Final report for Mini-project MS0505:

Experimental release and monitoring of cultured juvenile white teatfish (*Holothuria fuscogilva*) in Kiribati

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Introduction

Depletion of white teatfish, *Holothuria fuscogilva*, commonly known in Kiribati as "white teat" (Fig. 1a), is of concern to the Kiribati Ministry of Fisheries and Marine Resources Development (MFMRD) as it is a high value sea cucumber species and is heavily fished by local fishing companies. This species has declined in numbers and is now fished using SCUBA at depths of more than 30 m. The Kiribati Beche-de-mer Project (between the Government of Japan, through the Overseas Fisheries Cooperative Foundation (OFCF), and the Government of Kiribati) was initiated in 1995 as a result of concern over the depletion of commercial species of sea cucumber. The project focussed on white teatfish and ran until 1999. Spawning and larval rearing of white teatfish was achieved in 1997. Since then, the Government of Kiribati, through the MFMRD, has produced juveniles at their hatchery and carried out restocking in the Abaiang and Tarawa lagoons.

To date, the releases and monitoring have not provided good estimates of post-release survival of white teatfish juveniles. The juveniles are highly cryptic (see Figs 1b,c) and rarely found during monitoring. Moreover, individuals found in surveys cannot be distinguished from wild stock. This calls into question the economic and practical feasibility of restocking, in terms of number of surviving adults versus the cost of hatchery-production.

Under a separate ACIAR project (FIS/99/25 *Optimal release strategies for restocking and stock enhancement of the tropical sea cucumber*), the WorldFish Center in New Caledonia has studied transport methods, optimum time of day and habitats for release, and tagging methods for juvenile sandfish (*Holothuria scabra*). The tagging and monitoring techniques developed in this project can be applied to the related white teatfish, despite some morphological and ecological differences between the species. For example, both species have calcareous spicules which can be marked using fluorochromic chemicals.

This miniproject seeks to extend technology developed by WorldFish to improve restocking success of white teatfish by using the juveniles produced in Kiribati to: (i) conduct tagging trials; and (ii) design and implement a quantitative experiment to assess the success of restocking in different habitats. The study aims to provide reliable, long-term, survival estimates and target the best habitat for future releases of juvenile white teatfish. Management options will be proposed to maximise the ecological outcomes of the releases and reduce the risk of further stock depletion. This is an important aspect of the miniproject as restocking is unlikely to deliver the outcomes of long-term stock restoration without an appropriate fisheries management plan in place. Also, the potential of sea farming white teatfish could be assessed if effective grow-out methods are identified.

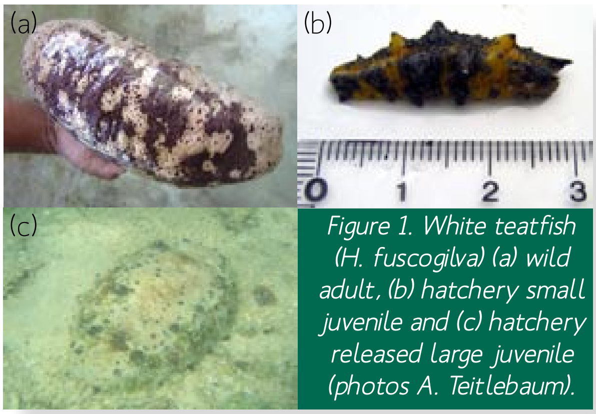

Figure 1. White teatfish (H. fuscogilva) (a) wild adult, (b) hatchery small juvenile and (c) hatchery released large juvenile (photos A. Teitlebaum).

Methods

An expert advisor from the WorldFish Centre Pacific office in Noumea (Dr Steve Purcell) travelled to Kiribati and worked with officers of the MFMRD, carrying out consultations and training.

Consultation on current and future management of sea cucumbers

Dr Purcell met with MFMRD officers to consult on current and future management of sea cucumbers and the purpose of restocking, with particular emphasis on white teatfish.

Release Site selection

Potential release sites around Abaiang were visited to determine appropriate sites and habitats for restocking.

Design an experiment and monitoring strategy

Dr Purcell, together with MFMRD staff, designed a release experiment and monitoring strategy for the release of white teatfish juveniles, based on the methodologies used in New Caledonia for sandfish.

Tagging of juvenile white teatfish

White teatfish juveniles held at the Tarawa hatchery were tagged with either tetracycline or calcein (fluorochrome dyes) by immersing them in a solution of 100 mg L^{-1} for 24 hours. The tagged juveniles were then kept separate in two rectangular tanks, about 1.5 m^2 area, with a thin layer of fine sand and some coral rocks.

One week after staining, a small dermis sample was taken from 10 juveniles from each immersion treatment (Fig. 2). Skin sample preparation requires them to be digested in bleach, rinsed 5-6 times in freshwater, and dried in multicell trays. They were kept in the dark by wrapping with aluminium foil, to avoid fading of the fluorescent stain.

Figure 2. Kiribati MFMRD officer taking skin samples from tagged juvenile white teatfish.

As part of the ongoing tagging study, body wall samples are to be taken from the tagged juveniles every two months and prepared for ultraviolet checking. These skin samples will be sent to Dr Purcell in Noumea for checking to determine how long the stain persists in white teatfish skin.

An ultraviolet torch was trialled to see if it was able to reveal stained spicules on microscope slides from sandfish from New Caledonia (in place of an expensive epifluorescent microscope). Several configurations of lighting were tried on four different types of microscope.

Release and monitoring of tagged juvenile white teatfish

After the consultative visit, the Kiribati Fisheries Division will tag several thousand juveniles and release them at the sites selected for the field experiment. Following release, Fisheries officers will return to the sites every three months for a period of two years and conduct the monitoring surveys on snorkel and SCUBA (using the experimental design and field methods developed during the consultative visit).

Results

Juvenile white teatfish produced at the Tarawa hatchery in April 2005 were used for the miniproject. About 2-3,000 juvenile white teatfish (approx. 10-20 mm in length) were available during the project planning stages. However, shortly before the consultative visit, mortality occurred and most of them died. Nonetheless, it was decided to proceed with the miniproject for the training component and produce more juveniles for release at a later time. Dr Purcell spent two weeks in Kiribati from 27 September to 10 October 2005. Most of this time was spent on Tarawa, where the white teatfish hatchery and MFMRD offices are located. Four days spent at Abaiang, where the MFMRD pearl farm is located.

Consultation on current and future management of sea cucumbers

The management of sea cucumber fishing in Kiribati was discussed in two sessions with Beero Tioti and Michael Tekanene. It was agreed that management regulations were needed to preserve breeding stocks and the long-term viability of sea cucumber fishing.

It was agreed that the management plan should include the following components:

- A legislated process by which processors of sea cucumbers, exporters, and perhaps fishermen, submit data on catch and trade, which should be compiled by Fisheries staff.
- Minimum legal sizes for both fresh and dried sea cucumbers should be regulated. This should be based on size at first maturity, but allowing a buffer so that animals have at least one if not two years of spawning before they reach harvest size.
- It is recommended to forbid the use of SCUBA or hookah for collecting sea cucumbers. These should not be permitted on boats of fishermen collecting sea cucumbers.
- No seasonal closures were recommended, since there was no ecological premise for this with white teatfish.
- If restocking is to be continued, that would be best within No-Take Zones.
- There is a need for stock assessments across broad areas in order to better gauge the status of the sea cucumber stocks.

Full details on proposed management planning are provided in Appendix 1.

Release Site selection

A potentially suitable release habitat exists at the nearby island of Abaiang where the current ACIAR pearl farm is located. The island was chosen as the location for experimental sites because of the existing support facilities. Several sites were inspected. The team checked one site (around the pearl farm) at which white teatfish were previously released (Fig. 3), as well as other lagoonal shoals, front reef, channels, outer rim bommies behind the reef, and an inshore seagrass bed. Although we were looking for sea grass habitat, the inshore sites were too turbid and shallow and would not be good places to release juveniles.

Twelve sites were marked with GPS: six lagoonal shoals with rubble and some hard reef on edges; six large bommies >200 m^2 just behind the outer rim, in ~8 m of water.

Figure 3. Pearl house site at Abaiang, where juvenile white teatfish had been released previously.

Experiment design and monitoring strategy

An experiment was designed to test two suitable release habitats; coral rubble habitat in lagoonal shoals, and hard reef matrix on sheltered outer-rim bommies. The design will also compare two release sizes by tagging large and small juveniles with different fluorochromes. There should be 5 replicate sites for both habitats - these sites were chosen and marked with GPS.

Tagging, release and post-release monitoring protocols were discussed and the experiment stages developed as follows:

1. As juveniles exceed 5 mm, put them into separate tanks at higher biomass density to slow their growth. This will allow faster growth of smaller juveniles. The densities in tanks should be optimised to yield two size classes of juveniles: small (2-5 cm), large (5-10 cm)
2. The juveniles should be well fed in the week prior to tagging - this encourages spicule growth, which is needed for successful tagging.
3. On the day before tagging, place large and small juveniles into tanks without substrate or feed to allow them to void their stomach contents (otherwise the stain solutions become fouled).
4. Tag large juveniles (e.g. 5-10 cm) with tetracycline and small juveniles (e.g. 2-5 cm) with calcein. Concentrations should be 100 mg L^{-1} for 24 h and immersion-staining done in darkened tanks, since the fluorochromes degrade with light.
5. Put back into raceways and feed as normal.
6. On the day before release, put juveniles in bare tanks again to void gut contents.
7. Bag the juveniles in the morning and transport to release sites. Due to time and cost constraints for release, juveniles should be released into one habitat first then into the other; i.e. there will be two transport trips from Tarawa.
8. On afternoon of transportation, place juveniles in bag nets at each site and acclimate overnight or for 2 days. Bag nets should be pegged down on the bottom corners, and the top bunched, bound and lifted off the sea bottom with a small float.
9. Release the juveniles at densities no more than 5 m^{-2}, and preferably at ~1-2 m^{-2}. The release site should be 200-300 m^2 in area, roughly square or circular. Effort should be made to keep the densities consistent between the two habitats and among replicate sites - (to reduce error in survival and growth due to density-dependent effects, which are important, but this is not a factor in the experiment). Place juveniles individually by hand into piles of coral rubble (in the lagoon shoals) or directly into small holes in the bommies (in outer rim sites).
10. Survey sites after 6, 12, 18, 24, and 36 months. At each survey, a survey area, with release site at centre, should be marked: at 6 and 12 months, 100 m x 100 m; from 18-24 months, 150 x 150 m; at 3 years, 200 m x 200 m. Surveys should be done using replicate (n = 10-15)

belt transects of 2 x 50 m, placed randomly within the survey area. At 3 years, the surveys can be done using 200 m x 2 m manta tow transects.

11. At each survey, if juveniles are found, they are recorded and brought to the boat, where a small (2-5 mm^2) area of their skin is taken and placed into a labelled vial with alcohol. These samples then need to be prepared as described and demonstrated.

12. A waterproof data sheet for the underwater surveys was prepared. A second data sheet for the boat and dermis samples was explained and needs to be prepared. Blank data sheet forms should be photocopied onto waterproof paper. Field data should be taken in dark lead pencil. At the earliest opportunity, as a matter of habit, completed data sheets from surveys should be photocopied in duplicate and stored separately by two people.

Release and monitoring of tagged juvenile white teatfish

Unfortunately, only 38 juveniles remained after the mortality event. These juveniles were successfully tagged but there were insufficient juvenile white teatfish to carry out the release experiment. It was decided that the experiment should be carried out with juveniles produced in the next spawning run conducted by Fisheries Division staff. However, to date (at the end of ACIAR Project FIS2001/075 *Sustainable aquaculture development in Pacific Islands region and northern Australia* in June 2007) there has been no production of juveniles with which to complete the release experiment. Fisheries do not currently have white teatfish broodstock and are having difficulty sourcing any, so the experiment is unlikely to take place in the near future, if at all.

Tagging trials

After returning to Noumea, Dr Purcell used an epifluorescence microscope to check the spicules samples of the 20 juveniles that were sampled after staining. All of the samples showed an average estimated proportion of 6% of stained spicules for both fluorochromes. The colours were distinct under the epifluorescent microscope and staining was generally bright (Fig. 3). After the initial skin samples collected in Tarawa by Dr Purcell, none of the two-monthly samples were submitted for checking. All tagged juveniles subsequently died, so there will be no long-term tag retention data from the trial.

Trials of using a UV torch to reveal stained spicules on microscope slides were not successful. This means that samples must be sent to Noumea for checking or Kiribati MFMRD will need to obtain an epifluorescent microscope to identify tagged animals.

Other training

In the course of the trip visit, training was provided on: (i) underwater data collection and recording (e.g. random laying and counting of belt transects, use of the Garmin GPS 72); (ii) release protocol for sea cucumbers, including transport, acclimatisation, handling at release; (iii) tagging of juvenile sea cucumbers using fluorochromic markers; (iv) collection of skin samples from tagged juveniles; (v) sampling outer body wall and processing of dermal spicules (this was done with broodstock animals).

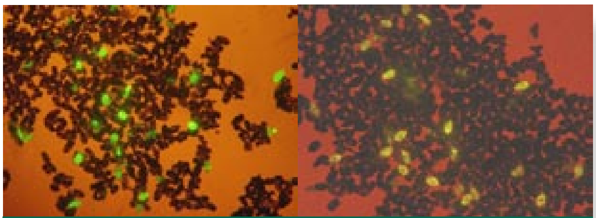

Figure 3. Calcein (left) and tetracycline (right) stained spicules from skin samples of white teatfish juveniles tagged in Tarawa.

Discussion

White teatfish are a high value species of tropical sea cucumber. They are fished throughout the tropical Pacific for processing into beche-de-mer and sold predominantly to markets in China. Due to their ease of capture, improved fishing methods (e.g. SCUBA) and strong demand, wild populations have been overfished in Kiribati. White teatfish is one of two tropical sea cucumber species that have been successfully produced in large numbers in hatcheries (the other is *Holothuria scabra*, sandfish). In the Pacific Islands region, with Japanese assistance, only Kiribati has produced white teatfish. However, despite repeated restocking efforts, there have been no signs of recovery of the fishery, raising questions regarding the cost-effectiveness of this activity. The major objective of the miniproject was to ascertain which habitat gave the best survival of hatchery-produced white teatfish juveniles and to indicate whether survival rates were high enough to warrant further investment in restocking, compared to the costs and potential returns from other forms of fisheries management. This information is not currently available but is of interest to anyone wishing to produce this species for restocking or ranching purposes. Unfortunately, the lack of juveniles for the release experiment means that this objective was not achieved. It seems unlikely that this experiment will be carried out in the short term as MFMRD are having problems obtaining broodstock for hatchery operations. They are very expensive and difficult to obtain due to declining numbers of mature white teatfish in the wild and longer distances required to source them.

There were, however, outcomes from other miniproject objectives. Training provided by Dr Purcell led to enhanced capacity for MFMRD through training of Fisheries Officers in (a) resource management (discussion of management options for sea cucumbers); (b) experimental design (development of the release experiment); (c) release methods for juvenile white teatfish (including handling and transport), (d) data collection and analysis; (e) tagging (using fluorochromic markers); and (f) monitoring techniques to assess restocking efforts.

In addition, tagging of juvenile white teatfish with fluorochromes was successful. This positive result shows that the tagging methods developed for sandfish are applicable to white teatfish, the first time it has been carried out on this species. Unfortunately, the trial did not proceed beyond the initial visit, so there is no information on the retention time for the tag in white teatfish.

During the consultative visit, photographs were taken of juvenile white teatfish and an article prepared on their colouration and morphology, including a length-weight relationship and results of a non-linear regression on that data. An article has since been published in the SPC Beche-de-mer bulletin (Purcell and Tekanene 2006, article is attached as Appendix 2).

It is hoped that the white teatfish hatchery will commence operations again and that the protocols developed in this miniproject will enable this trial to be successfully completed in the future.

Acknowledgements

We thank the Kiribati Ministry of Fisheries and Marine Resources Development, in particular Beero Tioti for help in developing the proposal. We also acknowledge the contribution of the Japanese Overseas Fisheries Cooperative Foundation (OFCF) in development of white teatfish culture techniques in Kiribati. Additional photographs and comments on the report were provided by Antoine Teitelbaum (SPC).

APPENDIX 1

Kiribati Sea Cucumber Restocking and Management

Recommendations from Advisory Trip from ACIAR Pacific Aquaculture Grant
Steve Purcell - The WorldFish Center

Tagging and release experiment

The release experiment will test two suitable habitats; coral rubble habitat in lagoonal shoals, and hard reef matrix on sheltered outer-rim bommies. At the same time, it will compare two release sizes by tagging large and small juveniles with different fluorochromes. There should be 5 replicate sites for both habitats - these sites were chosen and marked with GPS. The release experiment should follow the order set below:

1. As juveniles start to reach >5 mm, put them into separate tanks at higher biomass density to slow their growth. This will allow faster growth of smaller juveniles. The densities in tanks should be optimised to yield two size classes of juveniles: small (2-5 cm), large (5-10 cm)
2. The juveniles should be well fed in the week prior to tagging - this encourages spicule growth, which is needed for successful tagging.
3. On the day before tagging, place large and small juveniles into tanks without substrate or feed to allow them to void their stomach contents (otherwise the stain solutions become fouled).
4. Tag large juveniles (e.g. 5-10 cm) with tetracycline and small juveniles (e.g. 2-5 cm) with calcein. Concentrations should be 100 mg L^{-1} for 24 h and immersion-staining done in darkened tanks, since the fluorochromes degrade with light.
5. Put back into raceways and feed as normal.
6. On the day before release, put juveniles in bare tanks again to void gut contents.
7. Bag the juveniles in the morning and transport to sites. Due to time and cost constraints for release, juveniles should be released into one habitat first then into the other; i.e. there will be two transport trips from Tarawa.
8. On afternoon of transportation, place juveniles in bag nets at each site and acclimate overnight or for 2 days. Bag nets should be pegged down on the bottom corners, and the top bunched, bound and lifted off the sea bottom with a small float.
9. Release the juveniles at densities no more than 5 m^{-2}, and preferably at ~1-2 m^{-2}. The release site should be 200-300 m^2 in area, roughly square or circular. Effort should be made to keep the densities consistent between the two habitats and consistent among replicate sites - otherwise this increases error in survival and growth due to density-dependent effects, which are important, but this is not a factor in the experiment and we don't want to have it be one. :>). Place juveniles individually by hand into piles of coral rubble (in the lagoon shoals) or directly into small holes in the bommies (in outer rim sites).
10. Survey sites after 6, 12, 18, 24, and 36 months. At each survey, a survey area, with release site at centre, should be marked: at 6 and 12 months, 100 m x 100 m; from 18-24 months, 150 x 150 m; at 3 years, 200 m x 200 m. Surveys should be done using replicate (*n* = 10-15) belt transects of 2 x 50 m, placed <u>randomly</u> within the survey area. At 3 years, the surveys can be done using 200 m x 2 m manta tow transects.
11. At each survey, if juveniles are found, they are recorded and brought to the boat, where a small (2-5 mm^2) area of their skin is taken, placed into a labelled vial with alcohol. These samples then need to be digested in bleach, rinsed 5-6 times in freshwater, and dried in multicell trays. They should be kept in the dark whenever possible, to avoid fading of the fluorescent stain - that is best done by wrapping with aluminium foil. A data sheet for the underwater surveys was prepared. A second data sheet for the boat and samples was explained and that needs to be prepared. Blank data sheet forms should be photocopied onto <u>photocopyable</u> waterproof paper - a box of this paper was provided for this purpose. Field data should be taken in pencil, preferably dark lead such as B, 2B or 4B (not H, HB or F). At the earliest opportunity, as a matter of habit, completed data sheets from surveys should be photocopied in duplicate and stored separately by two people.

Development of a management plan for sea cucumbers

The management of sea cucumber fishing in Kiribati was discussed in two sessions with Beero and Michael. We came to the agreement that management regulations were needed to preserve breeding stocks and the long-term viability of sea cucumber fishing. The way forward is for the three of us to prepare a "Concept Paper" (perhaps 3-5 pages) on the proposed management arrangements and submit it to the Director, Permanent Secretary and Minister of the Division of Fisheries of Kiribati. The Concept Paper provides a means of briefing the fisheries heads on the reasons for a management plan and proposed regulations. This should start with a draft from Beero and Michael, Steve will then contribute to that draft, and finally it will be sent to the heads of the Division of Fisheries. After internal consideration, there should be soon after a sea cucumber workshop/meeting to discuss potential management arrangements and that should include fishers, processors, exporters, politicians and fisheries officers. There should be presentations at the workshop to bring pertinent information to the fore for all participants, then a discussion towards the formation of a management plan.

It was agreed that the management plan should include the following components:

- A legislated process by which processors of sea cucumbers, exporters, and perhaps fishermen, submit data on catch and trade. Ideally, that would include numbers and weights of sea cucumbers collected, broken down into species, and including effort (e.g. number of hours diving, number of divers). The fisheries department should supply the forms and their completion should be a requisite for re-issuing export licenses. The data should be compiled by Fisheries staff - these are also strong recommendations from other agencies, such as United Nations-FAO. How that would work best should be discussed at the meeting.
- Minimum legal sizes for both fresh and dried sea cucumbers should be regulated. This should be based on size at first maturity, but allowing a buffer so that animals have at least one if not two years of spawning before they reach harvest size. Fisheries officers should be allowed to inspect catches and processed sea cucumber and impose fines for undersized product.
- It is recommended to forbid the use of SCUBA or hookah for collecting sea cucumbers. These should not be permitted on boats of fishermen collecting sea cucumbers.
- No seasonal closures were recommended, since there was no ecological premise for this with white teatfish.
- If restocking is to be continued, that would be best within No-Take Zones - otherwise the released animals can be fished and there is no valued return on the investment of restocking (in terms of egg production from released white teats that survive to maturity). These need only be small areas of 1 km^2, so do not really exclude much fishing. The same No-take Zones could be used for restocking of other species such as Trochus or Giant Clam, assuming habitat for these species existed in these areas.
- There is a need for stock assessments across broad areas in order to better gauge the status of the sea cucumber stocks. Stock surveys need to be carried out to estimate densities and sizes of sea cucumbers in multiple sites on each island/atoll. Without these detailed surveys, management of the stock should be precautionary in nature. The scope of current stock assessments in Kiribati should be appraised.

Areas for improvement or consideration:

Sea cucumbers

Hatchery and aquaculture

- There has been no behavioural conditioning or 'life-skills training' of white teatfish at the hatchery in Kiribati prior to release. The need for this has been discussed in recent literature and should be considered. That could involve putting sand in tanks several weeks before release, adding coral rocks and rubble, and including some predators that could only disturb the juvenile white teatfish - eg. small lethrinids or balistids.
- The tanks currently used for sea cucumbers should have more light, since this will improve natural productivity in the tanks to allow more food to the juveniles. The corrugated iron

could be replaced with corrugated opaque fibreglass, at least in some sections. As is, the roofing blocks most sunlight and, thus, productivity of algae in tanks is reduced.

- Sand and coral rocks should be added to tanks after the animals are around 1 g. Shrimp starter pellets plus ground sargassum could be added to the tanks at that stage at the rate of 1 g/ m^2/day.
- There is still little known about the ecology of white teatfish juveniles. There is little evidence to guide where to release the juveniles or to understand the factors affecting their survival in the wild. White teatfish that could be produced at the hatchery are a valuable resource for answering such questions. Some very useful experiments could be conducted at the hatchery to examine habitat preferences, feeding preferences, predator avoidance and diurnal behaviour. It is recommended that funds be sought to support a M.Sc. student to spend a few months at the hatchery, when juveniles would be available, to conduct such experiments as their research project. That would allow numerous experiments to be conducted but would not impinge on the time of hatchery staff or take resources from the hatchery operations.
- Sandfish culture followed by grow-out to harvest size in the ponds used for milkfish should be seriously considered and evaluated. The suitability of ponds for sandfish should be evaluated by taking measurements of pH, D.O., and temperature of the water in each (or every second?) pond over at least 6 months. That would show whether some ponds have the right conditions for sandfish. The organic content of the pond sediments could be estimated easily and cheaply by weight loss after bleaching and washing sediments. Preferrably, organic content by weight would be in the range of 3-8% in order to allow good growth of sandfish. Lower values would indicate that extra organic material would need to be added – e.g. cheap shrimp feed.
- It was evident that the literature resource base at the hatchery was very limited. There were few relevant texts or research articles there for staff to consult and consider. A small, well organised, library should be constructed on texts and research articles relating to tropical aquaculture and the rearing of tropical invertebrates, particularly articles on sea cucumbers, trochus and giant clams. Most of that can be acquired at no cost, by consulting authors by email, or by requesting to the library at the SPC, or by downloading articles from the internet. For example, all of the SPC Beche-de-mer Information Bulletins and SPC Trochus Information Bulletins are available free of charge upon request and can also be downloaded free from the internet – and these appeared unfamiliar to hatchery staff. The acquisition, and consultation, of such literature is extremely important.

Restocking

- Releases have previously been at very high density (>1,000 per m^2). Future releases should be at less than 5 juveniles per m^2, and preferably at 1-2 per m^2.
- Releases have been without acclimation. They should use 'soft' releases in future. Immediately following transport, the juveniles could be acclimated in bag nets at the sites overnight or for 2 days. Five of these bag nets could be purchased from T&L Netmaking, Australia (Tom Osborne), for the release experiment – order these months before the release date.
- The proposed field experiment on release habitat and size for white teatfish will require monitoring, data collection, field samples and data management. These are quite different from the skills in the hatchery – in New Caledonia, we had two teams for these two disciplines of work. It is strongly advised that the release experiment involve the personnel of the monitoring section of Kiribati fisheries, since they have experience/training in these activities. Thus, it would be best as a collaborative effort: the hatchery team in charge of producing the juveniles, tagging and transporting; the monitoring team in charge of data collection in the field (although some hatchery staff should be involved in that); both teams involved in the release.
- It is worth taking heed that restocking is usually a relatively expensive management intervention. Costs of running a hatchery are substantial and there are field costs for finding restocking methods that work well. Annual costs of the sea cucumber Hatchery at Tarawa

are roughly AU$70-90,000 and, optimistically, 5-10% of 10,000 white teatfish juveniles [realistic annual production] could survive to harvest size. Currently, the releases of white teatfish in Kiribati is considered for stock enhancement; i.e. to release juveniles for the purpose of allowing fishermen to harvest them years later – a 'put-and-take' activity. However, rough calculations would say that this mode would at best be a 'break-even' exercise, or economic loss (i.e. stakeholders receive less value in the catch of all surviving animals than the cost to produce and release the juveniles). Releasing the juveniles for 'restocking' – to build small, discrete, breeding meta-populations -could be more economically viable, since there is a chance for future generations to give the 'return on investment. But, in order for that to work, those released animals must be protected from fishing for the duration of their natural lives. In Tarawa and Abaiang, the management and enforcement regulations are not yet developed to guarantee this. If the white teatfish fishery in Kiribati is so depleted that breeding populations on reefs need to be rebuilt, then of course it does not make sense to allow further depletion of stocks. The remnant stocks should be preserved (by fishing moratorium) to breed and recover population density. This is not to say that culturing sea cucumbers should be abandoned, but rather that other uses of the juveniles should be considered. The hatchery is a good facility and there are intelligent and motivated personnel with training and expertise in culturing sea cucumbers. It is therefore recommended to compare white teatfish restocking with other aquaculture options (e.g. sandfish grow-out in ponds) and ascertain which ones would be most profitable for Kiribati.

Trochus

- Trochus were severely stunted in their growth, in view that they were one year old. Additional cheap outdoor tanks should be considered to enable higher numbers to be cultured at lower density. Sea cages could also be beneficial. Trochus should be released at an earlier age – otherwise they will probably have behavioural and morphological deficits from the culture environment.
- Juvenile trochus were placed in front of the reef crest. This is not really the best habitat to release. Future releases should be at the fore-reef flat, well behind the reef crest. Areas with unconsolidated rubble beds or hard reef surfaces with deep holes (around 5-10 cm width) should be targeted. Areas with sediment deposition should be avoided.

APPENDIX 2

Ontogenetic changes in colouration and morphology of white teatfish, *Holothuria fuscogilva*, juveniles at Kiribati

Steve Purcell[1] and Michael Tekanene[2]

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Abstract

Little is known of the appearance or ecology of white teatfish (*Holothuria fuscogilva*) juveniles, which are very rarely found in the wild. In this study we use juveniles cultured in Kiribati to describe their ontogenetic changes in colouration and morphology, which differ strikingly from those of adults. Juveniles are mostly yellow up to ~15 mm in length, then gain more black blotching on the body and become brown with black blotches around 20-30 mm in length. At this size they have stout, spike-like, dorsal protrusions on the body. After ~50 mm in length, the body becomes progressively smoother and often cream-coloured with dark blotching. We present a length-weight relationship (r^2=0.95) from hatchery-produced juveniles that allows conversion of these measures among future studies. Our observations should assist in the identification of white teatfish at small sizes and shed light on suitable habitats for releasing them into the wild for restocking.

Introduction

The white teatfish, *Holothuria fuscogilva*, is one of three high-value sea cucumbers in the tropics. It is widely distributed across the Indo-Pacific, and apparently in parts of the Indian Ocean (Uthicke et al. 2004). The adults can be off-white or light brown coloured, sometimes with dark mottling, and sometimes almost entirely dark brown (but light brown ventrally).

Despite its value, the life history of white teatfish is poorly known. In particular, little is known of the juvenile phase, which is rarely recorded in field surveys and field studies (Conand 1981, 1989). Moreover, small juveniles of holothurian species may be quite different in appearance from adults, preventing their identification in the field. Correct identification will enable reliable sightings in the field to expand our knowledge of their habitat association and ecology.

In Tarawa, Kiribati (Gilbert Islands group), white teatfish have been produced by the Ministry of Fisheries and Marine Resources Development since 1997. The sea cucumber production was supported, both technically and financially, by the government of Japan through the Overseas Fisheries Cooperative Foundation (OFCF). Thousands of the juveniles have been released into the wild to try to restock breeding populations in Kiribati, which have been depleted by overfishing (Friedman and Tekanene 2005). Here, we use individuals produced in a hatchery to document the colour patterns and morphology of *H. fuscogilva* so they can be reliably identified in the field. In addition, we present a length-weight relationship for converting length measurement to body weight.

Colouration and morphology

Marked ontogenetic changes in colouration and morphology of white teatfish mean that juveniles bear little resemblance to adults. Juveniles of <15 mm (i.e. <0.2 g) are mainly yellow, with some patches of black (Figure 1). They have a few prominent spike-like protrusions of the dorsal body wall. From 15-30 mm in length (i.e. 0.2 to 1 g), the juveniles gain more dark blotches on the body and still have yellow colouration and possess anterior horn-like processes that are usually black. At this size, they have numerous broad, spike-like protrusions on the dorsal body wall. From 20-30 mm in length (i.e. ~0.4 to 1 g), the yellow colouration is replaced by beige, brown and black blotches. After about 50 mm (i.e. ~5 g), the juveniles progressively lose the prominent spike-like protrusions, becoming smoother on the dorsal surface. The colouration becomes generally lighter, often beige or cream in colour, but still with dark brown blotches.

We recognise the possibility that the hatchery environment could either modify colour patterns or the rate at which these change ontogenetically.

Figure 1. Photographs of white teatfish (Holothuria fuscogilva) juveniles cultured in the Kiribati Fisheries Department Hatchery at Tarawa, showing ontogenetic changes in morphology and colouration.

For example, hatchery-reared juveniles of the topshell (*Trochus niloticus*) undergo ontogenetic changes in shell morphology at a smaller size than wild juveniles (Purcell 2002). That is, the hatchery-reared juveniles are morphologically precocious. Therefore, the colouration and morphology of white teatfish juveniles produced in the hatchery may well reflect those of wild white teatfish juveniles, but the sizes at which those changes occur may be different.

The colour patterns of juveniles provide some clues to the ecology and likely nursery habitats for *H. fuscogilva*. The yellow-and-black banded colouration of small juveniles (<15 mm) could camouflage them in a specific microhabitat, but we note that this is a typical warning colouration in animals that are toxic or unpalatable when eaten (Brodie and Brodie 1999). Whether small juvenile white teatfish are toxic, or simply mimicing toxicity, is not known but this would be an interesting topic for future research.

In the Maldives, Reichenbach (1999) found that the juveniles of a closely related species, *H. nobilis* (then named *H. fuscogilva* - see Uthicke et al. 2004) occurred in shallow sea grass beds. Gentle (1979) reported to have found [Pacific] white teatfish juveniles <20 cm long among turf-like 'seaweeds' in Fiji. He hypothesised that their patchy brown colouration could act as camouflage in this microhabitat. Our study shows that the dark, blotchy, colour pattern occurred in hatchery-produced juveniles of 15-30 mm in length. We believe that dark coloured surfaces such as hard reef substrata with epilithic algae, or among certain sea grass, may indeed allow this juvenile phase to be camouflaged. Releases of juveniles into these habitats could provide protection from predation, and be more suitable than sand or coral rubble for releasing juveniles for restocking. This hypothesis will be examined in a restocking experiment in Abaiang, Kiribati.

Length-weight relationship

Hatchery-produced juveniles (n = 38) were weighed to ± 0.01 g and their body lengths measured ventrally to ± 1 mm. The length-weight relationship for juveniles 10 to 90 mm is given in Figure 2. The function explained 95% of the variation in body weight by measurement of length of the juvenile white teatfish. Since the exponent (slope of the curve) 2.629 (± 0.298, 95% CI) is significantly less than 3, growth is allometric, with white teatfish becoming progressively thinner (or flatter) for their length as they grow longer.

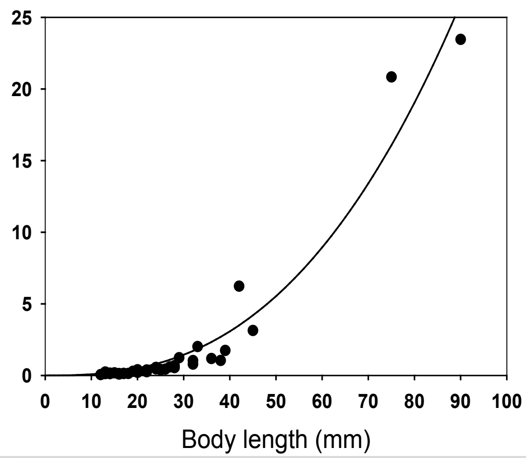

Figure 2. Length-weight relationship of hatchery-produced white teatfish juveniles, using the general morphometric equation, $y = a*length^b$.

The relationship should be useful when converting these measures between studies or for rapid conversion to weight from length measurements taken in the field. The range in juvenile sizes examined here mirror those used for restocking in Kiribati (see Friedman and Tekanene 2005). The curve from our morphometric equation for *H. fuscogilva* is steeper than that determined by Conand (1989) principally from adults (i.e. weight=0.0011*weight$^{2.407}$). Our results therefore present a function to estimate weights of juvenile white teatfish from length measurement, whereas Conand's (1989) function should be used for conversion of length to weight in adult specimens.

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References

Brodie E.D. and Brodie E.D. Jr. 1999. Predator-prey arms race: asymmetrical selection on predators and prey may be reduced when predators are dangerous. BioScience 49:557-568

Conand C. 1981. Sexual cycle of three commercially important holothurian species (Echinodermata) from the lagoon of New Caledonia. Bulletin of Marine Science 31:523-543

Conand C. 1989. Les holothuries Aspidochirotes du Lagoon de Nouvelle-Caledonia. PhD Thesis, ORSTOM, Paris, p. 393

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

Purcell S. 2002. Cultured vs wild juvenile trochus: disparate shell morphologies send caution for seeding. SPC Trochus Information Bulletin 9:6-8

Reichenbach N. 1999. Ecology and fishery biology of *Holothuria fuscogilva* (Echinodermata: Holothuroidea) in the Maldives. Bulletin of Marine Science 64:103-113

Uthicke S., O'Hara T.D. and Byrne M. 2004. Species composition and molecular phylogeny of the Indo-Pacific teatfish (Echinodermata: Holothuroidea) bêche-de-mer fishery. Marine and Freshwater Research 55:837-848