs and some years later, trochus started appearing in the local marketplace and annual harvests quickly increased in subsequent years. A 2010 study of sites on north-eastern Upolu Island by the Ministry of Agriculture and Fisheries (MAF) showed that trochus populations have been created at numerous reefs sites, and significant quantities are now sold in town markets and roadside stalls (Satoa and Sapatu 2010). More recent surveys of the north coast of Upolu in 2014 confirmed that trochus populations were established on many reef sites, that animals with large shells (>90 mm) can be found, and that significant quantities of trochus meat were being sold locally with an estimated annual value of AU\$20,000-25,000 (Tiitii and Aiafi 2016). However, the extent to which wild populations have been built, and the socioeconomic impacts, are yet unclear, since that study only covered a small part of the Samoan coastline and did not examine sales comprehensively. In addition, fishers are currently benefiting almost solely from sale of the flesh and not profiting much from value-adding that could be done to the shells. MAF has not yet allowed exports of trochus, in

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<sup>1</sup> lecithotrophic: meaning feeding on yolk energy stores from the egg and not feeding on any plankton

part because information about the fishery is incomplete, so the full economic value of the animal is largely underutilised.

Village fishers in Samoa are one of the most disadvantaged socioeconomic groups in the Pacific Islands, and there are promising opportunities to help improve their livelihoods and wellbeing. With a population of 186,000 (2011), Samoa faces significant challenges to provide income opportunities for its people, especially in rural villages. GDP per capita is \$2,700 p.a., and is ranked by the Human Development Index (0.688) in the lower half of countries worldwide. This contrasts starkly with Australia's GDP per capita of \$52,347 for the same period.

Current government strategy in Samoa<sup>2</sup> holds that *“human resource development and capacity building is a pre-requisite to achieving national and sectoral goals”*. This project's training workshops aimed to build capacity in rural communities by creating value out of trochus shells and contributing to sales in the tourism industry. The workshops on value-adding of trochus shells aligns with one of MAF's four key strategies, to promote *“a sustained increase in production, productivity, product quality, value adding and marketing of agriculture and fisheries products”*<sup>3</sup>.

Samoa's export capacity has had *“a downward trend over the past 10 years”* and export diversification is a *“key component”* of Samoa's policy reforms<sup>3</sup>. Our objective to appraise the potential exports of trochus out of Samoa aimed to inform export diversification and contribute to reversing the downturn in national export trade.

The principal activity of this project was to evaluate the ecological and socioeconomic impacts of ACIAR's trochus translocations. This will allow a better understanding about where trochus populations have been established, where they are being collected by village fishers, and its value to their livelihoods. The shell is the main economic interest in other trochus fisheries, but it is not exported from Samoa because the stock size is unknown and MAF is concerned that exports would spur rapid overfishing. Therefore, the study also aimed to identify and facilitate opportunities for value-adding of the shell locally for sale as ornaments and jewellery.

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<sup>2</sup> *Strategy for the Development of Samoa 2012-2016*. Ministry of Finance, Apia, Samoa.

<sup>3</sup> *Agriculture Sector Plan 2016 – 2020*. Ministry of Agriculture and Fisheries, Apia, Samoa.

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## 4 Objectives

The overall aims of this project were to evaluate the ecological and socioeconomic impacts of ACIAR's trochus translocations and to provide support through capacity building program for value-adding of the shell locally for sale as ornaments and jewellery.

The following researchable **questions** were addressed in the project:

1. How far have trochus populations spread in Samoa and how dense are populations?
2. What new insights for marine fisheries enhancement in other regions can be deduced from the trochus translocation to Samoa?
3. What economic benefit can be made from capacity-building in shell and jewellery making?
4. What are the socioeconomic impacts of the translocation of trochus to Samoa?
5. What are the differing roles of, and expected benefits to, men and women at various stages along the trochus value chain?
6. What is the economic potential for exporting trochus sustainably from Samoa and what administrative framework needs to be developed to realise that potential?

The specific **objectives** were to:

- 1) To build capacity in value-adding of trochus in Samoa.
- 2) To assess population densities of trochus in Samoa
- 3) Determine the socioeconomic impacts of trochus in Samoa
- 4) Appraise the economic potential for exporting trochus sustainably from Samoa and propose administrative frameworks

The achievement of these aims delivered instant impact on Samoan villages and provided proof of significant socioeconomic outcomes for fishers.

## 5 Methodology

The methods applied to accomplish every objective closely followed those planned in the Project Document (with few exceptions). This is a credit to the thorough project approval procedure within ACIAR and the commitment by the entire project team to plan and implement the activities following the approved project.

### ***Objective 1: To build capacity in value-adding of trochus in Samoa.***

The methods used for this objective are the same as those proposed in the Project Document, which included: 1) Contract a consultant jewellery maker and host workshops in villages; 2) Collect information on where shells are sold, the demand for shell ornaments, and market prices and 3) Purchase and provide shell grinders and jewellery making tools at two fishery stations on both Upolu and Savai'i.

We prepared and gave printed colourful manuals on the steps needed for polishing trochus shells and making trochus jewellery. MAF was provided with the master copy of the manual so that other copies could be made and given to other artisans in future.

### ***Objective 2: To assess population densities of trochus in Samoa***

The methods used for this objective are the same as those proposed in the Project Document, which included: 1) Use replicate belt transects on reef crests at 15 outer reef sites dispersed around both main islands, 2) take averages of densities from replicate transects for each reef site, and 3) allocate the found trochus into size classes and prepare graphs of size-frequency distributions for each reef site.

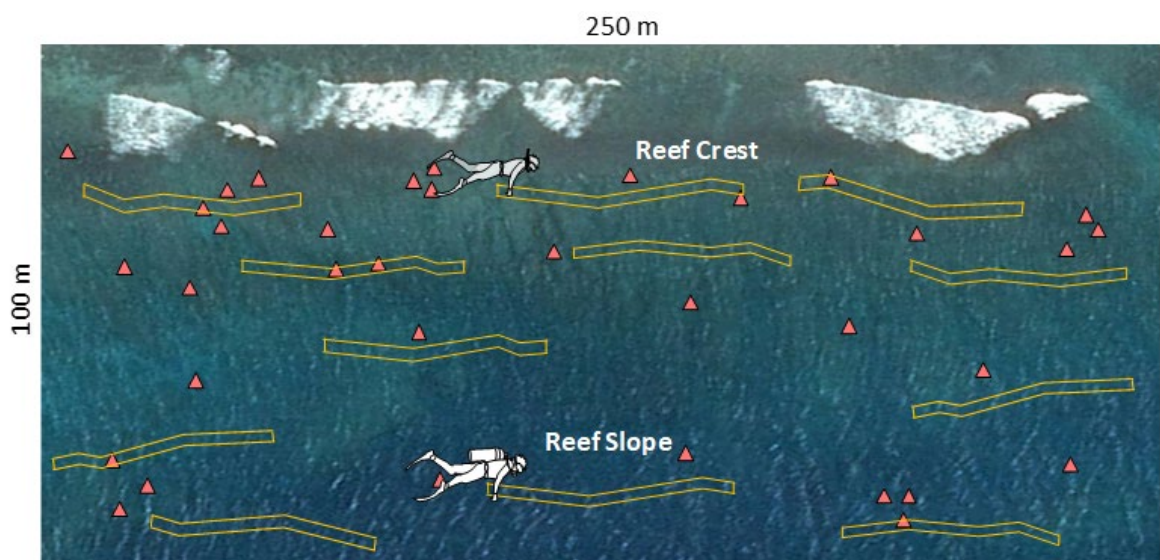


Figure 1. A schematic diagram of one of the reef sites with 12 belt transects (2 m x 50 m) laid on reef front habitats (reef crest and front slope). In this depiction, the site is 2.5 hectares in area. Transects were laid, with a measuring tape or measured rope, without looking for trochus, so that they represented random areas on the reef. Shallow transects were surveyed on snorkel, while deeper transects were surveyed on scuba. Only trochus found within the 2-m wide belt transect were enumerated and measured.

Sites were selected around the two main islands to give a broad geographic representation of the underwater surveys. The 28 sites (14 around Upolu, 14 around



Savai'i) were chosen on the basis of access and suitability of habitats, and the specific sites were chosen while on the boat. A total of 322 transects were surveyed at the sites (Fig. 2). This was **one of the largest assessments of trochus ever documented** in a single country. A couple days were taken to train MAF fishery officers in the methods prior to the surveys.

During the underwater population surveys, the graduate student, Kate Seinor, conducted a study to determine which habitat features were most associated with abundant populations of trochus, and to collect data to examine whether the abundances of trochus affected the abundances of native gastropod species (Fig. 3). She used a modern statistical tool, called gradient-boosted regression tree analysis, to assess the correlation between habitat variables and trochus populations. She also used multivariate analyses in PRIMER software and linear regression to look at whether trochus share the same niche as the endemic gastropods and whether their abundances were correlated.



Figure 2. Top left: Searching for trochus along a transect line. We searched under ledges and overhangs and within holes and crevices for trochus and other native grazing gastropods along the transects. Top right: a trochus being measured underwater. The maximum basal shell width was measured, as this is the standard measurement for the species. Lower left: the Samoan fishery officers on the survey team, with trochus that we collected. The large trochus that we found on transects were collected so that we had at least 100 shells for each workshop. Lower right: an adult trochus under a ledge under the transect tape.



Figure 3. Left: the project leader and the graduate (Honours) research student on the survey boat, geared up for underwater surveys. Right: the research student, Kate Seinor, measuring reef surface complexity along a transect. The suite of biophysical variables that she measured were used to relate with trochus abundance and average shell size, and to define the habitat niche occupied by trochus and the native gastropods.

### **Objective 3: Determine the socioeconomic impacts of trochus in Samoa**

The methods used for this objective are the same as those proposed in the Project Document, which included: 1) use questionnaire-based interviews of fishers and sellers; 2) prepare tables to show who fishes, ages, frequency, who sells, etc.; 3) conduct cross tabulations and conduct basic analyses; 4) estimate total annual economic benefit to villagers by extrapolating income per fisher and seller to entire country and 5) conduct general linear models to determine the influence of various factors on fisher income and other response variables. The socioeconomic surveys were approved for human research ethics and overseas research (Southern Cross University: ECN-18-204), and follow guidelines of the Australian National Statement on Ethical Conduct in Human Research 2007. We consulted village mayors for authorisation to conduct the surveys in villages, but MAF advised that the interviews of mayors would not yield reliable data, so we based our data on the interviews of fishers.

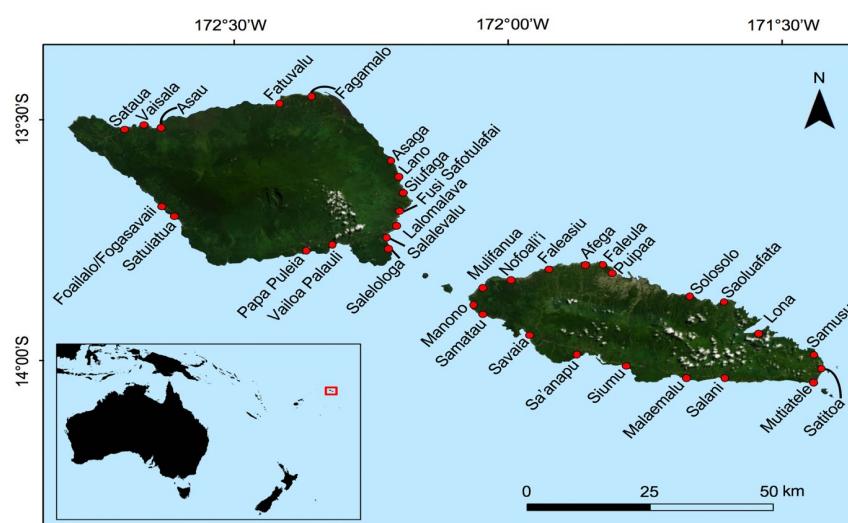


Figure 4. The two main islands of Samoa, and the villages visited for socioeconomic surveys.

We conducted the socioeconomic surveys in 34 villages surrounding the two main islands: Upolu (19 villages) and Savaii (15 villages) (Fig. 4). Around nine fishers were interviewed



in each village. In total, 302 fishers were interviewed. Each fisher was asked the same questions, in the same manner (Fig. 5). The respondents were also given time at the end of the survey to volunteer qualitative information or comments.



Figure 5. Surveying fishers in Samoa using structured questionnaires.

**High-level statistical support** was utilised for analyses of the complex socioeconomic data collected. Statisticians at University of Wollongong were partners in the project and tasked to conduct statistical modelling to examine how geographic scales, gender, ages of fishers, and other factors correlated with economic and social impacts. This strategy built on an existing partnership between SCU and UoW (project FIS/2010/096), which also previously involved complex modelling of socioeconomic data of impact in Pacific Island fisheries.

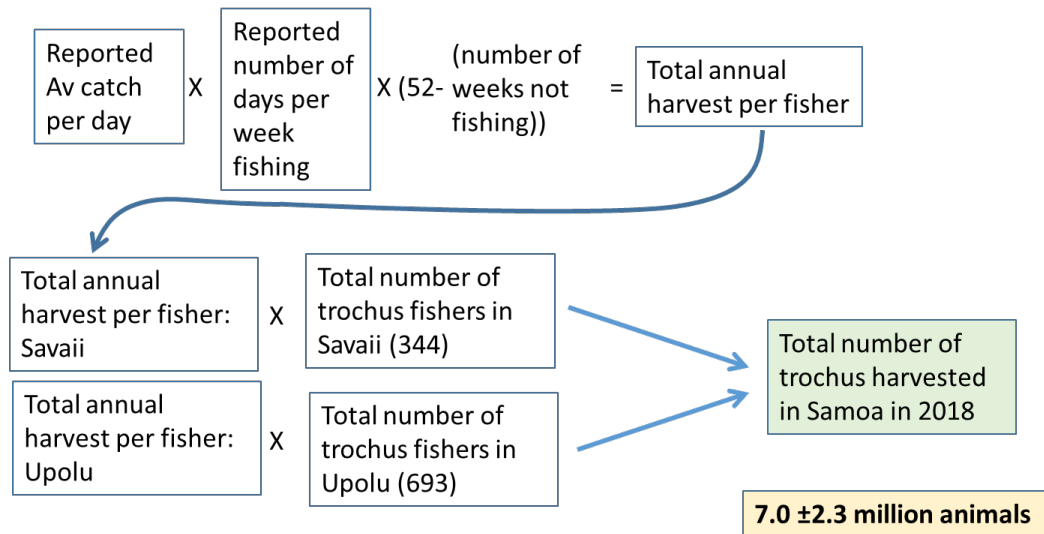
***Objective 4: Appraise the economic potential for exporting trochus sustainably from Samoa and propose administrative frameworks***

The methods used for this objective are the same as those proposed in the Project Document, which included: 1) use a constructivist approach based on population densities on reef crests and size-frequency distributions of trochus, the current market prices for different grades of trochus, and shipment costs; 2) review quotas and fishery performance in other fisheries compared to reef area; 3) check for local exporters and potential for foreign exporters to be involved; 4) determine market destinations; and 5) assess regulations for shell exports (e.g. permitting, inspections).



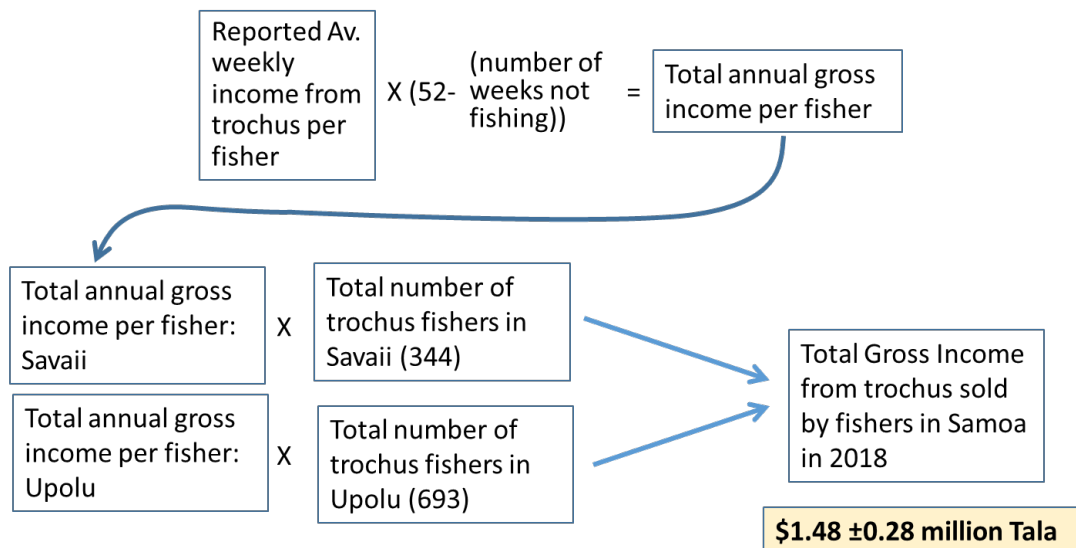
### *Economic potential*

The overall yield of trochus in the fishery for 2018 was calculated as follows:



The calculations gave an estimate of **7 million trochus** collected by fishers across all fishing villages in Samoa for the 2018 calendar year. This figure is not so extraordinary when one considers that 1037 fishers were estimated for the fishery and most fishers are fishing several times per week, equating to around 40 trochus per fisher per trip.

The gross total income earned by fishers selling trochus in Samoa for the year 2018 was calculated as follows:



This estimate is also **only the sales of trochus flesh** in Samoa, which are currently made by around 300 fishers. This economic appraisal does not input the non-monetary value of subsistence consumption.

The potential export value of legal-sized trochus shells that were collected by fishers in the 2018 year was calculated as follows:

Total number of trochus harvested in Samoa in 2018	X	Estimate of 15% of legal sized trochus in catch	X	Estimate of average weight of legal-sized shells	=	Total exportable weight of trochus shells that were harvested in 2018
<b>7.0 ±2.3 million shells</b>		<b>0.15</b>		<b>0.25 kg</b>		<b>= 263,000 kg</b>

A full container of trochus is about 16–18 Tonnes	<div style="border-top: 1px solid black; display: inline-block; padding-top: 5px;">263,000 kg</div> <div style="border-top: 1px solid black; display: inline-block; padding-top: 5px;">17</div>	=	<b>15 shipping container loads</b>	Total annual export potential of the shells that were harvested in 2018 in Samoa
<b>263,000 kg X \$5 Tala/kg = \$1.32 mil Tala</b>				

These last calculations gave an estimate that could be earned by trochus fishers if they sold the largest shells they collected in 2018 for export. It uses highly conservative estimates that just 15% of the trochus shells collected by fishers were of exportable size, and a fair estimate of 5 WST per kg if sold to exporters.

#### *Administrative framework*

This project found that there were no current exporters in Samoa with knowledge or contacts for exporting trochus. However, a Cook Island exporter was identified who was indeed prepared to be able to export trochus shells from Samoa. Administratively, that exporter would likely need to work with traders or business partners in Samoa to purchase trochus from fishers and prepare them for exports.

The Cook Island exporter asked if MAF could send him a small lot of shells so that he could inspect the shell quality, since the shell grade declines if they are damaged by tube worm borers. This shipment has not been prepared yet. We did note that shells from some areas where we collected them (during our underwater population surveys) had significant infestations of worm borers while shells in other locations were very clean. This means that potential prices that could be offered to fishers for shells might not be consistent among regions in Samoa.

The Project Leader thoroughly reviewed the draft Trochus Fishery Management Plan and submitted a comprehensive suite of recommendations to amend the draft. Overall, the draft was sound, and the management arrangements planned by MAF were sensible and feasible to implement.

The management framework in Samoa is **co-management**, since the government Ministry unilaterally takes decisions on most of the regulatory measures while consulting with communities about potential additional regulations (including fishing areas or local seasonal closures) and local compliance measures.

Regulatory measures posed in the draft Trochus Fishery Management Plan consisted of the following:

- Method restriction: Hand collection only
- Time restriction: Collection during daytime only
- Size restriction: A minimum legal 'slot limit' of 90–120 mm basal shell width for all trochus collected and sold
- Participation restriction: Only Samoan citizens can collect and sell trochus shells
- Reporting requirements: Fishers must submit fishing logsheets on their catches and sales

## 6 Achievements against activities and outputs/milestones

### *Objective 1: To build capacity in value-adding of trochus in Samoa.*

no.	activity	outputs/ milestones	completion date	comments
1.1	Conduct workshops with villagers on Upolu and Savai'i islands	Villagers have the know-how to extract trochus meat, polish shells and make jewellery for sale. Completion by 31 Oct 2017.	August 2018	<p>Four one-week-long workshops with participants from 30 villages on Upolu and Savai'i completed.</p> <p>Participants were trained on how to safely use the machines and to expose and polish the inner pearly nacre of the trochus shells. They made necklaces, ear rings and key chains from pieces of trochus.</p> <p>Now fishers know how to make value out of the shells from the trochus they already harvested for the flesh.</p> <p>Some women are now able to engage in the fishery even if they do not do harvest trochus.</p> <p>Shell jewellery making and shell polishing constitutes a form of livelihood diversification that could, potentially, take pressure off other reef resources.</p>
1.2	Assess local markets and demand for trochus shell products	Information to villagers about potential places for sale and expected prices.	August 2018	<p>Completed.</p> <p>During the training workshops, a special session was held to inform participants about pricing and marketing.</p> <p>The project team (and Review Panel) also informally assessed handicraft markets and souvenir shops. There is a strong market for shell jewellery in Samoa, and currently very little trochus handicrafts available. There appear to be promising opportunity for artisans to easily sell their polished shells and trochus jewellery in Samoa.</p> <p>Many of the participant sold later the jewellery and shells they made during the workshops, and were keen to continue making these handicrafts as an alternative livelihood activity.</p>
1.3	Enable villagers to engage in jewellery making and shell polishing	Villages have access to tools for shell polishing and jewellery making.	August 2018	<p>The polishing machines (lapidary grinding machines and buffing machines), rotary tools for making jewellery, hardware, and jewellery-making parts were imported from Australia to Samoa. All of the equipment was left with MAF to be set up at three stations so that artisans could access the tools and machinery. So far, one station at Asau has been set up.</p>

## Objective 2: To assess population densities of trochus in Samoa

no.	activity	outputs/ milestones	completion date	comments
2.1	Conduct field surveys of trochus on the two main islands, Upolu and Savai'i	Estimates of population density and size-frequency distribution of trochus.	Mach 2018	Completed. The data collected show the extent of colonisation (geographic distribution) of trochus around Samoa. The surveys informs about 'supply-side' ecology for other future trans-location programmes and informs about the potential yields of the fishery.
2.2	Calculate densities and size frequency distribution of trochus	Estimates of average population density on reef crest habitats at each of 30 sites in Samoa. Size-frequency distribution graphs for each site.	July 2018.	Analyses completed. 28 sites surveyed: 14 on Upolu and 14 on Savai'i. Manuscript submitted to <i>Restoration Ecology</i> . Currently in review.

## Objective 3: Determine the socioeconomic impacts of trochus in Samoa

no.	activity	outputs/ milestones	completion dates	comments
3.1	Conduct socioeconomic surveys of fishers in Samoa	Data on fishing frequency, uses, gender involvement, income and perceptions from villagers.	Dec 2018	Completed. Strong efforts by Samoan Fisheries officers made it possible to complete the surveys.
3.2	Conduct interviews of village head	Qualitative information about village-wide benefits and potential detrimental effects.	Nov 2018	This was omitted during the survey trips. The Senior Fishery Officer advised that these would be inconsistent among villages, and that data would be more reliable through asking fishers themselves and adding interview questions about uses of the income from trochus sales and about who fishers might give trochus flesh in the village.
3.3	Conduct summary statistics to show social impacts.	Description of who is involved, their time inputs and how the resource is used.	Feb 2019	Completed. The results showed who is engaged in the fishery, how often they go fishing, and what they do with the trochus once harvested.

no.	activity	outputs/ milestones	completion dates	comments
3.4	Perform analyses to assess economic impact to fishers	Reliable estimates of how much income people are gaining from fishing and selling trochus products Rough estimate of economic benefit of entire country.	March 2019	Analyses completed. Two manuscripts submitted to <i>Frontiers in Marine Science</i> and <i>AMBIO</i> . Both currently in review. The results inform on the return on investment from past ACIAR translocations. Also informs other future translocation projects about the likely/potential economic gain in introducing new marine species to island nations.
3.5	Perform modelling to determine the influence of fisher and community variables on economic impact	Analysis output of what factors correlate with higher income of fishers (e.g. age, gender, trochus use and sale, whether people were trained). Completion by 30 April 2019.	October 2019	Analyses completed. Manuscript submitted to <i>Ambio</i> . Currently in review. The results inform other future translocation projects about who benefits from translocation programmes.

PC = partner country, A = Australia

#### **Objective 4: Appraise the economic potential for exporting trochus sustainably from Samoa and propose administrative frameworks**

no.	activity	outputs/ milestones	completion date	comments
4.1	Broadly appraise the current stocks of trochus in Samoa	Qualitative appraisal of national stocks and potential for export, market grades and values, costs of shipments, and prices local fishers could expect for trochus shells. Recommendation for national annual quota.	March 2019	Completed. A media article submitted to <i>SPC Fisheries Newsletter</i> . Currently in review. The results give the Ministry of Fisheries an indication of stock size and an estimate of a sustainable annual harvest rate. Provides a methodological approach for other countries to use rapid assessment methods to gauge export potential.
4.2	Determine and outline potential modalities for exporting trochus	Proposed options for engaging with private industry for exporting shells.	March 2019	Completed.
4.3	Propose regulations and safeguards for sustainable exports of trochus shells	Proposed regulations and enforcement protocols for sustainable harvest and export of trochus shell.	March 2019	Completed. A <i>Policy Brief</i> was prepared and provided to the Ministry of Fisheries, and given to other Ministries, showing the potential yield if exports of trochus shells are allowed. Provided advice to MAF on their proposed regulations and enforcement protocols for trochus shell exports.

*PC = partner country, A = Australia*



## 7 Key results and discussion

### *Colonisation of trochus*

- This research shows that fishable stocks of shellfish can take 15 years or more to develop, after being introduced.
- Trochus can now be found on reefs around Samoa's two main islands, Upolu and Savai'i. The trochus populations appear developed enough to support a regulated export industry, and could almost double the income of present fishers who do not utilise the shell. At some sites, the abundance of trochus was very high (more than 500 per hectare) and could be a cause of concern. At these sites fishers could be encouraged to harvest them to keep numbers in check (Fig. 6).



Figure 6. Three large trochus under a reef ledge at Fafamalo, on Savai'i island.

- There was no clear evidence that trochus have excluded native marine snails nor impacted reef ecosystems; the graduate research project found no negative correlations between abundances of trochus and abundances of native gastropods. Conversely, the grazing on reef algae by trochus might help to regulate the overgrowth of algae and facilitate new corals to replenish those lost from recent coral bleaching events (Fig. 7).



Figure 7. At some reef sites in Samoa, the coral communities have been heavily impacted by bleaching events within the past decade, leaving coral skeletons covered with turfing algae. The re-establishment of new corals can be limited by turfing algae, which trochus help to control.



- The trochus shells were similar in weight and dimensions to those from Cook Islands, measured in other studies. The relationships are presented in one of the peer-reviewed publications of the project.

### **Trochus fishery**

- The fishery initially started in the mid- to late-2000s. Some villages only started harvesting trochus within the 5 years prior to our surveys in 2018.
- From 2004 to 2008, the trochus fishery expansion was quite slow. In 2009, numerous villages were incorporated to the fishery and expanded even more after 2012. In 2018, there are still no signs of an asymptote in fisher participation rates, thus **the fishery is still growing**.
- Men represented 83% of surveyed fishers ( $n = 252$ ), with their ages ranging from 16–68 y. Women represented 17% of surveyed fishers ( $n = 51$ ), and were of similar ages to fishermen; 19 to 65 y. The contribution of women in the fishery might be greater than represented by our survey since it seemed that we were sometimes directed to interview fishermen despite stating a preference to interview fisherwomen where possible.
- Men and women trochus fishers in Samoa can be considered to follow similar fishing practices, since our analyses found **few gendered differences among fishers** in terms of response variable including their fishing frequency, catch rates and perceptions. The fishery can therefore be considered **gender equitable**, at least in terms of outcomes for women and men. Similarly, the age of fishers was not significant among all the variables tested. Youth were clearly active participants in the fishery (Fig. 8).



Figure 8. A young Samoan fisher with trochus that he had collected for subsistence consumption within his family.

- **Diving (breath-hold) was the main method** (68% of fishers) to capture trochus, followed gleaning and diving (21% of fishers) and just gleaning only (11% of fishers) as a fishing method. Scuba gear or other compressed-air methods were not used.
- More women practiced gleaning when compared to men, but many of the fisherwomen also dived to collect the animals.

- Most fishers used paddling canoe, one-quarter of fishers did not use a boat (canoe or motor boat) to collect trochus, and few fishers used a motorboat.



Figure 9. Young Samoan fishers showing a trochus collected by diving from a paddling canoe.

- A smaller proportion (49%) of women used a canoe or motorboat compared to men (79%).
- We calculated an **extremely low carbon footprint** for the entire fishery in 2018 calendar year, by extrapolating fuel use of interviewed fishers across all fishers in the Samoa. This is in stark contrast to the high carbon footprint estimated for the sea cucumber fishery in Fiji (ACIAR project FIS/2010/096).
- On average, fishers collected trochus  $3.4 \text{ d week}^{-1}$ , and greater than one in three fishers went fishing for trochus at least 4 days per week.
- Once at the fishing grounds, fishers tended to spend 3 hours in the water in search of trochus and other marine resources. Fishers reported a total of 15 different marine resources being harvested along with trochus.
- The modelling analyses found that daily catches of trochus and catch-per-unit-effort were greater for boat users than for fishers without a boat. Boat users could access better grounds where trochus were more abundant.
- Catch rates varied greatly among villages, from just 1 trochus per fishing hour in some villages to 300 trochus per fishing hour in northern Savai'i.

### **Socioeconomic benefits**

#### **Subsistence consumption**

- Livelihood diversification benefits from this fishery appear to have occurred mostly within the past 5–10 years, with **inclusive socioeconomic impacts**, since young and old fishers and both men and women harvest trochus.
- The nascent Samoan trochus fishery is **diversifying income sources** and reducing the risk of livelihood failure through declining fisheries.
- Fishers captured an average of 42 trochus per day. As shown in Section 5, this daily rate was multiplied by the average number of days fishing per week, and multiplying by the average weeks fishing per year, and finally multiplied by the number of fishers

in the fishery, which yielded an estimate of **7.0 million trochus captured annually in Samoa** across all fishers (based on the 2018 year).

- Out of all the respondents, 71 % of fishers did not sell any of their catch. Therefore, **most of the catch was destined for subsistence consumption.**
- Most fishers expressed that **trochus is now the first or second-most harvested reef resource in Samoa**, despite populations only being established in the past decade
- Most fishers retained at least half of the trochus for their household consumption. Personal consumption varied among villages, yet was comparable among gender, age, fishing method or fishing experience.
- The majority of fishers broke the shell to get the flesh out, and the shells were very rarely used or sold (Fig. 10). Therefore, if exports were allowed, fishers would need training in how to extract the flesh while leaving the shell intact.



Figure 10. A pile of broken trochus shells in a village in Samoa.

### Fishing income and cost

- Fishers selling trochus (flesh alone or with shells) earned an average **net annual income of AU\$2,580 (WST4,689)** each. This annual income was significantly affected by how many times in the week they went fishing, but not by gender.
- Fishing costs were relatively low, and included the purchase of boat fuel, masks, wetsuit, fins, bags, and torches and batteries for fishing at night. Fishing costs represented 6% of the gross annual income from trochus.
- Twenty-nine percent of fishers sold some or all of their trochus catch. Most of them sold their trochus on roadside stalls, some in the large town markets, and relatively few sold to households within the village (Fig. 11).





Figure 11. Left: trochus in bottles being sold in a town market. Centre: a 'bundle' of trochus (still within the shell) being sold on a table by the roadside. Right: A young fisher selling trochus flesh in bottles by the roadside.

- **Informal markets and distribution networks within communities** were used significantly in distributing harvested trochus (Fig. 11). This project highlights the benefit in studying informal social networks in order to assess the overall importance of artisanal and small-scale fisheries.
- Based on their last recalled sale, fishers selling trochus grossed, on average, 56 AUD per day.
- Similar to the results for catches, the statistical modelling showed that gross incomes for boat users were more than 50% higher than non-boat users. Thus, the provision of boats to artisanal fishing communities (as a form of foreign or national) aid will likely rise catch volume and income, but needs consideration for resource sustainability.

### **Measures of wellbeing**

- The fishery has led to **positive psychological wellbeing** of village fishers (Fig. 12). Using a Likert scale, 46% responded that they were "very satisfied", 37% were "mostly satisfied", 15% were indifferent and just 2% of fishers were dissatisfied with the income they made from fishing and selling trochus.



Figure 12. A content fisher with bottles of trochus that he was selling on the roadside in Savai'i.

- Satisfaction in income from trochus was **comparable between men and women**.
- A slight majority of fishers who sold trochus affirmed that the trochus fishery improved their income.
- Fishers who dived were more optimistic about the current state of trochus stocks. This is possibly because they could see a wider range of habitats where trochus are abundant.
- Fishers spent the money earned from trochus sales on **socially positive expenditures**. The most frequently reported expenditure was on (in descending order): food, church, school fees, household expenses, fishing gear and medical costs. Unlike some other fisheries in the Pacific, where fishing income has been reported to often be spent on alcohol, we did not find this in Samoa.
- Trochus was **ranked more important (by catch volume) by women** than men. In this regard, the trochus fishery has been **more influential for women** than men, who often also earned money and food from other marine resources such as fish.
- More than two-thirds of fishers were “okay” with the having a minimum legal size limit imposed in the fishery, and around one-quarter “didn’t care”.
- Most fishers were “okay” with a possible seasonal closure in the trochus fishery but one in eleven fishers said they would not be happy about such a regulation. This is probably because trochus is now important for their household subsistence consumption.

### **Valuation of the fishery**

- For fishers selling trochus, the sale of these marine snails represented **17% of their total income**, considering all sources.
- The **average annual net income** to fishers from selling trochus was **AU\$2,580**.
- The total value of sales of trochus flesh in 2018 calculates to AU\$820,000 (WST1.48 million), when extrapolating across the ~1037 fishers estimated in the fishery (see methodology in Section 5). This figure is an improvement on the earlier valuation by MAF (Tiitii and Aiafi 2016) because: (1) more fishers added to the fishery since the 2014 data in that report, and (2) this ACIAR project interviewed fishers across a greater geographic scale. This demonstrates a **rapid return on investment** of the costs of the initial ACIAR project to introduce trochus.
- We calculated a total exportable weight of **263 tonnes of trochus shell** harvested in Samoa in 2018.
- At a conservative sale prices to exporters of just WST5 kg<sup>-1</sup> for trochus shells, this volume would equate to **740,000 AUD (1.32 million WST)** as a total production value of trochus shells for export for the 2018 calendar year (i.e., if the large harvested shells were exported). If Samoan fishers were able to sell their large shells for export, this means they could **almost double their present income** made from only selling the trochus meat locally.
- MAF has not allowed trochus exports because of a desire to see that the trochus stocks became well established before allowing for incentives for more intense fishing. Given that the initial intention of the trochus translocations was to create a fishery for shell exports, MAF could now consider allowing for exports in the fishery management plan. There are provisions for this, as an option, in the draft management plan.

### Value-adding of shells

- Our data indicated that keeping the shell intact would not add processing time. Fishers who kept the shell intact did not spend more time in postharvest processing, per shell, than fishers who simply cracked the shell to get the flesh out.
- The four one-week capacity building workshops on both Upolu and Savai'i islands were attended by trainee artisans from 30 villages. Months after the workshops, we revisited many of the artisans and found that they had sold most of their products for handsome prices (Fig. 13).



Figure 13. Some of the trochus shell products made by artisans in the training workshops, which they subsequently sold.

- Although we explicitly asked for each village to consider nominating a woman to attend the workshop, the participation was predominantly men. This was because Samoan culture holds that men are often the ones to attend such technical training, and many people said that women were afraid to use power tools, which are needed for both shell polishing and jewellery making. Nonetheless, we did have both women and youth participate at the workshops. The 42 participants came from a total of 30 villages.

Participation at the four workshops.

Island	Workshop Location	Women	Men
Upolu	Apia	1	6
	Apia	2	11
Savaii	Asau	0	9
	Salelologa	4	9

- Satisfaction forms (using a 5-point Likert scale for responses; ranked +2, +1, 0, -1, -2) filled in by workshop participants showed that the workshops were well received, taught new and relevant skills to the new artisans, and that they were keen to use the new skills for making handicrafts (Fig. 14).

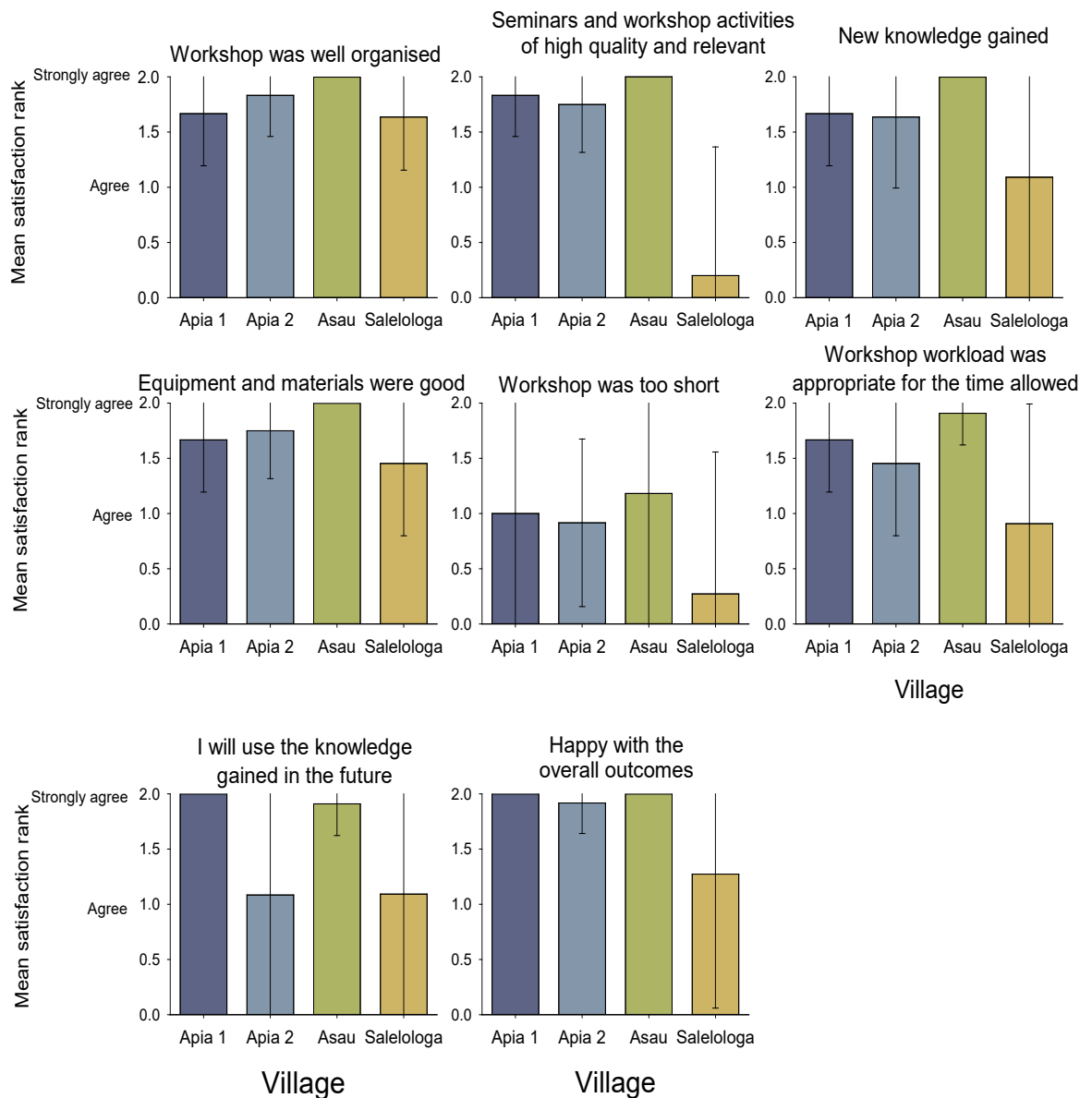


Figure 14. Results from the post-workshop satisfaction surveys of participants. Error bars are standard deviations of the mean.

- MAF has set up one station with shell processing equipment at the village of Asau (Savai'i) and is preparing to set up machines at two other stations so artisans can access them to polish shells and for making handicrafts.

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## 8 Impacts

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### 8.1 Scientific impacts – now and in 5 years

Scientific impacts are represented from the data analysed from the collected database. The data and analyses fall into four principal groups: 1) trochus colonisation (abundance, sizes, distribution), 2) association with reef habitats (biophysical variables at sites), 3) the fishery and fishing activity (daily captures, effort, fishing methods, etc., and 4) socioeconomic impacts (income, costs, fishery perceptions, wellbeing).

The project is set to publish four peer-reviewed journal articles, one newsletter article and one policy brief.

The project provides knowledge about the abundance of trochus around both main islands, Upolu and Savai'i. The results demonstrated that trochus stocks appear to be developed enough to support a subsistence fishery and shell exports.

Publication of the graduate-student study on habitat preferences of trochus in the journal *Frontiers in Marine Science*.

Publication of a study on gender differences in fishing modes, fishing frequency, catch rates, resource preferences and perceptions of the trochus fishers, in the journal *Frontiers in Marine Science*.

A manuscript about the abundance, shell sizes and distribution of trochus is in review in the journal *Restoration Ecology*.

A manuscript about the socioeconomic impacts of the fishery has been resubmitted to a new journal, *Ecology & Society*.

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### 8.2 Capacity impacts – now and in 5 years

The capacity impacts can be divided into those relating to capacity building of artisans and those relating to training of project staff and researchers.

#### **Capacity building of artisans**

The four training workshops built capacity and skills in new artisans on the techniques to polish trochus shells into ornaments, and make jewellery from pieces of trochus shells (Fig. 15).

The training has great potential to value-add to the industry because trochus shells are currently not utilised or sold much in Samoa. This assertion is supported by the fact that shell jewellery is popular among Samoan consumers and imported product is sold extensively in markets and stores as souvenirs, yet little if any of it is yet made from trochus.





Figure 14. A couple of the artisans from the training workshops with their trochus jewellery products.

MAF plans to coordinate further training workshops for value-adding of trochus shells. The equipment will be set up permanently at Asau, Salelologa and Apia.

### **Capacity building of project staff and researchers**

This project involved 12 collaborating staff and researchers, 6 of whom are women.

The project provided an opportunity for a graduate student, Kate Seinor, to gain invaluable training in working with Pacific Island collaborators and applying marine science methods to answer important ecological questions about the fishery.

The project provided further training to MAF fishery officers on methods and interpretation of stock assessment surveys. The underwater surveys were preceded by training inshore on how to standardise transect width and how to record accurate data on numbers and sizes of trochus on the reef. Gender norms and choices in Samoa mean that males tend to the boat-based research, although the project provided training to two female fishery officers in the underwater survey methods.

MAF officers also received further training in developing and delivering questionnaire-based socioeconomic surveys to examine gender in fisheries and to measure fishing activities and socioeconomic impact and wellbeing. Through the project, two female fishery officers and three male officers were supported to further develop techniques in conducting interview-based socioeconomic surveys of fishers. This support included a pre-survey workshop with officers to develop their skills in delivering questions and probing respondents if the answers did not directly address the questions. The capacity building also included decision-making in suitable replication within villages, seeking out respondents, and soliciting volunteered information from them during and after the interviews. This training will surely prove useful for both female and male MAF officers in other projects.

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## **8.3 Community impacts – now and in 5 years**

The project purchased specialized equipment for shell polishing and jewellery making, which MAF is making available to artisans. The project held four one-week shell polishing

and jewellery-making workshops with prospective artisans on Upolu and Savai'i. People from 30 villages now know how to transform trochus shells into attractive ornaments, or made into jewellery.

### 8.3.1 Economic impacts

The majority of fishers were satisfied with income from the new fishery. The total value of sales of trochus flesh in 2018 calculates to **AUD820,000** (WST1.48 million), when extrapolating to all the fishers estimated in the fishery (1037 fishers). Most of the interviewed fishers believed the trochus population is still increasing on the reefs.

Extrapolation of the catch data to the whole fishery reveals that approximately 260 tonnes of legal-sized trochus shell (90–120 mm diameter) were harvested by Samoan fishers in the 2018 year. The shells are being discarded by fishers, since exports are not yet allowed by MAF. These large shells could be sold to exporters, and **almost double the present income of fishers**. What we now know from this project is that the **potential value of shell exports from Samoa is estimated at \$1.3 million Tala** (AUD 730,000) (Fig. 15).

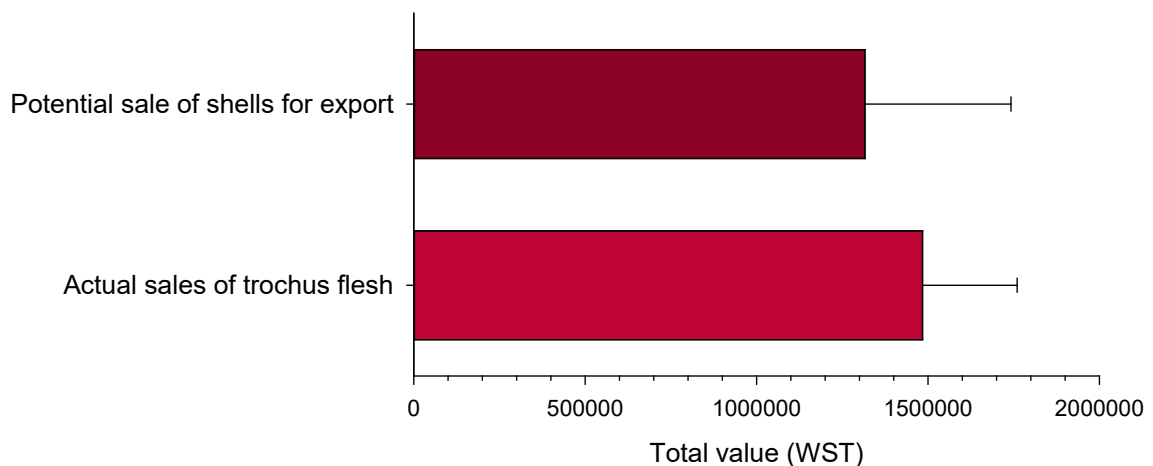


Figure 15. The value of actual sales of trochus flesh in Samoa, and the potential estimated income that fishers could make from selling the large shells already harvested in the fishery each year.

### 8.3.2 Social impacts

This study provides new evidence that some small-scale fisheries can be **gender equitable**. The project also shows that accounting for multi-level factors, by using sophisticated mixed-model analyses, can provide a rigorous evaluation of gendered impacts.

Young and old fishers and both men and women collect trochus in Samoa. The fishery was gender equitable in terms of catch rates, income, economic satisfaction and perspectives about the fishery. Yet, **trochus represent a more important part of the seafood caught by women than men**.

A formal *Policy Brief* was prepared and posted to ministers in Samoa highlighting the fact that many women also sell trochus and are active fishers, so deserve an **equal representation in decision-making** in the fishery. This should take the form of an equal involvement of fisherwomen as fishermen in fishery management consultation workshops and industry committees for this fishery. Implementation of this recommendation could have a long-term impact on the fishery management and gender equality in Samoa.

The findings give reliable insights to fishery managers about the value of the fishery. The submitted manuscript (*Ecology & Society*, in review) examines the socioeconomic impacts

of trochus fishery. The analysed data from hundreds of fishers interviewed in multiple villages explore factors affecting the wellbeing of fishers, in terms of their incomes, subsistence consumption and satisfaction from the fishery. **Positive wellbeing outcomes** are evident by the extent of subsistence consumption, income and virtuous expenditure of money from the fishery, and satisfaction with the fishery income.

The access to capital items (i.e., boats) had a big effect on fisher incomes, and is relevant to policy on aid to rural fishing communities.

The substantial distribution of seafood through informal networks within communities is a useful finding to guide future studies on fisheries trade. The evidence of significant livelihood diversification has important policy implications for the development of other small-scale fisheries.

### 8.3.3 Environmental impacts

An important finding was the **evidence against any significant negative ecological impacts** of trochus to native species or corals. The abundances of trochus were unrelated to abundances of the large native gastropods, and the density of trochus bore little relationship to corals apart from the result that the two tended to coincide. Actually, the grazing on reef algae by trochus might help to regulate the overgrowth of algae after recent deaths of corals from climate change.



An SCU honours student provided valuable information on the association of trochus with habitat features to aid future site selection. The article from that study was published in the journal *Frontiers in Marine Science* (see section 10.2; Seinor et al. 2020).

Fishing of trochus was done mainly out of paddle canoes or from shore. The calculations of average boat fuel use by fishers and extrapolations to the entire fishery revealed a small carbon footprint of the fishery. The fishery emits only around 20 metric tonnes of CO<sub>2</sub> per year compared with around 8,000 metric tonnes of CO<sub>2</sub> for the sea cucumber fishery in Fiji (ACIAR project FIS/2010/096). These results were part of the article published on trochus fishing in Samoa (see section 10.2; Purcell et al. 2020).

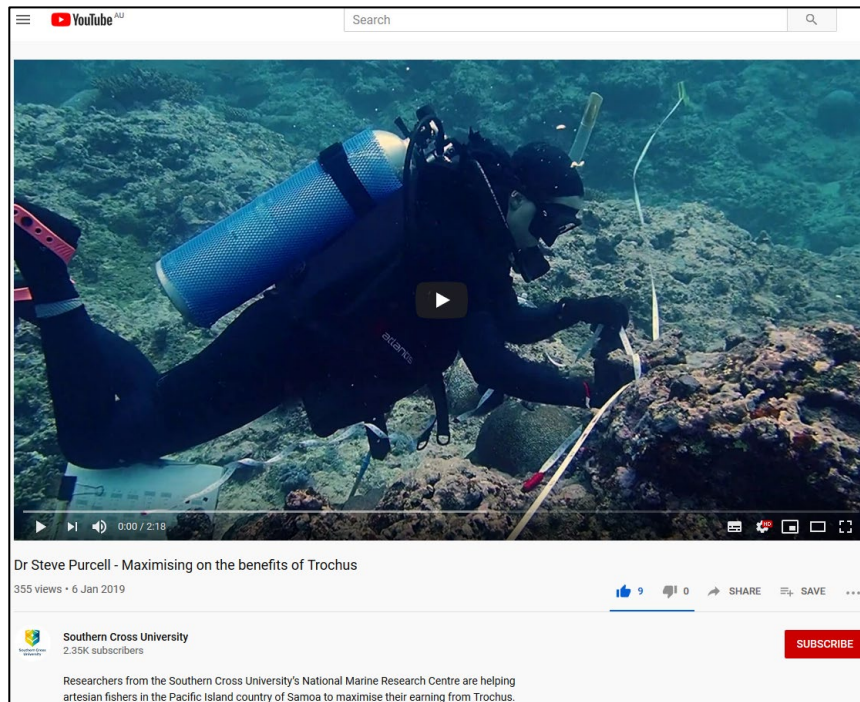


## 8.4 Communication and dissemination activities

### Media articles

- A media article about the project was published in the *SPC Fisheries Newsletter*.
- In 2019, SCU put out a media release about the project and the key findings. The Media release was accompanied by a 2.19-minute online video about the project.

<https://www.scu.edu.au/national-marine-science-centre/research/maximising-on-the-benefits-of-trochus/>



- A popular media article was published in July 2018, at the Samoan local newspaper *Samoa Observer*, entitled: 'Trochus shell bonanza for communities' (written by Ivamere Nataro). <https://www.samoaoobserver.ws/category/samoa/15692>



- Another media article was published about capacity building workshops training of the project, entitled “Shell project to benefit locals”, published in August 2018 in the Samoa Observer (written by Ivamere Nataro).  
<https://www.samoobserver.ws/category/samoa/19619>



- One published, the research articles will be distributed by email to institutions and fishery managers and fisheries researchers in Pacific Island countries. Referencing information about the articles will be posted on Google Scholar, ResearchGate, LOOP and ORCID.
- SCU has prepared a Case Study article to showcase the project as an example of its impactful research. This will appear at: <https://www.scu.edu.au/research/research-impact/impact-case-studies/>

### Social media

- A video of the project made by SCU, was posted in January 2019 in the NMSC Facebook page and on the SCU's YouTube Channel where it has received 350 visualisations. <https://www.youtube.com/watch?v=sDGSP7XC7E8&feature=youtu.be> and shared by twitter by the Project Leader: <https://twitter.com/stevepNMSC/status/1083504956559155200>
- The completion of the Trochus underwater surveys was shared by Twitter: <https://twitter.com/SCUonline/status/1087455084223582208>
- A series of tweets were posted by the author about the beginning and end of the four one-week value-adding workshops in Samoa  
<https://twitter.com/stevepNMSC/status/1023340524588003328>  
<https://twitter.com/stevepNMSC/status/1035401714117951488>
- A video has been prepared on the population surveys of trochus and some key findings, and will be uploaded on multiple social media channels once the article about the surveys (currently in review in *Restoration Ecology*) has been published.

### Oral presentations

- 2019 - Oral presentation to Pacific Island fishery managers at the 3<sup>rd</sup> Regional Technical Meeting on Coastal Fisheries. "*ACIAR Trochus project in Samoa: Insights for fishery development*". November, 2019.
- 2018 - Research seminars at Fisheries Division, Ministry of Agriculture and Fisheries Samoa. "*The publication process*" and "*Analysis and presentation of underwater population surveys of reef invertebrates*". 5<sup>th</sup> and 6<sup>th</sup> September, 2018.
  - Research seminar at Fisheries Division, Ministry of Agriculture and Fisheries Samoa. "*Population surveys of density and sizes of trochus in Samoa*". 27 July, 2018.

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## 9 Conclusions and recommendations

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### 9.1 Conclusions

- Trochus population stocks are plentiful around both main islands to support a subsistence fishery and shell exports.
- To date, most of the harvested trochus have been used for subsistence consumption.
- Discounting possible valuations of subsistence uses, the economic value of the fishery based on sales of trochus flesh in Samoa is significant, and has provided a rapid return on investment from the original ACIAR project that helped support the introduction of the animals to Samoa.
- If exports of trochus shells were allowed in Samoa by MAF, the sales of large (legal sized) shells is estimated to approximately double the current income of fishers. Fishers could make money from selling the flesh locally, as they currently do, and sell the shells to exporters for the global button manufacturing industry.
- Livelihood benefits from the trochus introduction have been significant, with minimal negative ecological impacts.
- The fishery was gender equitable. Women and men showed comparable catch rates, income, satisfaction and perceptions about the fishery.
- The complete benefits of the trochus fishery are likely underestimated due to informal market distribution.
- There are strong opportunities for further value adding in the fishery through shell polishing and jewellery making. MAF would need to implement a system to make the equipment available to artisans on both Upolu and Savai'i.

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### 9.2 Recommendations

- The under-utilisation of the trochus shells represents a good context to add value to the fishery and further increase fisher wellbeing and incomes. Yet, permitting exports might need to be complemented with a fishery management plan and a vigorous monitoring system, surveillance and control.
- Trochus might offer an alternative source of income and food for other Pacific Islands without the species, such as the Gilbert Islands in Kiribati.
- Our results provide guidelines for habitat types necessary to increase the probabilities of trochus success at translocation sites.
- Further research should use controlled, manipulative experiments to more fully examine potential ecological effects of trochus, since the introduction of foreign animals to ecosystems is usually scorned by the scientific community.
- The capacity building workshops to train artisans in shell polishing and jewellery making could be applied further to this fishery and could add significant value in other trochus fisheries. However, the provision of the equipment to artisans has not been straightforward in Samoa, and viable livelihood support program and small business models for artisans need to be investigated.
- The dramatic increase in the number of fishers in Samoa's trochus fishery should be a concern. The draft fishery management plan has the potential to provide sustainability to the fishery but still needs to be implemented in Samoa.



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# 11 Appendixes

## 11.1 Appendix 1: Socioeconomic questionnaire

Trochus Fisher and Seller Questionnaire – Samoa			
(ACIAR project researchers to fill in during interview)			
Surveyor: _____	Date: ____/____/____	Time start: _____	
Fisher name: _____	Gender: female: <input type="checkbox"/>	male: <input type="checkbox"/>	age: <input type="text"/>
Village/place of residence: _____		Waypoint # _____	
<b>Introduction to respondents:</b>			
★ Who are we? SCU and MAF. Purpose of project.			
★ The questionnaire is part of a project to assess the benefits of the (introduced) Aliao [ <i>Rochia nilotica</i> ] fishery in Samoa. It will take about 30–40 minutes.			
★ This study is funded by the Australian Centre for International Agricultural Research.			
★ Your responses are <u>completely voluntary</u> . You can choose to not respond to any questions.			
★ Your responses will be kept <u>confidential</u> and will be used in a project report and publications, which will show averages of responses from fishers in the village. Your individual information will not be shown. An Information Sheet gives contact details to get feedback about the project and an address in case you have complaints.			
★ Unless otherwise stated, our questions ONLY refer to the <i>introduced</i> Aliao, not Aliao Samoa.			
<b>Type and location of fishing</b>			
1. Do you only fish <u>commercially</u> for Aliao or do you also fish/collect other marine resources ( <u>to sell</u> )?			
Only Aliao: <input type="checkbox"/>		Other resources too: <input type="checkbox"/>	
2. How long ago was the <u>last time</u> you went fishing for Aliao? _____ days.			
3. Do you collect the Aliao by walking on the reef at low tide (gleaning)? Yes <input type="checkbox"/> No <input type="checkbox"/>			
4. Do you collect the Aliao by free-diving/snorkeling? Yes <input type="checkbox"/> No <input type="checkbox"/>			
5. In what part of the reef do you go to collect the Aliao??			
Reef flat: <input type="checkbox"/>		Reef crest: <input type="checkbox"/>	Front reef slope (3-10 m): <input type="checkbox"/>
<b>Fishing effort</b>			
6. Over the past 6 months, on how many <u>days</u> did you collect some Aliao each week, on average, during fishing months? _____ days per week.			
7. Were there some months that you didn't go out to collect Aliao? If so how many months per year not fishing _____.			
If you didn't fish some months, why? _____.			
8. If you use a boat to get out to the fishing sites to collect Aliao, what sort of boat?			
Canoe paddle only <input type="checkbox"/>		Canoe paddle+sail <input type="checkbox"/>	Boat with outboard <input type="checkbox"/> ....engine HP? _____

9. If you used an outboard motor, how much fuel did you use on the last trip in which you collected Aliao?

Litres: \_\_\_\_\_ Cost: \_\_\_\_\_ How many other people (not including you) shared that cost? \_\_\_\_\_

10. What other costs would you have for fishing Aliao?

Item	Cost (Tala)	Per time (day, week, month, year)
mask, snorkel		
fins		
wetsuit		
gloves		
sack		
torch		
batteries		

11. On a normal day during the past year, how many people are in the group fishing with you? \_\_\_\_\_.

Are all of them fishing too? Yes ☐ No ☐ \_\_\_\_\_ number fishing (not incl. you)

12. On your fishing trips, how many hours are spent to get to and from the fishing sites; i.e. not including the fishing time? \_\_\_\_\_ Hours round-trip (transportation only).

13. When fishing, how many hours per day would you spend in the water looking for Aliao? \_\_\_\_\_ hrs.

14. During the past 6 months, how many Aliao (not including Aliao Samoa) would you normally catch on average per day? \_\_\_\_\_ On a good day?: \_\_\_\_\_.

Is this average number that only you personally caught? Yes ☐ No ☐ (revise above)

15. Can you rank which marine resources you would, on average, collect the most of, by volume, and which ones you would collect less, by volume? '1' is most volume, '2' is second most volume, etc

Fish:	<input type="checkbox"/>	Giant clams:	<input type="checkbox"/>	Turbo shells:	<input type="checkbox"/>
Octopus:	<input type="checkbox"/>	Other clams/cockles:	<input type="checkbox"/>	Other gastropods:	<input type="checkbox"/>
Lobster:	<input type="checkbox"/>	Aliao Samoa:	<input type="checkbox"/>	Sea urchins:	<input type="checkbox"/>
Turtle:	<input type="checkbox"/>	Aliao (giant):	<input type="checkbox"/>	Sea cucumber:	<input type="checkbox"/>
Crabs:	<input type="checkbox"/>	Zoanthids:	<input type="checkbox"/>	Other _____	<input type="checkbox"/>

#### Processing and use

16. Do you break the Aliao shells to get out the meat or leave shells whole? Break: ☐ Whole: ☐

17. For the Aliao that you catch each month, what proportion would you give away?

All: ☐ Most: ☐ Half: ☐ Small part: ☐ None: ☐

18. For the Aliao that you catch each month, what proportion would you eat yourself?

All: ☐ Most: ☐ Half: ☐ Small part: ☐ None: ☐

19. For the Aliao that you catch each month, what proportion would you sell?

All: ☐ Most: ☐ Half: ☐ Small part: ☐ None: ☐

20. Who does the work to get out the meat of the Aliao if you sell the meat?

You: ☐ Spouse: ☐ Children: ☐ Other family member: ☐ Other (non-family) person: ☐

21. For one average day's catch, how much time do you (and your family) spend to do the work to take out the meat of the Aliao you catch? \_\_\_\_\_ hrs

#### Sale of Aliao

22. Do you catch and sell the Aliao, or do you only sell Aliao that someone else caught?

Catch and sells: ☐ Sells Aliao that someone caught: ☐

We would like to ask you some questions about income you earn from selling Aliao, and you can skip any of the questions if you feel uncomfortable answering them.

23. On a good week, how much money would you earn from the Aliao you sell? \_\_\_\_\_ Tala/week

24. This year, how much would you earn on an average week from the Aliao you sell? \_\_\_\_\_ Tala/week

25. This year, how much would you earn on average per week from all income sources? \_\_\_\_\_ Tala/week

26. How much money did you earn the last time you sold Aliao? \$ \_\_\_\_\_ Tala

How many shells/pieces was that (total) ? \_\_\_\_\_

Was that for just one day of fishing? Yes: ☐ No: ☐ \_\_\_\_\_ days

27. Where do you usually sell the Aliao?

Roadside: ☐ Market: ☐ Village stall: ☐ \_\_\_\_\_ ☐

28. Are you satisfied with the money that you earn from selling Aliao?

Very ☐ Mostly ☐ Indifferent: ☐ Not very ☐ No ☐

29. Do you ever sell empty Aliao shells, or parts of them (e.g. jewellery)?

Never ☐ Seldom ☐ Sometimes ☐ Frequently ☐

30. If you sell the empty shells, what price do you sell each shell for? \_\_\_\_\_ /shell

31. Has the sale of Aliao increased your weekly income, or has it remained the same, or declined because you are selling Aliao? Increased ☐ Same ☐ Declined ☐

32. If you earn more money now because you are selling Aliao, what things do you most spend that **additional income** on?

Food ☐ Alcohol ☐ School fees ☐ Other household expenses ☐ Medical costs ☐

House improvements ☐ Improvement of community infrastructure ☐ Church/tithing ☐

Boat/fishing gear ☐ Other equipment ☐ Funerals, feasts or customary occasions ☐

Phone/internet credit ☐ Other \_\_\_\_\_ Other \_\_\_\_\_

**Fishing history and perceptions**

33. How many years ago did you first start collecting the introduced Aliao? \_\_\_\_\_ years.

34. How many other people do you think are also collecting [introduced] Aliao in your village? \_\_\_\_\_.

35. Compared to recent years, do you think the numbers of Aliao on the reefs are declining, staying fairly stable, or increasing?

Decreasing ☐

Stable ☐

Increasing ☐

36. Would you be okay if the Ministry of Agriculture and Fisheries brought in a minimum size limit as a fishery regulation for collecting Aliao? No (unhappy) ☐ Don't care ☐ Okay ☐

37. Would you be okay if MAF brought in a seasonal closure (e.g. for a few months) each year as a fishery regulation for Aliao? No (unhappy) ☐ Don't care ☐ Okay ☐

**Is there any other information or comments that you would like to say? Or do you have any questions?:**

Time finished: \_\_\_\_\_.

## 11.2 Appendix 2: Policy Brief



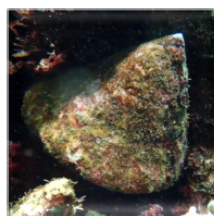
### Policy Brief Samoa's trochus fishery

In 2003–2006, adult broodstock trochus (Aliao) were introduced to Samoa, through funding and technical support from Australia's foreign aid program (ACIAR Project). The intention was to provide a new fishery resource for food and income.

MAF and Southern Cross University recently completed a project to assess the trochus colonisation on Samoan reefs, to determine the socioeconomic impacts of the fishery, to build capacity in value-adding of shells, and to appraise the potential for exports.

#### The fishery

**Colonisation of trochus:** Trochus can now be found abundant on reefs around both Upolu and Savai'i. Stocks have taken 15 years to develop.



*Trochus snail in Samoa.*

Populations are still building in some areas.

The stocks appear to be developed enough to support a subsistence fishery and shell exports.

The project found no clear evidence of negative ecological impacts of trochus to native species or corals. Actually, the grazing on reef algae by trochus might help to regulate the overgrowth of algae after recent deaths of corals from climate change.

**A majority of fishers believe trochus stocks are increasing on reefs**

**Views of fishers:** A majority of fishers (70%) believe trochus stocks are increasing on reefs.

Almost all fishers agreed with a legal minimum size limit. Some (8%) of them did not agree with the idea of seasonal fishery closures.

#### Socioeconomic benefits

**Economic benefits:** The average gross annual income to fishers from selling trochus meat was \$4966 Tala, representing 17% of their income from all sources.

The total value of sales of trochus flesh in 2018 was \$1.48 million Tala.

**Food security:** Currently, the main value of trochus in Samoa is in flesh for consumption. Over 1000 fishers collect trochus in Samoa.

Most fishers eat trochus themselves or give away a majority of the catch. About one-third of fishers sell trochus flesh. The extra cash is most often spent on food, school fees and church tithing.

**More than 1000 Samoan fishers collect trochus**

**Livelihood diversification:** Benefits of trochus to livelihoods have occurred mostly within the last 5 to 10 years. Trochus is now one of the top three most-harvested reef resources by a majority of fishers who collect them. Handicrafts made from trochus shells could offer an alternative livelihood.

**Gender analysis:** Young and old fishers and both men and women collect trochus in Samoa. The fishery was gender equitable in terms of catch rates, income and perspectives about the fishery. Positive wellbeing outcomes are evident by the extent of subsistence consumption and satisfaction with the fishery income.



*A socioeconomic interview of a fisher-woman.*

**Women should have equal representation in decision-making for the fishery**

Trochus represent a more important part of the seafood caught by women than men. Many women also sell trochus and are active fishers, so deserve an equal representation in decisions about the fishery.

**Carbon footprint:** Most trochus fishers use a paddling canoe or glean by foot. So, the fishery has a very low carbon footprint (20 tonnes of CO<sub>2</sub> per annum).



## Value-adding of shells

Trochus shells can be polished into attractive ornaments, or made into jewellery. ACIAR purchased specialized equipment for shell polishing and jewellery making, which MAF is making available to artisans. The project held four shell polishing and jewellery-making workshops with prospective artisans on Upolu and Savai'i.

MAF plans to coordinate further training workshops for value-adding of trochus shells. The equipment will be set up permanently at Asau, Salelologa and Apia.

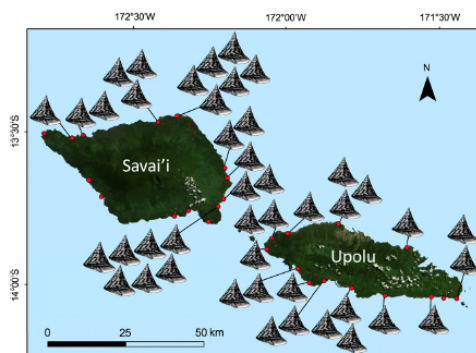


Artisan trainees at a workshop in Salelologa.

## Recommendations

Samoa's Trochus Fishery Management Plan needs to be implemented. The management plan sets a minimum legal size for harvesting trochus, collection during daytime only, and the potential to set seasonal fishery closures.

Approximately 260 tonnes of legal-sized trochus shell (90–120 mm diameter) are currently harvested by Samoan fishers annually. The shells are being discarded, since exports are not yet allowed by MAF. These large shells could be sold to exporters, and almost double the present income of fishers. The potential value of shell exports from Samoa is estimated at \$1.3 million Tala.



Map showing trochus abundance at 28 sites  
(more shells per site = higher abundance)

Most fishers distributed trochus through informal social networks within villages. The socioeconomic value of the fishery has therefore been underestimated until recently.



Polished shell and jewellery from Samoan trochus shells

Decision-making for the fishery should involve an equal representation of women fishers.

The potential value of shell exports from Samoa is estimated at \$1.3 million Tala

Further stocking of trochus in Samoa is not needed—populations are now well-established.

At some sites, trochus densities are very high (500+ per hectare). MAF could encourage fishers to harvest them to keep numbers in check at some sites.

Boat users tended to catch more trochus. Providing boats or canoes to fishers will improve their catch rates but could increase risks of over-harvesting.

Further research is needed to test whether trochus outcompete local species of marine snails.

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## 11.3 Appendix 3: SPC Fisheries Newsletter article

<https://coastfish.spc.int/en/component/content/article/508>

### Ecological and socioeconomic impacts of trochus introductions to Samoa – A project of the Australian Centre for International Agricultural Research

Steven Purcell,<sup>1\*</sup> Sapeti Tiitii,<sup>2</sup> Justin Aiia,<sup>2</sup> Audrey Tone,<sup>2</sup> Atapana Tony,<sup>2</sup> Moso Lesa,<sup>2</sup> Catherine Esau,<sup>2</sup> Brian Cullis,<sup>3</sup> Beverley Gogel,<sup>3</sup> Kate Seiner,<sup>1</sup> Daniela Ceccarelli<sup>1</sup> and Alejandro Tagliafico<sup>1</sup>

*Trochus* were introduced to Samoa from 2003 to 2006 with the goal of creating a new fishery that would diversify seafood supply for local communities. It took at least 10–15 years for trochus populations to become established on Samoa's reefs. Underwater visual censuses in 2018 showed that populations are now established around both main islands, Upolu and Savai'i, although they are spatially variable. The project estimated that over 1000 fishers now harvest trochus in Samoa, and 300 of them sell the flesh in villages, roadside stalls and markets. Informal networks are used to sell and distribute the seafood in villages. Analyses found the benefits to be inclusive and gender equitable. For a majority of fishers surveyed, trochus is now one of the most harvested reef resources by volume. The project found significant positive impacts to income, local diets and satisfaction of fishers. Further income from trochus could be made through handicrafts from the shells or shell exports. Permitting exports would need to be accompanied by the implementation of a fishery management plan and a robust system of monitoring, control and surveillance. The fishery is a welcomed success story in an era when seafood supply in the Pacific is under threat.

#### Background

Trochus, which now goes by the scientific name *Rochia nilotica* (Linnaeus, 1767) (World Register of Marine Species), is an herbivorous marine snail that is commercially important in the Pacific Islands region. A century ago, the distribution of trochus was restricted to the western Pacific and Southeast Asia. Starting in the 1920s, trochus broodstock were translocated to reefs of central Pacific Island countries (Gillett 1993). Sometimes, populations failed to colonise naturally, while in other cases, the translocated broodstock bred successfully and created populations on reefs that later yielded lucrative fisheries for Pacific Islanders (Bell et al. 2005). Until recently, trochus did not naturally occur in Samoa (Fig. 1).

Introductions of species from one country to another come with a risk to native populations of fauna and flora and reef systems. This is especially serious when foreign stock from one country is introduced to "enhance" or "restock" populations already native in another country, as the foreign stock can alter the genetic diversity of native stocks in detrimental ways. Alternatively, foreign stock might be introduced to a country where the species does not occur or has never existed. In such cases involving introductions to new

localities beyond geographic ranges ("assisted migration"), the risks to other native species and ecosystems need to be weighed against potential benefits to livelihoods. These considerations are especially pertinent today given that Pacific Island countries have been urged to diversify the supply of seafood in the future (Bell et al. 2009).

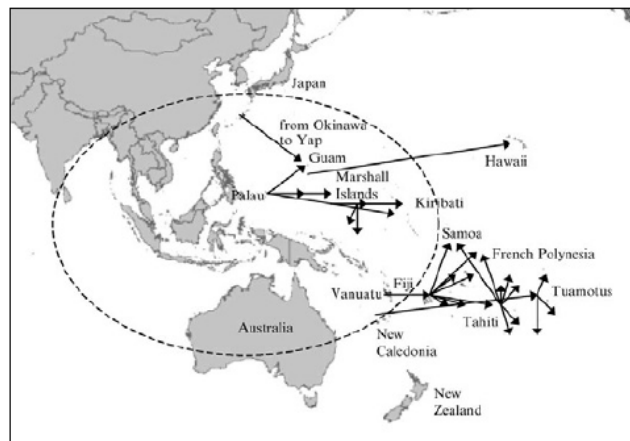


Figure 1. Translocations of trochus among Pacific Island countries. Source: Bell et al. 2005

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## • News from in and around the region •

An introduction of trochus to Samoa in 1990 was unsuccessful. From 2003 to 2006, a project by Samoa's Ministry of Agriculture and Fisheries (MAF), with expertise and funding from the Australian Centre for International Agricultural Research (ACIAR), introduced trochus from Fiji and Vanuatu to several sites in Samoa. The aim was for the animals to breed naturally to colonise neighbouring reefs and diversify the marine resources available to coastal villages. That project was unable to show that any new populations had been created, although the timeframe was too short to prove ecological success.

The broodstock eventually bred successfully on Samoa's reefs, as evidenced by fishers collecting animals and selling the flesh some years later (Tiitii and Aiafi 2016). Monitoring of local trade by MAF shows a rapid increase in the sales of trochus flesh over the following years (Fig. 2), and underwater surveys at some sites on Upolu Island showed that new populations were establishing one decade after the introductions (Tiitii and Aiafi 2016).

The extent to which wild populations have become established, and the socioeconomic impacts resulting from this, were still uncertain. In addition, fishers are currently benefiting almost solely from the sale of the flesh and are not profiting much from value-adding that could be done to the shells. MAF has not yet allowed exports of trochus, in part because information about the fishery was incomplete; therefore, the full economic value of the animal in Samoa has been largely underutilised.



Figure 2. Fisher with bottles of trochus flesh near Fusi, Savai'i. (Image: S.W. Purcell)

### Project objectives

Encouraged by the reported success of trochus introductions to Samoa, ACIAR funded a project (2018–2019) coordinated by Southern Cross University (SCU) and MAF. Its four objectives were to: 1) build capacity in value-adding of trochus shells in Samoa; 2) assess the extent of colonisation on Samoan reefs; 3) determine the socioeconomic impacts of the trochus fishery in Samoa; and 4) appraise the potential for exporting trochus sustainably.

### Activities

Underwater visual censuses were undertaken at 14 sites around Upolu and 14 sites around Savai'i (Fig. 3). The team counted and measured trochus and other reef gastropods (snails) on belt transects on the reef-front habitat at each site (Fig. 4). An SCU graduate student also studied the association of trochus with habitat features to aid future site selection.

Two capacity-building workshops were held on Upolu and two on Savai'i to train people from neighbouring villages in how to polish trochus shells and make trochus shell jewellery. Equipment from Australia was set up and left in Samoa for further workshops and use by artisans.

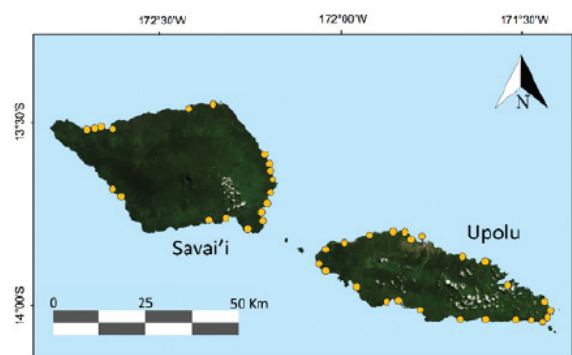


Figure 3. Study sites (yellow dots) in Samoa showing where the underwater survey and socioeconomic surveys occurred.

Socioeconomic surveys of 303 fishers using questionnaire interviews were conducted in 34 villages (Fig. 6). The surveys collected data on the fishing, consumption, sale and trade of trochus in Samoa. Modelling analyses of the data tested gender disparities in these variables and other factors potentially influencing socioeconomic impacts. Lastly, project data were used to assess the



• News from in and around the region •

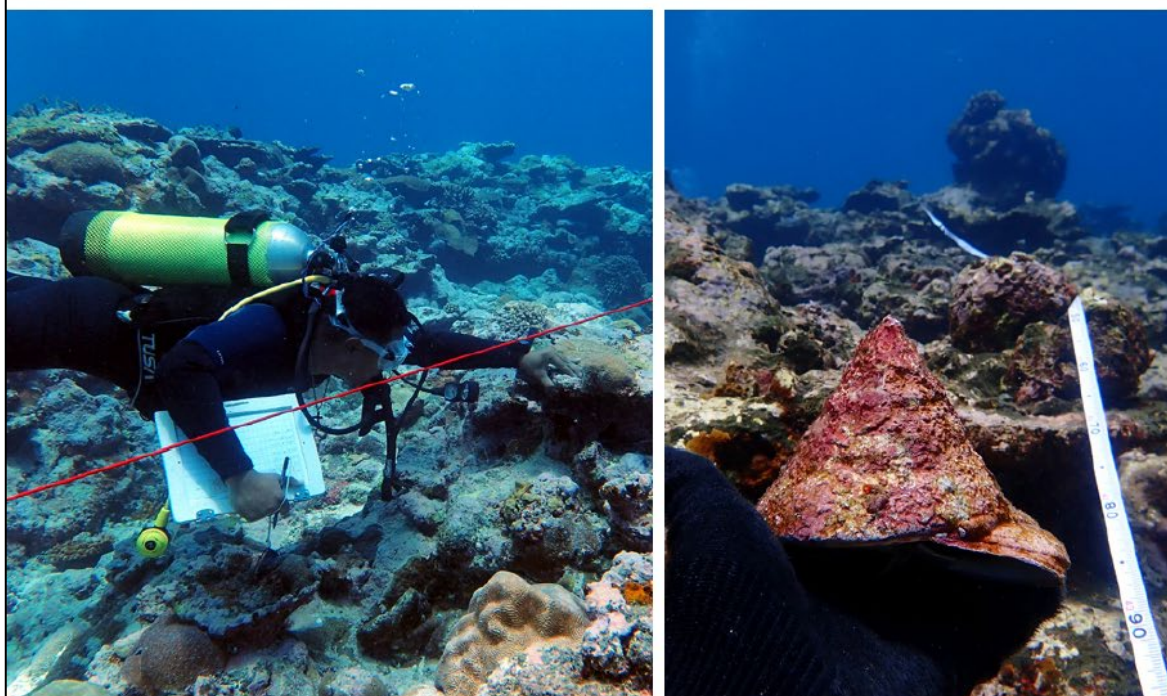


Figure 4. Underwater visual census surveys of trochus in Samoa. (Images: S.W. Purcell)

potential volume and value of trochus shell that could be sustainably exported from Samoa, and the management plan for the fishery was reviewed.

### Outcomes

Underwater surveys showed that trochus had colonised beyond the initial translocation sites. Two of the three initial translocation sites were not ideal for these populations to thrive. Future translocation and restocking programmes need a better understanding of the habitat requirements of species to be translocated or restocked. The graduate student project determined the specific habitat preferences of trochus, and that it is a generalist species. Reefs in Samoa have been heavily impacted by coral bleaching in the past decade (Fig. 6). Densities of trochus were very high ( $>500$  ind  $\text{ha}^{-1}$ ) at a few sites, and all of the populations contained some large individuals that could be used for jewellery making or shell exports. Large variations in colonisation among sites imply that we should anticipate that the benefits of such translocations will not be even across villages.



Figure 5. Catherine Esau interviewing a young trochus fisher for the socioeconomic survey. (Image: S.W. Purcell)

• News from in and around the region •



Figure 6. An adult trochus in Samoa next to dead plate corals that have been covered by algae. (images: S.W. Purcell)



Figure 7. A young Samoan fisher with trochus he caught for household consumption. (image: S.W. Purcell)

Our study shows that abundant, exploitable stocks can develop within 15 years, although trochus populations at some sites seem to still be developing. Our analyses did not indicate any negative impacts on native marine snails in Samoa. Trochus are food for a variety of fish and invertebrate species (e.g. wrasses, rays, crabs, octopus, triton and bailer shells), some of which are important for fisheries (Nash 1993). Trochus are grazers, keeping the growth of macroalgae (seaweeds) down to a short turf, and creating space for corals to settle and grow. These translocations of trochus could, therefore, support food webs and the resilience of reefs impacted by coral bleaching.

The fishery is now contributing to livelihood diversification and food security. Young and older fishers and both men and women collect trochus in Samoa, and most of the fishers retained or gave away a majority of their catch for

consumption within their villages (Fig. 7). One-third of fishers (both men and women) sold part of their catch using informal markets (mostly roadside stalls). The extra cash resulting from the fishery was spent mainly on other food, school fees and church tithing.

The majority of fishers were satisfied with the income they earned from the new fishery. Most fishers believe that the trochus population is still increasing on the reefs. More than two-thirds of fishers ranked trochus as their top three (out of 15) harvested resources. Fishing was done mainly from paddle canoes or swimming and wading from shore. Our calculations of annual fuel consumption by fishers using motor boats to collect trochus reveal a small carbon footprint for the fishery.

In many respects, the fishery was gender equitable because women and men had similar catch rates, income, satisfaction and perceptions about the fishery. Most fishers agreed with a minimum legal size limit being imposed on the fishery, but some were against the idea of seasonal closures. Finally, we observed an underutilisation of the trochus shells, showing that fishers could significantly increase the income they make from harvesting trochus if opportunities arise for selling the large shells either for handicrafts or for export. Project data showed that around 7 million trochus were harvested across Samoan villages in 2018, including approximately 260 tonnes of trochus legal-sized shell, which could serve in exports to increase the value of the fishery.

Shell jewellery and handicrafts are already popular in Samoa, and products from trochus shells offer a promising new niche. The four one-week-long workshops trained participants from numerous villages on Upolu and Savai'i. Participants learned how to safely use the machines and to grind off the outer layers of the trochus shells to expose and polish the inner pearly nacre (Fig. 8). They made necklaces, earrings and key chains from pieces of trochus. Many of them later sold the jewellery and shells, and were keen to continue making these handicrafts as an alternative livelihood activity. MAF has set up one station at the village of Asau (Savai'i) and is preparing to set up machines at two other stations so that artisans can use them for making handicrafts.

## Future activities

The Samoan trochus fishery management plan was reviewed, under the activities of the project, and is set to be implemented soon. Regulations include a "slot" size limit of 90–120 mm shell diameter<sup>4</sup>, daytime collection only, the option of a harvest season, and export licences (if exports are allowed).

<sup>4</sup> The shell diameter of trochus is measured across the base of the shell, taking the distance from the outermost tip of the whorl to the farthest edge on the opposite side of the shell. The measurement is also known as the maximum basal shell width.





Figure 8. Participants polishing trochus shells and making jewellery on Savai'i. (image: S.W. Purcell)

MAF has planned to coordinate further training workshops for value-adding of trochus shells. The stations being set up for shell polishing equipment will be managed by MAF, and artisans will pay a small fee that will contribute to maintenance costs and materials.

The success of trochus introductions in Samoa provide yet another example of fishery development of this species. Trochus could offer an important food and income source for other islands yet to have the species, such as the Gilbert Islands in Kiribati. This project gives clearer guidelines for habitat features needed at translocation sites. Further research should use controlled experiments to examine potential ecological effects of trochus, as the introduction of foreign animals to ecosystems is usually scorned by the scientific community.

Even for species with relatively strong potential for local colonisation, such as trochus (Bell et al. 2005), the Samoan case shows that fishable stocks might take at least 15 years to populate. Even longer timeframes could be expected for species with lower rates of productivity (e.g. giant clams and sea cucumbers). Careful judgement and a review of available data should precede any introductions. From a pragmatic viewpoint, resource managers must weigh the potential ecological risks with the potential benefits to livelihoods. The data, thus far, from Samoa suggest that livelihood benefits have been significant, with minimal negative ecological impacts.

### Acknowledgements

The work was funded by the Australian Centre for International Agricultural Research through project FIS/2016/128. Support was also provided by Southern Cross University, Australia, and Samoa's Ministry of Agriculture and Fisheries.

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## 11.4 Appendix 4: Article on habitat preferences of trochus

<https://www.frontiersin.org/articles/10.3389/fmars.2020.00223/full>



# Biophysical Habitat Features Explain Colonization and Size Distribution of Introduced Trochus (Gastropoda)

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The tegulid gastropod, *Rochia nilotica* is harvested in small-scale fisheries throughout Southeast Asia and the Pacific Islands, many of which were created from inter-country translocations. This species is found on structurally complex shallow reefs, but its specific habitat requirements have not yet been quantified in order to maximize the success of future translocations and help future-proof the fishery in changing ocean conditions. At 28 sites around Samoa, where the species was introduced in the early 2000s, we measured a suite of habitat variables along transects in which *R. nilotica* were counted and the shell sizes measured in a parallel study. Boosted regression tree analyses revealed that *R. nilotica* were most abundant at reef locations that were shallow, with fairly consistent depth, had high coverage of branching coral, low cover of erect macroalgae, low wave exposure and high surface complexity. Smaller individuals were associated with wide reef flats and high cover of branching coral, whereas larger animals occurred in deeper water with high surface complexity. Multivariate analyses showed this species to be a habitat generalist, sharing much of its niche with an endemic herbivorous gastropod, *Tectus pyramis*. Future stocking programs should focus on sites with habitats optimal for both adults and juveniles. *R. nilotica* populations are likely to be especially affected by broadscale stressors that result in declines in live coral cover and substratum complexity and increasing coverage of macroalgae on coral reefs.

**Keywords:** habitat association, invertebrate, fishery, climate change, coral reef, species translocation, *Rochia nilotica*

## INTRODUCTION

Coral reefs are naturally highly complex and provide habitat for a diverse suite of marine species (Spalding et al., 2001; Hoegh-Guldberg et al., 2007). Important habitat characteristics may include: substratum type, cover of benthic biota, reef surface complexity, wave exposure, and depth (McCormick, 1994; Graham and Nash, 2013; Komyakova et al., 2013). These habitat features are likely to influence key ecological processes such as recruitment, competition, foraging and predation (Luckhurst and Luckhurst, 1978; McCormick, 1994; Graham and Nash, 2013). In order to understand population patterns, we therefore require a clear understanding of the habitat requirements of animals in relation to potential biophysical factors. Such knowledge can reveal habitat traits driving distributional patterns of marine invertebrates and, importantly, enhance the success of stock restoration projects by identifying optimal deployment locations (Bell et al., 2005).

## 11.5 Appendix 5: Article on trochus fishing in Samoa

<https://www.frontiersin.org/articles/10.3389/fmars.2020.00297/full>



# Understanding Gender and Factors Affecting Fishing in an Artisanal Shellfish Fishery

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Fishing strategies, effort and harvests of small-scale fishers are important to understand for effective planning of regulatory measures and development programs. Gender differences in fishing can highlight inequities deserving transformative solutions, but might mask other important factors. We examined fishing modes, fishing frequency, catch-per-unit-effort (CPUE), resource preferences and perceptions of fishery stock among artisanal gastropod (trochus) fishers in Samoa using structured questionnaires and mixed effects models. The fishery has an extremely modest carbon footprint of 18–23 tons of CO<sub>2</sub> p.a., as few fishers used motorized boats. Trochus (*Rochia nilotica*), an introduced gastropod, was the second-most harvested resource, after fish, despite populations only being established in the past decade. Daily catch volume varied according to gender and villages ( $n = 34$ ), and was also affected by fishing effort, experience, assets (boat), and fishing costs of fishers. Boat users had much higher CPUE than fishers without a boat. Fishers who practised both gleaning and diving caught a greater diversity of marine resources; effects that explained otherwise seeming gender disparities. Trochus tended to be ranked more important (by catch volume) by women than men, and rank importance varied greatly among villages. Local ecological knowledge of fishers informed the historical colonization of trochus around Samoa and current trends in population abundance. Fishing efficiency, catch diversity and perspectives about stocks were similar between fishermen and fisherwomen, when accounting for other explanatory variables. Greater importance of these shellfish to women, and gender similarities in many of the fishing responses, underscore the need to ensure equal representation of women in the decision making in small-scale fisheries.

**Keywords:** small-scale fishing, artisanal fisheries, gender, CPUE, gleaning, shellfish, trochus

## INTRODUCTION

### Small-Scale Invertebrate Fisheries

The importance of small-scale fisheries (SSFs) to employment and livelihoods has underpinned the rising interest in this sector among researchers, NGOs and resource managers (Berkes et al., 2000; Chuenpagdee et al., 2006; Batista et al., 2014; Purcell and Pomeroy, 2015). Many SSFs target invertebrates, since resources like shellfish, crabs and octopus are often accessible close to shore