Overview of sea cucumber aquaculture and stocking research in the Western Pacific region

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Abstract

Sea cucumbers represent an important income source to coastal communities in many Pacific islands, but is now worth only a fraction of historical values. Sea cucumbers have been harvested for hundreds of years for trade with Asia and were probably one of the first real 'exports' from the Pacific islands. Unfortunately, the increase in demand and price, combined with the development of cash economies and growing coastal populations in many islands, has led to widespread overfishing of the resource across much of this region. There is a high level of interest in adoption of aquaculture techniques to restore production levels, but different capacity levels require implementation of different techniques. Some Pacific island countries and territories have completed successful research trials of hatchery and release techniques, and now have capacity to scale up this activity. Factors that work in favour of successful aquaculture include pristine marine environments, long familiarity with sea cucumbers as a commodity, and traditional marine tenure systems that in some places can provide a basis for management of released sea cucumbers. Challenges include lack of technical capacity, unproven effectiveness of sea cucumber releases and poaching.

Introduction

On 14 February 2011, prior to the Asia–Pacific Tropical Sea Cucumber Symposium, Noumea, official representatives of Pacific island countries and territories (PICTs) that are members of the Secretariat of the Pacific Community (SPC) met to discuss sea cucumber resources and aquaculture. This paper represents a synthesis of their status, and was presented on the first day of the symposium. When participants' experiences were compared and discussed, a number of common themes emerged:

- Sea cucumber represents an important income source to coastal communities in many Pacific islands. Sea cucumbers have been harvested for hundreds of years for trade with Asia and were probably one of the first real 'exports' from the Pacific islands.
- This is mainly an export market commodity, but it is also a subsistence food fishery in some Pacific island countries and communities; for example, as a whole cooked sea cucumber, as 'sashimi' (sliced raw meat), or as marinated guts and gonads in salt and lime.
- Catches from the Asian and Pacific regions are known to be the highest, with about 36 species being harvested in the Pacific region.
- Stocks are under heavy pressure with increases in demand and price, combined with the development of cash economies and growing coastal populations in many islands. This has led to widespread overfishing of the resource across much of this region. Through time, smaller individuals and lower valued species are forming a steadily increasing proportion of the total catch.
- Management of the fishery has essentially failed, for a number of reasons. PICTs are resorting to the extreme measure, and 'blunt instrument' management, of imposing fishing moratoria for extended periods (years at a time) to bring about stock recovery.

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- Concern about overexploitation has led to initiatives to promote sea ranching and restocking as an income-generating activity and a means to increase the production of wild stocks.

PICT status reports

Although there are similarities, differences also exist between PICTs—both in the species of interest for sea cucumber aquaculture and in the level of capacity to implement aquaculture techniques to increase production. A number of PICTs have made progress on sea cucumber aquaculture on a few key species. Key points about the main PICTs involved or interested in sea cucumber aquaculture are summarised in Table 1.

Research in PICTs

Despite the majority of PICTs having limited capacity for research and development of sea cucumber aquaculture, it is worth highlighting the notable exceptions where targeted research effort has been made. The countries with some history or current activity in the area are Kiribati, Federated States of Micronesia (FSM), Palau, Fiji, Solomon Islands and New Caledonia. Sandfish continues to be the focus of research and development activity in FSM, Fiji and New Caledonia. Substantial research was done in the late 1990s in Solomon Islands on sandfish culture (e.g. Battaglene et al. 1999), but Japan is now funding research into peanutfish or dragonfish (*Stichopus horrens*) production. Kiribati is the first (and only) country to consistently produce high-value white teatfish (*Holothuria fuscogilva*) juveniles (Friedman and Tekanene 2005; Purcell and Tekanene 2006) (Figure 1). Since 2009, Palau has produced surf redfish and hairy blackfish (*Actinopyga mauritiana* and *A. miliaris*) both medium-value sea cucumber species. In all the PICTs active in sea cucumber production, the emphasis is currently on production technology that has been provided either by private investment (e.g. Palau and FSM, Yap) or through the efforts of overseas aid assistance and government support (e.g. Kiribati, Fiji, Solomon Islands, FSM, New Caledonia). Hatcheries are being built, and staff are being trained or technicians imported in some cases to boost capacity.

Figure 1. Cultured white teatfish juveniles produced at Tanaea hatchery, Kiribati (Photo: Antoine Teitelbaum)

Table 1. Summary of sea cucumber aquaculture in Pacific island countries

Country	Availability of high-interest species	History of sea cucumber aquaculture	National strategy
Fiji	White teatfish Sandfish	ACIAR sandfish hatchery mini-projects at Savusavu (Vanua Levu island) and Galoa (Viti Levu island) First spawning started in 2009, training also provided to community wardens	Fisheries Department aquaculture priority included in work plan from 2011 A regulation on sea cucumber is in place. Sandfish are reserved for subsistence fishery and prohibited from export
Federated States of Micronesia (FSM)	White teatfish Sandfish *Actinopyga* spp. Lollyfish Black teatfish	Hatchery-based releasing project for sandfish and black teatfish, College of Micronesia, Land Grant Program, Pohnpei Private hatchery and sea ranching in Yap for *Actinopyga* spp. 1 staff was trained in Fiji in 2008 (ACIAR), and has transferred their knowledge to other staff	National Aquaculture Strategy (2002) identified sea cucumber as a priority for development Yap: there is a regulation on licensing system in place Pohnpei: all harvests banned since 1995 Kosrae: all exports banned Chuuk: intensive fishing activity, and no sea cucumber fisheries management systems are in place
Kiribati	White teatfish	Overseas Fishery Cooperation Foundation of Japan (OFCF) hatchery projects, initiated in 1995, started production in 1997, and released about 10,000 sea cucumbers per year from 1999–2004 and again in 2008–09 ACIAR research on release strategies	Government wishes to develop white teatfish further No specific legislation for sea cucumber Sea cucumber fishery management plan currently formulated Wish to introduce sandfish because it is more suitable than white teatfish for culture in ponds
New Caledonia	White teatfish Sandfish Black teatfish	Large WorldFish–ACIAR St. Vincent Project on juvenile grow-out, release techniques and pond trials (2001–07)	Government is supporting development with pilot projects and research for sandfish

Hatchery capacity	Community-based management capacity	Broodstock availability	Constraints
Private blacklip pearl oyster hatchery (Savusavu) with micro-algae culture facility Government shrimp hatchery (Galoa) with micro-algae culture facility Seawater laboratory at the University of the South Pacific in Suva, with micro-algae culture facility Government and private-sector staff trained on sandfish under ACIAR project, and on micro-algae	Fiji Locally-Managed Marine Area Network projects in Fiji: 259 registered marine protected areas (MPAs) Natuvu village in Cakaudrove province created an MPA especially for sandfish restocking (2008)	Sandfish are available, although there is localised scarcity White teatfish availability is unknown but probable	Government micro-algae production facility and expertise needs upgrading Need for more people to be trained on seed production and grow-out
Functional hatchery at College of Micronesia in Pohnpei There has been a hatchery facility in Yap since 2007 (*Actinopyga* spp.) There is a private hatchery in Chuuk Kosrae National Aquaculture Centre has a micro-algae culture facility	MPAs are getting support, and communities are now requesting that those MPAs be stocked with sea cucumber	Availability in Yap and Pohnpei, with sufficient sandfish in the wild. Often used 100–200 adults for spawning Kosrae and Chuuk not surveyed but likely to be the same	Lack of local investors Lack of skills and local technicians, so there is reliance on foreign technicians Need for better communication between national and local governments, private sector and traditional tenure holders
White teatfish hatchery Government pearl oyster hatchery	No community-based MPA in Gilbert and Line groups, only the Phoenix Islands Protected Area A few community-based fisheries management (CBFM) plans	White teatfish becoming difficult to find Sandfish are not present in Kiribati, so for aquaculture to become possible it would first need to be introduced	Scarcity of broodstock, so they are kept in captivity White teatfish are not suitable for pond culture High mortality rate during juvenile stage Release effectiveness unknown Very difficult to monitor post-release juveniles High staff turnover, so a continual need for training
One private sea cucumber hatchery under construction, and another being proposed Have six shrimp hatcheries and two for finfish	23 MPAs in Province Sud and 4 in Province Nord CBFM in one community	Still have good stocks, both in and out of MPAs, but high variability between sites Genetic survey of broodstock has been conducted	Spawning season may be limited by cold temperature Production and grow-out economic assessment needed Expert advice sought on protocols, especially grow-out Need to develop tagging methods for monitoring (sea ranching and restocking) Availability of juveniles for restocking and enhancement may be limited by hatchery capacity

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Table 1. (continued)

Country	Availability of high-interest species	History of sea cucumber aquaculture	National strategy
Palau	White teatfish Sandfish Surf redfish Blackfish	Has had a project since 2009 producing *Actinopyga mauritiana* and *A. miliaris*	Government aims to develop sea cucumber aquaculture
Papua New Guinea	White teatfish Sandfish	None	Priority species, especially since sea cucumber harvest moratorium imposed
Samoa	White teatfish Dragonfish (*Stichopus horrens*) are targeted by the fishery Sandfish not present in Samoa	None	Sea cucumber restocking is in the Aquaculture Section Workplan for 2011–15 (subject to hatchery) Government's current main priority is management of the sea cucumber fishery A private-sector initiative to introduce sandfish for aquaculture is now underway Ban on commercial harvest for export of any sea cucumber species, ban on harvest within reserves
Solomon Islands	White teatfish Sandfish Peanutfish (dragonfish (*S. horrens*)) to be targeted in a new project developed by Japan (OFCF)	Large WorldFish–ACIAR project on hatchery techniques (1996–2000)	One of four priorities government wishes to develop, according to 2009 National Aquaculture Development Plan
Tonga	White teatfish Golden sandfish	None	Aquaculture Plan identifies sea cucumber species as highest priority. Sea cucumber plan (2009) in place for the fishery
Vanuatu	White teatfish Sandfish	Two imports of hatchery juveniles of sandfish from Australia (2006–07), but have not been effective	Sea cucumber aquaculture identified as a priority in the National Aquaculture Strategy Draft sea cucumber fishery management plan in place Moratorium on export in place for 5 years since 2008

Hatchery capacity	Community-based management capacity	Broodstock availability	Constraints
Palau has expertise in producing surf redfish and blackfish Palau Community College has a hatchery under the Land Grant System	There is active support for MPAs (e.g. HOPE Network)	Unknown but probably available, as for Pohnpei and Yap	No specific technical skills base for sea cucumber. Project run by Korean technicians Lack of micro-algae production facility and expertise
Private pearl and shrimp hatcheries New government multispecies hatchery at Kavieng	PNG Centre for Locally Managed Areas is active in New Britain and New Ireland Current moratorium on fishing will benefit release activities	Available, although overfishing will have reduced numbers of large animals	No specific expertise for sea cucumber No specific expertise for micro-algae production
Clam hatchery has been decommissioned. Does not have a mariculture hatchery facility at the moment. Proposed new hatchery not built yet	History of community-based management since 1995 (fisheries by-laws) Good success with trochus introduction and stocking onto reefs 54 village-level reserves, 2 district-level MPAs and 84 village CBFMs currently effective	Sandfish not present in Samoa White teatfish and other high-value species in good sizes very scarce	No specific expertise for sea cucumber Lack of micro-algae production facility and expertise Low biomass of high-valued species based on previous surveys
WorldFish Center Nusa Tupe clam hatchery OFCF–government sea cucumber (peanutfish) hatchery has four local technical staff, but they need training on sea cucumber	Three main active MPAs in place Solomon Islands Locally Managed Marine Areas Network and World Wildlife Fund both active in engaging with communities	Sandfish available. Severe overfishing has probably limited broodstock availability, but this needs a survey Broodstock for peanutfish readily available and will be collected from the three MPA sites	Lack of micro-algae production facility and expertise Peanutfish is a new species for aquaculture, so not much information about it yet
Trained on sandfish in 2008 under ACIAR at Department of Primary Industries in Cairns Clam and pearl oysters produced at Sopu government hatchery New micro-algae facility in place but not yet operating	History of community-based management Special Management Areas in place since 2002, regulation in 2008	Sandfish available	MPAs are not very effective due to enforcement problems Micro-algal unit not yet operating due to lack of funds.
Private shrimp hatchery Government clam/trochus hatchery	Traditional community-based *tabu* areas (closed to fishing or harvesting) and MPAs are in place (e.g. Village Based Resource Managed Areas Network) Customary Marine Tenure very active but commercial pressures intense	Probably okay Will conduct a survey in 2011–12 to determine stock status	No specific expertise for sea cucumber Lack of micro-algae production facility and expertise Lack of hatchery space

Fiji, Palau, Kiribati and New Caledonia have released locally cultured juvenile sea cucumbers into the wild, and cultured juveniles from Australia have been released in Vanuatu. Although Kiribati has had success in the spawning and rearing of white teatfish, there has been high mortality of juveniles in the hatchery. For those that reach release stage, it has been established that fluorochrome marking can successfully distinguish them from wild animals (Purcell and Blockmans 2009). However, their highly cryptic nature and the lack of appropriate release strategies have constrained efforts in that area. Despite the release of tens of thousands of juveniles of approximately 10 mm length on numerous occasions, monitoring for survival and growth has been unsuccessful. Recent attempts to release into enclosures failed due to storms that destroyed the pens (Teitelbaum and Aram 2010). In another project, over three million juvenile *A. mauritiana* and *A. miliaris* were produced and released into the wild in three states in Palau. However, the success of this release program is unknown. The results of a small pilot release of juvenile sandfish in Fiji were promising (average 28% survival after 6 months and 166 g size at 8 months: Hair et al. 2011; Hair 2012), but the project needs to be scaled up to gain commercial confidence in the activity.

FSM has not released any juveniles yet but the College of Micronesia in Pohnpei has developed a land-based system ('habitat simulator') for long-term holding of broodstock and juveniles, which uses a combination of flow-through and closed recirculating water techniques (Figure 2). Hatchery-produced juveniles were used for tagging trials (M. Ito, pers. comm., March 2011). In the habitat simulator, tag retention rates for larger individuals (ind) were 70–87% at 2 months (stocking density ~20 ind/m^2 or ~3,000 g/m^2), while for smaller sandfish it was 80% at 2 weeks (~8 ind/m^2 or 210 g/m^2). Numbers of juveniles were released into enclosures in the wild 2 months after tagging; retention rates on these are to be monitored for a period of 2 years. Batches of hatchery-produced juveniles (5,000 × 6 weeks old and 30,000 × 4 weeks old) are being maintained for large-scale tagging trials. The project will soon move to a restocking program, which will involve mass hatchery production of juveniles.

Figure 2. Habitat simulator system and hatchery technician tagging a cultured sandfish (College of Micronesia, Pohnpei, Federated States of Micronesia) (Photo: Masahiro Ito)

Much of our current knowledge regarding sandfish grow-out and release strategies was generated from research carried out between 2000 and 2006 in New Caledonia (e.g. Purcell 2004; Purcell and Simutoga 2008; Agudo 2012). Private-sector production in New Caledonia's northern and southern provinces is currently underway and, once available, cultured juveniles will be released into MPAs and grown in ponds. The experience from Vanuatu of importing juvenile sandfish and releasing them into the wild was perhaps unsuccessful because of poor release strategies, but information is lacking because post-release monitoring was not undertaken.

The problems associated with sourcing and holding broodstock have been identified as a bottleneck to developing sea cucumber aquaculture in a number of PICTs. In particular, the scarcity of white teatfish in Kiribati continues to constrain their hatchery efforts. The high cost of obtaining them and subsequent difficulty of keeping them in good spawning condition means that new broodstock have to be obtained for each hatchery run. This has led them to consider importing sandfish, which can be maintained more easily in secure pond facilities and which have well-established release strategies. In Fiji, FSM and New Caledonia, there are generally sandfish broodstock available, but stock status can be variable between locations. This is problematic if responsible release practices are being followed, since progeny should be released into the area where parent stock originated (Uthicke and Purcell 2004; SPC 2009). FSM is sourcing broodstock of black teatfish (*Holothuria whitmaei*) with the intention of culturing this species in the near future.

Discussion

There is universal interest among PICTs in the application of aquaculture techniques to increase production from sea cucumber resources. The main species of interest is sandfish, except in Kiribati (white teatfish) and Solomon Islands (peanutfish). Two countries that lie outside the natural geographical distribution of sandfish (Kiribati and Samoa) have expressed interest in introducing it for aquaculture.

The range of experiences with, and capacities in, sea cucumber aquaculture research vary greatly. Some PICTs have no capacity or experience at all. In others there has been successful completion of research projects, from which the capacity to produce juveniles in hatcheries for restocking trials on a pilot-commercial scale is now established. The leading PICTs in sea cucumber research activity to date are New Caledonia, FSM and Palau, followed by Kiribati, Fiji and Solomon Islands.

Technical capacity in-country is a vital prerequisite for successful sea cucumber aquaculture, but by itself it is not enough to guarantee success. The capacity for marine tenure systems in PICTs to deliver sufficient protection to investment in restocked or ranched sea cucumbers is another important consideration. There have been some positive experiences with management systems based on custom and traditional marine tenure, to achieve better conservation of inshore fishery resources. Community-based management provides one possible basis for protection of released sea cucumbers until ready for harvest. However, some PICTs have attempted sea cucumber aquaculture for a variety of other reasons, often with misguided intentions: for example, past experiences include projects that were very much investor-driven, with inadequate feasibility studies undertaken prior to development. The term 'aquaculture' can be used misleadingly by unscrupulous investors to lead PICT decision-makers into accepting an unsustainable development where wild stocks can be harvested at the same time as the so-called aquaculture is taking place. Policy advice and technical assistance are currently being provided by the SPC to member countries so that they can recognise and assess development proposals that are genuine and distinguish those that are purely to lure PICTs into allowing access to their wild stock (see Pakoa et al. 2012).

Taking these technical and institutional issues into account, the attributes of the Pacific islands region that lend themselves to sea cucumber aquaculture can be summarised as follows:

- Pristine marine environments and suitable marine habitat are available for restocking and sea ranching of priority species of interest.
- Community-based management systems are in place in many areas.
- Sea cucumber is an ideal commodity for rural and maritime community engagement because the harvesting techniques are simple, and because sea cucumbers do not require large investment capital for processing.
- The sea cucumber industry in this region has a history stretching over more than two centuries, so it does not require large investment in familiarisation or retraining, and it is already well-integrated within traditional lifestyles and practices.

- Sea cucumber hatchery requirements are similar to those of other species already being cultured in the region (e.g. shrimp, pearl, giant clam, trochus), so infrastructure can be shared with these other commodities.

The experiences shared by PICTs in sea cucumber aquaculture reveal some common challenges, however, including the following:

- In some places it is difficult to find sufficient numbers of broodstock-size animals for aquaculture.
- Expertise in sea cucumber aquaculture is limited.
- The effectiveness of sea cucumber releases is not yet proven: optimal release techniques are still being finetuned for some species (e.g. sandfish) and are unknown for others (e.g. white teatfish).
- Land-based nursery areas can be limiting.
- Land disputes can affect released juveniles and broodstock if release sites are open access or under dispute.
- Control and enforcement of restocked or sea-ranched populations to prevent poaching can be difficult to achieve.
- The consequences of translocation of juveniles are not yet known and could cause irreversible genetic problems, so care must be taken to preserve genetic integrity wherever possible.
- There needs to be more research into the economic feasibility of restocking.

Pacific regional priorities for sea cucumber aquaculture, to address these challenges and thereby enable PICTs to capitalise upon their favourable attributes, include:

- demonstration of the effectiveness of sea cucumber restocking and sea ranching through larger scale experimental releases and post-release monitoring
- research to develop optimal release strategies for improved survival and growth
- capacity-building and technology transfer among PICTs for sea cucumber aquaculture
- economic analysis of sea cucumber aquaculture and restocking scenarios
- social analysis of traditional marine tenure systems and of the effectiveness of community-based management, to identify the best governance and/or business models for protection of investment in sea cucumber aquaculture.

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References

Agudo N.S. 2012. Pond grow-out trials for sandfish (*Holothuria scabra*) in New Caledonia. In 'Asia–Pacific tropical sea cucumber aquaculture', ed. by C.A. Hair, T.D. Pickering and D.J. Mills. ACIAR Proceedings No. 136, 104–112. Australian Centre for International Agricultural Research: Canberra. [These proceedings]

Battaglene S.C., Seymour J.E. and Ramofafia C. 1999. Survival and growth of cultured sea cucumbers, *Holothuria scabra*. Aquaculture 178, 293–322.

Friedman K. and Tekanene M. 2005. White teatfish at Kiribati sea cucumber hatchery: 'Local technicians getting them out again'. SPC Beche-de-mer Information Bulletin 21, 32–33.

Hair C.A. 2012. Sandfish (*Holothuria scabra*) production and sea-ranching trial in Fiji. In 'Asia–Pacific tropical sea cucumber aquaculture', ed. by C.A. Hair, T.D. Pickering and D.J. Mills. ACIAR Proceedings No. 136, 129–141. Australian Centre for International Agricultural Research: Canberra. [These proceedings]

Hair C., Pickering T., Meo S., Vereivalu T., Hunter J. and Cavakiqali L. 2011. Sandfish culture in Fiji Islands. SPC Beche-de-mer Information Bulletin 31, 3–11.

Pakoa K., Bertram I., Friedman K. and Tardy E. 2012. Sandfish (*Holothuria scabra*) fisheries in the Pacific region: present status, management overview and outlook for rehabilitation. In 'Asia–Pacific tropical sea cucumber aquaculture', ed. by C.A. Hair, T.D. Pickering and D.J. Mills. ACIAR Proceedings No. 136, 168–176. Australian Centre for International Agricultural Research: Canberra. [These proceedings]

Purcell S.W. 2004. Criteria for release strategies and evaluating the restocking of sea cucumbers. In 'Advances in sea cucumber aquaculture and management', ed. by A. Lovatelli, C. Conand, S. Purcell, S. Uthicke, J.-F. Hamel and A. Mercier. FAO Fisheries Technical Paper No. 463, 181–191. Food and Agriculture Organization of the United Nations: Rome.

Purcell S.W. and Blockmans B.F. 2009. Effective fluorochrome marking of juvenile sea cucumbers for sea ranching and restocking. Aquaculture 296, 263–270.

Purcell S.W. and Simutoga M. 2008. Spatio-temporal and size-dependent variation in the success of releasing cultured sea cucumbers in the wild. Reviews in Fisheries Science 16, 204–214.

Purcell S. and Tekanene M. 2006. Ontogenetic changes in colouration and morphology of white teatfish, *Holothuria fuscogilva*, juveniles in Kiribati. SPC Beche-de-mer Information Bulletin 23, 29–31.

SPC (Secretariat of the Pacific Community) 2009. Use of hatcheries to increase production of sea cucumbers. Background Paper 4, Sixth SPC Heads of Fisheries Meeting, February 2009. Secretariat of the Pacific Community.

Teitelbaum A. and Aram K. 2010. White teatfish aquaculture project in Kiribati. SPC Fisheries Newsletter 131, 6–7.

Uthicke S. and Purcell S. 2004. Preservation of genetic diversity in restocking of the sea cucumber *Holothuria scabra* planned through allozyme electrophoresis. Canadian Journal of Fisheries and Aquatic Science 61, 519–528.

Natuvu (Fiji) community sea ranch warden with sandfish after a cyclone (note broken pen in background) (Photo: Cathy Hair)