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Sea cucumber abundance, diversity and fishery in Samoa. An assessment of lagoon occurring sea cucumbers

Part I

Commercialization of the sea cucumber fishery in Samoa? A survey to explore the potential for a commercial beche-de-mer fishery in Samoa

Part II

The subsistence and artisanal sea cucumber fishery, with particular focus on *Stichopus horrens*, in Samoa

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Minor Field Study 122
ISSN 1653-5634

August 2006 Uppsala

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Hampus Eriksson

This paper reports my degree project (20 ECTS) towards an M.Sc in Biology at the Department of Animal Ecology, Centre for Evolutionary Biology (EBC) at Uppsala University, Uppsala, Sweden.

Supervisors: Assoc. Prof. Bo Tallmark (Department of Animal Ecology, Uppsala University)
Dr. Kim Friedman (Secretariat of the Pacific Community (SPC), Nouméa, New Caledonia)

Cover photo: Women from the village Vailele taking the opportunity to collect sedentary invertebrates (gleaning) at low tide. All pictures are taken by the author.

Preface

This study was performed in Samoa through September to December 2005 and finalises my university studies at Uppsala University towards an M.Sc in Biology. The work presented in this paper came about after a series of events and I owe greatly to all of those that are mentioned in the acknowledgement section.

During 2005 a request to perform a survey on the coastal resources (including sea cucumber resources) around the country of Samoa in the South Pacific was presented to the Secretariat of the Pacific Community (SPC) from the Samoan Fisheries Division. The coastal component of the Pacific Region Oceanic and Coastal Fisheries (PROCFish/C) section of SPC started up this work in collaboration with the Samoan Fisheries Division in June and August 2005 and covered finfish and invertebrate resources in parts of Upolu and Savaii. The invertebrate surveys included fisheries dependent and fisheries independent data collection. The fisheries independent surveys were in-water assessments of stock and habitat in grounds that were pre-selected because of fishing activities in that area. The data collected were generally density estimates (incl. species composition) across shifting habitats, but also biological data, such as length and weight measurements. Alongside this information fishery dependent data were also collected. Using fisheries data gives a good view of targeted species and sizes and provides a good complement to the biological assessment of the harvested resource.

After the completion of PROCFish/C work in Samoa the Samoan Fisheries Division was given the opportunity to retrieve more specific information on sea cucumber resources and an extension of the PROCFish/C survey was planned. This report is the result of the extension survey. As the sea cucumber fishery for export of beche-de-mer products from Samoa is currently closed, the extension survey was considered vital in order to provide fundamental information when re-considering the closure.

My part in this project was to perform the extension of the survey in collaboration with the Samoan Fisheries Division and provide data from six new sites around Upolu, Samoa. The data collection methods were the same or similar as in previous surveys and performed along with Fisheries Officers from the Samoan Fisheries Division.

This paper reports the study in two parts. The first part is an assessment of the surveyed sea cucumber resources and explores whether Samoan sea cucumber stock may hold potential for commercial harvest. The second part examines the subsistence and artisanal fishery activities of sea cucumbers in Samoa.

Keywords: Samoa, sea cucumbers, beche-de-mer, stock assessment, coastal fisheries, traditional fishery, fishery development

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2006-08-07

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Part I

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B.G.H. Eriksson

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Executive summary

The sea cucumber stock of Samoa was surveyed and assessed using fishers' dependent and independent information. Density data were collected on two scales (spatial) to fit the heterogeneous distribution of sea cucumbers and to more accurately assess the commercially important *Stichopus chloronotus*. The data collection incorporated manta tow and general transect methodology, with manta tows surveying the entire site area and shorter transects covering hard benthos (mostly back reef) areas, with the additional purpose of also collecting length data. A total of seven species were recorded at a range of densities. *Holothuria atra* was recorded at highest densities and also showed the highest occurrence. *Stichopus chloronotus* was found in second highest numbers. *Bohadschia argus* and *Bohadschia vitiensis* were both found in moderate numbers. Only two specimens of *Holothuria nobilis* were recorded, both were in areas of high oceanic influence. *Holothuria hilla* and *Stichopus horrens* were also irregularly encountered. The density records in general show a restrained stock despite absence of fishing pressure for over ten years (fishery was closed in 1994). Some processes generating this pattern is arguably linked to previous commercial harvest and cyclones of some magnitude that have periodically devastated coastal zones, possibly affecting the sea cucumber survival and recruitment. Anthropogenic development is also argued to have affected sea cucumber populations. An interview based household survey further suggests that a majority of fishers think that the availability of sea cucumbers in their lagoon has decreased over 5 to 10 years. Some fishers argued that this was due to both previous commercial harvest and cyclones. In essence this survey finds that the present sea cucumber stock in Samoa does not hold numbers that would justify a long-term commercial fishery and that traditional fishing plays an important role in coastal communities' subsistence. Increased fishing effort will conflict with the traditional sea cucumber fishery (with the clear exception of *S. chloronotus* that is not fished locally) with over fishing as a result. The survey finds some potential for experimental (at this stage) harvest of *S. chloronotus*. Some points of interest are included for management and monitoring if the commercial fishery for sea cucumbers in Samoa is decided to be re-opened.

1. Introduction

Sea cucumbers occur in temperate and tropical waters and a variety of species are harvested across the Indo-Pacific. The demand for sea cucumbers as beche-de-mer (boiled and sun dried sea cucumbers) is localized to South East Asia, which opens up a market for export from other countries with potential for commercial harvest. Most countries in the Indo-Pacific region that export, or hold potential for sea cucumber export, are under developmental status (with the exception of Australia). This may regrettably affect the possibility to manage and monitor the fishery. Indeed, today many sea cucumber fisheries in the world are considered over fished or depleted (Nash and Ramofafia 2006; Conand 2004). During early 1990s the sea cucumber resources in Samoa was commercially harvested for export as beche-de-mer. Since 1994 the export fishery is closed and banned in Samoa (Mulipola 1994). There are few species that were commercially harvested that are continuously being fished by local fishers. This would infer that stocks of most species have had some time to recover.

There are approximately 15-20 species of sea cucumbers occurring in Samoa (table 1). Many of them are of low value and were not harvested during export years or today for subsistence. Some of the species are solemnly found in inshore lagoon habitats whereas equally many are found mainly in reef front- or offshore areas (or lagoon areas with strong ocean influence). The occurring species have different trade value (table 1).

Table 1. Some species of sea cucumbers occurring in Samoa. Table derived from Mulipola (1994). Species value may vary between trade areas. Average prices and catchdata are from export years in Samoa (Mulipola 1994). Weight is exported (processed) weight.

Species	Trade name	Samoan name	Value	Avg.Price /kg (USD)	Weight (kg)
Actinopyga miliaris	Blackfish	Loli aau	Medium		
Actinopyga mauritiana	Surf redfish	-	Medium	6.04	12299
Thelenota ananas	Prickly redfish	Sauai	High	8.90	97
Bohadschia vitiensis	Brown sandfish	Fugafuga	Low	2.72	18078
Bohadschia argus	Tigerfish	Mama'o	Low	3.78	7875
Holothuria atra	Lollyfish	Loli	Low	1.75	771
Holothuria (Microthele) fuscogliva	White teatfish	Susuvalu	High	12.33	153
Holothuria (Microthele) nobilis	Black teatfish	Susuvalu	High	8.00	977
Holothuria fuscupunctata	Elephant trunkfish	-	Low		
Holothuria hilla	-	Amuu	-		
Stichopus chloronotus	Greenfish	Maisu	High	9.00	1056
Stichopus (hermanni) variegatus	Curryfish	Sea amu'u	Medium		
Stichopus horrens	Dragonfish	Sea	-		

1.1 Background to the study

The closure of the commercial fishery in Samoa was a result of several companies utilising the sea cucumber resources to the point where the available stock could not provide a viable return. Since the ban sea cucumbers are only allowed to be collected for subsistence by village fishers and only local village regulations exist (King and Faasili 1999). Recently investors have presented requests to the Samoan Fisheries Division of re-starting a commercial sea cucumber fishery for export as beche-de-mer. For such a request to be approved the Fisheries Division requires information over the accessible stock today. This work extends the data collected by the Pacific Region Oceanic and Coastal Fisheries/Coastal section (PROCFish/C) of the Secretariat of the Pacific Community (SPC), in surveys performed July and August 2005. Both surveys were performed as a response to a request from Samoan Fisheries Division. The survey consists of fisheries independent in-water assessments together with data on subsistence catch and associated socio-economics, collected trough a household survey conducted over a wider area around the country.

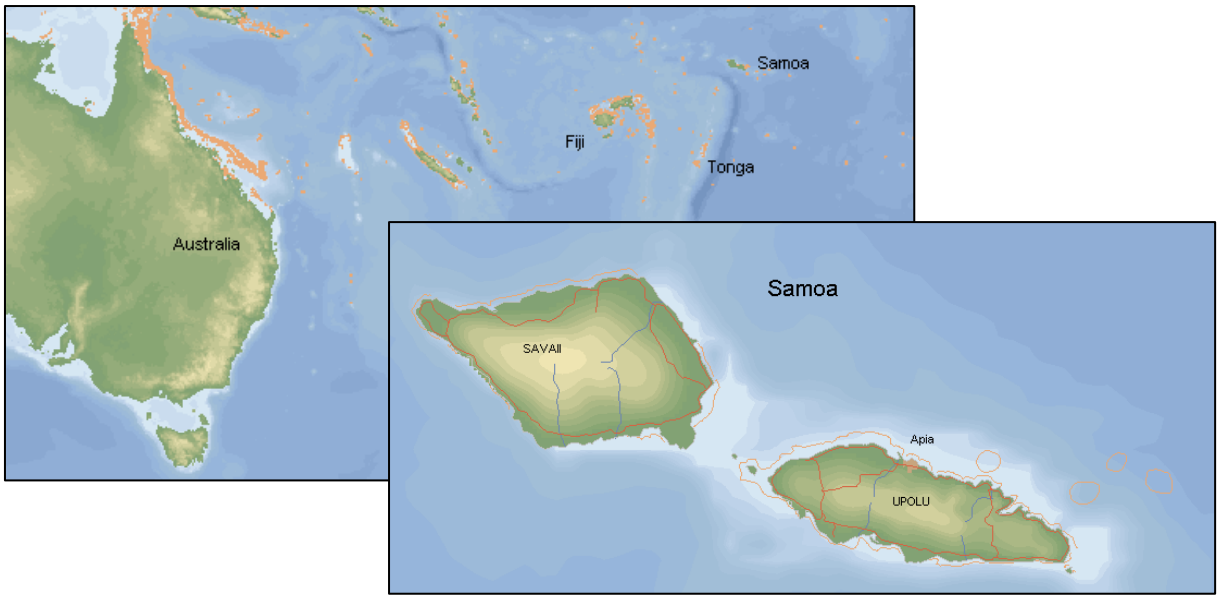
1.2 Objectives of the study

The purpose of this extension survey is to collect density estimates of lagoon sea cucumber resources from six sites around the island of Upolu, Samoa, with the aim of providing a quantitative assessment. Where data are available the survey outcome will be compared to other countries to, if possible, draw conclusions on stock status in Samoa. Any evaluation whether stock has recovered from previous commercial exploitation is difficult because no early specific fishery independent data exist. The greenfish (*Stichopus chloronotus*) will be given extra attention in this report, as it is a species of some commercial value that is commonly observed in easy access areas along the coastline of Samoa. This study also includes a household survey that aims to provide dynamic information on sea cucumber resources along with information on local consumption. Ultimately, this report will advice whether the present stock is likely to withstand commercial exploitation, or if any increased or new harvesting would be un-profitable for potential stakeholders including Samoa. Table 1.2 summarizes some of the objectives of this survey.

Table 1.2. **Objectives of the study**	
1.	Provide a quantitative density estimate for all recorded sea cucumber species in lagoon habitat (with particular interest to commercially important *S. chloronotus*), and to some extent examine their distribution within and between surveyed areas.
2.	Provide a qualitative assessment of the stock and, where possible, put results in context to other sea cucumber fisheries.
3.	Provide length data (incl. frequency distributions) and length weight relationships (for *H. atra* and *S. chloronotus*) for species found in the small scale survey,
4.	Interpret trends in sea cucumber availability and importance to local communities from a household survey.
5.	Highlight issues to adhere to when considering re-opening of fisheries and its management plan.
6.	Provide an adequate general background to this resource and biology to clarify its importance and related issues for management to a wider public.

1.3 The country

Samoa (previously Western Samoa or Independent Samoa) is an independent country consisting of two main islands, Upolu (1108 sq. km.) and Savaii (1695 sq. km.), and seven smaller islands scattered along the coast of the main islands. Two of the smaller islands, Apolima and Manono, are inhabited. The capital, Apia, sits on the north coast of the larger and southern island of Upolu. The population was estimated to ca 175.000 year 2001 (Passfield et al. 2001), whereof the majority is residing in the country's 326 villages, 230 of which are coastal villages situated along the 447 km long coastline (FAO 2002). The islands are of volcanic origin and both Upolu and Savaii have rugged terrain. Savaii is still considered volcanic active with its latest eruption in early 1900s. The young volcanic nature of the country has resulted in a loss of arable land due to lava flows and also the creation of lava shores and cliffs along the coastline (Zann 1999). The volcanic origin also results in a small shelf and coral reef area, with ca 30 000 ha to the 40m isobath (Zann 1994). The country occupies a small area in the SW Pacific and sits between latitudes 13° 25'S and 14° 05'S, and longitudes 171° 23'W and 172° 48'W (map 1.3).



Map 1.3. Samoa lies in the South Pacific between latitudes 13° 25'S and 14° 05'S, and longitudes 171° 23'W and 172° 48'W. Samoa consists of two main islands, Savaii and Upolu, and seven smaller islands. The capital Apia sits on the north coast of Upolu (map derived from www.reefbase.org GIS downloadable files).

The Samoan traditional way of life is on a subsistence level as farmers or fishers. That is why most villages are in the more arable coastal zones. Historically, the people have looked to their family land or the village lagoon for subsistence resources (Paulson and Rogers 1997; Zann 1999). The extended family system ('aiga') in Samoa is very strong. Each family, 'aiga', elects its leader, the 'matai', who represents the family in the village council, 'fono'. The 'matai' also controls all resources and work within the family. The family and village have a strong influence on day-to-day life, land tenure and user rights within many south pacific island communities (Cornforth 1994). It is possible that this has maintained the availability of subsistence resources in Samoa, but an increasing population and western lifestyle may prevent such authorities to act. Samoa is experiencing an increasing western influence with introduction of modern fishing and harvesting techniques and availability of imported food and medical care. This has resulted in a steadily growing population (Zann 1999). The increasing population poses problems in a country such as Samoa, with limited land area and few natural resources. Development of resources and infrastructure to keep up with the growing populations yield problems such as land reclamation from lagoons, loss of important mangrove for road construction and elevated sediment and nutrient levels in lagoons and on reefs from increased runoff. Samoa already has some of the highest natural deposition of fluvial sediment in coastal zones in the world (Terry et al. 2006). The development of the country also poses problems for land living biota (Cowie and Robinson 2003).

During the early 1990s several cyclones struck Samoa. The biggest cyclone, Ofa, struck 1991 and had great impacts on the country. From a coastal resource perspective they were devastating, causing coral rubble to end up on top of fringing reef, which in turn elevated the reef tops to form barriers thereby limiting the oceanic influence and water turnover in the lagoon. Reports of lagoon eutrophication as a result of this have been reported (Zann 1999). The great forces of the cyclones also knocked over live coral and brought with it sediment that was deposited on reef and in lagoon. Although no reports exist it is likely that many sedentary invertebrates suffered from the great oceanic forces generated by the cyclones.

Samoa is not rich in natural resources and therefore exports are low, which in turn results in the lowest GDP in the region (Zann 1994). In terms of fishing as a natural resource, the country has the smallest Exclusive Economic Zone (EEZ) in the region. The EEZ yields less than 1% of the region's Tuna resources, a region that in turn supplies 50% of the global catch (Fisheries Division 2005). Still the Tuna fishery is one of the biggest income earners for the country (Mulipola 2002). In the year 2000 the fisheries export (ca 4500 metric tonnes (mt)) yielded foreign revenues of WST 40 million (ca USD 14 million), which in turn is equivalent to ca 60-70% of all Samoan export value (Passfield et al. 2001). The offshore fishing is facing recent hardship in that the Tuna fisheries catch has plummeted. The catch has decreased from 6180 mt to 1944 mt, from 2001 to 2004, for domestic longline activities in Samoa EEZ (Fisheries Division 2005).

1.4 Inshore fisheries resources

Most of the Samoan coastline is sheltered by fringing and barrier reefs, forming lagoons in which inshore fishing activities by local villagers are common. Whereas most of the commercial fishing is carried out outside of the reef, the inshore fisheries provide villagers subsistence and artisanal resources. Since most of Samoa's population lives at a subsistence level (Zann 1994), and because of the high number of people living in the country's coastal regions, fishing activities for inshore resources are a very important part of many peoples subsistence and nutrition (Mulipola 2002). According to Passfield et al. (2001) the inshore fishing activities dominate in terms of trips (82%) and fishing time (72%).

The villagers fishing in the lagoon and on the reef utilise a variety of fishing methods. In terms of number of trips, gleaning activities are the second largest fishing method utilised (Passfield et al.2001). The method also reflects the targeted resource, whereas gleaning means searching for sedentary invertebrates (snails, sea urchins and sea cucumbers), spear fishing is mainly for finfish species and gillnetting is a non species-specific method of harvesting finfish resources.

The catch from the local lagoon provides a large part of the dietary protein intake and a per capita consumption of sea food of 57kg/yr for Samoa has been presented (includes offshore fishery products) (Passfield et al. 2001). Even though the inshore fishing activities are mainly for household consumption, parts of the catch from fishing activities in lagoon areas are also sold at roadside or market, this artisanal fishing provides income for local fishers. According to Mulipola (2003) the proportion of fishers that eat all of their catch is 57%, and the proportion of fishers that sell all of their catch is 13%. Further, 25% of the fishers eat some of their catch and 24.5% sell some of their catch (proportions vary).

With the increasing population the fishing pressure on the lagoon resources is growing. Refined fishing activities are increasing the pressure on already fading fish stocks, with reef catch declining almost 40% between 1983 and 1991 (Zann 1994). The increasing effort and efficient methods of gillnetting and spear fishing had already in 1994 caused overfishing of finfish stocks such as mullet (Mugulidae), mackerel scads (Selar), trevallies and serranids (Zann 1994). Further, invertebrate resources such as sea urchins, snails, sea hare, bivalves and jelly fish have also suffered greatly together with giant clams (Tridacnidae) (Zann 1994). The nature of the sedentary organisms makes them easily accessible and therefore prone to over fishing. Multi-species fisheries, such as the inshore activities in Samoa, often pose challenges to manage. Management procedures derived from high valued single-species fisheries may well not be applied to small-scale fisheries (Caddy and Bazigos 1985), and low cost alternatives have to be sought for. Striving for new management procedures are vital as, despite substantial investments, many fisheries in the world are considered overexploited. Utilising management tools and models from high-valued fisheries usually requires data that are expensive to collect (both in terms of labour and technology). Instead, for fisheries of small scale the methods of stock assessment and monitoring need to be simple and low cost (Caddy and Mahon 1995). The Samoan Fisheries have set up a community-based management programme for fisheries, the program supports devolution from central management to local village management where the goal is to assist local communities in managing their own fisheries resources (King et al. 2001).

Potential problems for coastal resources go outside that of just heavy fishing, the increased development of villages and infrastructure is causing loss of habitat and creating poor water conditions for reef and lagoon fauna. The village development and the land clearing associated with agricultural activities have also resulted in inland soil erosion and sediment deposition on reef and in lagoon. The runoff from village and urban areas also brings with it increased nutrient levels, causing outbreaks of red tides and algal blooms due to eutrophication (Zann 1994), and is also a factor contributing to increasing cover of sea grass. In neighbouring American Samoa such anthropogenic disturbances are argued to be the main factor for a 99% loss of soft coral communities (Cornish and DiDonato 2004). Further, toxins and waste influx into lagoons are increasing with the increasing population and development. The result of this is that the coastal zone of Samoa is in a poor condition. According to Zann (1994) it is probably the most disturbed coastal zone in the region.

1.5 Sea cucumber resources

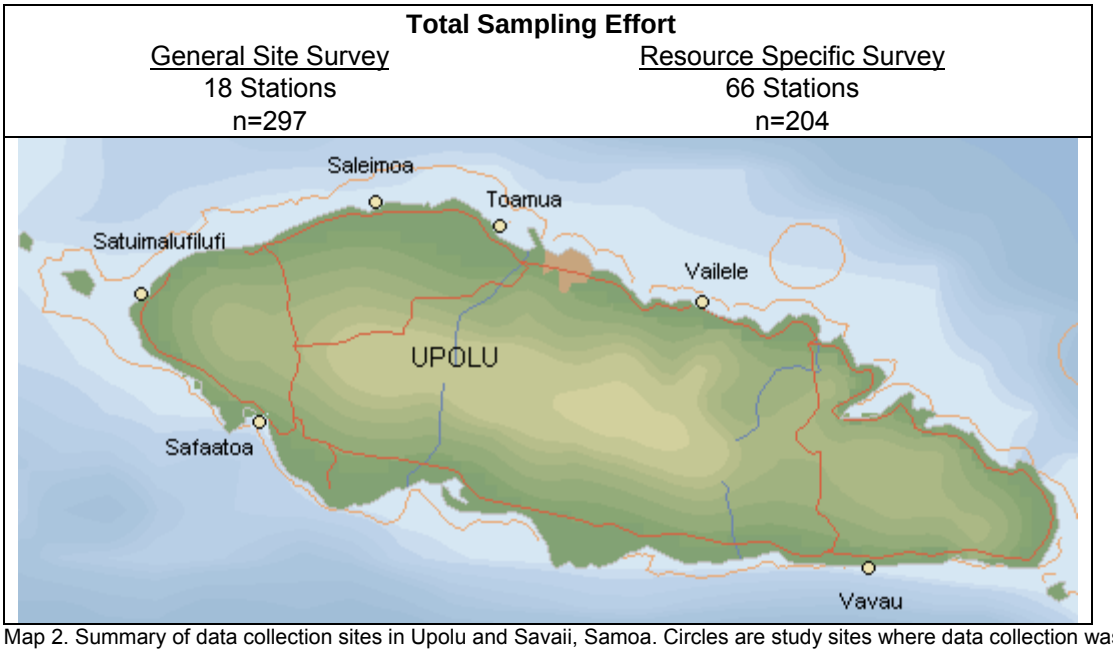
Sea cucumbers are among the targeted fisheries resources in the inshore subsistence fishery. This echinoderm is prevalent in many forms around most tropical waters in the world, and a highly sought for resource in East Asian countries. As food items sea cucumbers possess high nutritional values (Taboada et al. 2003), and are important to the local communities harvesting these resources for subsistence.

In Samoa the local fishers target sea cucumbers for household consumption, to give away as gift or sell at roadside or markets. The sea cucumber resources of the country have never been independently assessed. With the collapse of the commercial fishing for sea cucumbers as beche-de-mer in 1994, a report on the resource status was compiled by Samoan Fisheries Division, based on catch and trade data from the exporters (Mulipola 1994). According to Mulipola (1994) the commercial fishery for beche-de-mer started taking place in Samoa during the 1960's and 70's (no records of catch exist), and there are records of a short beche-de-mer export period in the mid 80's. As a result of the collapse of the fishery in many other pacific countries in the early 1990's the Samoan beche-de-mer resources were once again looked to for exploitation. There were reportedly five companies involved in the export fishery, but all of these only managed to stay economically feasible for a brief period of time (less than 2 years). After this the fishery for sea cucumber for export from Samoa was closed.

In Samoa the sea cucumbers have been recognised as food since the Polynesian people colonised the country (Mulipola 1994). There are mainly two species that are being harvested for subsistence and artisanal purposes, namely, *Stichopus horrens* (local name 'sea') that is fished for its viscera, and *Bohadschia vitiensis* (local name 'fugafuga') that is fished for its body wall. Locally consumed sea cucumber products are generally raw and stored in glass bottles with seawater, but may be cooked on occasion. The products are sought after and regarded somewhat of a delicacy. The bottles are sold at the Fugalei market in Apia on Upolo and at the Salelologa market on Savaii. The bottles are also often used as food-gifts and readily sold at the roadside around the country. In Samoa sea cucumbers are not consumed as beche-de-mer, which refers to boiled and sun dried products. General sea cucumber biology and some regularly found species in Samoa are presented in Appendix 1.

2. Methods

In the in-water survey fishery independent data were collected on the abundance and diversity of sea cucumber species in designated sites (map 2). All in-water survey work was geographically mapped using a hand held Garmin 60® GPS unit.



Map 2. Summary of data collection sites in Upolu and Savaii, Samoa. Circles are study sites where data collection was performed (map derived from www.reefbase.org GIS downloadable files).

The household survey targeted village households to provide information on sea cucumber fishing and consumption. The questionnaire also targeted fishers that harvest sea cucumber, to complement technical data and provide dynamic information on fishing activities and provide insight in fishing purpose (subsistence or artisanal).

2.1 In-water survey

The methodology adopts the wider approach of working at two scales. The reason for this is to have one general site assessment that indiscriminately of benthos provides a subsample of sea cucumber resources from all lagoon habitats within the site, and one resource specific (fine scale) assessment targeting areas where sea cucumbers (in particular high value *S. chloronotus*) are known to occur, or where the habitat is favourable. The precision in the resource specific data is increased through the more accurate sampling technique. As a result the general site sampling is covering all site benthos, whereas the resource specific survey represents the density of resources where they occur.

2.1.1 General site survey, manta tows

Manta board surveys can be used to map reef and lagoon areas. The manta board survey provides the general site survey. The methodology requires access to a small boat and follows the method outlined in English et al. (1997) that is based on a snorkeller getting towed after a boat at low speed hanging on to a board. The board, called a manta board, has waterproof sheets for recording observed data. The board allows the researcher being towed to manoeuvre over particular areas and to dive closer to bottom for species identification. The researcher gets towed over a short distance, during which numbers of species and individuals observed are recorded along with benthos attributes.

The general site survey was performed using an aluminium boat with a 15 hp engine. It required one researcher in the water and at least one person on the craft to manoeuvre the boat

and handle GPS and data sheets for coordinate recording. To gain a high replication, and allowing several independent tows over a wide area, each tow was kept at 100 meters. This is considered a short distance. Performing a higher number of shorter replicates has been shown to increase precision and the effective sample size in other types of surveys (Pennington et al. 2002). During the tow the researcher recorded sea cucumber and indicator species as well as benthos attributes within a two metre swathe. Each survey site was virtually divided into three stations for the broad scale survey; and each station was sampled individually. The stations are; close to shore (in), mid-section of lagoon (mid) and reef side of the lagoon (out) (fig 2.1.1). For each station 18 replicate transects were performed, which means a total of 54 transects for the site. Dividing the lagoon into stations provides the opportunity to discriminate distribution among species within the lagoon.

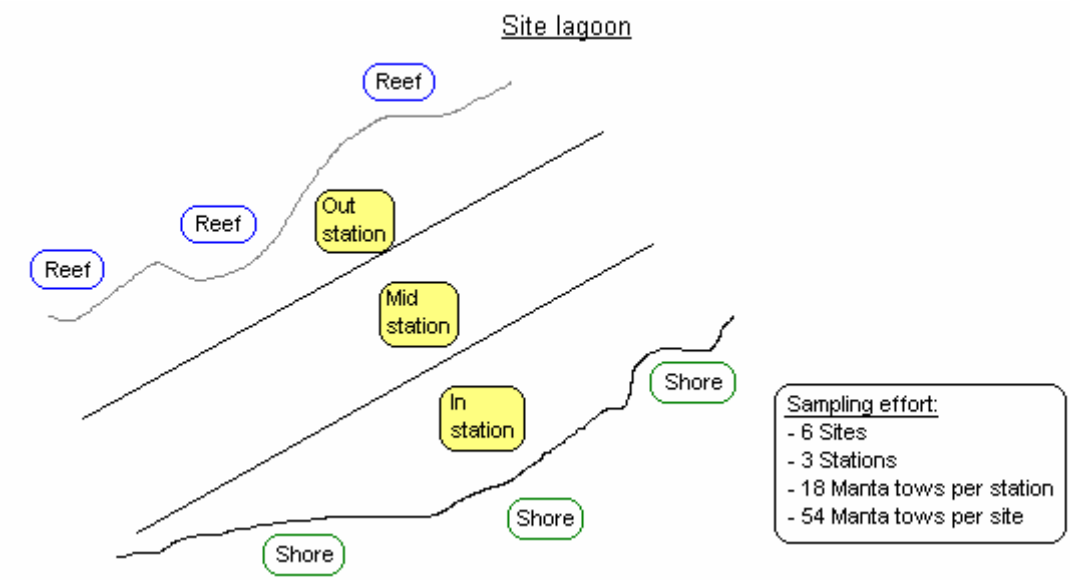


Fig 2.1.1. General site survey overview, for each station (in, mid, out) 18 manta tow replicates were performed.

Ideally, 18x100m tows should have been performed for each station (54 tows in total per site = 5.4 km = 10.8 km^2). Some sites are not big enough to allow for that many tows, instead reliable information of the site was collected at a lower sampling effort (i.e. Vavau, Safaatoa due to MPA). Each tow was performed at approximately 2-4 km/h, speed and distance were calibrated using the trip computer function on a hand held Garmin GPS 60®. The start and end of each manta tow replicate was marked with a waypoint (<10 m) this allows the same sample being taken later in time if necessary.

2.1.2 Resource specific survey, fine scale transects

Within each site, six stations were designated for resource specific transects. These stations were chosen because they had favourable habitat, people commonly fished there, or because a larger number of sea cucumbers had been noted during the general site survey. The position of a resource specific station may be anywhere in the lagoon and follows no strict geographical scheme. However, most stations targeted hard benthos areas in mid lagoon to inside reef as that is the most favourable habitat for the sea cucumber species with commercial value. For each site six stations were sampled and each station consisted of six transect replicates (fig 2.1.2). Targeting aggregated stock areas creates an assessment with high accuracy, and using a high number of replicates within each station provides high precision.

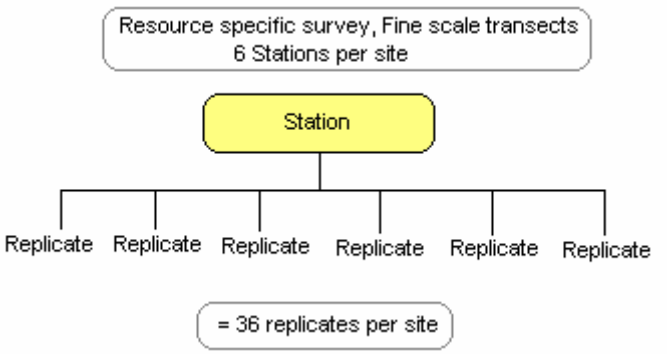


Fig 2.1.2. Resource specific survey overview, for each station six transects replicates were performed

The resource specific survey was carried out using a transect methodology where each transect is 40 m. The transects were laid out randomly within the designated stations at each site, and in shore-reef direction rather than along shore or reef (generally across gradient). Each transect covered a two metre swathe. Within this area benthos were mapped and observed sea cucumber species counted and measured for length. At areas with very high numbers of sea cucumbers, ca 40 individuals were measured for length. This provided a good length subsample of the whole transect (ca 10-100% of observed animals within transect). Each transect was sampled along a 40m tape measure that was laid out before the start of the sampling. In shallow regions where transects were sampled on foot or by swimming, one person held the tape while the other swam holding the other end. A waypoint was marked at the start of the transect (using Garmin GPS 60®). For each time the tape measure was laid out, a transect was performed. At areas with high visibility, two or three transects could be sampled along the tape measure, still trying to maintain symmetry around the tape measure. Each transect was at least 10 meter away from the other within one waypoint.

2.1.3 GPS Coordinate mapping

For all in-water survey work coordinate waypoints (WPTs) were recorded using Garmin GPS 60®. For the general site survey, the waypoint was recorded for the start and stop of each replicate. This also provides the GPS trip computer being used on the boat to calibrate speed and distance for each replicate. Recording coordinates allows calibrating lengths (using Garmin MapSource® software) of the replicate to reweigh the contribution of data input into pooled data (see section 2.3). The resource specific survey uses one WPT per station, but often several WPTs are recorded depending on the width of the station. The GPS records coordinates with a precision of <10m.

2.2 Household survey, socio-economic data

The household survey questionnaire was put together to retrieve information on household consumption on subsistence harvested sea cucumber species. Information such as catches and catch composition, fishing effort and changes in resource availability over time, is revealed trough the questionnaire based interviews. The interviews were performed in Samoan language by Samoan Fisheries Division, Extension and Inshore section. Interviews were performed in all six villages that this study cover. The household survey covers 20% of all households in the village, and a majority (>50%) of the people fishing for sea cucumbers. The US Peace Corps volunteers also assisted in collecting information (in Samoan language) from other villages around both Upolu and Savaii. The US Peace Corps Volunteer data from other villages cover a smaller percentage of the households, but provides a wider ranging dataset.

2.3 Data analysis and presentation

The data are density estimates and presented per species and site, or per species and pooled for all sites. The Results section also presents species distribution data and outcomes from the household survey

All presented density measures are mean values from either stations or transects extrapolated to fit a per ha figure (no. animals x ha^{-2}). Each mean value is presented with its standard error (SE), as a measurement of variation of the recorded densities and calculated means (SE= St.Dev/√(n)). Further, a percentage number describing the presence and absence of each species at transects within the site is included. Density data are given at different scales (table 2.3).

Table 2.3. **Density measures for in-water survey**	
Mean site density	– Is the total site mean density estimate. It utilises the mean of all transect replicates within the site and includes replicates where sea cucumber recordings where absent (record=0). Hence the mean site density will always have the same sample size as the amount of replicates within the site.
Mean presence density	– Is the mean density estimate of the entire site using presence records only (record ≥1). It is the mean of all replicates within the site that has a record of sea cucumbers. Therefore the sample size varies according to each species presence within the site.
Mean station density	– Similarly to mean site density, the mean station density utilises all transect records, including transects where sea cucumbers were absent (record=0). Only the mean station density shows the mean for the discrete station (used for general site survey to compare in, mid and out stations and to present resource specific stations).

The presence of sea cucumbers within the site is also given as a percentage of transect replicates with a recording ≥1.

The mathematical nature of extrapolating the recorded number to a per hectare figure, weighs the data according to deviation in length (i.e. area) from transect to transect. The recorded number of individuals is multiplied with the fraction of the transect area compared to the total area of a hectare. Hence, if the same number of individuals is recoded in two transects with varying length the contribution of species density in the shorter transect is going to be higher than the contribution of the same in the longer transect (see table 2.3.1 for an example).

Table 2.3.1. The area of each transect is a fraction of a hectare. When the record is extrapolated to fit a per hectare figure the area of the transect weighs the contribution of each recording according to relative area to a hectare.

Record	Transect length (m)	Transect area (m^2)	Hectare/Transect fraction	Density (no. animals x ha^{-2})
11	89	178	56,2	618,0
11	100	200	50	550,0
5	118	236	42,4	211,9
32	98	196	51,0	1632,7

Distribution analysis is performed using 2-sample t-test to examine H_0 that there is no difference in location for the examined distributions. To adjust for multiple testing the Dunn-Sidak method is used (Quinn and Keough 2002). The Dunn-Sidak method (equation 1), is a modification from the Bonferroni procedure:

$$\alpha_{(corrected)} = 1-(1-\alpha)^{1/c} \qquad (1)$$

Where; α is the nominated significance level (e.g. 0.05), $\alpha_{corrected}$ is the corrected significance level and *c* is the number of comparisons within the data set. The formula yields a very conservative test when number of comparisons is high (yields a low $\alpha_{corrected}$). Statistical analysis is performed on species specific site- and pooled station data for Samoa. Analysis is performed using statistical software package MINITAB® Release 14.1.

2.3.1 General site survey, manta tows

The recorded benthos data has been aggregated to better fit the purpose of graphic presentation. 'Soft' mean records of all types of soft sediment including sand bottoms; 'Hard' includes rubble, boulders, consolidated rubble and pavemented rubble, 'LiveCoral' is record of live coral, 'DeadCoral' similarly means record of dead coral.

For the general site survey, all three types of the mean density estimates are presented. Mean site density and mean presence density is given together in table format. The general site survey covers the entire site lagoon, and can provide a similar estimate to the resource specific survey on density of sea cucumber resources if presence density is calculated.

The mean station density from the general site survey is also presented. The mean station density is given for each station (in, mid and out) to reveal distribution patterns of encountered species within the site lagoon.

2.3.2 Resource specific survey, fine scale transects

The resource specific survey presents the mean site and station density. Because the fine scale transects already target sea cucumber favourable areas it was thought appropriate to include all transect replicates. Extrapolating data from the fine scale transects to mean presence density would likely over-estimate the density, particularly for species recorded at few transects.

The length recordings from the site are also presented as a length frequency distribution graph, together with mean (±SE) and min and max length values. Length frequency distributions are only given for species with a total number of ca >~30 records. For all other species mean (±SE) together with min and max length values are presented.

3. Results

Results are here presented pooled for all sites and per species. Data on length weight ratio, lagoon distribution and total length frequency distribution are presented for selected species. This chapter also summarizes some of the results from the household survey.

3.1 General site- and resource specific survey

The benthos attributes were mapped for all sites examined during the general site survey (fig 3.1a). No station is entirely exclusive in benthos, where some near shore stations ('in') had more live coral cover than mid and out stations.

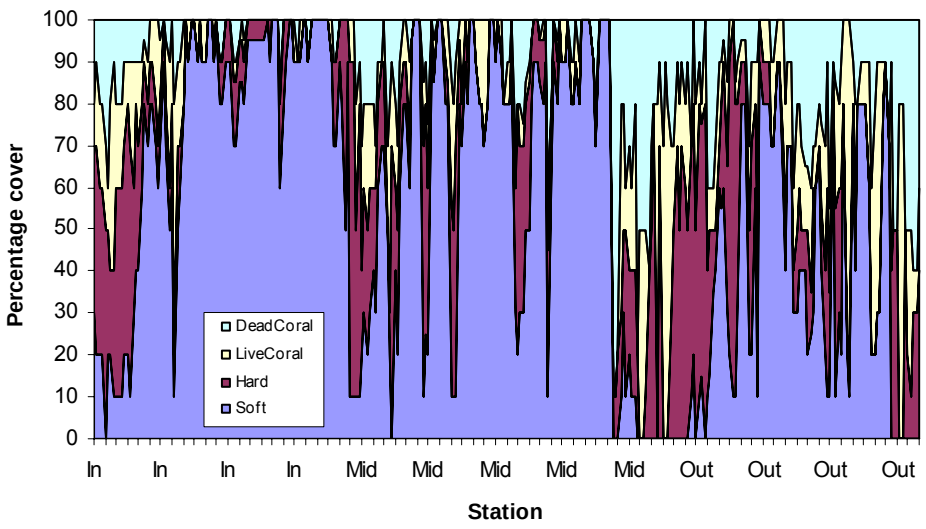


Fig 3.1a. Summary of recorded benthos attributes, where area represents total recorded percentage of particular benthos. Soft: soft sediment i.e. sand silt etc. Hard: Parameters summarize records from 'rubble' 'boulders' 'consolidated rubble' and 'pavemented rubble'. Live- and DeadCoral are percentage record of live and dead coral. (n=297).

A total of seven sea cucumber species was found in the assessed lagoons of which six were recorded in the general site survey, which covered a total area of 6.4 ha (in-station 2.1 ha, mid station 2.2 ha, out-station 2.2 ha). Table 3.1a summarizes the general site survey densities generated for the pooled data from all sites. Two species were recorded at all sites, *Holothuria atra* and *Stichopus chloronotus*, of which *H. atra* showed the absolute highest density. Only one specimen of *Holothuria nobilis* was recorded within the broad scale survey (in Toamua). *Bohadschia argus* was recorded at a low density occurring in 22 manta tow transects at 4 sites. *Bohadschia vitiensis* showed a higher density while occurring in the same amount of transects (but only 3 sites). *Holothuria hilla* was periodically observed.

Table 3.1a. Summary of densities of sea cucumber species for site and presence means of general site survey (broad scale assessment) in Samoa. Data are given as no. animals x ha^{-2} with ±SE. Percentage is number of transects that had a record (hence the variation in n between densities)

Site	Parameter	*B.argus*	*B.vitiensis*	*H.atra*	*H.nobilis*	*S.chloronotus*
Safaatoa (n=50)	*Site (±SE)*	**16,8** (5,8)		**774,3** (238,0)		**171,1** (27,8)
	Presence (±SE)	**93,3** (15,3)		**1382,7** (390,4)		**231,3** (32,2)
	$n_{presence}/n_{site}$ *(%)*	9/50 (18)		28/50 (56)		37/50 (74)
Saleimoa (n=54)	*Site (±SE)*	**6,0** (3,0)	**13,6** (5,6)	**142,5** (30,1)		**53,5** (13,3)
	Presence (±SE)	**65,0** (17,5)	**104,9** (24,0)	**233,1** (42,4)		**120,3** (23,8)
	$n_{presence}/n_{site}$ *(%)*	5/54 (9)	7/54 (13)	33/54 (61)		24/54 (44)
Satuimalufilufi (n=52)	*Site (±SE)*	**4,4** (1,9)	**57,6** (27,7)	**7289,8** (1180,0)		**66,3** (20,6)
	Presence (±SE)	**45,5** (1,2)	**230,3** (98,6)	**7289,8** (1180,0)		**181,5** (46,2)
	$n_{presence}/n_{site}$ *(%)*	5/52 (10)	13/52 (25)	52/52 (100)		19/52 (37)
Toamua (n=54)	*Site (±SE)*	**3,0** (1,7)	**2,9** (2,2)	**2359,7** (543,0)	**0,9** (0,9)	**20,6** (6,2)
	Presence (±SE)	**53,5** (1,8)	**78,7** (26,6)	**2770,1** (618,3)	**50,0** (-)	**79,6** (15,4)
	$n_{presence}/n_{site}$ *(%)*	3/54 (6)	2/54 (4)	46/54 (85)	1/54 (2)	14/54 (26)
Vailele (n=53)	*Site (±SE)*			**948,3** (427,8)		**18,0** (6,6)
	Presence (±SE)			**1738,9** (731,0)		**89,6** (22,0)
	$n_{presence}/n_{site}$ *(%)*			30/53 (56)		11/53 (20)
Vavau (n=34)	*Site (±SE)*			**2,9** (2,1)		**13,3** (5,0)
	Presence (±SE)			**50,1** (5,5)		**64,7** (10,2)
	$n_{presence}/n_{site}$ *(%)*			2/34 (6)		7/34 (21)
Total (n=294)	*Site (±SE)*	**5,2** (1,2)	**13,1** (5,1)	**2037,6** (284,1)	**0,2** (0,2)	**58,6** (7,3)
	Presence (±SE)	**70,6** (8,3)	**176,6** (59,6)	**3168,4** (420,3)	**50,0** (-)	**154,1** (15,4)
	$n_{presence}/n_{site}$ *(%)*	22/297 (7)	22/297 (7)	191/297 (64)	1/297 (0)	112/297 (38)

The resource specific survey found seven species in the surveyed sites around Upolu and covered a total of 1.6 ha. It was performed in 204 replicates over 24 stations. Data from the resource specific survey are summarized in table 3.1b. The two species recorded at the most stations and sites were again *H. atra* and *S. chloronotus*, of which *H. atra* was recorded at the highest density. One specimen of *H. nobilis* was recorded within the resource specific survey. *B. vitiensis* and *B. argus* again showed similar occurrence (11 and 7 transects respectively). *H. hilla* and *S. horrens* were only sporadically encountered.

Table 3.1b. Summary of sea cucumber mean site density of resource specific survey (small scale assessment) in Samoa. Data is given as no. animals x ha^{-2} with ±SE. Percentage is number of transects that had a record (also presented in actual numbers (n))

Site	Parameter	*B.argus*	*B.vitiensis*	*H.atra*	*H.nobilis*	*S.chloronotus*
Safaatoa (n=30)	*Mean (±SE)*	**4,2** (4,2)	0,0	**4 637,5** (1060,6)	0,0	**287,5** (54,7)
	$n_{presence}/n_{site}$ *(%)*	1/30 (3)	0/30	28/30 (93)	0/30	24/30 (80)
Saleimoa (n=36)	*Mean (±SE)*	**6,9** (4,8)	0,0	**357,6** (68,3)	**3,5** (3,5)	**309,0** (46,0)
	$n_{presence}/n_{site}$ *(%)*	2/36 (6)	0/36	22/36 (61)	1/36 (3)	28/36 (78)
Satuimalufilufi (n=36)	*Mean (±SE)*	**10,4** (7,7)	**59,0** (30,5)	**12 656,3** (2137,9)	0,0	**118,1** (35,5)
	$n_{presence}/n_{site}$ *(%)*	2/36 (6)	4/36 (11)	36/36 (100)	0/36	13/36 (50)
Toamua (n=36)	*Mean (±SE)*	**13,9** (8,3)	**13,9** (8,3)	**1 055,6** (155,9)	0,0	**135,4** (37,4)
	$n_{presence}/n_{site}$ *(%)*	3/36 (8)	3/36 (8)	33/36 (92)	0/36	16/36 (44)
Vailele (n=36)	*Mean (±SE)*	**3,5** (3,5)	0,0	**3 083,3** (1313,8)	0,0	**229,2** (43,8)
	$n_{presence}/n_{site}$ *(%)*	1/36 (3)	0/36	36/36 (100)	0/36	25/36 (69)
Vavau (n=30)	*Mean (±SE)*	**12,5** (9,2)	0,0	**4,2** (4,2)	0,0	**37,5** (13,6)
	$n_{presence}/n_{site}$ *(%)*	2/30 (7)	0/30	1/30 (3)	0/30	7/30 (23)
Total (n=204)	*Mean (±SE)*	**8,6** (2,7)	**12,9** (5,7)	**3 709,6** (559,0)	0,6 (0,6)	**187,5** (17,7)
	$n_{presence}/n_{site}$ *(%)*	11/204 (5)	7/204 (3)	156/204 (76)	1/204 (0)	113/204 (55)

3.1.1 *H. atra*

The most prevalently occurring species was *H. atra.* It was found at all sites and with a recording in 64% of all broad scale transects in the general site survey (table 3.1a). The density of the lollyfish was also the highest among the recorded species and records range from 0 to 33 950 animals per ha over all broad scale transects. The mean site density varied (fig 3.1.1a), with Satuimalufilufi showing the significantly highest record (table 3.1.1a). The lollyfish was distributed throughout the entire lagoon but showed a higher record in near shore and reef side stations than in mid stations (t-test $(\alpha_{corrected} = 0,017)$; In/Mid: p=0.001 df;102; In/Out p=0,189 df;143 Mid/Out p=0,000 df;123) (fig 3.1.1b).

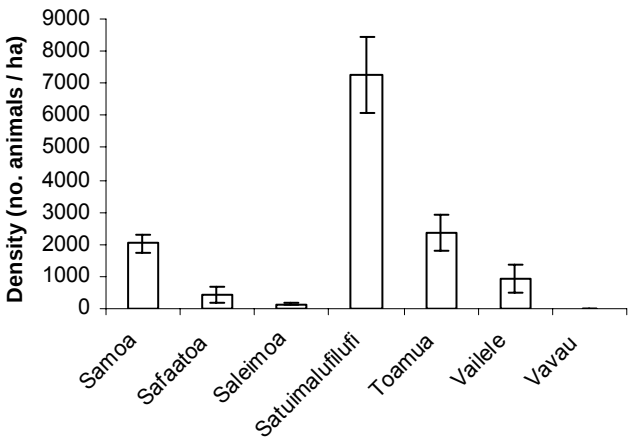


Fig 3.1.1a. Site means for *H. atra.* Bars are SE. Samoa is total sampled mean for all sites in Samoa.

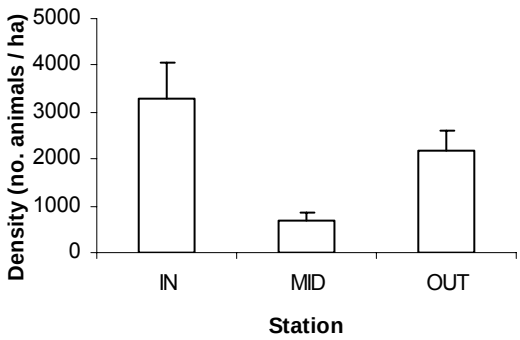


Fig 3.1.1b. Distribution of *H. atra* within lagoon stations for general site survey in Samoa. Bars are SE.

Table 3.1.1a. Multiple univariate analysis of distribution means between all sites where *H.atra* was recorded. T-test analysis was performed on each possible combination of site means. α is corrected using Dunn-Sidak procedure*.

	Safaatoa	Saleimoa	Satuimalufilufi	Toamua	Vailele
Saleimoa	*p*=0,011 *df*;50				
Satuimalufilufi	*p*=0,000 *df*;55	*p*=0,000 *df*;51			
Toamua	*p*=0,009 *df*;72	*p*=0,000 *df*;53	*p*=0,000 *df*;71		
Vailele	*p*=0,669 *df*;80	*p*=0,055 *df*;52	*p*=0,000 *df*;64	*p*=0,049 *df*;99	
Vavau	*p*=0,002 *df*;49	*p*=0,000 *df*;53	*p*=0,000 *df*;51	*p*=0,000 *df*;53	*p*=0,026 *df*;52

*$\alpha_{corrected}$=0,003

The resource specific survey revealed a density almost twenty-fold that of any other species (table 3.1b). It was found in a majority of stations, with the exception of Vavau, where it was only found in one transect (fig 3.1.1c). Satuimalufilufi showed the absolute highest densities of this species within the small scale transects (fig 3.1.1c).

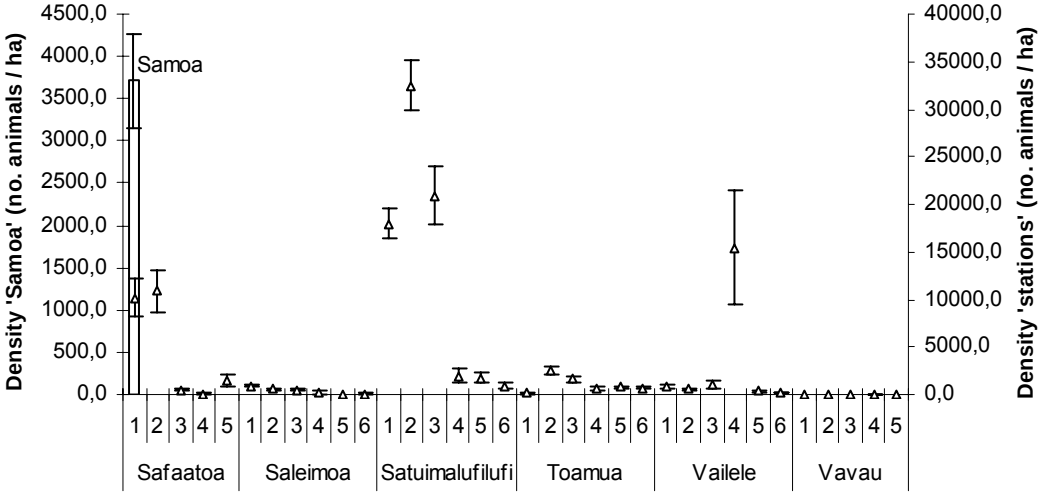


Fig 3.1.1c. Records from all stations within all sites for *H.atra*. Mean is mean station density and bars are SE. Transparent bar ('Samoa') is the total sampled mean.

H.atra showed a unimodal length frequency distribution with a clear mode at 110 and 120 mm (n=1841) (fig 3.1.1d). The species had an overall mean length (±SE) of 119.4 ± 0.7 mm. The longest specimen measured was 260 mm and the shortest was 20 mm.

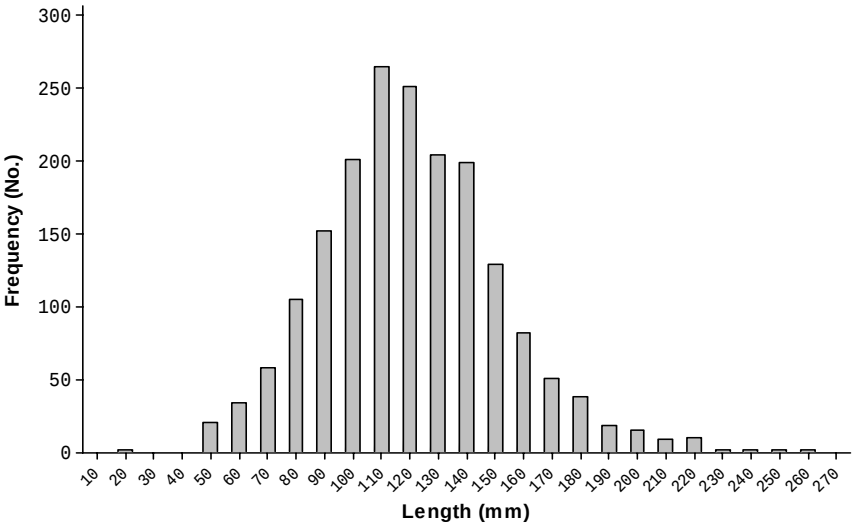


Fig 3.1.1d. Length frequency distribution for *H.atra* across all sites in Samoa (n=1841).

For *H. atra* a length weight correlation was established. The logarithm-transformed data show a good linear relationship (r^2=0.73; y=1.9215x – 2,028) (n=148) (fig 3.1.1 e and f).

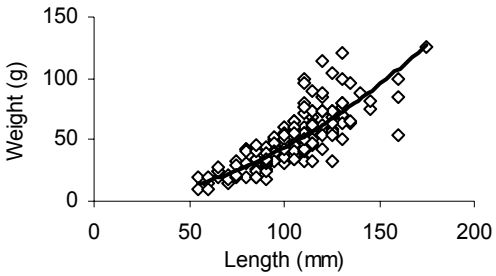


Fig 3.1.1e. Length weight relationship for *H. atra*
Data collected from specimens in Vailele, Samoa.
Power analysis: R^2=0.72 (n=148).

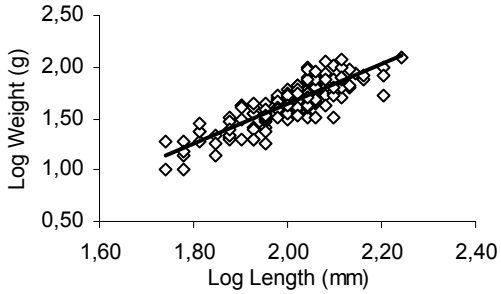
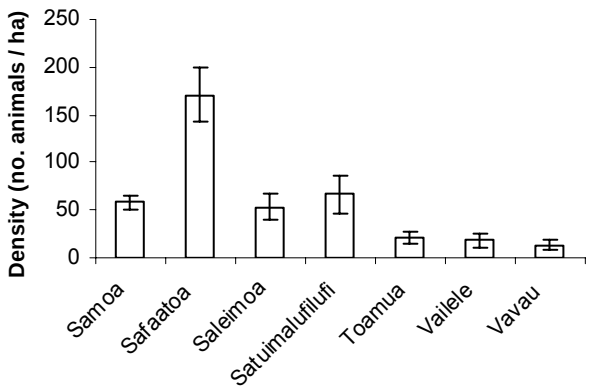


Fig 3.1.1f. Logarithmic length weight relationship for *H. atra*.
Data collected from specimens in Vailele, Samoa.
Linear regression: r^2=0.72 (y=1.9215x – 2,028) (n=148).

3.1.2 *S. chloronotus*

S. chloronotus was the second most occurring species within surveyed sites (table 3.1a). The mean site density recorded in the general site survey varied between sites. Safaatoa showed a significantly higher density than all other sites, whereas no other significant difference was detected (fig 3.1.2a and table 3.1.2). The greenfish was present in 38% of all manta board transects and showed a slightly higher distribution in mid-station compared to out-station, whereas there was no significant difference between other station comparisons (t-test *($\alpha_{corrected}$ = 0,017)*; In/Mid: *p*=0.060 *df*;193; In/Out *p*=0,043 *df*;138 Mid/Out *p*=0,000 *df*;134) (fig 3.1.2b). The greenfish, which is the only species of higher value found in this survey, was recorded at a density interval of 0 - 485.4 animals x ha^{-2}.



3.1.2a. Site means for *S.chloronotu,* Bars are SE.
'Samoa' is total sampled mean for all sites in Samoa.

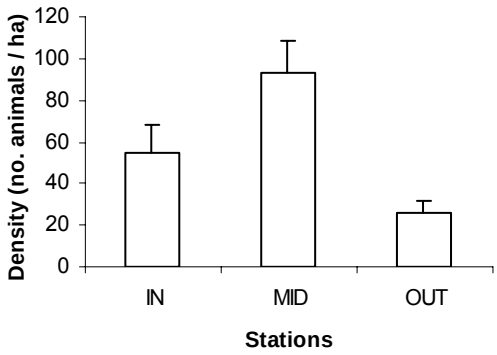


Fig 3.1.2b. Distribution of *S. chloronotus* within lagoon stations for general site survey in Samoa. Bars are SE.

Table 3.1.2. Multiple univariate analysis of distribution means between all sites where *S. cloronotus* was recorded. T-test analysis was performed on each possible combination of site means. α is corrected using Dunn-Sidak procedure*.

	Safaatoa	Saleimoa	Satuimalufilufi	Toamua	Vailele
Saleimoa	*p*=0,000 *df*;70				
Satuimalufilufi	*p*=0,003 *df*;91	*p*=0,601 *df*;87			
Toamua	*p*=0,000 *df*;53	*p*=0,028 *df*;74	*p*=0,038 *df*;60		
Vailele	*p*=0,000 *df*;54	*p*=0,019 *df*;77	*p*=0,029 *df*;61	*p*=0,768 *df*;104	
Vavau	*p*=0,000 *df*;52	*p*=0,006 *df*;66	*p*=0,015 *df*;56	*p*=0,357 *df*;85	*p*=0,572 *df*;84

*$\alpha_{corrected}$=0,004

The resource specific survey found *S. chloronotus* in a majority of stations across all sites (fig 3.1.2c).

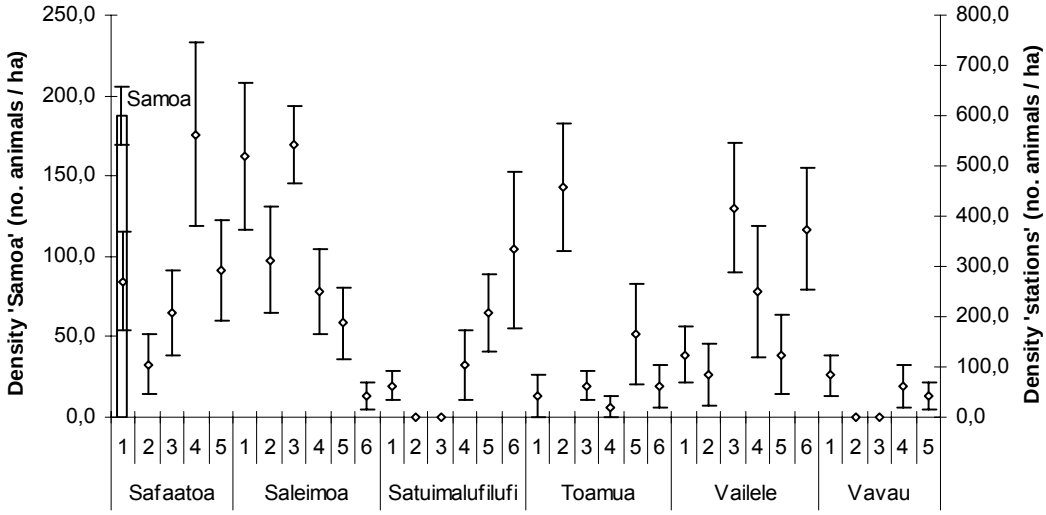


Fig 3.1.2c. Records from all stations within all sites for *S. chloronotus*. Mean is mean station density and bars are SE. Transparent bar ('Samoa') is the total sampled mean.

S. chloronotus was recorded at a mean length (±SE) of 168.4± 2.7 mm, with a maximum recording of 350 mm and a minimum recording of 50 mm. The length frequency distribution shows a split peak with two modes at 150 mm and 180 mm (n=359) (fig 3.1.2d).

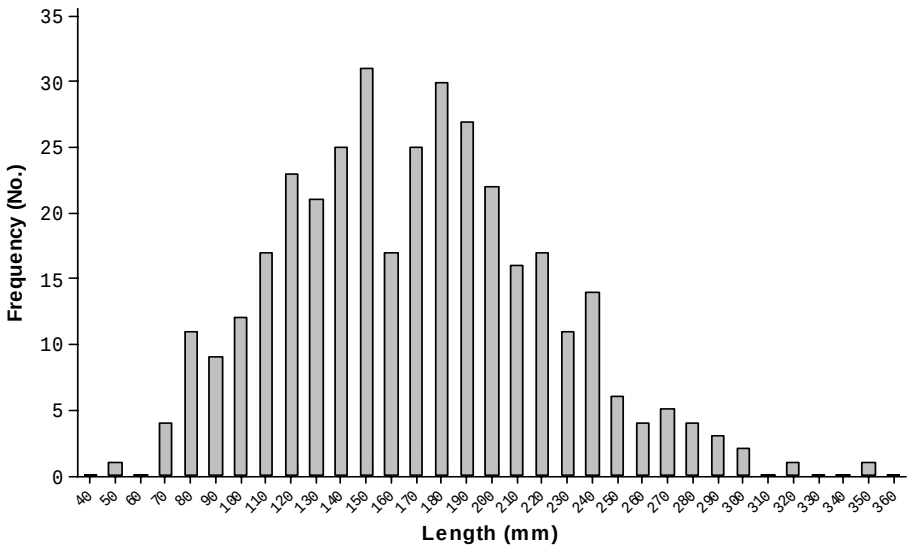


Fig 3.1.2d. Length frequency distribution for *S. chloronotus* for pooled data across sites in Samoa (n=359).

For *S. chloronotus* samples were taken for length weight relationship estimate (fig 3.2e and f). The relationship shows a strong logarithmic linear relationship (r^2=0.84; y=1,9178x – 2,026) (n=48).

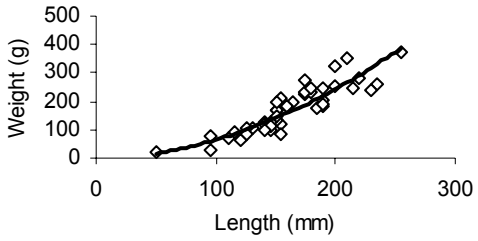


Fig 3.1.2e. Length weight relationship for *S. chloronotus* in Samoa. Specimens collected in Vailele.
Power analysis: R^2=0.84 (n=48)

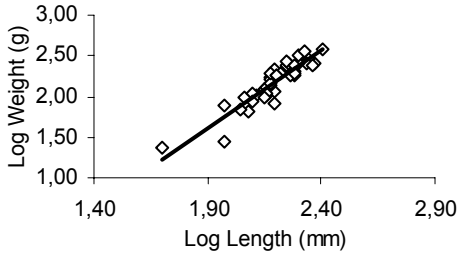


Fig 3.1.2f. Logarithmic length weight relationship for *S. chloronotus* in Samoa. Specimens collected in Vailele. Linear regression: r^2=0.84 (y=1,9178x – 2,026) (n=48).

3.1.3 *B. vitiensis*

The brown sand fish was found in 7% of all general site survey transects (table 3a). It was recorded in a density range of 0 to 1336.2 animals x ha^{-2}. *B. vitiensis* was recorded at three sites and no significant difference in densities was detected (table 3.1.3). The brown sandfish was recorded in higher numbers in mid stations but no significant difference was recorded in means between broad scale stations (t-test *($\alpha_{corrected}$ = 0,017)*; In/Mid: p=0.082 df;105, In/Out p=0.868, df;170 Mid/Out p=0.078 df;109) (fig 3.1.3b).

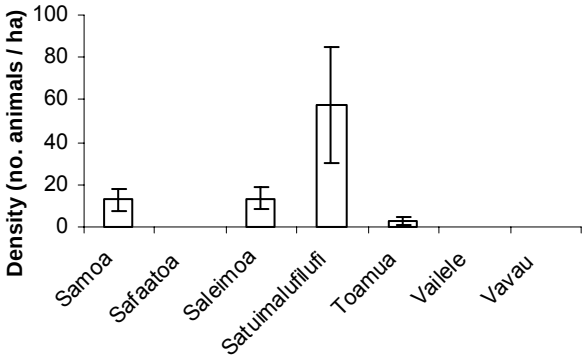


Fig 3.1.3a. Site means for *B. vitiensis*. Bars are SE. 'Samoa' is total sampled mean for all sites in Samoa.

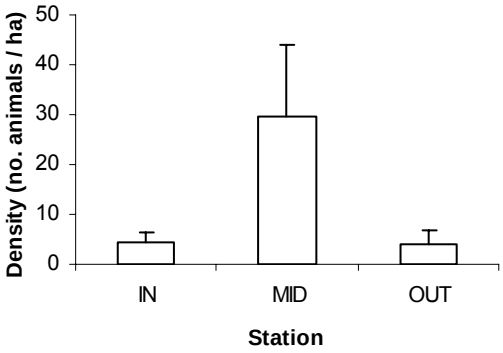


Fig 3.1.3b. Distribution of *B.vitiensis* within lagoon stations for general site survey in Samoa. Bars are SE.

Table 3.1.3. Multiple univariate analysis of distribution means between all sites where *B. vitiensis* was recorded. T-test analysis is performed on each possible combination of site means. α is corrected using Dunn-Sidak procedure*.

	Saleimoa	Satuimalufilufi
Satuimalufilufi	*p*=0,125 *df*;55	
Toamua	*p*=0,082 *df*;68	*p*=0,054 *df*;51

*$\alpha_{corrected}$=0,017

The small scale transects in the resource specific survey identified this species on few occasions (in two sites, Satuimalufilufi and Toamua) and revealed a modest density (fig 3.1.3c).

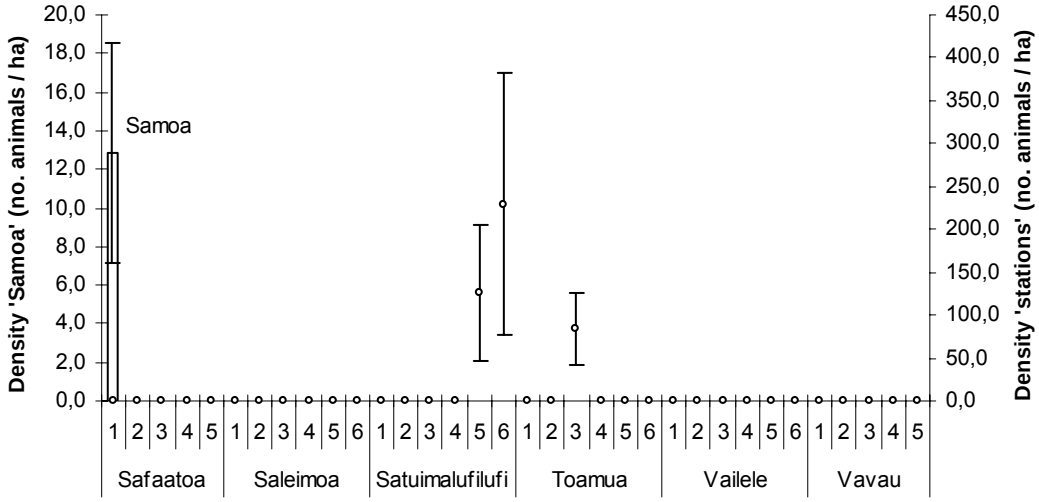


Fig 3.1.3c. Records from all stations within all sites for *B. vitiensis*. Mean is mean station density and bars are SE. Transparent bar ('Samoa') is the total sampled mean.

B. vitiensis was recorded to have a mean length (±SE) of 239.0 ± 9.0 mm, with a maximum recording of 320 mm and a minimum of 160mm.

3.1.4 *B. argus*

The tigerfish occurred in 7% of the broad scale survey transects (table 3a) and was recorded at a density range of 0 to 154.6 animals x ha^{-2} during broad scale surveys. *B. argus* was found in four out of the six surveyed sites (fig 3.1.4a) and only found in mid and out-stations (fig 3.1.4b). No difference was detected in density between mid and out station (t-test; p=0.092 df; 184). The site distribution to outer parts of lagoon is also reflected in that it was found in higher numbers in the small scale transects, targeting hard benthos areas (often reef back), than in the general site survey (table 3b).

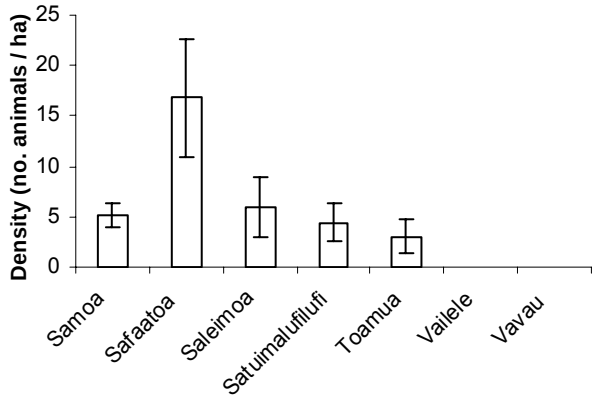


Fig 3.1.4a. Site means for *B. argus.* Bars are SE. 'Mean' is total sampled mean for all sites in Samoa.

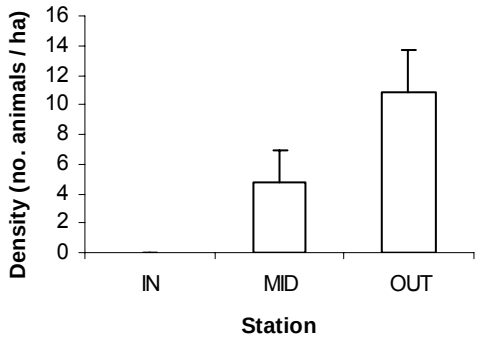


Fig 3.1.4b. Distribution of *B. argus* within lagoon stations for broad scale survey in Samoa. Bars are SE.

Analysis of distribution means show no significant difference in densities between sites (with a record) in the general site survey (table 3.1.5).

Table 3.1.4. Multiple univariate analysis of distribution means between all sites where *B.argus* was recorded. T-test analysis was performed on each possible combination of site means. α is corrected using Dunn-Sidak procedure*.

	Safaatoa	Saleimoa	Satuimalufilufi
Safaatoa			
Saleimoa	*P*=0,101 *df*;73		
Satuimalufilufi	*P*=0,045 *df*;59	*p*=0,641 *df*;89	
Toamua	*P*=0,025 *df*;57	*p*=0,375 *df*;83	*p*=0,580 *df*;102

*$\alpha_{corrected}$=0,008

The resource specific survey found *B. argus* in all sites but occurrence was sporadic (fig 3.1.4c).

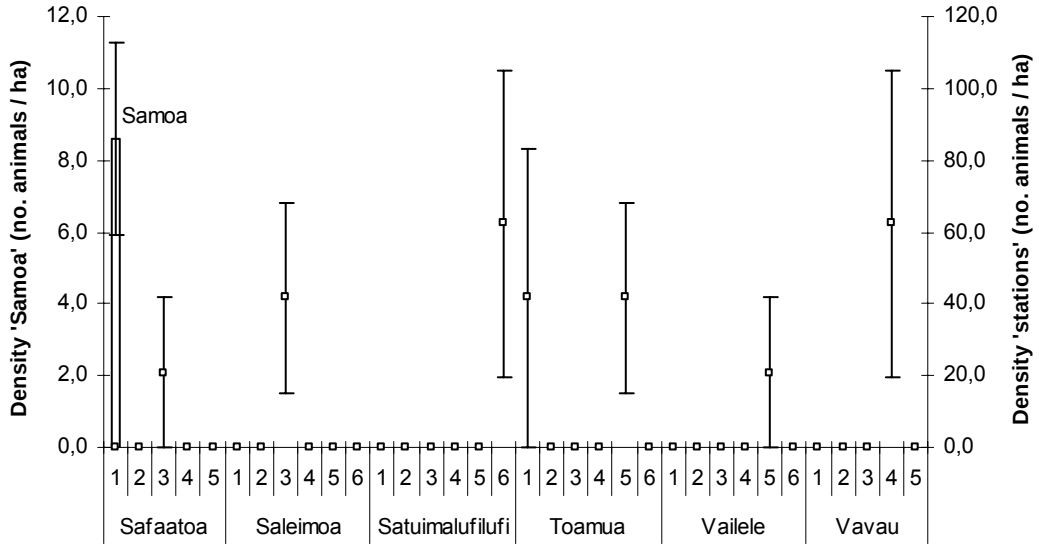


Fig 3.1.4c. Records from all stations within all sites for *B.argus*. Mean is mean station density and bars are SE. Transparent bar ('Samoa') is the total sampled mean.

B.argus was recorded at a mean length (±SE) 295.4 ± 18.4 mm with a maximum recording of 470mm and a minimum of 250 mm.

3.1.5 *H.nobilis*

The black teatfish was only found in two sites, Saleimoa and Toamua, with one specimen recorded at each site.

3.1.6 *S.horrens* and *H.hilla*

H.hilla and *S.horrens* were sporadically encountered.

3.2 Household survey, socio-economic questionnaire

The following summarizes some of the trends and answers collected through the questionnaire based village household interviews. To obtain better accuracy, answers or entire questionnaires that do not seem reliable have been removed.

A total of 109 reliable interviewees from 11 villages were fishers, out of which 85 said that sea cucumbers are their main fishing target. Many of these fishers have been fishing for a long time (the majority between 10- and 40 years) with the exception of fishers in Auala and Salua where many answered that they have been fishing for a year, which may indicate a recent demand in the region. When asked how many men and women fish in their village, the answer varied depending on who was asked and in what village. Reported numbers are summed (with mean reported number of fishers from each village) and show that over 11 villages a total of 89 men and 116 women regularly fish for sea cucumbers (table 3.2a).

Table 3.2a. Summary of reported number of fishermen and women across 11 villages where interviews were performed by Samoan Fisheries and US Peace Corps in Samoa.

Village	MEN	WOMEN
Auala	8	9
Salua	11	11
Amaile	-	8
Salepouae	11	22
Saleimoa	7	8
Vavau	6	8
Toamua	4	8
Safaatoa	8	12
Vailele	6	15
Satuimalufilufi	12	13
Faleasiu	14	2
Total	89	116

No offshore fishing activity at all was recorded but all fishing was targeting reef or lagoon areas (fig 3.2a). Further, most fishers answered that they fish 1-2 times per week and 12% answered that they fish every day (not on Sundays) (fig 3.2b).

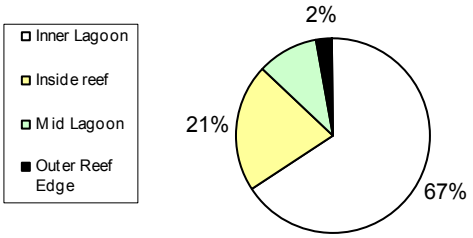


Fig 3.2a. Areas targeted by fishers for sea cucumber.

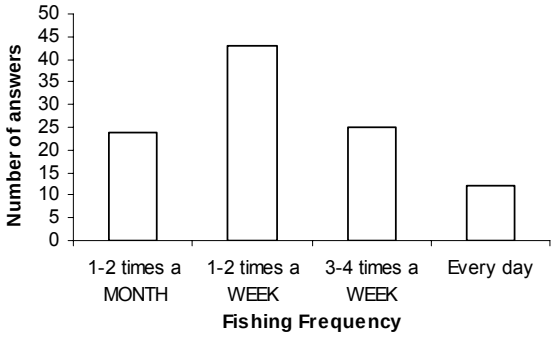


Fig 3.2b. Fishing frequency among 109 fishers in 11 villages.

The household survey further found that the interviewed fishers, with reliable answers in this section (n=104), perform a total of 236 trips per week (average 2.3 fishing trips per week and each trip is on average 2.7h).

Catch composition shows that fishers regularly target three species, *S. horrens, B. vitiensis* and *H. atra*. 2% answered that they fish for *S. chloronotus*, but this seems unlikely as no one eats this species in Samoa. The fisher may be referring back to export years when *S. chloronotus* was fished for commercial purposes (fig 3.2c).

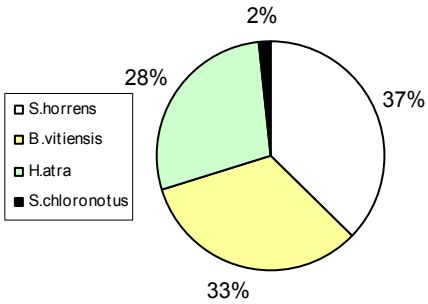


Fig 3.2c. Target species of sea cucumbers according to fishermen (n=109).

As an estimate on trends in subsistence catches over recent years the interviewees were asked whether he/she has noted a difference in availability of sea cucumbers. The answers diverged and were to some extend different depending on species. The general opinion however was that there has been a negative trend in catches and availability since export years and cyclones (particularly Heta) (fig 3.2d). Some interviewees also argued that they have not detected a difference or in some instances a positive trend was suggested.

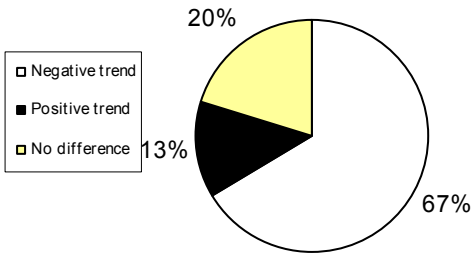


Fig 3.2d. Distribution of interviewees' opinion on catch trends in Samoa. Most of them said that there is a negative trend in catch/availability of sea cucumbers over past 5 to 10 years (n=104).

The majority of fishermen arguing for a negative trend said that the two most affected species are *S. horrens* and *B. vitiensis*. *H. atra* does not seem to be as badly affected although some fishers said that lollyfish stocks in their village (Auala) never really recovered from commercial harvest. In terms of greenfish, interviewees said that stocks suffered severely from cyclone Heta and have not returned to similar numbers as before. It should also be noted that some fishers said that they believed marine reserves in Safaatoa and Vavau has contributed to an increase in sea cucumbers. Similarly, the fishers where asked if there are more people selling sea cucumbers now than ten years ago. Most people answered that there are more today, while some said that there are fewer or equally many (fig 3.2e).

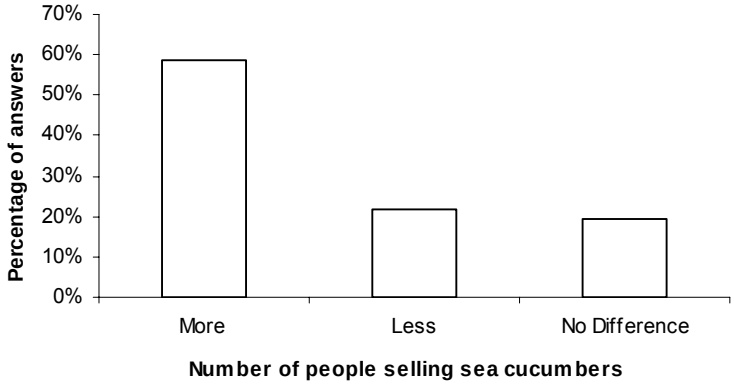


Fig 3.2e. The general perception whether there are more people selling sea cucumbers. A majority answered that there it is more common today than five years ago.

When asked about the fractions of catch sold most interviewees answered that none of their catch is sold (fig 3.2f). It seems that only ca 10% of fishers sell all their catch. The fraction of answers stating that none of their catch is sold may be an overestimate as several people that do not fish answered the question (likely referring to fishing family members). Still, it remains likely that the majority of fishers keep most of their catch within their family.

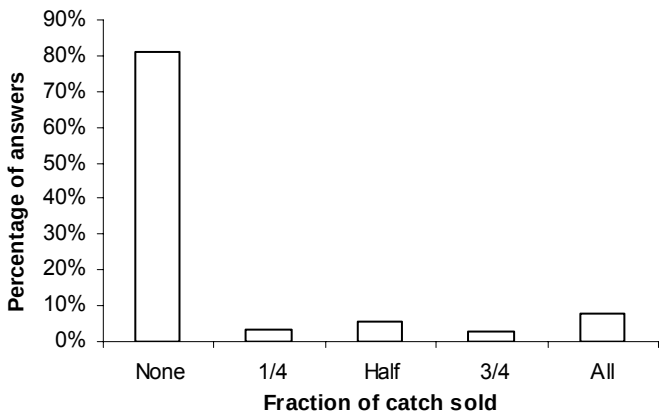


Fig 3.2f. Fraction of sea cucumber catch sold. Most fishers sell none of their catch but keep it for family consumption (n=317).

4. Discussion

The survey found seven species of sea cucumber, out of which two were more frequently encountered (i.e. *H. atra* and *S. chloronotus*). Most encountered species were of low to moderate value. The study failed to find some important commercial species such as; *Actinopyga mauritiana* (Surf redfish), *Thelenota ananas* (Prickly redfish) and *Holothuria fuscogilva* (White teatfish) – all of which were exported from Samoa previously (but survey did not cover reeffront and deeper waters). The distribution of species was found to be heterogeneous. Even within the resource specific survey's small scale transects, that were targeting similar types of biotopes consistently the distribution of species densities is heterogeneous. Heterogeneous distribution has been presented before (Pouget 2004) and is an important feature that should be kept in mind when assessing stocks of this resource. The spatial scale of the survey did not permit abundance correlations to benthos.

The benthos mapping showed that several types of substrates may occur within a wider part of the lagoon, and that no single station is mutually exclusive in substrate. One lagoon's out-station may resemble another lagoon in-station. In essence a specific habitat emerges from a variety of geographic and geomorphological properties of the lagoon (e.g. width, aspect, depth, reef type (fringing/barrier), freshwater and sea water influx) as well as anthropological factors (Tenore et al. 2006; Núñes-Lara et al. 2005). As a result a variety of species may be expected to be found in both near shore and reef back areas in different lagoons, depending on the attributes of each lagoon since the distribution of sea cucumber species is strongly determined by habitat (Dzeroski and Drumm 2003; Uthicke and Karez 1999). The distribution analysis performed here covers a variety of lagoon types and not specific benthos. The wider range of lagoon types included here provides reliability to presented results in that it better represents the wide types of occurring lagoons along the Samoan coastline. It should also be noted that the wide density ranges for these species provide mean values with high deviations (ultimately a result of a patchy distribution), and the analysis of data was performed using a conservative approach (Dunn-Sidak variant of a Bonferroni correction of significance level). This makes it difficult to detect statistically significant levels of variation between sites and stations.

4.1 Assessment of Samoa sea cucumber stocks

The household survey pointed out that the trend in availability of sea cucumbers is that the catches are lower today than five to ten years ago - with some interviewees claiming previous commercial fishing and cyclone damage as contributing factors to the low numbers. The overall low recorded densities may be a result of several factors. When spawning, the success

of oocyte fertilisation is dependant on proximity to partner. In an already transparent population the recovery may require several generations because of this. The density dependant success of fertilisation in conjunction with the low numbers likely caused by previous commercial fishery and cyclone damage may provide an answer to the recorded moderate density for many species. Further, the recent terrestrial and coastal development may have resulted in loss of preferred settlement areas and/or unfavourable environment factors, such as variation in salinity and pH or toxins in the water column. Both substrate and environment have been showed to affect spawning as well as larval settlement and development (Asha and Muthiah 2005; Mercier et al. 2000; Battaglene et al. 2002). Therefore decrease in recruitment may be expected in disturbed coastal zones.

This survey did not cover any areas of deeper water where firstly, other species may have been encountered, and secondly higher densities of recorded species may have been found. In a fished population of *H. scabra* in the Red Sea, Hasan (2005) found that as fishing progressed the deeper zones became sanctuaries from fishers. Other studies have also shown that underwater breathing devices are employed when shallow water stock is depleted or over fished. This is an incentive not to allow SCUBA or Hookah gear. Although genetic work on population genetics and dispersal exist (Uthicke and Benzie 2003; Uthicke and Purcell 2004), the role that deeper areas and un-fished zones play in recruitment processes is not scientifically established.

4.1.1 *H. atra*

H.atra was found in the absolute highest numbers. This species was found in seemingly all occurring habitat across lagoons in various densities but was more commonly found in near shore and reef back areas. This species is generally also the most common species in the Indo-Pacific region (Uthicke 2001; Conand 2004; Pouget 2005). The small scale stations in Satuimalufilufi recorded this species in very high numbers. The dense patch found at the site is likely a result of relatively still water generating a high amount of detritus providing rich feeding opportunities. Although Samoan density is relatively high Conand (2004) when performing a study on Reunion Island (Indian Ocean), reported a mean density of 48 000 animals x ha^{-2} (4.8 specimens x m^{-2}) over eight years in a stable population. Densities reported from Mayotte, Indian Ocean, are not of the same magnitude as presented here (88 animals x ha^{-2} compared to 3710 animals x ha^{-2} in small scale transects targeting similar benthos) (Pouget 2005). The lollyfish is not a commercially valued species, it is usually harvested when stocks of high value species are depleted. It was the least paid for product during export years in Samoa.

One important note to make on *H. atra* length records is that results show on average short individuals. The largest individual of *H. atra* recorded in this study in Samoa was 260 mm, with a mean length (±SE) of 119.4±0.7mm. In Papua New Guinea (PNG) there is a minimum legal length (MLL) restriction set at 300 mm as a management regulation. Utilizing the PNG MLL would not allow any *H. atra* catch in Samoa. The variation in size could be a response to environmental factors. Further, if the length information is used in conjunction with that of price depending on beche-de-mer size, it is probable that because of the small size of *H. atra* specimens from Samoa, they may provide a lower price (Lo 2004; South Pacific Trade Commission 1996). Still, because they occur in such high numbers in easy accessible shallow water, Sri Lanka fishermen earned their living from this species and *H. edulis* (Terney Pradeep Kumara 2005). In the long run though, the high catch required to maintain income caused stocks to dwindle, with fishermen now using SCUBA gear in distant deep water areas. In conclusion the high densities recorded from *H. atra* favour a possibility of increased harvest. However the already low value of the species and the modest size of the specimens

would require large catches to yield return, which may result in over fishing and a probable conflict with traditional harvest.

4.1.2 *S .chloronotus*

The commercially important *S. chloronotus* was found in lower numbers than expected considering the absence of fishing pressure and time to recover. Generally across most sites there is seemingly good habitat but the numbers remain moderate, possibly a result of cyclone damage according to some household survey notes. The survey site of Safaatoa in Lefaga bay on the south side of Upolu recorded the highest numbers of this species. The Safaatoa site differed from the others in that it was rich in hard substrate and had a higher oceanic influence than the sites in the more urbanised regions on the north and north-western shorelines. It is possible that the relatively high ocean influx, hard substrate and less anthropogenic effect (and possibly proximity to healthy mangrove regions) may contribute to the relatively high densities. In general the Safaatoa site also held seemingly healthier coral communities.

The greenfish has been surveyed in other areas and as a comparison of records from Samoa, the densities can be balanced to recent data out of Kosrae state, Federated States of Micronesia (Lindsay and Abraham 2004). There *S. chloronotus* occurred in 20% of all transects, compared to 38% found in the general site survey and 55% in the resource specific survey in Samoa. The study in Kosrae further found greenfish at a density of 150 animals per hectare (which is a dramatic decrease from a 1997 study of 12 100 animals per hectare (reported 1.21 animals x m^2)). Here a mean density of ca 60 animals per hectare for the general site survey and almost 190 animals per hectare for the resource specific survey were recorded. These records show a lower density for the general sites. However the surveyed area by Lindsay and Abraham (2004) better match that of the area included within small scale stations, which show that Samoa holds a slightly larger density (190 animals/ha compared to 150 animals/ha). It should here be noted that Lindsay and Abraham (2004) suggest a complete ban on commercial harvest of sea cucumber in Kosrae due to declining stocks and unsatisfying management. Harvested individuals of this species degenerates rapidly and harvesting and processing procedures needs to be careful to assure high quality products.

The greenfish densities found here can further be compared to those of the moderately fished island of Mayotte in the Indian Ocean outside East Africa's coast. Where a mean density of 6 animals x ha^{-2} was found during inventory on outer reef flats (Pouget 2005). It is possible that the low amount of replication used in the Pouget (2005) survey did not fit the patchy distribution of these organisms. This becomes evident as records of 120 animals x ha^{-2} were recorded within the same survey (Pouget 2005). With 187 animals x ha^{-2} found in small scale transects specifically targeting benthos favourable for *S. chloronotus* (table 4b), it is probable that Samoan stocks are slightly richer.

The length frequency distribution shows that there are few observed juvenile individuals among adults (this species is not cryptic). This may infer evidence for slow recruitment, as has been suggested for other species (Uthicke and Benzie 2000). Further, for future monitoring length information provides a very important tool, as it has been argued that using length-frequency data probably is the most cost-effective way to monitor/assess fished populations (finfish) (Munro and Fakahau 1988).

In conclusion *S.chloronotus* was found to occur in patches in moderate number in shallow waters across several substrates. Compared to other areas the numbers here indicate a restrained stock considering the potential for recovery, but still densities are higher than in other areas - that in turn may be depleted, i.e. Kosrae. The greenfish produces a high grade beche-de-mer product and being a relatively high value species (yielding 9 USD during export years 1993/94) it is probably the one species found in this survey that has potential to generate

a return in the short term. But because densities are moderate it seems unlikely that any high-volume long-term harvest should be expected from this stock.

4.1.3 *B. vitiensis* and *B.argus*

B. vitiensis occurred in the same numbers in both broad scale and small scale surveys. This species was distributed across the lagoons but a higher mean was recorded in mid-stations in the broad scale survey. Generally this species was found in areas with coarse sand and moderate oceanic influx. Because the brown sandfish is locally harvested it is perhaps the one species in this survey that has not had the same possibility to recover from commercial exploitation. Further, *B. vitiensis* was the main export species 1993/94 with 18078 kg (processed weight). The species is moderately common (occurrence in 7% of broad scale manta tows) and the mean site density across sites in Samoa was ca 13 animals x ha^{-2}. This is higher then what was found in Solomon Islands in 1992 (3.1 ±1.2 animals x ha^{-2}) (Adams et al. 1992), but lower than reported by Pouget (2005) with 22 animals x ha^{-2}. This species is of medium to low value; during the export years of 1993/94 it yielded an average price of 2.72 $US.

Similarly to *B. vitiensis* the tigerfish (*B. argus*) was found in both broad and small scale transects. *B. argus* occurred in 22 out of 297 manta tow transects (same as *B. vitiensis*) and showed a surprisingly low density considering the large available habitat. The resource specific survey mainly targeted the hard benthos areas where this species occur, and showed a mean density of 8.6 ±2.7 animals x ha^{-2} across all sites. *B. argus* was sold at and average of 3.78 USD when exported, and was caught at half the weight of *B. vitensis* (7875 kg).

The densities for these species (*B. vitiensis* and *B. argus*) were less diverging in the small scale transects than in the broad scale. This is likely a result of the small scale transects targeting hard benthos areas generally favoured by *B. argus.* The already modest numbers and the relatively small expected price do not favour any long-term harvest. Here it is also important to remember that the brown sandfish in particular is already harvested for subsistence, hence any additional incentive to fish for it may result in overfishing. Their value as a subsistence and artisanal resource is high and the traditional fishery for these species should be valued accordingly. Hence, any increased fishing effort in Samoa should not overlap with these species.

4.1.4 *H. nobilis*

The important commercial species *H. nobilis* was only found at two sites and in very low numbers. It is possible that if outside reef slopes or flats had been included in the survey higher densities would have been recorded. However, at present the recorded densities of *H. nobilis* are so low they are only a fraction of the numbers recorded within 'No Take Zones' in the Great Barrier Reef (GBR) area, and still lower than fished sites in the same area (Uthicke 2004). Records here show a mean density of (±SE) 3.5 ±3.5 animals x ha^{-2} as the highest recording over a site (and 0.6 ± 0.6 animals x ha^{-2} over all sites for small scale transects) compared to densities in GBR 'No-Take Zones' where numbers of 20-30 individuals per hectare are presented (Uthicke 2004). Uthicke and Benzie (2000) found *H. nobilis* in fished reefs to be ca 5 animals x ha^{-2} where it is suggested that densities below this will not provide an economic return. Although no density data exist for pre-export years in Samoa, it seems that *H. nobilis* stock is still recovering from previous exploitation although over ten years have past. In previous studies the recovery of stocks has been discussed to take a long time. Uthicke et al. (2004) shows, by resurveying reef two years after closure of fishing on the GBR, that the *H.nobilis* population shows no signs of recovery with very few new recruits observed. Ultimately suggesting that stock recovery of *H.nobilis* may be in the magnitude of

decades (Uthicke 2004). At this stage it seems that a commercial fishery should not expect to rely on *H.nobilis* catch and whatever specimens found should be left untouched for the sake of preserving this species in the region and any potential fishery at a later stage.

4.1.5 Other species

S. horrens is nocturnal and cryptic. It hides under rubble and boulders during daytime, which makes it difficult to find. Similarly *H. hilla* is also active at night and hides under boulders. Hence, records from both species are of coincidental nature and should therefore not be used as a scientific tool to estimate any population size or status from (but for *S. horrens* see Part II). None of these species have any commercial value.

4.2 Samoa compared to Solomon Islands

Solomon Islands make up an interesting example to compare to Samoa for two main reasons: 1. When fisheries were closed in Samoa it persisted in Solomon Islands. 2. In December 2005 the fishery in Solomon Islands was closed due to "dwindling export volume" (Nash and Ramofafia 2006). According to Sulu et al. (2000) the most commercially fished for (exported) species in Solomon Islands year 1991 was *B. argus, B. vitiensis, H. atra* and *S. chloronotus* (table 4.2a). These species coincide with the most frequently recorded species in Samoa, and to some extent with the most exported species from Samoa during the export years of 1993/94 (table 4.2a; and see table 2.2).

Table 4.2a. The most traded species in Solomon Islands 1991. The species composition coincides with the majority of lagoon sea cucumber resources found in Samo. Note that this is the main fished species in terms of quantity (data from Sulu et al. 2000).

Species	Trade value (H/M/L)	Export % (Samoa Export %)	Price / kg ($ SBD)
B.argus	M	27% (19.1%)	5$
B.vitiensis	M	18% (43.7%)	3.30$
H.atra	L	18% (1.9%)	1.6$
S.chloronotus	H	9% (2.5%)	10.00$

Sulu et al. (2000) presented export volumes and values from Solomon Islands over the time period of 1983-99 (represented in fig 4.2a). These data reveal an export peak during 1991-1993, the same period during which Samoa was an active exporter. Similarly to Samoa the catches plummeted after which fishing ceased in Samoa, but persisted in Solomon Islands.

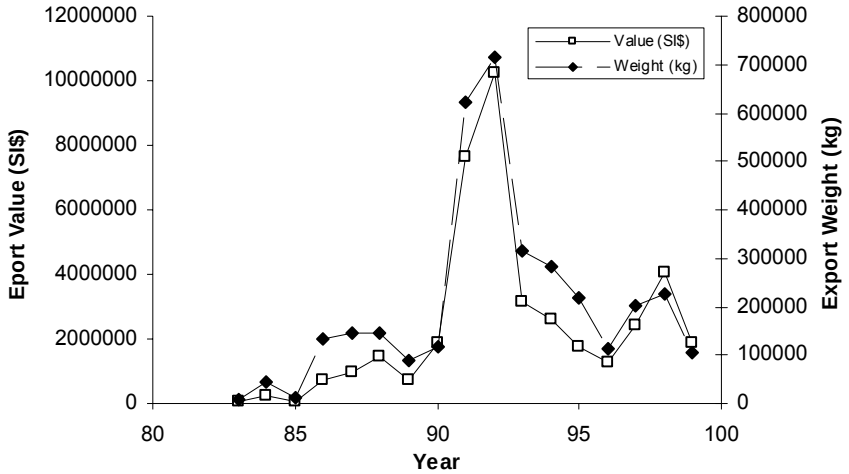


Fig 4.2a. Export data from Solomon Islands from 1983-99. Data derived from Sulu et al. (2000). The export data shows a clear peak in catch and income during 1992, after which a rapid decline in catch and value has occurred.

Thanks to data accessible through *www.reefbase.org* density estimates from the fishery independent survey performed by Adams et al. (1992) in Solomon Islands, can be compared to estimates from Samoa presented in this paper. Densities for species found in both surveys

are compared in table 4.2b. It should be noted that although both surveys provide density estimates, the methodology differs and the target areas does not entirely coincide.

Table 4.2b. Density estimates from Samoa (this study) and Solomon Islands (derived from Adams et al. 1992). Both surveys present density estimates (sampling methodology inconsistent between surveys). Data accessible via *www.reefbase.org* (trough http://www.spc.org.nc/coastfish/reports/ifrp/solomon/SURVEY.xls).

Species	Samoa mean site density no. x ha^{-2} (±SE) 2005	Solomon Islands mean site density no. x ha^{-2} (±SE) 1992
B.argus	5,2 (±1.2)	4.2 (±1.0)
B.vitiensis	13.1 (±5.1)	3.1 (±1.2)
H.atra	2037.6 (±284.1)	55.0 (±26.1)
S.chloronotus	58.6 ±(7.3)	1.6 (±0.8)

The only available data that can be correlated are the export data from 1993/94. Here Samoa exported a volume of 41333 mt whereas Solomon Islands exported more than ten times the volume (601 018 mt). Solomon Islands have a coastline ten times that of Samoa. Export volume was hence at a, relatively to accessible coastline, comparable rate. After the fishery peaked in the Solomon's 1992 the export volume and value plummeted (fig 4.2a), but the fishery persisted. The same year surveys performed by Adams et al. (1992) showed a lower density of commercially harvested species than was found in Samoa today (table 4.2b).
If the assumption is made that densities provided by Adams et al. 1992 from Solomon Islands where similar 1993/94 in Samoa when stocks where depleted, then the difference in densities presented in table 4.2b may provide a rough estimate of stock recovery in Samoa. However, it should be noted that there was variation in catch, i.e. the greenfish was more heavily fished in Solomon Islands (9% of catch, 56000kg) than in Samoa (2.5% of catch, 1056kg). So what seems as a recovery may be a result of variation in target species. According to Mulipola (1994) the moderate harvest of greenfish in Samoa was a result of the difficulties associated with harvesting it (rapid degeneration).

4.3 Socio-economics and potential conflict with traditional fisheries

In areas where sea cucumber stocks are commercially harvested they have become an important source of income. In Madagascar 100% of women, and children under the age of 10, earn their income from gleaning (searching, mainly for sedentary invertebrates) (McVean et al. 2005). In Samoa the household survey showed that there are several fishers utilizing the sea cucumber resources in their village lagoon. This provides nutrition and income to their households. In Samoa the species primarily targeted for subsistence harvest (*S. horrens*, *B. vitensis* and to some extent *H. atra* and *B. argus*) partially coincide with the potential species that may be attractive for commercial exploitation. Greenfish is generally not at all targeted and is likely the species with the highest harvest potential. This means that, depending on the catch composition, a commercial fishery may not initially affect local subsistence or nutrition, with the clear exception of *B. vitiensis*. However, examples are numerous where catch composition shifts to a wider range of species, particularly lower value species that have been left unfished, when primary targeted stocks move towards depletion (Lovatelli et al. 2004, Bruckner et al. 2003). It should also be kept in mind that a majority of interviewed fishers claimed that catches, or availability of sea cucumbers, are declining along with an increasing number of fishers. This does not favour increased harvest. If the fishery is re-opened the local target species (*S. horrens*, *B. vitensis, H. atra* and *B. argus*) should not be included for export purposes as results from the household survey show that these species plays an important role in subsistence and have a high economic and cultural value to local communities.

4.4 Conclusions

Prediction is the main objective of ecological research (Fogarty 1989), where the fundamentals of ecology is identifying patterns and related processes. Here a pattern has been established of a stock that seems to recover or is not at its full potential. Some processes that has led to this pattern can be identified; 1) previous commercial harvest exhausted stocks in Samoa, 2) the frequent occurrence of tropical cyclones in the area (particularly in the early 90's after commercial fishery was active) have prevented stock recovery, 3) the low numbers have affected the recruitment (density dependent reproductive strategy) and 4) the development of the country's infrastructure and industry may have caused loss of settlement areas and poor spawning conditions. To predict the outcome of a commercial fishery in Samoa today would be dependant on all identified processes where process 1) and 3) (and to some extent 4)) can be controlled trough appropriate management, preventing further stock depletion and Allee effect. But further, information on holothuroid general ecology with particular emphasis on recruitment and factors affecting it is needed. More specifically, to determine and isolate the factors that are suppressing these populations that remain modest despite absence of fishery will help predict and manage the processes that control life history and population dynamics in Samoan holothuroid stocks.

In terms of densities the results here generally show a recovering stock that is not likely to stand any long term exploitation. At this stage only a short-term small-scale commercial exploitation would seem possible. However, it seems ecologically sound to leave stock untouched to allow recovery and prevent further depletion until more holothuroid ecological knowledge is gained. The traditional use of most species is important to coastal communities and it is advised that to allow this to persist only consider *S. chloronotus* for commercial fishing. Hence, any overlap (commercial/traditional fishery) is advised against. This may sustain traditional use and provide a better opportunity of holding a sustainable beche-de-mer fishery at a later stage. Table 4.4 concludes the assessment.

Table 4.4. **Conclusions from assessment**	
1.	The coastal near shore lagoon habitats sampled in this survey show a higher presence of species of low to moderate value. Except for two specimens of *H. nobilis* no high value species was recorded.
2.	In comparison to density data from other countries, results here in general show a restrained stock with some commercial potential. Also, the household survey revealed a pattern in that a majority of fishers are detecting a negative trend in catch/availability of sea cucumbers in their lagoons.
3.	Out of the four species consistently found in some numbers *S. chloronotus* is the only species that should be considered for commercial harvest. The greenfish, *S. chloronotus*, is found in similar or slightly richer densities in Samoa than in Kosrae (Lindsay and Abraham 2004), Mayotte (Pouget 2003), Solomon Islands (assuming densities have not increased during export years 1992-2005) (Adams et al. 1992). It is the highest valued species found in some numbers in this survey and is not targeted in traditional fishing. The greenfish degenerates rapidly and processing and harvesting needs to be cautious to certify the products value.

4.	Lollyfish, *H. atra*, is generally the most abundant species in the Indo-Pacific region and does here show a rich density compared to Mayotte (Pouget 2003) and Solomon Islands (assuming densities have not increased during export years 1992-2005) (Adams et al. 1992), but lower than found in Reunion Island (Conand 2004). The high recorded densities favour successful harvesting but the traditional use, low value and on average short length of *H. atra* in Samoa (seems lower than in other regions) do not.
5.	*B. vitiensis* and *B. argus* both shows moderate numbers; with the tigerfish recorded in similar numbers to that of Solomon Islands 1992 (Adams et al. 1992), and *B. vitiensis* in larger numbers than Solomon Islands 1992 (Adams et al. 1992). The high traditional value and modest numbers and price of these species exclude them from commercial harvest.
6.	Encountered species showed a, more or less, heterogeneous distribution on several scales; within single lagoon and between sites. This should be taken into account when extrapolating these results and when setting up management.
7.	*H. nobilis* was found in such low numbers that it should not at all be considered for commercial fishery.

4.5 Management considerations

Today, most beche-de-mer fisheries are considered over-fished or threatened. However, many of the reported fisheries collapses are anecdotal and scarcely based on scientific stock data (Uthicke and Conand 2005). The lack of fisheries related research on sea cucumber resources has been recognized for a long time together with an absence on models to estimate yield (Conand and Sloan 1989). For any type of fishery an estimate on recruitment is central when setting up management (Conand 1993). The information on recruitment within encountered species is scarce and although further work is underway (Conand et al. 2006) the level of biological knowledge of this resource remains limited. Important information that is required is regarding reproduction and other population parameters and how biotic and abiotic processes control them (this may be particularly important for re-stocking purposes). With the background and recommendations from other surveys and examples of over fishing (e.g. Adams et al. 1992; Uthicke 2004, Conand 2004; Lawrence et al. 2004; Verónica Toral-Granda 2005) a precautious approach is here taken to summarize some relevant points for consideration in management decision making if fishery is decided to be re-opened (table 4.5a).

Table 4.5a. **Summary of management considerations**	
1.	The satellite breeding strategy that is directly proportionate to population density seems to favour managerial strategies that leave out areas where fishing is prohibited. Such as 'No-Take Zones' found in GBR (Uthicke 2004). Adopting no-fishing zones should make a majority of coastline inaccessible for harvest as protected areas need to be large in size (Uthicke and Benzie 2000). Rate of dispersion from non-fished regions is not scientifically established. The patchy distribution of most species should here be taken into account.
2.	As a complement to closed areas, length restrictions provide a managerial tool that can be utilized so as to maintain population with sexually mature individuals. Length restrictions can be set up according to provided length data in this paper (see table 4.5b for suggestions). For instance, ca 20% of sampled *S. chloronotus* specimens was longer than suggested MLL (220mm), this does not sound as cautious as may be wanted or in line with what has been suggested in that only 5% of virgin biomass may be sustainable to harvested (for *H. nobilis*) (Uthicke 2004). But used in conjunction with no-fishing zones it may provide an applicable restriction. Theoretically, If there is 1000mt of available greenfish in Samoa, then by closing 50% of accessible fishing ground 500mt will be available for harvest (assuming homogeneous distribution). With the MLL restriction on top of that 20% of 500mt is available for harvest (=100mt), which is 10% of the theoretical total stock. Not all available stock will be found and harvested. Similarly *H. atra* MLL of 180mm yields 5% of half stock (and lollyfish occurs in numbers that are at a magnitude of 30 times greater than greenfish). For *B. vitiensis* and *B. argus* a precautious MLL has been set up according to available length data.
3.	Length data will also provide an indication on stock change. In the case of commercial fishing, Samoan Fisheries is given the opportunity to monitor changes in sea cucumber length frequency by collecting length samples from harvested (or live) individuals to monitor catch and stock. Utilizing changes in average size and frequency distribution for each harvested species, can indicate stock change and that management measures may need to be strengthened
4.	In addition, licensees should adhere to collect and report species specific catch data. Such data should include weight data from each fished area.
5.	The inshore fishery in it self involves a wide range of targeted species as well as fishing techniques. It is important to understand this system as any restrictions on-, or change in future availability of-, sea cucumber resources can put more pressure on another inshore fishery. In other areas concern is raised over communities becoming economically dependant on a resource that may falter and in turn put heavy pressure on other reef resources (Sulu et al. 2000).
6.	If commercial fishery is opened it would be desirable to follow up on stock resilience and subsequent assessments should be performed according to what decision is made for rate of harvest.
7.	Should species that are locally harvested for subsistence and artisanal purposes also be open for commercial harvest for export? Species that provide livelihood to coastal communities and would be commercially interesting are particularly *B .vitiensis* but also *B. argus* and *H. atra*. It is advised that these species are preserved for traditional fishing purposes only.

Table 4.5b. Summary of length records (mm). PNG MLL is the Minimum legal length restriction on catch in Papua New Guinea. MLL suggestion is the suggested length restriction for any potential beche-de-mer fishery in Samoa. MLL is roughly estimated to allow as many individuals within the mean length interval for each species to persist (if it is assumed that in a relatively undisturbed population a majority of individuals with mean length is sexually mature).

	Mean length	Min length	Max length	Mode	PNG MLL	MLL Suggestion
B.argus	295±18	250	470	-	200	350
B.vitiensis	239±9	160	320	-	200	280
H.atra	119±1	20	260	110	300	180
S.chloronotus	164±3	50	350	150, 180	200	220

Acknowledgements

The acknowledgements are presented in the order each person or organization occurred in this project.

Initially, I would like to thank the Swedish International Development Agency (SIDA) that trough the Committee of Tropical Ecology (Arbetsgruppen för Tropisk Ekologi) and Assoc. Prof. Bo Tallmark, at Uppsala University, granted me the scholarship that made my travel to the other side of the world possible. The grant not only allowed me to perform this work but also provided vital contacts for my future career as well as giving me the opportunity to meet people I now call my friends.

I would further like thank Dr. James Scandol at NSW DPI, Fisheries Division in Cronulla, Australia. When writing this report James has been of great help, but his role in this work started before that as it was James' kind words that provided me the opportunity to make contact with Dr. Kim Friedman at the Secretariat of the Pacific Community. Dr. Friedman not only set me up with the possibility of performing this work in Samoa, he has also been an invaluable supervisor throughout the entirety of this work - from directions in data-collection to advice in culture. I wish to extend my deepest gratitude to Kim.

My appreciation further extends to the Samoan Fisheries Division whose hospitality made me feel at home and confident working in a very different country and culture. In particular I wish to express gratitude to Mr Atonio Mulipola and Ms Anama Solofa, both have provided support and instructions throughout the fieldwork and data collection. The field data collection was performed together with staff from Fisheries Inshore, Village Extension and Aquaculture section. In particular I wish to thank Tevita Apulu, Misipele Afamasaga, Mikaele Faamai, Joyce Samelu, Faasulu Fepuleai, Peleti Paia, Ferron Fruean, Clifton Sae and Aleluia Taise who have all helped to collect the information presented in this report; it would not have been possible without their assistance. Further, I would also like to thank the United States Peace Corps Volunteers (US PCVs) Danielle Toole, Robin Rosenau and Sarah Valencia working at the Samoan Fisheries Division, their assistance in data collection, handling and cultural advice remains much appreciated. The US PCVs also assisted in the household survey by performing interviews in their 'home'-villages which gave breadth to the socio-economic data collected at survey sites. I would also like to thank Niclas Backström and Ingvar Backéus for valuable input on the report.

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Appendix 1. Sea cucumbers (Echinodermata: Holothuroidea) and beche-de-mer

There are ca 1 400 different species of sea cucumbers (Holothuroidea) occurring world wide (Richmond 2002). For over 1000 years the Indo-Pacific region have harvested some of these sea cucumbers processed into beche-de-mer (or trepang), which is the dried body wall. The fishery has supplied the Asian markets, with major actors being Hong Kong SAR (China), Singapore and Taiwan (Conand and Sloan 1989; Hamel et al. 2001; Conand 2004). In some areas it is regarded as a delicacy, an aphrodisiac and a natural medicine. Some scientific evidence exists that several sea cucumbers may contain pharmacological agents for a variety of afflictions (Fredalina et al. 1999). The market has experienced an ever-increasing demand for beche-de-mer, and a majority of harvested stocks around the tropical Indo-Pacific are today heavily over fished (Hamel et al. 2001; Conand 2004; Uthicke and Conand 2005). This is generally a result of poor management response to the increasing harvest. The Holothurians also suffer from limited biological knowledge and being easy to access within the intertidal or subtidal. Landings in many traditional sea cucumber fishing nations are declining (Nash and Ramofafia 2006). As a result new fisheries are emerging in new countries. For instance a fishery for the temperate North Atlantic sea cucumber *Cucumaria frondosa* developed during the 1990s, a fishery that today makes USA and Canada top exporting countries in the world (Therkildsen and Petersen 2006). Using SCUBA or Hookah has been practiced in several countries and has even become necessary as resources get scarcer in near shore shallows. As a management regulation banning such methods is considered (Bungitak and Lindsay 2004; Lindsay and Abraham 2004).

There are several species of Holothurians being harvested around the world, some for local consumption, but most of the world wide catch is for export as beche-de-mer to East Asian countries. Despite that ca 20 species are targeted by fisheries, only a few species make first grade beche-de-mer (Hamel et al. 2001). This creates a skewed demand on the market since first grade species command a higher price. This usually results in a rapid reduction in high value species after an initial fishing boom, after which the fishery target a wider catch composition including species of lower value, a clear indication of overfishing (Lawrence et al. 2004; Uthicke 2004). The biology of holothurians is generally not well researched, particularly for species of low commercial value. However, studies are on the way that aim to increase the knowledge of this resource (Conand et al. 2006). Increasing the level of knowledge, particularly within recruitment and reproduction, would prove invaluable for fisheries management.

1.1 Sea cucumber (Class: Holothuroidea) biology

The class Holothuroidea (sea cucumbers) is within the Echinodermata phylum and general for all organisms within this group is that they are believed to fill a very important role in reef and lagoon ecosystems (Birkeland 1988; Richmond 2002). The class Holothuroidea (sea cucumbers) consists of 25 families distributed over six orders, some of which are summarised in table 1.

Table 1. Condensed sea cucumber systematics. (Table derived from http://saltaquarium.about.com /cs/seaslugcuccare/l/ blcucumberfam.htm and Hutchins et al. 2003).

Phylum:Echinodermata			
Class:	**Holothuroidea**		
	Order:	*Elasipodida (deep-sea sea cucumbers)*	
	Order:	*Molpadiida (rat-tailed sea cucumbers)*	
	Order:	*Dactylochirotida (U-shaped sea cucumbers)*	
	Order:	*Apodida (footless sea cucumbers)*	
		Family:	*Synaptidae (medusa or sea worms)*
			Genera: *Synapta or Euapta, Ophiodesoma and Plyplectana*
	Order:	*Dendrochirotida (suspension feeding sea cucumbers)*	
		Family:	*Cucumariidae (sea apple cucumbers)*
			Genera: *Paracucumaria and Pseudocolochirus*
	Order:	*Aspidochirotida (Shield-tentacle sea cucumbers)*	
		Family:	*Holothuriidae (common sea cucumbers)*
			Genera: *Actinopyga, Bohadschia, Holthuria and Labidodemus*
		Family:	*Stichopodidae (warty sea cucumbers)*
			Genera: *Parastichopus or Stichopus*

The sea cucumbers vary in sizes, from a few millimetres to several meters (*Synapta maculata* can grow as big as 3 m). Sea cucumbers typically have a worm or slug like appearance, with soft or muscular body walls. The skeletal structure of the holothuroids differs from that of other echinoderms in that it is reduced to small calcareous structures, ossicles. The ossicles vary in size (10 µm – 1 mm) and shape and provide an important tool for taxonomic classification (Hutchins et al. 2003). Holothuroidea also possesses a skeletal feature that enclose the mouth parts (or pharynx), serving as an attachment for oral muscles, tentacles and longitudal body muscles.

The gas exchange for Holothurians (in general) occur trough the cloacae. Here paired respiratory trees are attached and run trough the body cavity (Hutchins et al. 2003). In the Holothuriidae family (Bohadschia and Holothuria etc.) a morphological feature called cuverian tubules are also attached at the base of the respiratory tree. These tubules are expelled from the anus/cloacae when the animal is stressed, such as when being handled or in the event of a predator.

The sea cucumbers are part of the regeneration process of organic matter in reef and lagoon systems (Ward-Rainey et al. 1996). Most species feed on bacteria, algae or detritus (Hutchins et al. 2003). Experiments have shown that the presence of *H.atra* and *S.chloronotus* has a positive effect on growth of micro algae thanks to the high nutrient level (Nitrogen and Phosphorus) in their excretion (Uthicke 2001), and may inhibit anaerobic processes (Michio et al. 2003). The excretion rate is also shown to be dependant on size (which is a parameter expected to decrease with any increased fishing effort) (Uthicke 2001). The natural predators for this class of animals include elasmobranches, large fishes, crabs, gastropods and sea stars. There are only a few animals however that are specialised in feeding on holothuroids (Hutchins et al. 2003.).

The spawning events of the Holothuroids are mostly annual or bi-annual. The reproduction event is seasonal and depends on water temperature with many species spawning during the warmer summer months (Skewes et al. 2004). Indeed, temperature, salinity and pH have been shown to affect survivorship of reared *Holothuria spinifera* larvae (Asha and Muthiah 2005). Most species occurring in tropical waters are broadcast spawners, where eggs and sperm are released into the water column. The fertilization and larvae development occur in the water column, the initial planktonic larva is supplied with lipid stores (Hutchins et al. 2003). The larvae go trough a planktonic stage and a feeding auricularia larvae stage before

metamorphosing to a miniature adult stage of doloiolaria and settling as a pentacula. The recruitment process is generally not well studied (other than for commercial important species and species that are reared through aquaculture). For some species release of juveniles in sea grass beds and mangrove areas have showed high rates of survival (Skewes et al. 2004; Mercier et al. 2000).

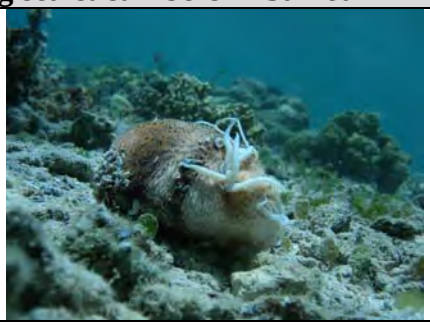
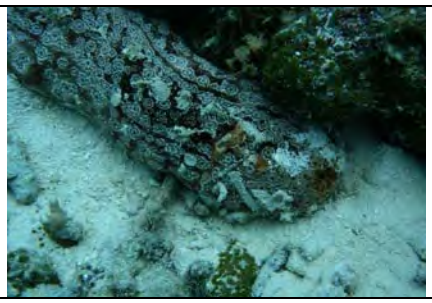
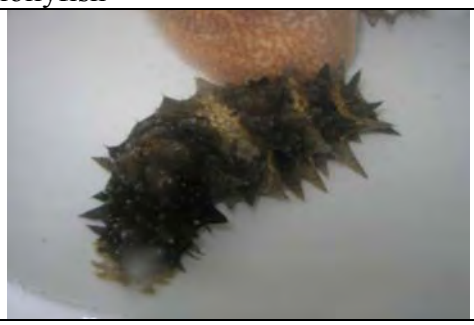
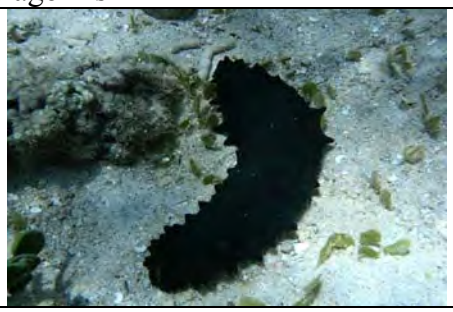
Since the holothurians spawn in the water column, the success rate of oocyte fertilisation also becomes dependent on the proximity to partner (Levitan and Petersen 1995). The Allee effect is the term assigned to the disproportionate reduction in recruitment as a result of a reduction in density. Hence the success rate of the density dependent sexual reproductive system occurring in the holothurian phylum is lowered disproportionate to a decrease in density. This very important part of holothurian broadcast spawning must be taken into account when considering management issues, as Uthicke (2004) discusses the probability of fertilization success may be a low as 10% of initial value if initial density is reduced with 50% (based on population model for scallops). Further, Uthicke (2004) means that 'No-Take Zones', rather than catch quotas and length restrictions and may serve the purpose of maintaining high density of spawners and hence increase the probability of successful recruitment.

1.2 Species and products in Samoa

The processed (boiled and dried) sea cucumber is referred to as beche-de-mer. Different species yield different quality products with widely varying prices (2-50 USD/kg). Besides species identity, the size of the individual beche-de-mer also affects its value, with a larger individual yielding a higher price. In New Zealand, to provide a size measure the number of individuals per kilogram is counted, where larger animals yield a higher price. Other factors than species and size such as origin, shape, odour, condition and appearance also affect the value of the individual beche-de-mer (South Pacific Trade Commission, NZ 1996).

When Samoa was an active exporter of beche-de-mer, based on weight, its catch consisted of mainly eight species, of which *B. vitiensis, A .mauritania* and *B. argus* were the absolute main export items during the 1993/94 export period (table 2.2a). These species yielded a moderate per kg price but due to the large quantities caught the value of these species together made up 89% of the total market value (Mulipola 1994).

Given that the fishery for export has been closed for several years only some of these species are harvested today. In Samoa subsistence fishery is targeting a few species namely: *Bohadschia vitiensis* and *Stichopus horrens* and to some extent *Holothuria atra* and *Bohadschia argus*. Any type of fishery for other species is non-existing today. None of these species are traditionally processed to beche-de-mer, but eaten raw or cured in seawater. The sea cucumbers are sold in glass bottles in markets and at roadsides. The following section presents these species and their products, with the addition of the valued species *Stichopus chloronotus*, which is readily found in lagoon areas but is not locally harvested. The information provided below is a combination of references, observations from assessment work and personal communication with fishers and women selling the products at the Fugalei market in Apia. Each species presented will also be referred back to available data on catch during the export years 1993/94. For detailed information on subsistence and artisanal sea cucumber fishery in Samoa see Part II of this report. Table 1.2 presents pictures of each species later presented in text.

Table 1.2. **Pictures of important lagoon occurring sea cucumbers in Samoa**	
	
Bohadschia vitiensis, brown sandfish	
	
Bohadschia argus, tigerfish (or leopardfish)	
	
Holothuria atra, lollyfish	
	
Stichopus horrens, dragonfish	
	
Stichopus chloronotus, greenfish	

1.2.1 *Bohadschia vitiensis*; Trade name: Brown sandfish; Local name: Fugafuga

B. vitiensis occurs mainly in soft benthos habitat in coastal lagoons. During the day it is often partly or completely burrowed in sand or mud and sometimes difficult to spot. Although it is mainly nocturnal it can still be observed at daytime. *B. vitiensis* expels sticky white threads (cuverian tubules) that stick to just about anything when handled. This is believed to be a defence mechanism (Hutchins et al. 2003). Local fishermen seem to fish for *B. vitiensis* together with *S. horrens* at early night, usually at low tide. When it comes out and looses its cover of sediment it becomes almost white and is easily spotted against the darker substrate, even from above the surface. This along with a high demand makes it a relatively popular species to fish for.

The animals are prepared by gutting and cleaning, the skin is thin and apparently is not removed but just thoroughly cleaned. The body wall is then diced into little pieces that fits through (and can be taken out again) the opening of a glass bottle. The bottle is filled with the body wall pieces and topped up with fresh seawater; the product is consumed raw and requires little extra preparations. The *B. vitiensis* bottles are sold at the markets or roadside, usually in 750ml Coke bottles. The *B .vitiensis* products are often mixed with the viscera from *Stichopus horrens* ('sea'), and these mixed bottles are more expensive. Sometimes the *B .vitiensis* bottles can be mixed with *H .atra* or less commonly *B. argus* (both harvested for their body wall), which does not seem to affect the price. In terms of volume *B.vitiensis* is becoming more prevalently occurring as a product in Samoa (see Part II). Further, in terms of processed weight, *B .vitiensis* was the most fished for species for export (43.7% of total landed catch), during the export years of 1993/94, and had the seconds highest catch count at 26% of all landed sea cucumbers (Mulipola 1994). It seems this species has been harvested at a consistently high rate throughout the export years as well as the following years of subsistence and artisanal fishing.

1.2.2 *Bohadschia argus;* Trade name: Tigerfish or leopardfish; Local name: Mama'o

B. argus occurs mainly in the outer parts of coastal lagoons. It prefers a harder substrate and a moderate to strong degree of oceanic influence, usually in the backwash zone behind the reef. The majority of the observed individuals were on hard substrate in reef back areas. It is active at daytime but conspicuous due to its coloration. Occasionally some individuals have small parts of coral rubble attached to their body mucous, which makes them even harder to spot.

B. argus is similar in size to *B. vitiensis* and shares the attribute of expelling cuverian tubules when stressed. *B. argus* is not locally harvested at a notable rate and it rarely occurs as a product. When used it is handled in the same manner as *B. vitiensis*, with gutting and cleaning. The major difference is that the skin of *B. argus* is scraped off. *B. argus* products were never encountered at the market or roadside, but according to personal communication it is harvested, possibly for personal consumption rather than for sale. One fisher said that she believed that some people use it for medicinal purposes. *B. argus* yielded 19% of total exported (processed) weight, during 1993/94, with a small count of 4% of landed species (Mulipola 1994).

1.2.3 *Holothuria atra;* Trade name: Lollyfish; Local name: Loli

H. atra is the most commonly occurring species in Samoa. It is considered a low value species in most trade countries and is currently unexploited in northern Australian fishing grounds (Northern Planning Area) (Skewes et al. 2004). *H. atra* occurs over many types of substrates and may show a variety of attributes depending on environment found in. It is readily found in high numbers in soft benthos, sand to muddy areas in mid to inner part of coastal lagoons. Here it is often covered in sediment leaving a few black spots along the

dorsal side. *H. atra* can also be found in hard benthos areas, even on coral rubble, in the outer parts of the lagoon, where its body seems to be less covered with sediment, and at a distance gives an altogether more "robust" appearance, similar to that of black teatfish (*Holothuria nobilis*). Here they seem to occur in lower numbers but in larger size. *H. atra* is fished for its body wall, but it only occurs occasionally together with *B. vitiensis* and *S. horrens* in glass bottles and no single bottle with just *H. atra* was observed. Because of its high density in many lagoons it is easily accessible and might therefore be considered as "filler" – to top up the bottles of *B. vitiensis* and *S. horrens*. Still most people that were asked about preference said they enjoy eating 'loli'. Since *H. atra* is a low value species it was only fished for in lower numbers during the export years 1993/1994, where 1.6% of the landed catch (in numbers) and 1.9% of total landed (processed) weight was *H. atra* (Mulipola 1994).

1.2.4 *Stichopus horrens;* Trade name: Curryfish or dragonfish; Local name: Sea

S. horrens is nocturnal and has a cryptic appearance, making it difficult to find. It hides under rubble and boulders during daytime and in some areas in the pacific region it is fished for at day by turning over boulders and feeling at the base of sea grass fronds (*i.e.* in Tonga, pers. comm. Kim Friedman). In Samoa *S. horrens* is fished for at night using underwater torch and mask or goggles. It occurs mainly in soft benthos areas with patches of rubble or boulders and sea grass. It was observed on macro algae (such as *Sargassum* sp.) when feeding at night. 'Sea' is fished for its viscera (*i.e.* mainly intestine but also gonads and respiratory tree). The viscera are stored in seawater and sold in Coke bottles at roadside, markets or within the village. Harvesting the viscera product means that the animal does not necessarily die, as there are examples of organ regeneration within this group of organisms (Quinoñes et al. 2002, Mashanov 2005). The animals are collected at the fishing ground and brought back to shore in filled up canoes or in buckets. They are then kept overnight (4-6 hours) in buckets to allow the organism to empty its intestine from sand. In the morning the animals are cut across the side, and the viscera is expelled trough the cut. The animal is then disposed of in another bucket where all cut animals are collected before being dispersed close to shore. The viscera are checked for sand before being put in the bottle.

The 'sea' can either be sold separately in bottles, which are more expensive, or together with *B. vitiensis* and/or *H. atra*, which reduces the price. Among local Samoans the *S. horrens* viscera are regarded as the most sought for of all sea cucumber products in Samoa. There is no export data from 1993/1994 on *S. horrens*, as this is generally not a sought for beche-de-mer species. The fishing for *S. horrens* occurs around the country but high catches seems localised to a few places around the country. Aleipata on Upolu, and Salelavalu on Savaii, provide most of the *S. horrens* sold at Fugalei market as well as bottles sold at road side at other villages (Toamua for instance). This species and its fishery is thoroughly dealt with in Part II of this report.

1.2.5 *Stichopus chloronotus;* Trade name: Greenfish; Local name: Maisu

S.chloronatus occurs mostly on hard substrates, and is readily found in areas with coral rubble. However, it also occurs in sandy areas, with at least a moderate oceanic influence. It ranges from shallow waters down to ca 15 m. Its average length is 18 cm and it has a fairly thin body wall (2mm). During the survey most greenfish were found in reef benthos areas generally occurring in the mid to outer part of the lagoon (typically not deeper than 4 meters). But in some areas where lagoons are narrow and oceanic influence is high all the way trough the lagoon area, some numbers was recorded in the near shore areas too. The greenfish is commercially graded as a high value species in this area. In other parts of the world it seems the value is lower. During the export years 1994/93 the greenfish was not heavily fished. The greenfish is somewhat harder to handle than many other species and its body wall

degenerates, which is believed to be the reason for the low export volumes despite a reasonable market value (Mulipola 1994). The Samoan local name for *S. chloronotus* is 'maisu'. Maisu is generally not fished for by local communities and some people think 'it hurts your stomach' (interview in Savaii). From a commercial exploitation point of view this species is the most interesting found within lagoon habitats. If preparations for processing are set up properly and generated products are of high standard, good return may be expected for the greenfish.

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2006-08-07

Sea cucumber abundance, diversity and fishery in Samoa.
An assessment of lagoon occurring sea cucumbers

Part II

The subsistence and artisanal sea cucumber fishery, with particular focus on *Stichopus horrens*, in Samoa

B.G.H. Eriksson

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Executive summary

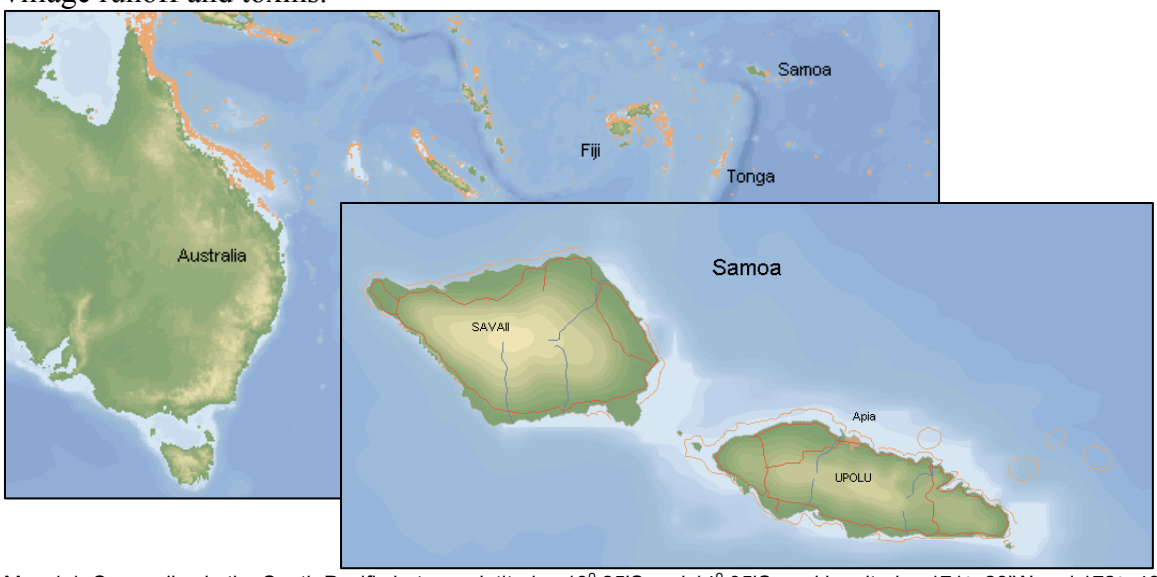
This text reviews the small- scale fishery for sea cucumbers, in particular *Stichopus horrens,* in Samoa. It presents the fishing procedures and the trade of the products at markets and along roadsides and is put together to reveal recent fishing patterns and catch data that have not until now been accessible. The information presented has been collected trough observations, household interviews and by accompanying fishermen and show that the traditional sea cucumber fishery in Samoa is significant. Further, catch data collected by the Samoan Fisheries Division are also included. Together the information indicates that the fishery is utilized to a point where active management is needed. Here, a pilot study to test whether *S. horrens* can survive the procedure of being harvested for its viscera is also presented, a 'full scale' experiment (template is included in this text) may provide important information for future management. Brief suggestions for monitoring and management are presented at the end.

1. Introduction

In Samoa sea cucumbers are harvested for subsistence and artisanal purposes. This traditional sea cucumber fishery provides nutrition, income and a social activity to people in Samoa's coastal communities. A total of four species is generally targeted by local fishers (i.e. *Stichopus horrens, Bohadschia vitiensis, Holothuria atra* and *Bohadschia argus*).

1.1 Samoa

The country of Samoa lies in the central South Pacific, between latitudes 13° 25'S and 14° 05'S and longitudes 171° 23'W and 172° 48'W. The country is independent and was formerly known as Western or Independent Samoa. It consists of two larger islands; Upolu (1108km^2) and Savaii (1695km^2) and seven smaller islands (map 1.1). Being an island state of recent volcanic origin the country has few natural resources but an extensive coastline and the majority of the country's population resides in coastal communities. Samoa has previously experienced commercial exploitation of sea cucumbers, but the fishery was closed in 1994 (Mulipola 1994). Outside of commercial harvest the marine resources in general have suffered from the numerous cyclones that have struck the region. The bigger ones, 'Heta' and 'Ofa' in the early to mid 90's, caused considerable damage on reef and lagoon ecosystems. Samoa's coastline is also suffering from increased development with sea wall reclamations, roads, village runoff and toxins.



Map 1.1. Samoa lies in the South Pacific between latitudes 13° 25'S and 14° 05'S, and longitudes 171° 23'W and 172° 48'W (map derived from www.reefbase.org GIS downloadable files).

1.2 The subsistence and artisanal sea cucumber fishery

In Samoa *Stichopus horrens* (Picture 1 and 2) (local name: 'sea') is fished for its viscera. The viscera product is consumed raw and the process of harvesting the species involves keeping the animals alive. It is believed among the fishermen that the animal survives the harvesting procedure and that returning it to the sea allows it to be harvested again after it has re-generated its organs. The survival of the animal, and the possible re-generation of viscera after cutting have attracted researchers attention, but little research on survival has been performed (Lambeth 2000). There are studies showing that intestine regeneration is possible among Holothurians (Quinoñes et al. 2002; Mashanov et al. 2005), but whether *S. horrens* in Samoa survives the harvesting process has not been actually tested in the field, even less so whether re-growth of its internal organs take place.

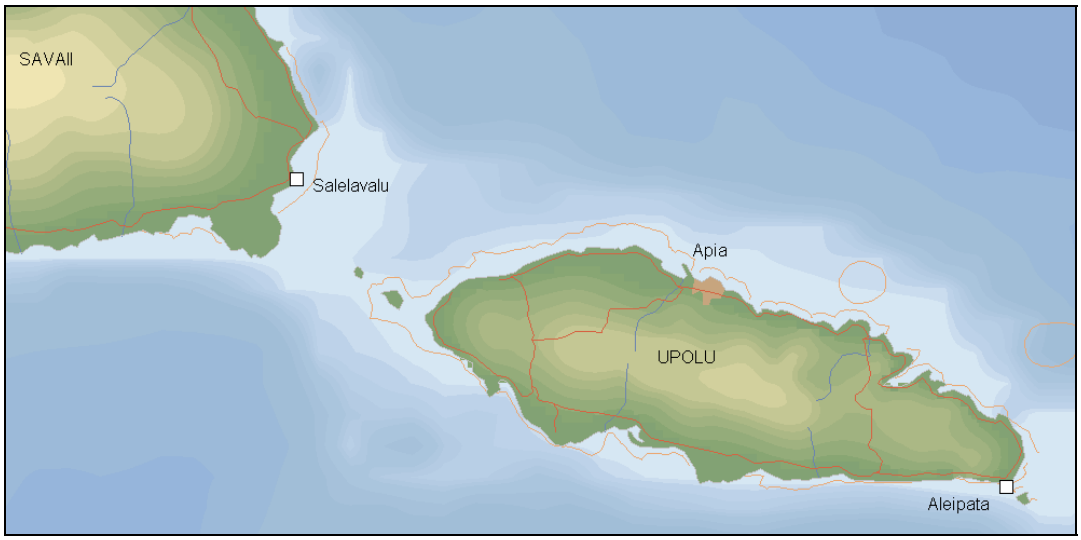
Picture 1 and 2. *Stichopus horrens*, pictures taken in catch bucket when accompanying fisher in Toamua, The species shows variability in colour pattern and appearance.

Viscera from *S.horrens* is a sought after sea cucumber product in Samoa, and it is regarded as a delicacy by many. The 'sea' product is placed in empty glass bottles together with seawater and sold at markets and at the roadside. One 750 ml bottle of only 'sea' fits on average 102 viscera (product from 102 animals, see section 2). This bottle (full) costs ca $20-30 Tala at the market or at the roadside (the Tala, WST, is the local currency which will be referred to throughout this text. 1 WST = 0.35 USD). Bottles with 'sea' mixed together with other species of sea cucumber contain less 'sea' and are therefore somewhat cheaper, selling at ca $15-25 Tala (Picture 3 and 4).

Picture 3 and 4. Bottles of 'sea' (from left) and one bottle of 'sea' and fugafuga (*Bohadschia vitiensis*) mix. Left picture from Fugalei market in Apia. Bottles are from Salelavalu in Savaii. Right picture from Toamua roadside. 'Fugafuga' is fished locally but 'sea' is transferred to these bottles from bottles from Salelavalu.

The bottles for sale tend to have 'sea' only or 'sea' mixed with *Holothuria atra* (local name 'loli') and/or *Bohadschia vitiensis* (local name 'fugafuga'). Bottles can also be mixed with other products such as pieces of seahare (*Dolabella auricularia*). Most bottles contain at least some 'sea' but bottles without it also occur, although they seem to be less sought for and sell at lower prices. This usually means that the fishermen selling the bottles want to have at least some *S. horrens* viscera in them to generate a higher price and a higher probability to sell.

According to personal communication with fishers, *S. horrens* harvesting is highly localised to only a few places around the country. The two main areas are the Aleipata district in SE Upolu and Salelavalu village in SE Savaii (map 1.2). Most of the 'sea' sold at Fugalei market in Apia has its origin in these two areas.



Map 1.2. The two most heavily fished regions for *S.horrens* in Samoa at present seem to be Salelavalu on Savaii and the Aleipata district on the southeast corner of Upolu. (map derived from www.reefbase.org GIS downloadable files).

Many of the other areas where *S. horrens* and other species are fished for do not hold enough 'sea' resources to mix up the bottles. The village of Toamua makes an example: According to a fisherman in the village, there used to be plenty of 'sea' in Toamua - but today there is so little that in order to attract buyers for the bottles he sells at the roadside, he buys bottles of 'sea' from the fishermen from Salelavalu, that travel into Apia to the market. The 'sea' is then distributed into the bottles of 'fugafuga' (which is still caught in Toamua at a lower effort). Using a small stick the 'sea' is pushed down the sides of the bottle to look like it is containing more 'sea' (Picture 5).

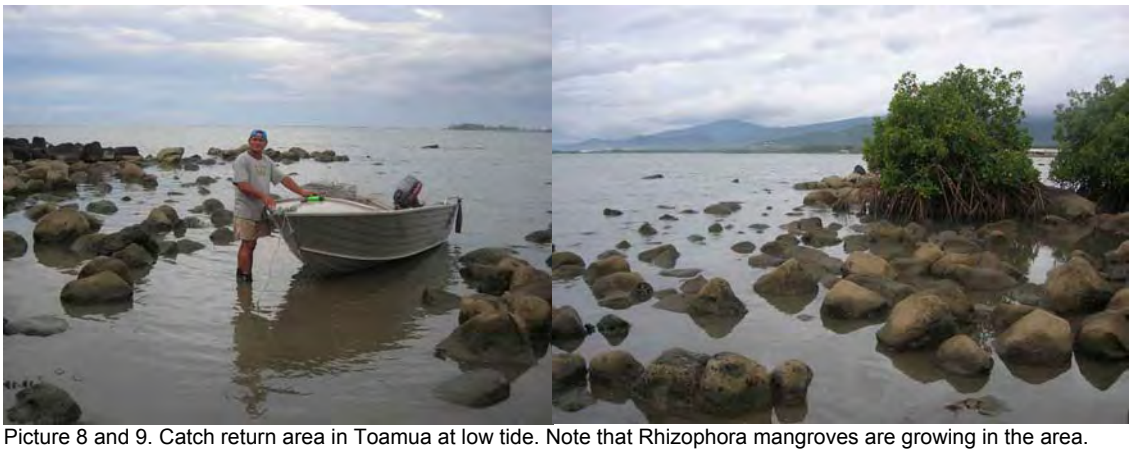
Picture 5. Using a stick to push the 'sea' viscera down along the side of the bottles. Note the bottle of "unmixed" *B.vitiensis* in the bottom right corner and the bowl of 'sea' in front of the woman working.

1.3 Fishing for *S. horrens*

In Samoa *S. horrens* is generally fished at night (the species is nocturnal). The fishers use their paupaus (dugout canoe) to collect the animals. The local canoe is used to transport fishers but also to hold 'sea' when at the fishing ground. The bottom of the paupau is filled up with seawater and collected animals are kept there for the duration of the fishing trip. The collection procedure can be stressful for the animal and several individuals were noted to eviscerate or collapse (disintegrate) during fishing trips. The 'sea' is collected using an underwater torch and mask/snorkel or goggles. The fishermen showed great skills in finding the cryptic *S. horrens*, as compared to researchers at a comparative rate of 3 to 1 for the same effort. Back at shore, after the fishing trip is finished, the animals are divided into several buckets. Each bucket is filled to 1/3 with animals and then topped up with fresh seawater. Keeping the 'sea' in buckets allows the animals to empty its intestine from sand so that the viscera product is edible without getting sand stuck between your teeth. The animals are left in the buckets for 2-5 hours, but this time seems to vary between sites and fishermen and sometimes the catch is kept till morning. After the animals have been kept in buckets the fishermen harvest the viscera. This is done by cutting a slit in the side of the animal - a gentle squeeze is all it takes to expose the viscera (Picture 6 and 7).

Picture 6 and 7. The cut is performed over the side, almost halfway trough the animal. Talented women can extract the viscera with the same hand as the cut was made with.

Sometimes the animal eviscerates as a reaction to the stress of being handled, and the viscera literally pour out of the cut. When the intestine is exposed it is checked for sand before put in a glass bottle. After the animal has been cut and emptied of its viscera, it is discarded in a bucket, which is filled with animals and with a little water (less than in buckets before cut) and it seems less care is taken of these animals after processing. The "empty" animals are returned to the sea, estimated to within 10-20 metres from shoreline.
Even if the animals survive the cutting procedure they may stand less chance of surviving due to being removed from its preferred habitat. In Salelavalu and Toamua (where fishing was observed) the near shore areas are high in sediment, exposed to wave action or had very little oceanic influence (Picture 8 and 9).



Picture 8 and 9. Catch return area in Toamua at low tide. Note that Rhizophora mangroves are growing in the area.

2. *S. horrens* catch data

Results from catch estimates and biological data collection are here presented parallel with catch estimates from a household survey. Two fishers (one man and one woman) in Salelavalu were accompanied for a night's fishing. The aim was to collect catch data from fishers, and to fish for animals to collect biological data for length weight and product weight correlations. In Salelavalu 'sea' is fished for in the outer to mid part of the lagoon. Here the substrate is hard, mostly rubble with patches of live and dead coral. In between there are small sand areas. There is also a high density of macro-algae (*Sargassum* sp. or *Turbinaria* sp.) on which *S. horrens* sometimes sits and feed (Picture 10).

Picture 10. *S.horrens* on *Turbinaria* sp. in Salelavalu.

Fishing was performed during three hours at evening to late evening as the tide was going out. After fishing the catch was left in buckets on the shore as usual. Five hours later the fishers filled up a paupau with seawater and put all their catch in it. They then started cutting the animals, taking them out from the paupau one at a time. While the fishers were cutting, the numbers of 'sea' put in each bottle was counted, which provided a total count of animals caught as well as amount that fits into one bottle (fig 2a).

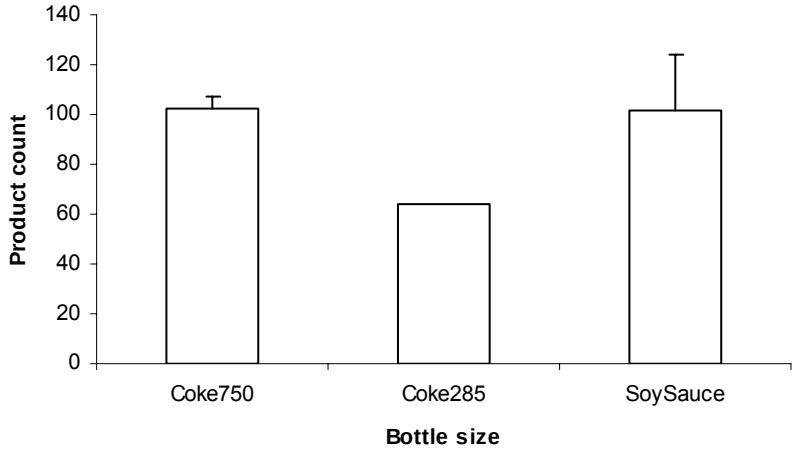


Fig 2a. Mean number of viscera that fits into one bottle (of various sizes). Bar shows mean value and errors bars are S.E. (St.dev/√n). (Coke 750ml n=8, Coke 285ml =1, Soy sauce 650ml n=2)

The total count of each fisher's catch was divided with the total time spent fishing to yield a catch per unit effort estimate (CPUE) (table 2a). Using the animal mean weight (derived from researchers' catch, see section 3) the total weight of the fisher's catch was extrapolated (mean weight of animal x total number of animals). This was necessary to yield a weight per unit time CPUE (table 2a).

Table 2a. Catch data from accompanying fishermen in Salelavalu, Savaii. Fisher one is a woman and fisher two is a man. Weight of catch extrapolated from mean weight of one animal (derived from parallel collected biological data). CPUE = catch per unit effort estimate.

	Fisher 1	Fisher 2	Mean	Total
Total catch (No.)	599	487	543	1086
Fishing time (h)	3	3		3
Total weight (g) (extrapolated from mean)	46243	37596	41919,5	83839
CPUE (No/h)	200	162	181	362
CPUE (Kg/h)	15,41	12,53	13,975	27,95

According to these data the fishers can on average catch the equivalent of 1.8 750ml bottle of *S. horrens* per hour of fishing in Salelavalu. As a comparison to these numbers the CPUE was estimated from the reported catch in the household survey. The questionnaire asked for trips per week and catch per week and presented data are mean of reported trips and time spent fishing per week (table 2b). The CPUE is given as ml/h because fishers refer to catch in number of bottles (of various sizes).

Table 2b. Catch data from household survey form several sites around Samoa. Catch is total volume caught per week, divided by number of fishermen (that reported catch for each species), fishing frequency and time per trip to yield an estimate on catch (volume) per hour.

Species	Catch (ml/week)	No. Fishers	Fishing Frequency (average trips per week)	Average time per trip (h)	CPUE (ml/h)
S.horrens	137 400	/76	/ 2.3	/ 2.7	Ca 290
B.vitiensis	67555	/43	/ 2.3	/ 2.7	Ca 250

From the household survey the total reported catch is ca 180 750ml bottles of *S. horrens* per week from 76 fishers, and ca 90 750ml bottles of *B. vitiensis* per week from 43 fishers. Across areas where fishers were interviewed the average catch of *S. horrens* is ca 290ml/h (table 2b). This is 1/4 of the recorded catch in Salelavalu. For *B. vitiensis* the CPUE is similar that of *S. horrens* (table 2b).

During fishing it was also noted that 4.7% (13 out of 275 animals) of the animals were empty of viscera (probably eviscerated due to stress) at the time of cutting.

3. Biological data for *S. horrens*

The biological data were collected from animals caught by researchers. Length and weight were first recorded using a ruler and electronic balance (accuracy 0.1gram). The animal was then cut open and the viscera product was weighed. The animals were collected individually to avoid affecting fishermen in their routine work of catch collection, and to avoid slowing them down in their routine of viscera harvesting. Researchers collected the animals used for biological data at the same time as fishermen were fishing. The animals were treated the same way as the rest of the catch except that they were weighed and measured for length before cutting. Analysis was performed using statistical software package MINITAB® Release 14.1. The length weight data show a good correlation (r^2=0.73; p=0.000; df_{tot}264) and the length to weight relationship formula is y=1.8744x – 2.1113 (fig 3a and b).

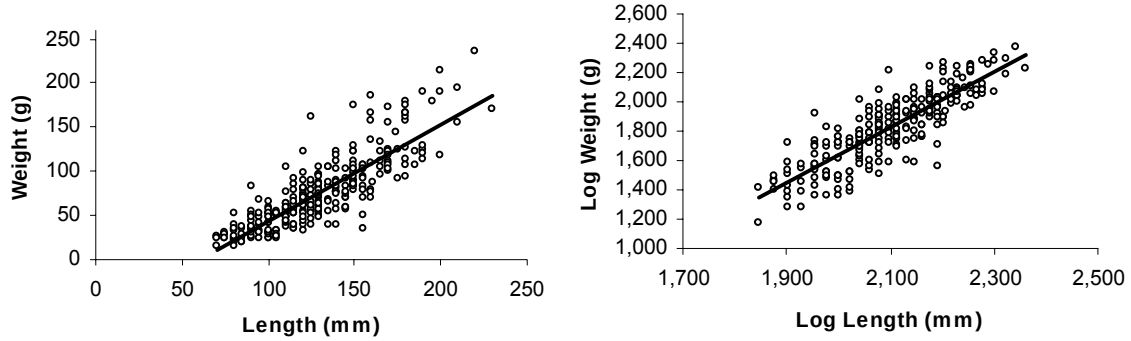


Fig 3a and b. Length weight and Logarithmic length weight relationship for *S. horrens* caught in Salelavalu, Savaii. Animals were collected by researchers. Logarithmic data show a good correlation between length and weight (r^2=0.73; p=0.000; df_{tot}=264; y=1.8744x – 2.1113).

The viscera of each individual were also weighed after removed from the animal. This weight was correlated to animal length (r^2=0.44 p=0.000; df_{tot}264; y=2,0351x – 3.2278) (fig 3.2c and d) and animal weight (r^2=0.61; p=0.000; df_{tot}264; y=1.0893x – 0.9422) (fig 3 e and f).

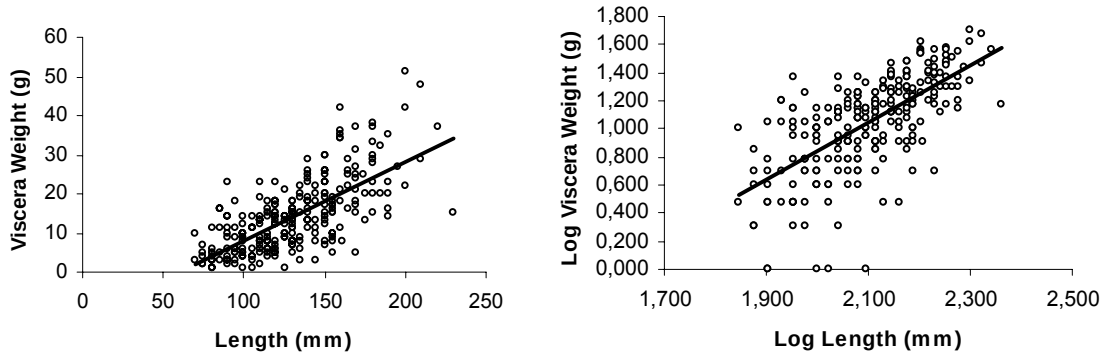


Fig 3c and d. Length viscera weight relationship for *S. horrens* caught in Salelavalu, Savaii. Animals collected by researchers. Data are noisy and show weak relationship (r^2=0.44; p= 0.000; df_{tot}=264; y=2.0351x – 3.2278).

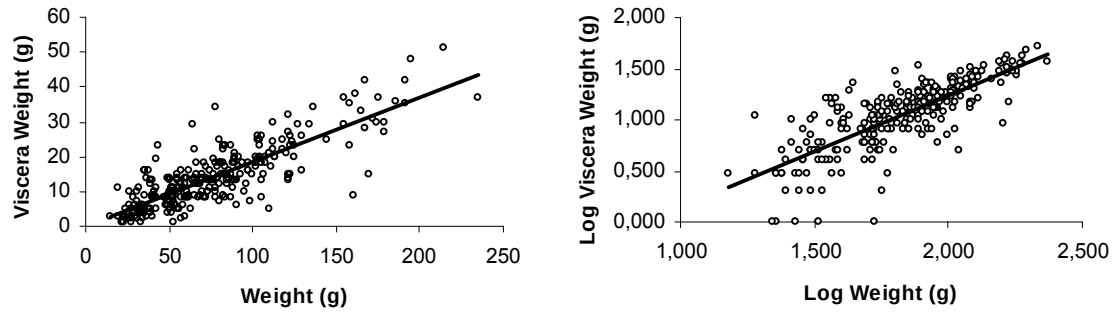


Fig 3e and f. Weight viscera weight relationship for *S. horrens* caught in Salelavalu, Savaii. Animals collected by researchers. Data reveals a good relationship between animal weight and the weight of the viscera (r^2=0.61; p=0.000; df_{tot}=264; y=1.0893x – 0.9422).

The weight of the animal proves to be a stronger indicator of the size of the product than the animal's length. The mean values of all biological data are presented in table 3.1

Table 3.1. Mean values (±SE) for recorded biological parameters for *S. horrens* in Salelavalu (n=287).

Mean length (mm)	129.3 ± 1.9
Mean weight (g)	76.0 ± 2.4
Mean product weight (g)	14.2 ± 0.5

All collected (by researchers) length data were pooled to generate a length frequency distribution (fig 3g). The frequency distribution shows a (relatively) steep decline at small lengths, which is probably due to small animals being cryptic and hard to find.

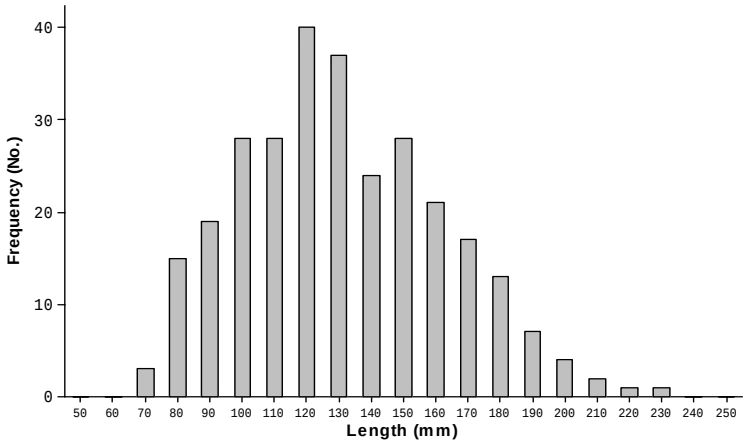


Fig 3.2g. Length frequency distribution of *S. horrens*, collected by researchers in Salelavalu, Savaii. The frequency shows a node at 120mm. The steeper decline at low lengths can be a result of small animals being even more cryptic and hard to find.

4. Household survey

A house hold survey questionnaire was put together for interviews of local villagers and fishermen on consumption, catch and sales of sea cucumbers around the country. The household survey aimed at interviewing 20% of local village households and ca 50% of local fishers. Samoan Fisheries Division staff and US Peace Corps Volunteers performed the household survey in Samoan language.

From the household survey it is established that the fishers' regularly target three species, *S.horrens, B.vitiensis* and *H.atra* (fig 4a) in similar proportions, and further, that consumers target the same species but proportions differ from that of fishers' catch (fig 4b). Personal communications with fishers also indicate that *B.argus* is targeted outside these species.

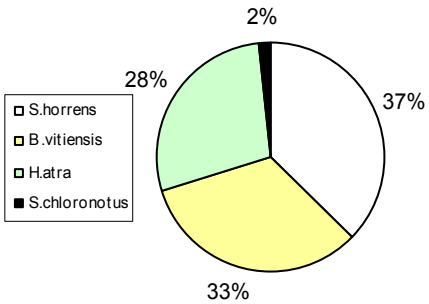


Fig 4a. Target species according to fishermen (n=109).

Fig 4b. Distribution of species sought for by consumers (n=298).

These results suggest that *S.horrens* is the more sought for species (60% of answers) whereas *B.vitiensis* and *H.atra* are less sought for (36% and 27% of answers respectively). If one person replied that he/she buys more than one species then it does not reveal a preference. However, most people that answered that they only buy one species said that they buy *S.horrens*.

When asked about the fractions of catch sold most interviewees answered that none of their catch is sold (fig 4c). It seems only ca 10% of the fishers sell all their catch. Since the great majority of fishers (ca 80%) keep their catch to themselves this proportion of catch is not available for market or roadside surveys. This should be kept in mind for future monitoring.

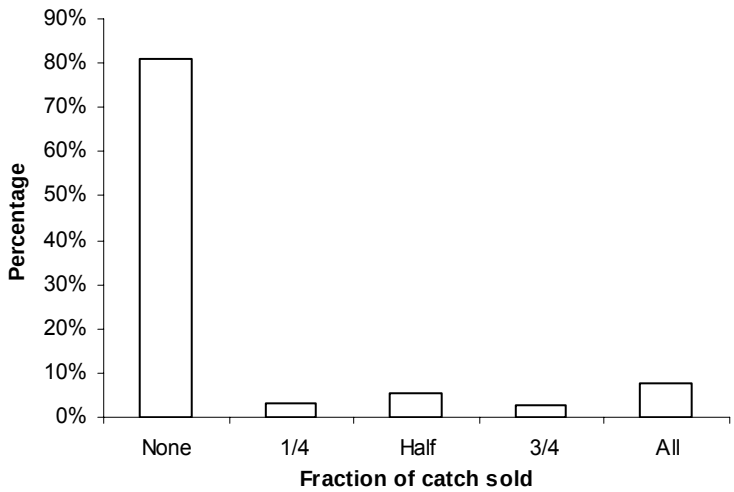


Fig 4c. Fraction of catch sold (n=317).

When asked a similar question, what the general fate of the catch is, a majority (61%) of the interviewees answered that they eat all or a part of the catch within the family (fig 4d). Further, 29% answered that they sell part or all of their catch, whereas every one that answered that they give catch away (9%) give away 25% of their catch. Note that proportions of catch eaten and sold varied. This result still emphasises that most of the catch is kept from the buyers (market and roadside). Although numbers are not as extreme as presented in fig 4c.

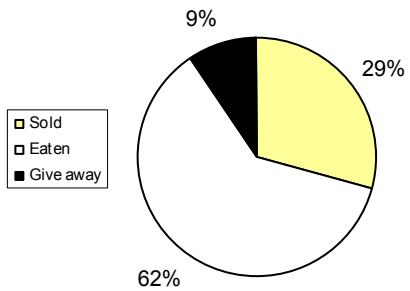


Fig 4d. Proportion of catch sold, eaten or given away. (n=117). Note that proportions of catch sold and eaten varied between fisher. All who said they use their catch as gifts, give 25% of their catch away. Proportions of catch sold and eaten varied

To understand the channel the local fisherman utilizes to sell his/her catch the fishers were asked where the catch is sold. The results show that 66% of the catch is sold at the roadside and the remaining 34% of catch is sold at the market (fig 4e). Further, when asked where the

general public buys their sea cucumber the results show that the market is the most common place whereas roadside is smaller than both 'village' and 'market' sales (fig 4f). It should be noted that 'village' sales might include roadside sales depending on whom you ask (i.e. 'roadside' if you are in a car and 'village' if you walk to your neighbour who sells bottles at the side of the road).

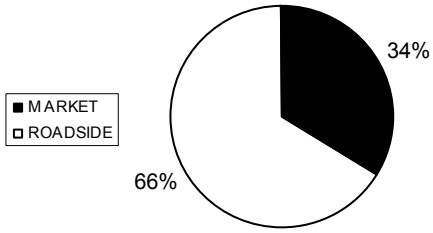


Fig 4e. Percentage of catch sold at market and roadside in Samoa.

Fig 4f. Where most of the bottles are bought (n=298).

The buyers generally showed a preference for the 750ml and the 285ml bottles (fig 4g). These are also the most readily observed bottles sold both at market and at roadside.

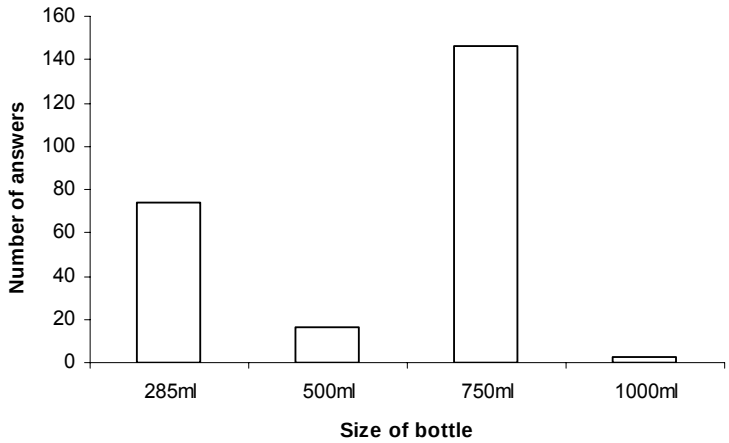


Fig 4g. The most bought bottle sizes. There is a preference for 285ml and 750ml bottles.

As an estimate on how much each bottle and product is worth, the public was asked how much they pay per bottle for *S. horrens* and a *S. horrens/B. vitiensis* mix. The results show that the most expensive bottle is the *S. horrens* 750ml with an average price of $22.7 Tala (fig 4h). To further illustrate the price range of the products fig 4i presents the frequency of answers within a price range.

Fig 4h. Mean prices for the four most available products. Bars are SE (St.dev/√n).

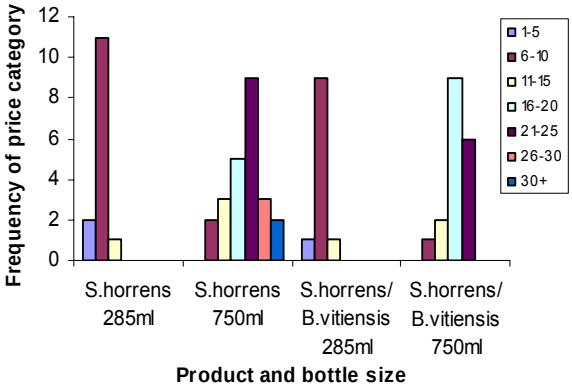


Fig 4i. The frequency of reported price ranges for the most occurring products. Prices are in Samoan Tala.

5. Market and roadside sales data

Since the year 2000 Samoan Fisheries Division collects catch data at Fugalei market in Apia, which is where most sea cucumber products (bottles) are sold in the capital. In 2001 the fisheries also started collecting such catch data trough roadside surveys. The roadside surveys complement the market survey in that several families buy their sea cucumber bottles driving to and from Apia. The market survey is routinely performed every week covering a majority of products for sale. The roadside survey is also performed routinely and covers the vicinity of Apia (Apia west towards Faleolo). The bottle data recorded are not entirely accurate as several mixes occur, but the data provide useful estimates.

In 2004 a total of 1.71 mt (product) of *S. horrens* and *B. vitiensis* was sold at Fugalei market and roadside, at a total value of $73,748 Tala. The quantity of caught and sold sea cucumbers for artisanal purposes has varied over recent years. Since Samoan Fisheries Division started collecting data at Fugalei Market in 2000 the quantity of sold sea cucumber bottles had a peak in 2002 for *S. horrens*, and has since decreased, whereas the amount of *B.vitiensis* bottles has increased from 93 bottles year 2000, to 468 bottles year 2004 (fig 5a).

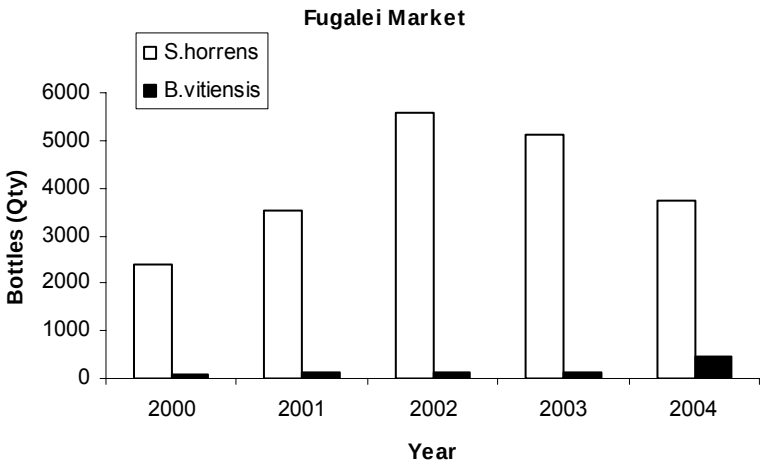


Fig 5a. Number of bottles of *S. horrens* and *B. vitiensis* sold at Fugalei market in Apia since data collection started in 2000.

The trend is similar for the roadside data. Since the year 2001 the number of bottles sold of *B. vitiensis* has increased with 676% from 25 to 169. The *S. horrens* bottles sold at roadside

increased from 884 in 2001 to 2052 in 2003, only to plummet to 36% from previous year in 2004 (735 bottles) (fig 5b).

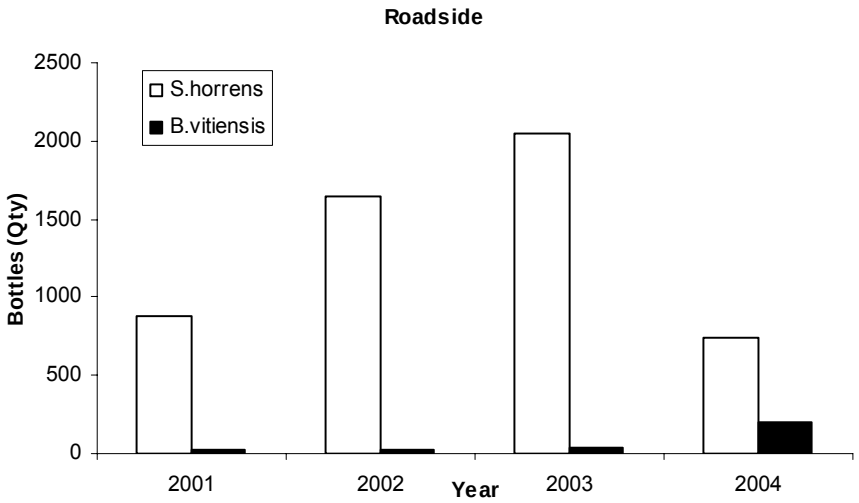


Fig 5b. Number of bottles of *S. horrens* and *B. vitiensis* sold at the roadside since year 2001. The trend is similar to that of Fugalei market.

Since data collection started products at a total value of $366 719 Tala has been sold at Fugalei market and at the roadside. This equals a total of 12.2 mt (product). The value of this for the local fishers, and their families, cannot be under emphasized. The trends in lower sales of *S. horrens* in 2004 do not necessarily reflect declining catches. Fishermen may find other channels of selling their catch, or catch disappears from the market due to own consumption, use as gifts or sold in areas not covered by fisheries surveys. The fact that the less sought for product *B. vitiensis* is increasing, as the popular (and more expensive) *S. horrens* sales are declining may however indicate that the availability of *S. horrens* is declining and not satisfying the market, hence *B. vitiensis* is increasing as an alternative to fill the gap. Such trends are common in areas where overfishing is apparent (Uthicke 2004; Lawrence et al. 2004; Conand 2004; Nash and Ramofafia 2006). Therefore, attention should be directed to these numbers and future sales data kept under close surveillance.

As an example of how much the biomass catch of *S. horrens* was in 2003 at Fugalei market and roadside, catch and biological data from above are used to extrapolate an estimate of total biomass (table 5a).

Table 5a. Biomass estimate calculated from 2003 catch data and bottle and biological data (mean values) collected in Salelavalu 2005.

Bottles sold in 2003	Products from 1 bottle	Weight of animal	Biomass estimate
7160 pcs	102.375 pcs	75.979 g	55.7 mt (wet weight)

The biomass estimate is probably an overestimate as a majority of bottles recorded as 'sea' are sold as mixes with other species, meaning that the mean number of 'sea' in the average bottle is lower than above.

6. *S. horrens* survival after harvesting

A pilot study was set up as an attempt to understand what happens to *S. horrens* animals after they have been cut and emptied of its viscera. This was performed as a small-scale survival project using cages to keep harvested animals in (Picture 11 and 12).

Picture 11 and 12. The cages used for the survival experiment was 450x450x200mm (bxlxh), and had a mesh size of 12-17mm.

The project attempted to get a glimpse of the rate of survival among *S. horrens* individuals that are returned to the area where local fishers return their catch. The survival project was performed Dec. 8 to Dec. 12 2005 in the village of Toamua, just west of Apia. Three hours were spent fishing from 19:30 to 22:30, and during this time a total of 23 *S. horrens* individuals were caught (compare catch data to Salelavalu: $CPUE_{Toamua}$=7.67 no./h – $CPUE_{Salelavalu}$=362 no./h). The catch was brought back to shore as per usual and left over night in a bucket. The animals spent a total of 8 hours in the bucket, which is a bit longer than they are usually kept. In the morning the animals were cut to access the viscera and then collected in a second bucket. The cut animals were put in cages (3 cages x 6 animals and 1 cage x 5 animals) in a near shore area (where animals are usually returned). Two to tree large rocks that also provided shelter for the animals held down the cages. The following day the cages were checked for survival and possible heal of cut. After 24 hours in the cages 13 animals were still alive, and one animal was missing (fig 6a). On day four (due to the weekend the cages were inaccessible for day 2 and 3) only 4 animals were found in the cages and the rest were missing. Either they were poached or they died and were carried through the mesh by the current, or they escaped through the mesh of the cages.

Out of the 13 surviving animals on day one, 9 had healed their cut, and 3 had almost healed (fig 6b). The 4 animals that were left at the end of the survey were cut open to check for possible re-growth of viscera. No viscera re-growth was noted for any of the animals. In spite of its small scale the study still reveals a rough survival estimate of ca 50% the first 24 hours in the cages, and that out of those a majority had completely healed their cut.

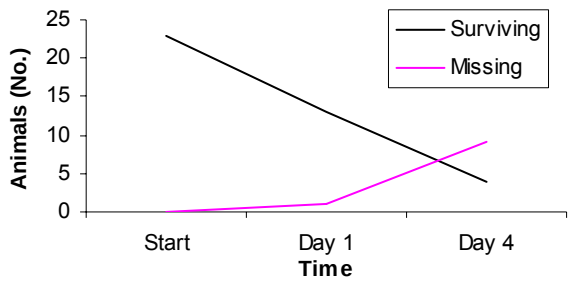


Fig 6a. Number of surviving animals after cut. The increasing number of missing animals after day 1 might have been poached.

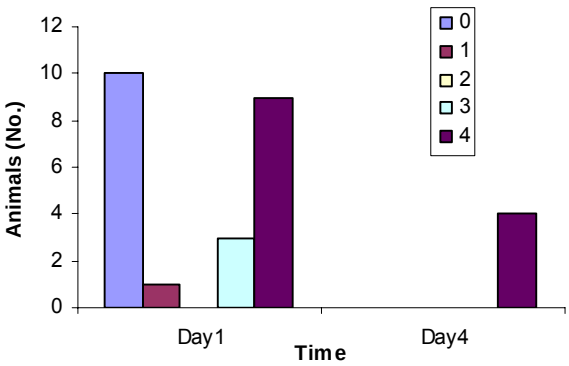


Fig 6b. Degree of heal from cut. It should be noted that out of the 13 surviving animals on day 1, 9 had healed their cut completely. (0=Dead, 1=No heal, 2=Moderateheal, 3=Almost healed, 4=healed.)

Although it was shown that the animals could survive harvest, no clear conclusions can be derived from these results. This study should be considered a pilot study and shows that there is potential for obtaining valuable information for management. A template of an extended

experiment to provide conclusions in the *S. horrens* rate/probability of survival is included in an appendix (appendix 1).

7. Conclusions

The most commonly used bottle for product storage and sale is the Coke 750ml. From the catch data from Salelavalu it is known that these bottles on average fit ca 102 viscera products. Usually 5-10 bottles from Salelavalu of 'sea' can be observed per day at Fungalei market (plus the mix bottles with 'sea' and fugafuga) (See Picture 3). That is 500 to more than 1000 animals. Products from Salelavalu are not available everyday which means that this number is not on a daily basis, but still reflects that Salelavalu is an area under heavy fishing pressure. The catch data show that 'sea' can be collected at a reasonably low effort in Salelavalu compared to estimates from the country in general (table 2a and 2b). To allow this pattern to persist it is suggested that the fisheries division, monitor this area for declines in catch (see suggestions on monitoring procedures and management in next section). This goes for the Aleipata district also, which is the other big supplier of 'sea'. However no data have been collected there. The catch data show variation over the country. This is in line with personal communication with fishermen. The decline in catches in many areas is said to be a result of over fishing and due to not returning harvested *S. horrens* individuals to the sea.

The results from market and roadside surveys show a decline in *S. horrens* catch, whereas *B. vitiensis* is caught in higher numbers by the year. The trend suggests that as 'sea' is becoming scarcer fishermen look to alternative species of lesser value. It should be noted that during a roadside survey some bottles of *H. hilla* were observed (in the village of Toamua), this species was never encountered as a sought for species during interviews. This again shows that fishermen may be turning to other species due to declining 'sea' catch.

The morphological correlations show that the animal weight is a better indicator to viscera weight than length.

7.1 Future monitoring and management

It is suggested that the *S. horrens* survival experiment is performed at a larger scale. This could reveal specific patterns in survival depending on handling procedures and catch return area. The introduction of sanctuaries (release zones) where cut animals are returned may allow harvested animals to re-grow its viscera and disperse accordingly. A rotational fishing scheme would also fit the purpose of allowing harvested animals to be left to re-grow before harvested again. This would be a simple management procedure that would not mean restrictions on length or bag size etc. and hence would seem appealing to fishers. Catch restrictions may however prove necessary.

Today the fisheries perform monitoring of many seafood species (sea cucumbers and others) at Fungalei market, Salelologa market (Savaii) and roadside. This seems reasonable against the background of the sales data presented in the household survey here, as a majority of the catch is sold at markets and roadsides. However, it should be kept in mind that a large proportion (at least 50%) is consumed within the family, sold or given away. Hence, recorded catch is only a fraction of actual catch. If further roadside surveys were performed in other parts of the country it may reflect the true catch over a larger region more accurately. It is probable that future data from market and roadside surveys will further acknowledge the trend that there is a shift in catch composition (from *S. horrens* to *B. vitiensis*). If this is the case then active management will be necessary to restrict the fishing pressure on both these species.

Table 7.1. **Two suggestions on components that could help sustain 'sea' catches:**	
1.	An extension of the pilot study presented here may yield information on whether *S. horrens* survives the harvesting procedure. As it seems there is some chance of survival after harvest this can provide the background for a simple management procedure that may allow catch to persist. This could for instance be a rotational fishing scheme - with the proposed outcome of maintaining a viable *S. horrens* resource without (at this stage) catch restrictions.
2.	Raise awareness and increase knowledge among local fishers (as well as general public) regarding the sea cucumber species and the products occurring in the lagoons around the country (to some extent this has already been initiated by the village fisheries extension section at the Samoan Fisheries Division). This should highlight that the sea cucumber resource is an exhaustible resource that may be fading and perhaps suggest caution in fishing effort and consumption. Ideally coastal communities should be supported into initiate fishing and management strategies such as catch and length restrictions or closed seasons or areas (such as MPA's). This can only be achieved with the assistance of the Fisheries Division.

Acknowledgements

The *S. horrens* catch data were collected in the village of Salelavalu on Savaii. First I would like to thank Ms Anama Solofa, Mr. Clifton Sae and the entire Sae family for their great hospitality and warm company during three beautiful days on their island. I would also like to thank the fishermen and women that so patiently assisted us in collecting these data and sharing their knowledge on this amazing resource, despite the extra effort it meant for them.

The pilot study on *S. horrens* survival was performed in the village of Toamua on Upolu. Here I would like to thank the fisherman Tasi that assisted us (myself, Misipele Afaamasaga and Peleti Paia) in collecting animals and looking after the cages during the experiment. I also thank the Samoan Fisheries Division Aquaculture section for supplying material for the cages.

The household survey was performed by staff from Fisheries Inshore, Village Extension and Aquaculture section. Tevita Apulu, Misipele Afamasaga, Mikaele Faamai, Joyce Samelu, Faasulu Fepuleai, Peleti Paia, Ferron Fruean, Clifton Sae and Aleluia Taise.

I would also like to thank the United States Peace Corps Volunteers (US PCVs) Danielle Toole, Robin Rosenau and Sarah Valencia working at the Samoan Fisheries Division; their assistance in data collection, handling and cultural advice remains much appreciated. The US PCVs also assisted in the household survey by performing interviews in their 'home'-villages which gave breadth to the socio-economic data collected at survey sites.

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Appendix 1. Survival of *S. horrens* after harvest – experiment template.

This appendix is a brief template of an extension on the *S. horrens* survival after harvesting experiment. An extended experiment should aim to set out cages in both near shore areas and fishing ground areas to possibly distinguish between rates of survival depending on environment. Using treatments with immediate cut and release alongside usual catch return procedures may provide an indication on whether the time spent in catch buckets affects survival. Here sample sizes of 6-8 animals per cage and 6 cages per treatment are recommended (table 6).

Table 6: Description of survival study treatments.

Treatment	Description	Numbers
1	Immediate cut and release.	6 Cages á 6-8animals
2	Fishing ground – return after viscera harvesting (after usual handling procedures).	6 Cages á 6-8animals
3	Near shore – return after viscera harvesting (after usual handling procedures).	6 Cages á 6-8animals
Control 1	Fishing ground control – release without viscera harvest.	6 Cages á 6-8animals
Control 2	Near shore control – release without viscera harvest.	6 Cages á 6-8animals

Fig. 6c further illustrates the study template derived from the pilot study. More treatments could be used to isolate other survival factors such as predators and wave energy exposure (using open cages).

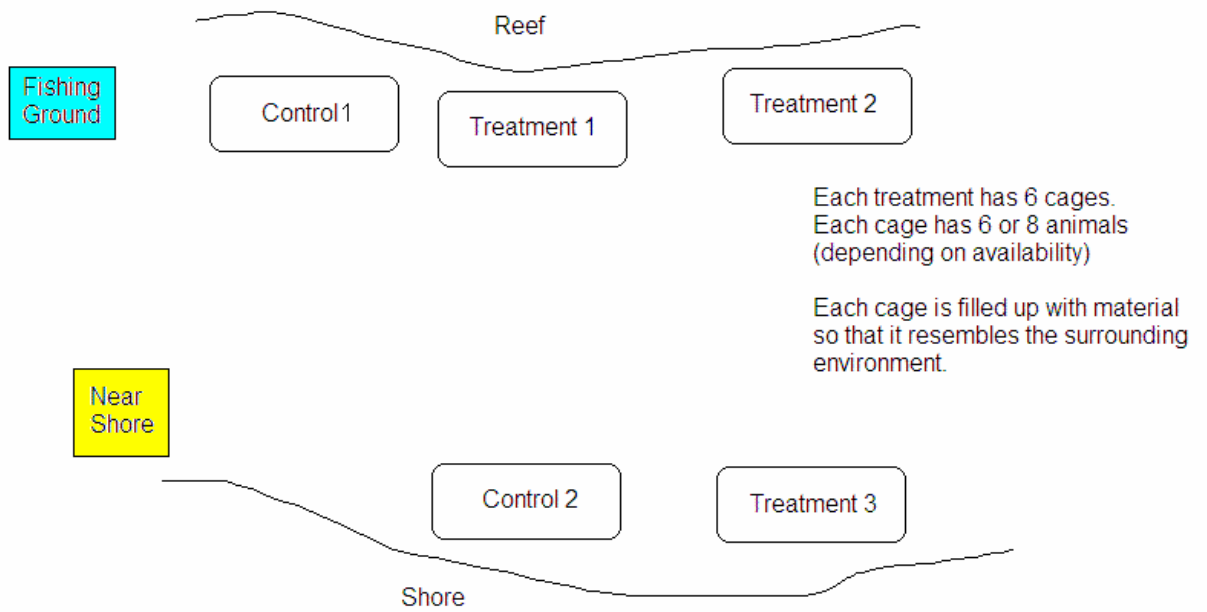

Fig 6c: *S.horrens* survival after harvest study template. Each treatment aims to isolate for factors possibly affecting rate of survival after viscera harvest. Factors include time between catch to return and area of return.