Final report for Mini-project MS0604:

Experimental stocking and community management of tilapia in Lake Satoalepai, Samoa

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Introduction

Fishing has been a major source of food, income, recreation activity, employment and various other economic benefits for the people of Pacific Island Countries and Territories (PICTs). However, with increases in population, urbanisation and development of fisheries, it has been realised that fisheries resources, although renewable, are not infinite. They must be properly managed if their contribution to the nutritional, economic and social well-being of the growing population is to be sustained.

Samoa consists of two large islands, Upolu and Savaii, and seven smaller islands (two of which are inhabited). The total land area is 2,935 sq. km. The 1999 population of about 168,000 reside in 326 villages, of which 68% are on the island of Upolu (FAO 2002). About 230 of these villages are considered to be coastal (FAO 2002).

Barrier reefs enclosing narrow lagoons encircle much of the coastline except for the north coast of Upolu, the main island, where there is an extensive fringing reef which extends several kilometres offshore. There are few freshwater bodies and thus no important inland fisheries.

Samoa has a long history of aquaculture research and development directed at providing alternative sources of fishery products, mainly through the introduction of exotic species. For example, mussels, tilapia, carp, oysters, trochus, giant clams, freshwater prawns, marine prawns, seaweed and mud crabs have been trialled at some stage.

In 1954, SPC investigated the possibilities of establishing fish ponds near Apia, on the island of Upolu, for the purpose of raising milkfish, *Chanos chanos* (Van Pel 1954), but no milkfish fry were found. Soon afterwards, Mozambique tilapia (*O. mossambicus*) was introduced from Fiji. In 1991 the Samoa fisheries Department (SFD) introduced the Nile tilapia (*O. niloticus*), thereafter a number of tilapia farms were established and a Nile tilapia hatchery consisting of a series of concrete raceways at Apia. From 1993-1996, tilapia demonstration farms were established with the assistance of the Food and Agriculture Organization (FAO) and study tours were conducted for SFD staff and potential tilapia farmers to Fiji (by the second author).

In 1999, the AusAID/Samoa Fisheries Division assisted Fisheries Extension and Training Project (FETP) developed a new framework for the better management of fisheries resources. This framework led to a reduction of fishing pressure on the over-exploited near-shore fishery resources with initiation of conservation programs through Marine Protected Areas (MPA's), provision of information for village-level management and aquaculture projects, including stocking of tilapia in natural lakes and ponds. Following AusAID initiatives, SFD continued to carry out fisheries management and conservation activities including development of

Figure 1. Aerial view of the lake showing the upstream and downstream sections of Lake Satoalepai, divided by the road. The red line approximately indicates where Lake Safa'i begins.

aquaculture farms. By late 2000, there were 19 tilapia farms: 11 on Upolu and 8 on Savaii (FAO 2002). Tilapia fingerlings were distributed free as part of a government initiative to promote fish farming for food security. Growth rates were acceptable where ponds were managed properly and tilapia grew to harvestable size (180-250 g) within 6 months (FAO 2002). In late 2003, SPC aquaculture section was asked to develop a project for the better utilization and management of Satoalepai Lake in Savaii.

Satoalepai Lake is a part of a large wetland situated on the island of Savaii. The area is vegetated by mangrove and native forest. Fresh water springs feed into the lake on the inland side and the lake is open to the sea through the adjoining, smaller Lake Safa'i (Fig. 1).

Mozambique tilapia was stocked into this lake in 1996 (pers. communication) and forms an important artisanal fishery for the communities of Satoalepai and Safai, the two main villages on the banks of the lake. The SFD prefers to re-stock the lake with hatchery-produced Nile tilapia because, unlike Mozambique tilapia, Nile tilapia has superior growth characteristics and matures at a larger size than Mozambique tilapia. Under good growth conditions, Nile tilapia will reach sexual maturity in farm ponds at an age of 5-6 months and 180-250 g in weight compared with Mozambique tilapia, which may reach sexual maturity in less than 3 months of age, with a weight of 50-80 g. Other positive aquacultural characteristics of tilapia are their tolerances to poor water quality and the fact that they eat a wide range of natural food organisms. Biological constraints to the development of commercial tilapia farming are their inability to withstand sustained water temperature below 20°C

The importance of aquaculture development as a means to provide food and livelihood had been recognized by SFD for a long time and in this study we had the overall goal to increase production of fish through stocking of fingerlings in the Lake, and management of these stocks through community management. This study was funded by the Australian Centre for International Agricultural Research (ACIAR) and jointly undertaken by SFD Aquaculture Officers, SPC officers and local communities at Satoalepai.

The major objectives of the project were to:

- evaluate growth performance and survival of stocked *O. niloticus* in Lake Satoalepai;
- conduct village consultations to develop a co-management regime for the tilapia restocking program; and
- conduct training to improve skills of SFD staff in skills for tilapia restocking including hatchery operations, fingerling grow out and transport.

Materials and Methods

Site description

Lake Satoalepai is situated in the Matautu District on the north east coast of Savaii Island, with around 600 people living within 2 km of the lake. A road, constructed to link the villages in the area, divides the lake into two parts (refer to Figs 1 & 2). Three culverts (~1 m diameter), located approximately in the centre of the road, allow water exchange between tides and during heavy rainfall. Despite the water exchange, the upstream (inland) side of the lake is mostly fresh water while the downstream side [seaward side] remains brackish (5-10 ppt).

Figure 2. Lake Satoalepai, showing the upstream (right) and downstream (left) sections from the road.

The upstream lake has an approximate surface area of about 4 hectares, with an average depth at mid tide of 40 cm. The lower side of this up stream lake consists of rocks and boulders and the upper side is muddy with small coral pinnacles. This portion of the lake is 0.5 meters above sea level, with a holding capacity of 50,000 cubic meters of water. This was the designated site for the fish stocking and subsequent study.

According to anecdotal reports, the lake was stocked with *O. mossambicus* in 1966 and *O. niloticus* in 1991 and 1998. A number of estuarine species including mullet, trevally, prawns, shrimps and mud crab inhabit the lake with tilapia being the most abundant. Fish and crustaceans are caught mainly by gill nets, cast nests, fine spears, hand and fishing lines.

Community consultation

Prior to stocking, two separate consultations were carried with village chiefs and communities residing at Safa'i and Satoalepai by SFD staff, Satya Nandlal (SPC Aquaculture Officer) and Etuati Ropeti (SPC Community Management Officer), on July 22, 2006 (Fig. 3). Approximately 50 village members including their chief attended the meetings which lasted for almost 3 hours. The meetings started with elaborate Kava ceremonies, prayers, discussions on the project purpose and activities and participation of the villagers in monitoring of the stocked fish. During the discussions the council stated that the lake is an important source of food for the villagers and many villages are actively engaged in fishing activities in the lake as it also provides a source of income for some fishermen as well. Tilapia has been the dominant species for a long time and they were unsure of the number of tilapia species present in the lake. They had no records of the number and the dates of stocking of tilapia. The size of the fishes caught especially tilapia had been small and, five months prior to this study, the village council had placed a moratorium on any form of fishing to allow stocks to recover.

Given the importance of the Lake in providing fish for the villages, the council thanked SFD for the initiation of the project and committed to cooperate fully with its activities. Members agreed to close the lake to all forms of fishing for the duration of the project and to provide manpower for any project activities, including monitoring, security and sampling. A final consultation will be carried out to disseminate the outcomes of the projects and provide advice to the village on appropriate management strategies and further restocking of the lake.

Figure 3. SFD Officers holding community consultation with Satoalepai village council.

Pre-stocking observations and fish survey

Following the community consultations and prior to stocking, sampling of fish stocks present in the upstream portion of Lake was carried out using a 40 m long, 3" mesh gillnet during day time. A survey of both portions of the Lake was carried out at night using a push net in the shallow sections of the Lake. Observations of fish were also made from the roadside and the shoreline.

Stocking

Fingerlings were sourced from the SFD hatchery and Chanel College fish pond in Apia. These fingerlings were seined, graded, counted and conditioned in hapas for 30 hours at SFD hatchery. A sample of 200 fingerlings was sampled for their body weight and length. The fingerlings were transferred into a 2 tonne FRP tank with approximately 1,500 litres of water with aeration, and transported to Satoalepai Lake by truck, a five hour trip. At the bank of the Lake, tanks, basins, and aerators were set up in a temporary shed for tagging, conditioning and stocking of the fingerlings into the lake. The fingerlings were tagged by cutting off the right pelvic fin. The villagers and SFD staff assisted in this exercise. Batches of fish were weighed before release into the Lake. The first set of tagged fingerlings was released by the village elders as is customary in Samoan culture for such activities.

Three fish cages (1 m^3 each made of 1 cm plastic mesh) were also stocked with tilapia (to ascertain growth rates) in the event that no tagged tilapia were recovered at the end of the trial. The first cage was stocked with 30 tagged *O. niloticus*, the second with 15 tagged and 15 wild *O. mossambicus* and the third, with 30 wild *O. mossambicus*. The *O. mossambicus* used for stocking in the cages were caught at the time the tagged fish were released into the lake. The cages were placed about 30 m from the shore near the village Mayor's house.

Tissue samples of 30 individuals of *O. niloticus* and 30 wild *O. mossambicus* were preserved in 70% ethanol, for possible future genetic analysis at Queensland University of Technology, Brisbane, Australia.

Monitoring

Monitoring water parameters and providing security for the fish were carried out by the village community. SFD staff carried out monthly samplings to monitor growth of the tagged fish. A cast net was used for catching samples of the fish. Individual weight and length of tagged fish were recorded. Fish stocked in cages were also monitored by SFD staff.

Final sampling

The scheduled final sampling at the end of the four month trial period (i.e. November 2006) was deferred by the village council due to the small size of fish. The sampling was therefore carried out on 2nd of April 2007 (251 days after stocking) by Satya Nandlal (SPC), Cathy Hair (QLD DPI&F), SFD officers and community members. Prior to sampling, a meeting was held to inform the council of the completion of project activities and also to seek their assistance in the final harvest. The villagers were requested to fish heavily in order to collect a large number of tagged and other fish using any non-destructive fishing methods.

All the fish caught were counted and weighed in bulk and the tagged fish were measured individually for their weight and length. The sex and maturity condition were also determined.

A 100 m long, 3" mesh gill net (Fig. 4), hook and line, cast net (Fig. 5) and seine net (Fig. 6) were used for catching fish. Other species captured were counted and recorded and a sample of *O. mossambicus* weighed. Fish in the cages were retrieved and their length and weight measured. All table size fish were given to the community. Some fishermen and fisherwomen were also interviewed (Fig. 7).

Figure4. Community members and SFD Officers using gill net method to harvest

Figure 5. SFD Officer, Siulagi using a cast net to sample fish in Lake Satoalepai

Figure 6. SFD Officers using a seine to sample fish in Lake Satoalepai

Figure 7. SFD Officer interviewing one of the fishermen

Results

Pre-stocking observations and fish survey

Visual observations indicated that Mozambique tilapia (*O. mossambicus*) was the most abundant fish species in the lake, with large numbers seen from the roadside. Mullet, trevally, half-beak and a few *O. niloticus* were also caught mainly in the seine net while many *O. niloticus* and some *O. mossambicus* were caught by gill nets. One potential reason for lower numbers of *O. mossambicus* is that they were smaller in size (~ 30% smaller than *O. niloticus*) and may have passed through the 3" mesh of the gillnet. Small *O. niloticus* were released back into the lake and the larger ones taken by the villagers. Numerous freshwater prawns, *Macrobrachium lar* and another shrimp, possibly *Palaemon* species, were caught during night sampling.

Stocking

The transportation of fingerlings to the Lake site was carried out successfully with hardly any mortality. A total of 9,000 *O. niloticus* fingerlings were tagged and released into the lake with a further 1,300 stocked soon after Mr Nandlal's departure. The mean individual weight of stocked fish was 28.9 g and length was 9.8 cm.

Final sampling

Nine separate gill net drives to collect samples were made from 2-3 April 2007. Four netting drives were made on the first day and five on the second. On the first day, 25 people assisted in netting in the upstream section while on the second day, a smaller group of seven people worked in the downstream section of the lake.

A total of 54 tagged *O. niloticus* were caught in the upstream section on the first day (although as many as 100 tilapia were not presented for recording), and 67 in the downstream section on the second day. Of the total 121 tagged *O. niloticus* (i.e. fin-clipped fish) that were caught by gill net, there were an additional 14 large *O. niloticus,* (over 400g) presumably from a previous stocking, and four juveniles caught by seine net. All fish were measured (total length and weight). At night, many small *O. niloticus* juveniles were observed around the lake edges but were difficult to catch as there was too much water (high tide) at that time to allow effective cast netting. During the day, it was also difficult to use the seine net effectively due to the uneven surface of the lake bottom (i.e. rocks, debris and snags). Several efforts were made resulting in a catch of only four juveniles.

Table 1. Mean weight (g) and length (mm) (±se) for tagged *O. niloticus* at time of stocking, during monthly monitoring by SFD and at the final harvest in Lake Satoalepai.

Date	n	Mean weight (g)	Mean length (cm)
		(±se)	(±se)
23/07/2006 (stocking)	267	28.9 (±1.0)	98.0 (±0.1)
24/08/2006	12	50	105.2
24/10/2006	10	96.1 (±13.6)	120.6 (±3.9)
29/11/2006	8	88.9 (±6.3)	125.8 (±2.1)
22/02/2007	22	134.2.0 (±11.8)	146.3 (±3.5)
02/04/2007 (Final sample)	121	141.4 (±4.0)	201.0 (±2.1)

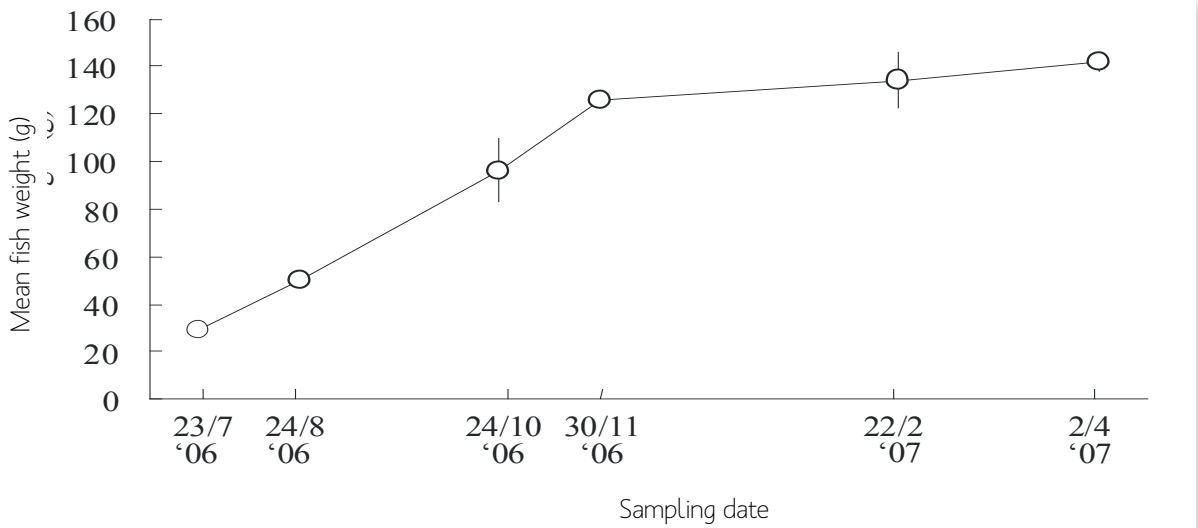

Figure 8. Mean weight (g) (±se) for tagged O. niloticus *sampled at time of stocking to final sampling in Lake Satoalepai.*

Catch results showed that tagged *O. niloticus* grew from around 29 g to 140 g (and 98 to 201 cm) in 251 days (Table 1, Fig. 8). Average daily weight increment (from the day of stocking 23 July 2006 to final sampling on 24 April 2007) was 0.44 g/day.

It was difficult to distinguish tagged fish easily since the clipped pelvic fin had regenerated, i.e. after 9 months, the fins had regrown. However, with careful examination and comparison of the left and right pelvic fins, the tagged fish were identified and this was reflected in a distinct weight cohort (Fig. 9). Of the tagged *O. niloticus* sampled, the sex ratio was 1:1 (60 males to 61 females). Of the female fish, 39 had spawned and 21 were assessed to be still virgin. About 35 of the tagged fish showed signs of hybridisation, possibly as a result of mixing in the original *O. niloticus* broodstock with wild *O. mossambicus* at Chanel College pond.

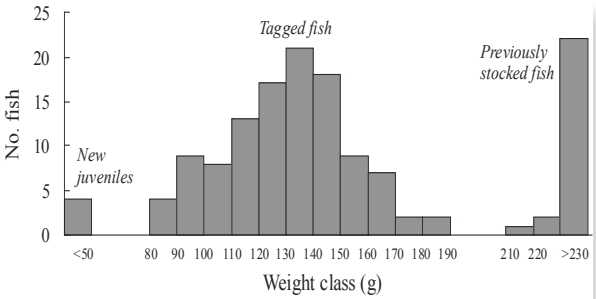

Figure 9. Weight frequency distribution of O. niloticus sampled during the final harvest on 2-3 April 2007 in Lake Satoalepai.

During harvesting, the water in the lake was clear indicating low density of plankton. A number of fish were dissected and stomach contents were examined. The stomachs were found to be empty.

Caged fish were also monitored throughout the project (Table 2). However, two cages were stolen between the November and February samplings, so the final results were available from a single cage. At the final sampling, all the *O. niloticus* female fish in the cage were assessed to be virgin (i.e. had not spawned).

Table 2. Mean weight (g) of caged *O. niloticus* and *O. mossambicus* based on initial, monthly and final sampling in Lake Satoalepai.

Date	*O. niloticus*	*O. mossambicus*
24/07/2006	36.4	54.5
24/08/2006	39.8	61.9
24/10/2006	43.8	66.7
30/11/2006	42.3	80.8
22/02/2007	64.7	80.0
3/04/2007	52.3	81.0

The by-catch consisted of 135 *O. mossambicus* (mean weight 160±8 g) plus a variety of juvenile estuarine species. The estuarine species were mostly caught with the cast and seine nets and included halfbeaks (n=3), diamond fish (n=3), queenfish (n=1), trevally (n=1), milkfish (n=2), perchlets (n=1) and mullet (n=11).

Interviews and observations of fishing activities

The portion of the Lake downstream from the feeder road was used by some villagers to earn income by establishing a tourist attraction displaying live turtles, known as "Swimming Turtles". Some families raised Nile tilapia in their backyard pools.

Various methods are used for catching fish, for instance hook and line, cast net and gill net, while others use their hands to catch fish from the Lake bottom. Fishing is normally carried out three times a week in the lake. It is easier for people to catch fish by hands (involves snorkelling and catching the fish hiding under boulders or feeling with feet for fish hiding in the mud) rather then fishing in the sea. Furthermore, the people interviewed usually caught 50 fish per fishing trip and these were mostly for home consumption (Fig. 10). Only a small number of fishers sold their catch. On average, $60 is earned per week from selling fish according to some fishers. The villages relied on marine fish when the village council had placed a moratorium on fishing in the Lake.

Figure 10. Lake Satoalepai resident preparing a meal of Mozambique tilapia, caught by hand in the downstream part of the Lake.

Consultation

During the village meetings, monitoring and sampling of tagged fish, fishing methods for sampling and re-stocking the Lake were discussed. It was revealed that fishing had not been banned throughout the entire period of the study. Due heavy rainfall in October 2006 the Lake flooded, resulting in water flowing over the feeder road. The netting material (screen to prevent fish passing through the culverts) placed at the mouth of the culverts was also damaged/ lost during the flood. The chiefs suspected that stocked fish had moved to the lower part of the Lake from the upstream section when the floodwaters rose above the road. After the flood had receded, fishing with hook and line was permitted in the upstream section and gill netting in the downstream section of the Lake. After the final sampling, a meeting was held with the village mayor to present the preliminary results. SFD Officers agreed to stock more *O. niloticus* fingerlings and discuss management strategies with the village chiefs.

Discussion

Tilapia growth in this stocking trial indicated that conditions prevailing in both upstream and downstream Lake Satoalepai were tolerable for these fish. There appeared to be an increase in the population of *O. niloticus* after the restocking as pointed out by the villagers and also from observations during the final sampling. However, we were unable to predict survival rates as sampling was not designed to estimate this and it would be impossible to catch all the tilapia unless the lake was drained completely. The large number of *O. niloticus* sighted is an indication of good survival of the stocked fish. The total initial stocking weight was about 300 kg and based on the average size at final sampling of 140 g, the total biomass of the fish in the lake could have been 1,442 kg (a net gain of 1,143 kg) if all the stocked fish had survived.

The final sampling activity was limited to two days of netting and we were not able to sample at night due to spring tides at that time. However, sufficient fish were caught to obtain good estimates of growth rates. The average weight of tagged fish was 141 g which, although low compared to published data for Nile tilapia growth in ponds, was acceptable as local people consider this to be edible size (table size). Smaller *O. mossambicus* (50-80 g) are commonly caught by villagers and consumed. The small size (low growth rate) of the stocked fish could be due to low productivity in the Lake (based on indications of clear water i.e., less primary production in the lake and also empty stomachs of the dissected fish) or stunted fish may have been used for stocking, or a combination of these factors.

Close to 25 community members assisted in the gillnet drives to harvest tilapia prior to stocking and also at the final sampling. This is the preferred method of catching tilapia by the local fishers. After the sampling, villages pointed out to SFD staff that there was no equitable distribution of the harvested fish during netting drives. Therefore, some fish were kept by villagers and were not included in the results of the final sampling.

The community had been managing the Lake fishery prior to the commencement of the project as indicated by the fact that the council had closed the Lake for fishing activity for five months. The Council had also agreed to ban fishing for the duration of the trial. However, the ban on fishing in the lake was revoked i.e., opened for fishing at half way of the study period and thus the impact of the fishing ban cannot be ascertained. The villages did not use gill nets to catch fish in the top half of the Lake for the complete study period, i.e., nets were not used when the moratorium was removed midway through the study, however, there was no significant difference in fish sizes upstream of the feeder road (mean weight 142 g) versus the downstream part (mean weight 141 g). Thus there was no evidence to suggest that the fish in the top part were larger unless some fish that were caught were large and taken away by villagers without it being sampled on day one. If these fish were included, then, this would have resulted in a larger mean size of fish indicating that the ban on using gill nets for fishing had a positive effect on fish size. The project results were acceptable despite not having a complete moratorium or ban as agreed by the village council.

During the final sampling, we observed little community involvement and there were no women fishers seen fishing. Communication between SFD staff and the village council regarding management of the lake may need to be increased.

Tagged tilapia and non-tagged tilapia (old original stock) escaped from the upstream to the downstream side of the Lake during the flood and afterwards since the net mesh (screen) to prevent the fish from passing through the culverts was lost. It may not be appropriate or sensible to restrict fishing of the Lake on either side of the feeder road because both sides belong to the Satoalepai community. There should be no conflict in having the fish pass freely through the culverts. As for some fish moving down to Lake Safa'i, since SFD carries out restocking as part of government program, it is not unreasonable for the neighbouring community to share the benefits. The Safai village owns a small section of the lake which is more saline and it is more likely that there are only *O. mossambicus* as they are more tolerant of high salinity. It would be worthwhile for SFD to sample fish at this part of the lake and also carry out surveys to determine if *O. niloticus* does occur in Lake Safa'i.

Mozambique tilapia seems to be preferred by many people as they have been eating it for a very long time, i.e. since 1966. Local people catch them by hands after scaring them into rocks at the bottom of the lake. There should not be concerns about eradicating them rather encourage people to fish them intensively. Contrary to the situation in many fresh water bodies in the Pacific region, the *O. mossambicus* in Lake Satoalepai did not appear to be stunted and neither did we observe large numbers of fry or fingerlings.

Two cages were stolen during the project and it is suspected that larger Nile tilapia were also taken out of the remaining cage as indicative of the change in mean weight between last and second to last sampling. Results showed that *O. mossambicus* had a higher growth rate compared to that of *O. niloticus* in the cages, suggesting that *O. mossambicus* are good competitors and may be able to access more varied food and thrive in more difficult environment. Alternatively, *O. niloticus* may have been larger but were removed from the cages and no data are available on them.

In general, very little is known about introduction of fish in the lakes, specifically tilapia species. There are no reports or information on the baseline condition of the Lake prior to the stocking of *O. mossambicus* as far back as 1966 when the Lake was stocked for the first time. In addition, the Lake was stocked with *O. niloticus* in 1991 and 1998 and at other times cage culture of *O. niloticus* was attempted, but there are no reports available. At the ecosystem level, more data would be needed to examine the effects of *O. mossambicus* introduction into the lake on ecological processes such as food web structure and energy

flow. There are concerns that *O. mossambicus* is feeding on mullet eggs and thus negatively affecting the mullet population, but this study was not intended to address this issue.

Tilapia is an introduced species in this lake system and should be managed for the maximum benefit for the local community. Regarding future community management of the lake and its fisheries resources, the village council should be fully aware of the reasons behind various management options. For example, a fishing ban is usually imposed when there are very few broodstock left in the population i.e., their reproductive success is compromised, or when there is a seasonal spawning which has to be protected. In the case of Lake Satoalepai where restocking is carried out by SFD and there is also natural spawning occurring, there seems to be little justification for banning of fishing for long periods, although imposing bans on fishing for at least 2 months after stocking may be useful to allow fish to attain edible size (50-80 g). Enforcing a size limit (greater than size at first maturity) on *O. niloticus* catches is another important tool to control over-exploitation of stocks and also allow more fish to breed naturally in the lake, reducing the reliance on SFD restocking. Community members should be encouraged to catch fish using appropriate methods (e.g. use of minimum 3" mesh size gill nets, hand lining, catching with hands, cast nest and not use destructive methods such as poison etc).

Recommendations

Based on the miniproject results and discussions with Satoalepai chief and community, the following suggestions are made with regard to the future of restocking and management of the Lake:

- There is a need to involve all stakeholders from initial stages of any restocking, and for them to be in agreement on all aspects of the management of the Lake fishery.
- Based on above, a Fishing Accord should be developed, which describes the management options which stakeholders wish to adopt. These may include defining who is allowed access to the resource, gear limitations, size limits on Nile tilapia and closed seasons.
- Presently fingerlings are transported from Apia. This is a costly and time-consuming exercise. It may be more sustainable and cost effective to produce fingerlings for restocking programs using the hapa method in the Lake. Experience elsewhere has shown that heavily government subsidised projects are generally unsustainable in the long term. SFD should solicit funds to establish hatchery facilities (e.g. pond, tank or hapa method) and training of villagers including follow-up extension visits to the Lake.
- SFD has the responsibility for stocking the Lake and advising the community on managing the stocks. There is a need for regular monitoring of the Lake fishery. Useful information can be obtained if a local person is assigned to collect and record catches of tilapia and other fish from the Lake.
- There is an unexploited freshwater prawn resource in the Lake, which could be fished for food or income. Training would be required.
- A formulated feed/diets using locally available feed resources, for example 'benu' (a by-product of copra after extracting oil), imported fish/meat meal, commercial stock feed, and other local resources like breadfruit and bananas, should be developed. This diet should be used for tilapia broodstock maintenance as well as for raising tilapia in ponds and cages. These ingredients (as well as the completed formulated diet) will need to be analysed for crude protein, carbohydrate and fats and moisture level.
- Efforts should made to establish a demonstration commercial farm, encourage pond culture by fish farmers and utilise the newly installed feed mill for production of formulated diets (see previous point) to be made available to farmers.

References

FAO Fishery Country Profile-Samoa 2002. http://www.fao.org/fi/fcp/en/WSM/profile.htm.

Van Pel, H. 1954. Possibilities of fish culture in ponds in Western Samoa. South Pacific Commission, Noumea.

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