SPC Secretariat of the Pacific Community

Capture-based Aquaculture of Milkfish *Chanos chanos* in the Pacific Islands

Proceedings of a Regional Workshop at Vitawa Village, Fiji Islands

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by
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1. Workshop opening

1.1. Address by Chief Guest

The Resident Representative of the Japan International Cooperation Agency (JICA), the head of the Secretariat of the Pacific Community (SPC) delegation, Turaga na Tui Navatu and the community of Raviravi, distinguished guests, fellow participants from Fiji and around the region, ladies and gentlemen:

The hosting of regional participants, representing ten countries from around the Pacific in this remote village for the first ever Milkfish Farming Workshop to be held in Fiji, marks a milestone achievement.

The Fiji Government is currently embarking on its road map for Change, Peace and Prosperity. To this end, the Ministry of Fisheries and Forests is working strategically toward its vision, '*Our future generation inherits a prosperous, bountiful and enhanced fisheries sector*', and mission statement, '*Improving livelihood through SMART policies on sustainable management of our fisheries resources*'. To achieve its goals, the government is initiating developments that are environmentally conducive and sustainably achievable.

The Vitawa Pilot Milkfish Integrated Project is an example of such development that is here to stay. Today I acknowledge:

- the generosity and contribution of JICA for opening its door and helping the Vitawa community to fund the pilot project;
- Fisheries and Aquaculture International Co. Ltd (FAI) for implementation and managing the farm;
- SPC for consultancy, research and advisory services;
- all other stakeholders who helped in any way to build the project as it is today;
- the Vitawa Village community; and
- the participants of the Pacific Island countries and territories present.

The Vitawa Pilot Project was initiated way back in 2006 but construction and implementation started in late 2009. Last year JICA again approved additional funding for 2 more years for fine tuning, management aspects and production of the pilot project. We have now started to understand the importance of this community-based coastal resource development and we need to understand more about it in the coming days of the Workshop.

This project is community based, which means it takes a community-centered approach to development, targeting the grass-roots level through food security and healthy living, optimization of resources, alternative livelihoods, income generation, import substitution, and community empowerment and participation.

Dear participants, I hope you will make the most of the coming 8 days and, importantly, learn and share your experiences in a Pacific way and go back to develop your own country. The co-organizers JICA, SPC and Fiji Fisheries Department can impart necessary knowledge and skills to uplift your know-how, empowering you to be agents of change and make a difference through new initiatives.

Turaga na Tui Navatu and the Vitawa community may God bless your vanua, for the task ahead of you in the coming days and for being part of this historic moment in hosting the first ever Milkfish Farming Workshop in Fiji.

With these words, on behalf of the Government of Fiji I declare this Workshop open. May God bless everyone.

Vinaka.

Penina Cirikiyasawa
Deputy Permanent Secretary
Ministry of Fisheries and Forests
Government of Fiji

1.2. Workshop objectives

The broad aim of this Workshop was to provide participatory learning opportunities in practical techniques for low-cost aquaculture of milkfish *Chanos chanos* (*yawa* in Fijian) by people who are currently, or will soon be, engaged in low-cost milkfish farming projects in the Pacific.

The specific objectives were to:

1. understand the background of the Vitawa Pilot Project
2. know about Milkfish biology
3. learn how to produce Milkfish
4. learn lessons about community based fish farming

Vitawa community was chosen because of similarities to Okinawa fishing communities in the 1970s (see Figure 1), for example, unsustainable fishing practices like dynamite fishing are occurring. The role of government to strengthen and enforce fishery regulations in Okinawa was largely ignored by fishers. The alternative strategy was to develop other income from seaweed aquaculture and from fish aggregation devices (FADs), with community co-management. This led to recovery of resources, and empowerment of Okinawa communities for self-development.

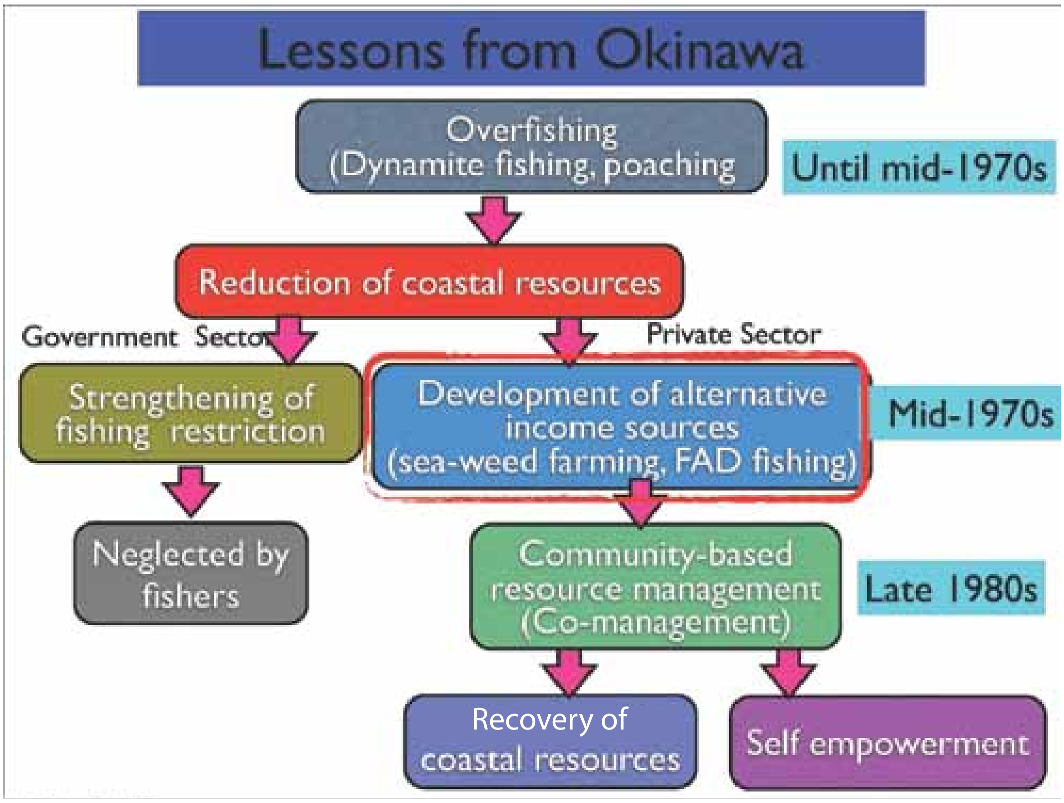

Figure 1. Lessons from Okinawa

Initially the Vitawa community was interested in shrimp farming, but was asked instead to consider milkfish because of the natural availability of seed, ease of culture, and relatively low investment. Milkfish are produced on a large scale in other parts of Asia and the Pacific, led by Philippines at 289,000 tonnes annually, Indonesia at 254,000 tonnes and Taiwan at 50,000 tonnes (see Figure 2). Global aquaculture production is rising, and milkfish are becoming an increasingly important food fish. Philippine milkfish production increased by 6.6% during 2011.

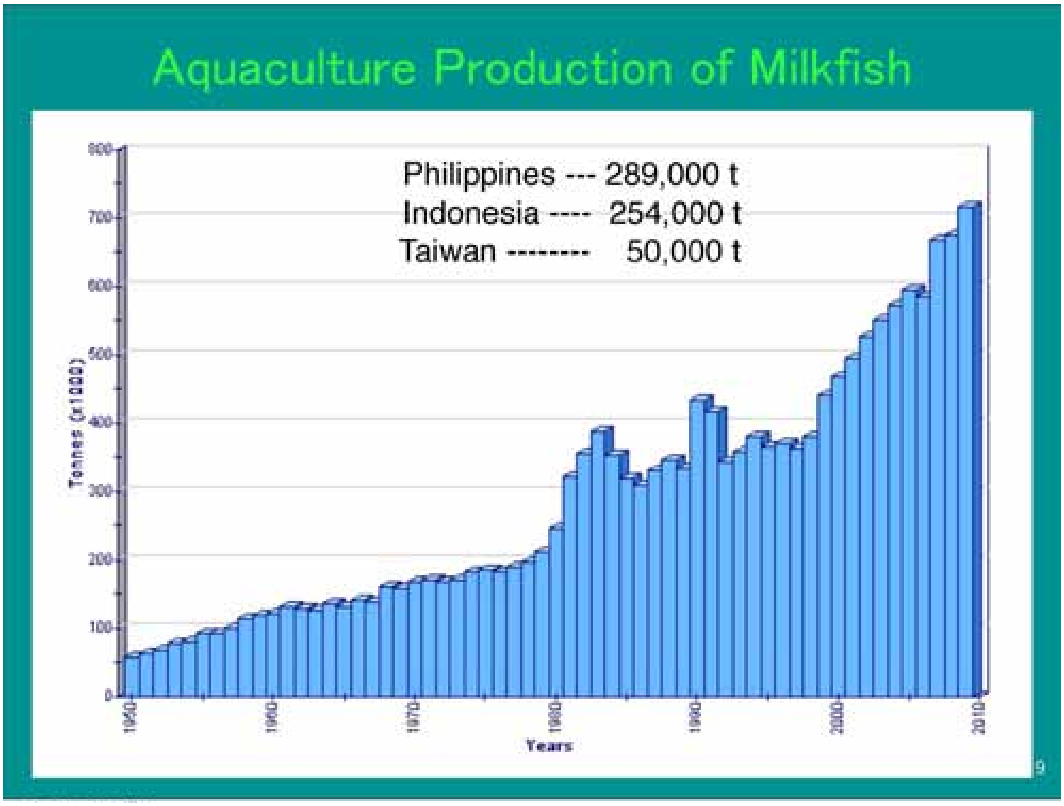

Figure 2. Milkfish production

As a result, a Vitawa Aquaculture Development Project was proposed to JICA as a *Fiji Rural Coastal Community New Livelihoods Project*. This pilot project could be a means of coastal resource management and community empowerment. The proposal was accepted, and construction of ponds completed in 2009 (see Figure 3).

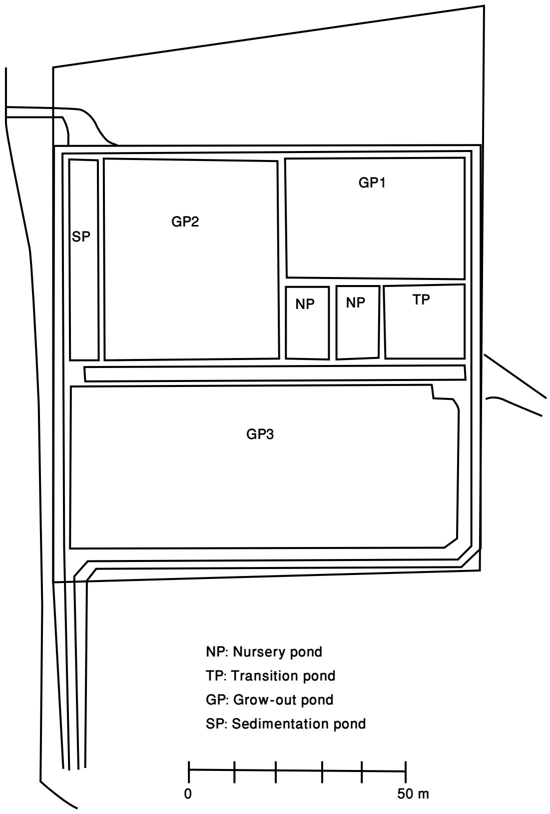

Figure 3. Vitawa ponds

Activities during the workshop were aimed at understanding and learning about milkfish farm management, and making a field survey of potential milkfish farming sites. These activities were:

1. pond environment
2. preparation of nursery pond
3. fry collection
4. feeding
5. transfer (rotation) of fish
6. harvesting
7. post-harvest and storage of milkfish
8. sales
9. book keeping, pond maintenance and so on.

Hideyuki Tanaka
Project Manager of Vitawa Aquaculture Development Project
Fisheries and Aquaculture International Co., Ltd.

2. Keynote speakers

2.1 Milkfish aquaculture at Vitawa village

Vitawa village has an estimated population of 422, comprising 106 households in 3 *Yavusa* (tribes) and 11 *Mataqali* (clans). The social hierarchy of the village is illustrated in Figure 4. There are 46 primary school, 19 secondary school and 10 tertiary students. The village has a church, a community hall and an administration centre, with Fiji Electricity Authority power and a running water supply from a spring. The main sources of income are agriculture, fishing, remittances and wage employment. The surrounding soils are not so good for cultivation, and the fish catches in the coastal area are declining.

Figure 4. Social hierarchy of the village

The historical steps toward establishment of the Aquaculture Development Project were:

- 2000–2003 Mr Solomone Nateba, Development Committee member, approached the Japanese Embassy in Suva
- 2004–2006 they approached a retired FAO employee, Mr Hideyuki Tanaka, to complete site analysis
- 2006–2008 Mr Tanaka made several attempts to gain financial assistance to fund this project
- 2008 funding was approved through JICA
- 2009 A memorandum of understanding was signed between the Fiji Government, JICA and the Vitawa Community
- 2009 funding was released for 2 years

Milkfish *Chanos chanos* was selected as the fish species to be farmed because:

- in 1998 a survey of milkfish made by FAO and Fiji Fisheries Department revealed that the northwestern part of Viti Levu is a natural habitat for milkfish fry;
- JICA was familiar with milkfish as an economically important commodity in Southeast Asia;
- SPC has recommended milkfish for its potential not only for food but also as a bait for tuna fishing; it is reputed to be a low-cost species for aquaculture.

We anticipate that this project will continue to assist the Vitawa community to secure food sources and provide an alternative livelihood to many of us in the future. We acknowledge our main funding donor, JICA, the technical assistance of Fisheries and Aquaculture International Co Ltd (FAI) and the Fiji Fisheries Department, and the assistance provided by other agencies such as the University of the South Pacific and SPC, which have been a great help in boosting the Vitawa Milkfish Project.

Rusiate Waqata
Vitawa Pond Committee
Ministry of Fisheries and Forests Fisheries Assistant (Rakiraki)

2.2. Milkfish fry collection in Fiji

Milkfish fishing for juveniles is traditional to most communities in Fiji. Fingerling sizes are in abundance in the wild during the spawning season in places like Vanuabalavu in Lau, Udu in Cakaudrove, Rewa Delta, the coastal area of Rakiraki up to Rabulu, Fawn Harbour in Cakaudrove, Lekutu and Bua Bay in Bua, the Nakalou and Navidamu coastline, Nadogo coastline and Wainikoro river mouth area in Macuata, the coastal area of Tavualevu up to Vatia point, Ba river mouth and nearby villages, and Navua river mouth up to Naitonitoni, the Sigatoka river mouth and coastline mudflats towards Momi, and the Vuda coastal area up to the Nadi river mouth.

A coastal survey conducted from 1996 to 1999 by the Fiji Fisheries Department and an expert consultant from the Food and Agriculture Organization of the United Nations (FAO) established that the season when fry are abundant starts at the end of September and finishes at the end of April (see Figure 5) with a peak in December to February. During this time, the abundant wild fry can sustain a coastal culture program for milkfish.

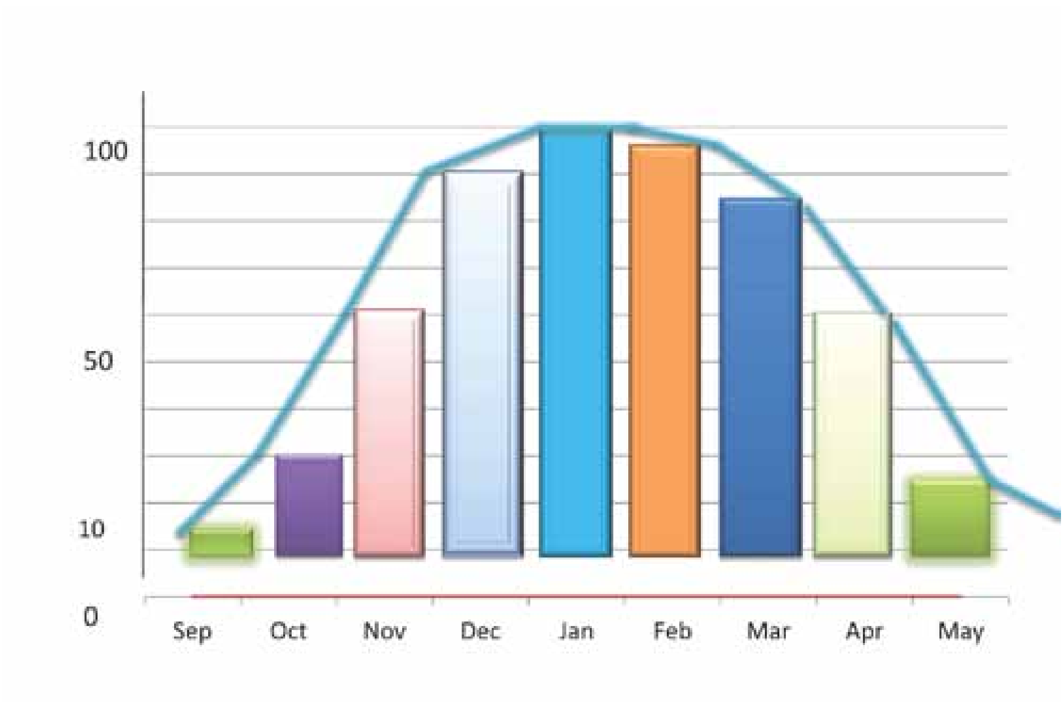

Figure 5. Milkfish – Seasonality of wild fries in Fiji

In 1998 a government milkfish farm was established in Dreketi, Macuata, through the Commodity Development Framework initiative (CDF), but this was terminated after the 2000 political events when the farm was looted of all stock.

Vunitogoloa in Rakiraki was chosen in 1999 as the first community-based project site with FAO back-up funding, but construction was halted by senior management of the Ministry due to differences among community members.

Consultation on the Vitawa project site started in 2006 and construction started in 2009 thanks to generous funding from JICA. Fisheries and Aquaculture International Co Ltd and Fiji Fisheries Department are the implementing agencies.

Fry collection methods used in past surveys in Fiji, and for the current project, utilize five main items of equipment:

Hand scoop net - made from fine blue netting with an iron frame and wooden handle, mostly used in mudflats, pool and canals. It is not as effective in open water.

Seine net collector - fine blue netting is strung on a rope with a float line on the top and lead line on the bottom. A collection pocket is sewn in the middle, lower part to act as a cod-end, and the seine is pulled through the water with the help of two sticks attached to the ends of the net. It is very effective in shallow water areas (a few cm) and mudflats.

Beach drag seine net – a longer net used for catching fingerling sizes up to 50 mm long, in deeper and more open water than the previous two methods.

Bulldozer net or 'fry-dozer'– made from fine mesh netting coloured blue or white, strung into a floatable bamboo frame held together using ropes. This method is very effective in open water in both deep and shallow water areas, especially for fry collection during the peak season.

Barrier net – a fixed net extending out from a beach with a down-shore current (see Figure 6). Milkfish fry are collected by one of the above methods along the leeward side of the barrier net, where fry will take shelter. Materials other than nets can be used as a barrier, such as coconut palm leaves, bamboo, plastic sheeting or rope.

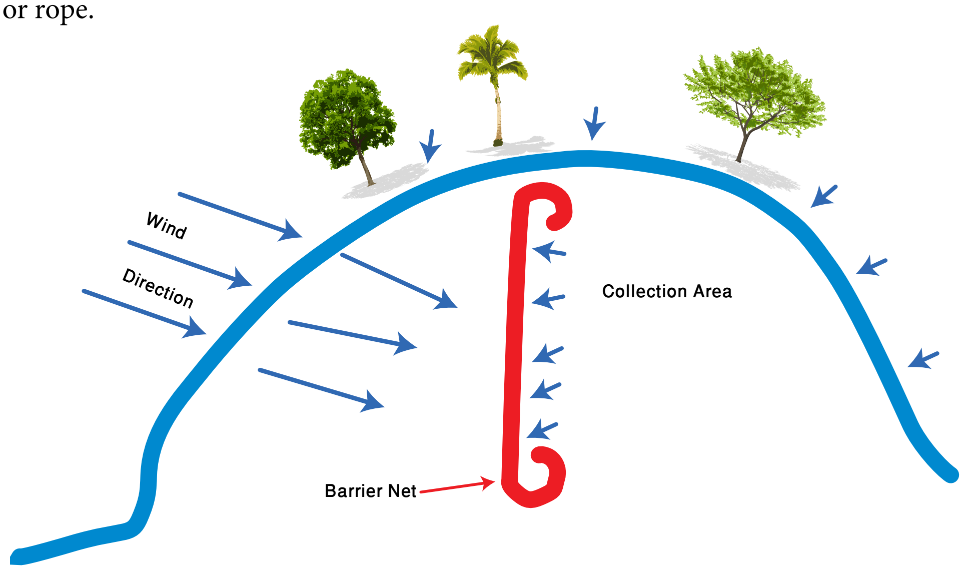

Figure 6. Barrier net

The techniques being used most often for the current Vitawa project are the hand scoop net, the seine net collector, and the beach drag seine net, because these are well suited to the shallow pools left remaining on mudflats near mangroves at low tide along the coast from Vitawa down to Vunitogoloa.

Alifereti Senikau
Fisheries Officer Extension/Advisory Services West
Ministry of Fisheries and Forests

2.3. Milkfish fry collection – the Tuamotu experience

In French Polynesia during the 1980s, milkfish fry collection was successful at different sites of Rangiroa atoll. The goals of this research were to develop collection, culture and production of milkfish as tuna bait or for human consumption, and to develop a new economic activity for this atoll population.

Sites stocked with milkfish were 100–350 metres long, 8–10 metres wide and up to 0.6 metres deep, holding brackish water and with an organic layer of algae and detritus on the bottom. Fry 10–12 days old (post-larvae) were trapped in artificial channels. Synthesis of data collected over 4 years showed that fry abundance is sufficient for aquaculture development (see Figure 7) and is quite predictable between November and February. An annual catch of 80,000 pieces is possible from the Rangiroa sites. In 1994 and 1996 some small-scale trials of pond rearing showed that this culture technique is simple and relatively inexpensive, but no scale-up was attempted at that time to grow fish out to commercial size, and demonstrate the profitability of milkfish culture for food.

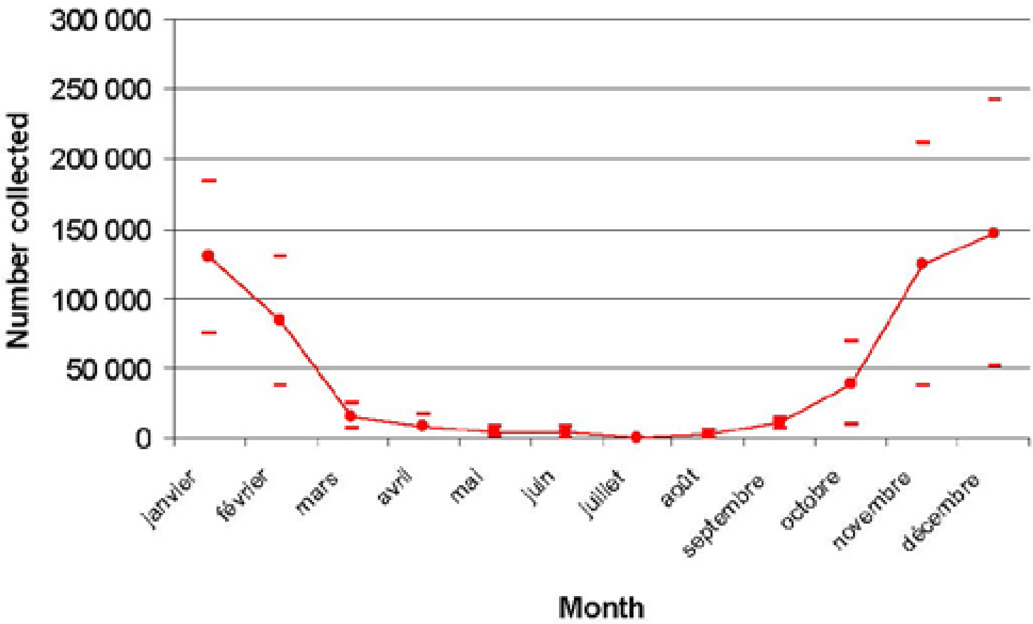

Figure 7. Milkfish fry collection results in Rangiroa from 1983 to 1986

This study concluded that milkfish are a 'very rustic fish' amenable to aquaculture at household level (this is a government new priority), and are appreciated as a food fish by locals (in particular in the Tuamotu Group). However the trial did not continue to the point where production costs for fish grown up to market size could be estimated.

A milkfish fishery in Niau atoll has also been studied, in order to:

- collect information from the local population about milkfish, such as uses of the resource, the techniques and places of fishing, biology of the species, and existing management measures;
- identify trends through time of the milkfish stock in the lagoon, and any problems or threats that could affect this resource;
- assess the quantities of *pati* and *opara* (see explanation below) which are taken by the inhabitants;
- make recommendations for the management of this natural resource.

In Niau atoll a famous tradition is to catch and eat *pati opara*, which are milkfish with greatly distended stomachs as a result of grazing on algal floc (*kopara*) made up mainly of cyanobacteria but also containing other marine algae, bacteria and detritus. The *opara* or stomach and its contents are the part of *pati opara* that is highly prized for eating (see Figure 8). *Opara* is the 'caviar' of Niau, according to the inhabitants, and they recognize several types of *pati* which differ according to their degree of corpulence and eating qualities:

Figure 8. ***Pati opara***

Pati paroro: 'The really fat fish - this is in good health, and is the best *pati* for eating.'
Pati ivauvau: 'This is intermediate *paroro* and *otefa*. It looks like the *otefa,* but it's good to eat.'
Pati otefa: 'This is the thin fish, that has a lot of flesh. It's not good to eat.' When this one is caught, it is either discarded or used to feed pigs.

It was estimated during the study that 36.5 tonnes of *pati* were fished in Niau lagoon in the space of one year.

Aquaculture potential in French Polynesia can thus span both high-tech and low-tech finfish culture strategies. High tech can focus on the high-value batfish *Platax* for hotels and restaurants, while milkfish offer a low-tech alternative for more remote places with poorer infrastructure. Options to produce milkfish fry include hatchery or fry collection, with grow-out either in artificial ponds or in the mesocosm (natural pools). Milkfish can also be a suitable fish species for use in aquaponics.

Moana Maamaatuaiahutapu
Direction des ressources marines
French Polynesia

2.4. Keys to successful milkfish farming

Milkfish are found in waters that remain warmer than 20°C. Broodstock mature at 5–7 years, and will spawn if the seawater is in the range of 26°–32°C and the salinity is higher than 29 ppt. Fish 65–80 cm long, or weighing 4–8 kg are the most fertile. The maximum length of female fish is 124 cm, while males reach 180 cm. Females produce 100,000 to 400,000 eggs per kilogram of body weight.

Egg division begins an hour after spawning and hatching occurs 35–36 hours after spawning. The eggs are 1.1–1.2 mm in diameter. In the wild, eggs are probably released in deeper oceanic waters and in the outer reef region. The breeding season in the Philippines is from May–June to October–November.

Larvae are 3.5 mm long at hatching, and by the time they begin aggregating along shorelines they will be 10–17 mm long. They are active swimmers, as proved by migration to near-shore areas where they can be caught by fine-mesh nets operated along sandy beaches and in mangrove areas. Their movement is heavily influenced by both wind-driven and tidal water currents.

Fry can appear inshore in great numbers, distributed mainly at the surface. They enter coastal wetlands seeking food. At this age they are attracted by light. Fry can be caught by filtering and driving using nets. Fry will be found mostly in the upper 10–30 cm of the water column. They will be abundant at river mouths, swamp outlets, and along sandy beaches. Notable peaks in abundance coincide with a semi-lunar rhythm, that is, at both new moon and full moon. Abundance is usually greatest on a rising tide 1–3 hours before high tide.

Adult milkfish are both filter feeders and benthic feeders, and eat both plants and animals. Their feeding is most active in daytime. They are euryhaline (tolerant of a wide range of water salinity), are resistant to diseases, and not cannibalistic. They exhibit compensatory growth whereby, after a period of slow growth due to adverse conditions, they can undergo a rapid growth spurt to 'compensate' when conditions improve.

Breeding in captivity can be done successfully, but fish must be reared from smaller size up to broodstock size and will take 5 to 10 years to mature. Capture of large fish from the wild for breeding is usually unsuccessful due to the high level of stress and mortality during capture and transport. Once mature, milkfish will spawn spontaneously in concrete tanks or in cages. Fry survival, quality and grow rate is comparable with that of wild fry. Milkfish farming can therefore be based upon either wild or hatchery fry, according to the farming cycle illustrated in Figure 9.

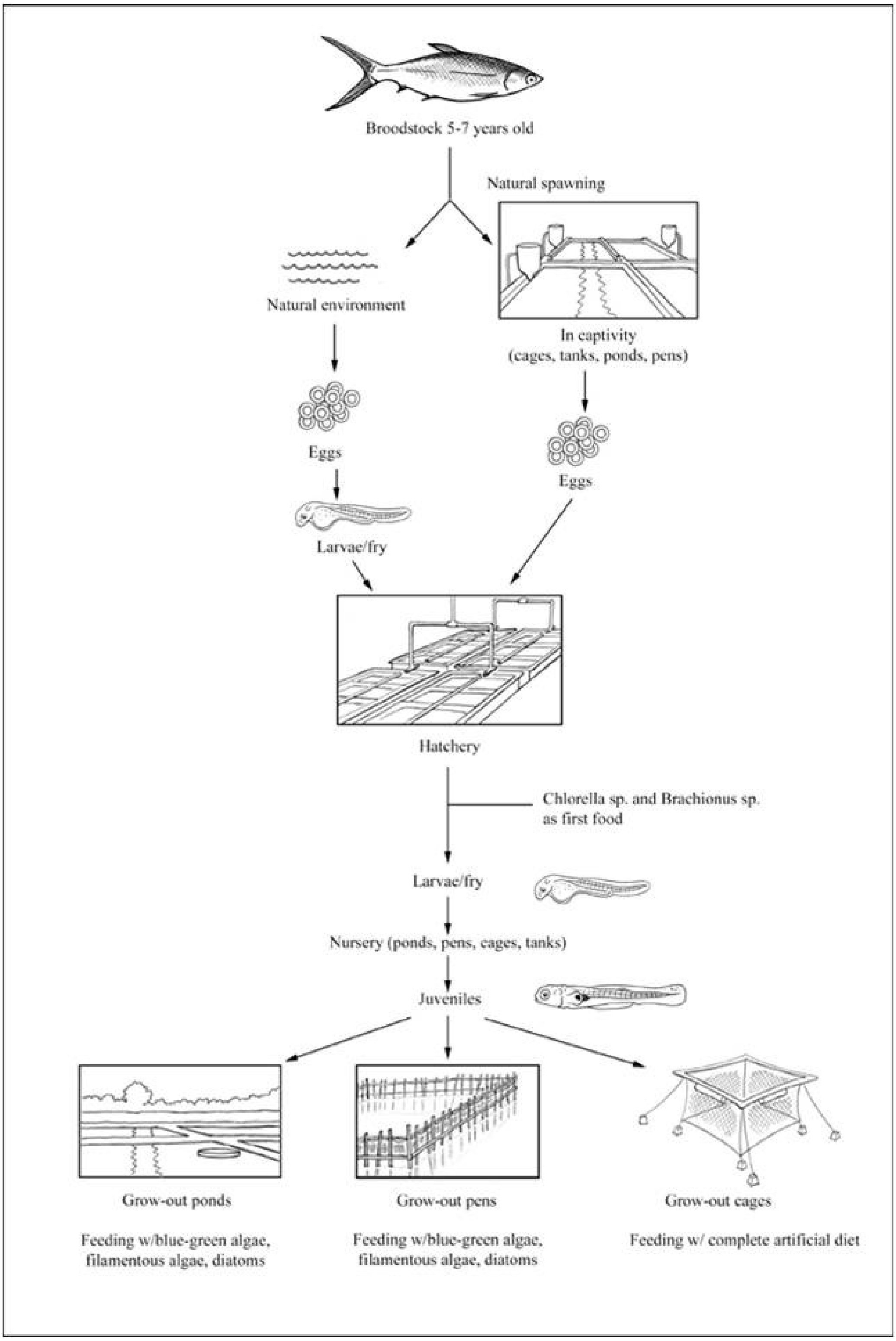

Figure 9. Culture cycle

Milkfish can be farmed in ponds or by cage-culture in lakes and sheltered bays (see Figure 10), though this can be problematic in some locations due to fish kills. In the Philippines milkfish farming by cage culture uses a stocking density of 20 to 30 fish m^{-3}. Production per 600 m^{-3} cage ranges from 2400–3600 kg, or 40–60 tonnes ha^{-1} yr^{-1}.

Figure 10. Cages

Common problems that reduce farm output in the Philippines include:

- loss of genetic quality in hatchery reared fingerlings due to inbreeding;
- insufficient supply of quality fry in remote areas;
- fish kills in cage culture due to eutrophication in enclosed water bodies;
- high cost of farm inputs;
- lack of manpower to effectively transfer technology to the municipal level;
- marketing layers (middlemen) which stand between producer and consumer; and
- lost opportunities to participate in the global market for value-added fish products.

Pond stocking procedures need to pay careful attention to:

Release at correct stock density

- computing the target stock density for the nursery pond or hapa;
- by counting fish from one container to another, and sorting the sizes and estimating the number of fry in the containers, to ensure that the target density will not be exceeded;
- identifying and removing predators when sorting fingerlings (tarpon *Megalops cyprinoides* and ten-pounder *Elops machnata* can closely resemble milkfish, but will eat them), and by maintaining a fine-mesh screen around pond water inlets

Acclimatization of fish to pond water, to avoid temperature shock and salinity shock

- if the salinity difference between transport water and pond water is equal to or less than 5 ppt then acclimation in a 50:50 mix of the two waters in an aerated container for 15 mins before release into the pond will be sufficient (see Figure 11);
- if the difference is more than 5 ppt then gradually add pond water to the transport water, so that the salinity change is accomplished in stages of no more than 5 ppt of change per 15 mins.

Figure 11. Acclimation pondside

Acclimation steps

- open the plastic bags (if fry are being transported in bags);
- let the bags float in the pond so that bag temperature can adjust to that of the pond;
- add pond water gradually, splashing it into the bag by hand;
- check salinity and temperature;
- when salinity and temperature in the plastic bags is equal to that of the receiving pond, partially submerge the plastic bag or container and allow fry to swim out by themselves, leaving behind any dead fry for counting to estimate the percent mortality during handling and transport.

Ideal salinity for fry rearing

- The ideal salinity for rearing of fry through the nursery phase to fingerling size is 20 ppt.
- Gradually acclimate fry to 20 ppt as soon as possible after capture.

Farm management encompasses four main steps to set up and run a milkfish farm (see Figure 12). Always remember the term 'carrying capacity' (the biomass of fish matched against their food supply) because the main objective of a farm manager is to ensure that fish do not run out of natural food in the pond. You MUST know the number and average size of fish stocked in the pond, so that you can calculate the appropriate feeding rate of supplementary feeds.

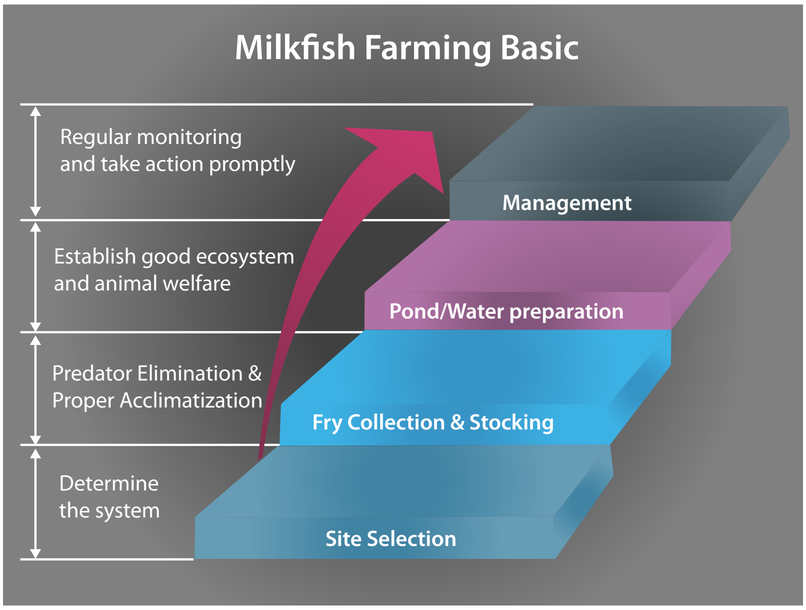

Figure 12. Farming basics

Pond preparation involves four steps before any water is filled:

- sun drying pond bottom sediments to kill bacteria and pest organisms;
- ploughing the pond bottom to oxygenate the sediments;
- eliminating unwanted animals like predators or pests (can use agricultural lime to do this);
- fertilizing with dried chicken manure, to promote growth of natural food.

When the pond is filled with water, it will start to form plankton blooms (denoted by greenish golden colour) both in the water column and on the pond bottom (like a carpet, known in Southeast Asia as 'lablab'). These will provide sources of natural food for the fry when the pond is stocked. The best pond water conditions to initiate and maintain natural food production, and to avoid environmental stress to the fish, are set out in Table 1.

Table 1. Optimum water quality parameters

Water Quality Parameters	Ideal level	Measurement frequency	Instruments used
Salinity	0–35 ppt	Daily	Refractometer
pH	7.5 to 8.5 pH	Daily	pH meter
Dissolved oxygen	>4 ppm	Daily	D.O. meter
Temperature	26–32°C	Daily	Thermometer
Transparency	20–30 cm	Daily	Secchi disc

Pond dynamics of water quality differ between day (Figure 13) and night (Figure 14), and with rain (Figures 15 and 16). In day time the pond water quality is characterized by high temperatures, high pH and high dissolved oxygen (DO). Night time low temperatures, low pH and low DO suggest a need for water exchange during night time to encourage mixing of water layers, especially after heavy rain. If heavy rain occurs, a good response is to reduce feeding and to surface-drain water during exchange to remove the fresh layer. The colour of the water is important, and should be a nice-looking greenish or golden colour with a 'crisp' and fresh look to it.

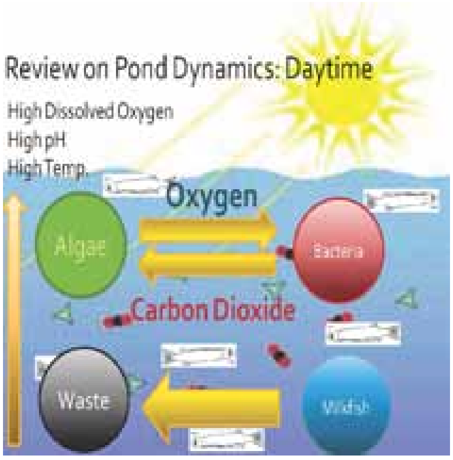

Figure 13. During daytime algae take up carbon dioxide (which increases pH) and release oxygen

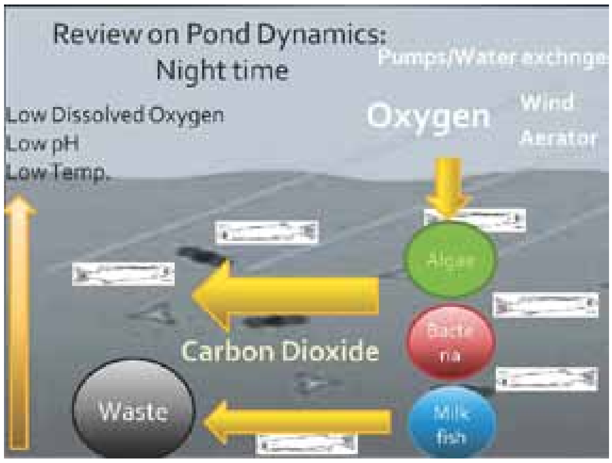

Figure 14. During night time algae release carbon dioxide and use oxygen, which can cause problems of low oxygen and low pH for the fish at night time if the algal bloom is too heavy

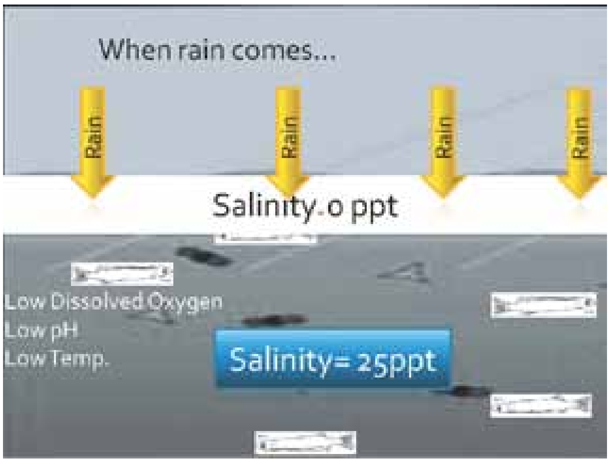

Figure 15. When it rains, a surface layer of fresh water (the white layer shown in the diagram) will build up that seals off the salty layers underneath (the grey layer) from getting oxygen from the air

Figure 16. The farm manager's response to heavy rain should be to top-drain the pond to remove freshwater, add new saltwater, and add some more lime and fertilizer, once the rain has stopped

Maintaining the growth of brackish water algae depends upon the farm manager being diligent and experienced about:

Water replenishment

- to reduce sedimentation;
- to dilute fish waste and remove it;
- to follow the recommendation to replenish 30% of the pond volume 4x during every spring tide.

Fertilization

- replenishes plant nutrients;
- the recommended application rate is 30 g m^{-2} of chicken manure into the pond.

Monitoring and adjustment

- take a secchi disk reading every day (see Figure 17); the ideal reading is 20–30 cm;
- replenish water before the algal bloom reaches stationary or death phase (see Figure 18); if water goes dark and dull in colour and the secchi value goes below 20 cm, then do a water exchange and reduce feeding;
- add more fertilizer or manure if secchi value exceed 50 cm; chicken manure is best (preferably from a broiler farm);
- avoid over-grazing the pond's natural food, by reducing fish stock density or by adding supplementary feed.

Figure 17. When the black&white zone of the secchi disk *just* disappears from view when lowered into the pond water, read off the secchi value in cm from the graduations marked on the rope

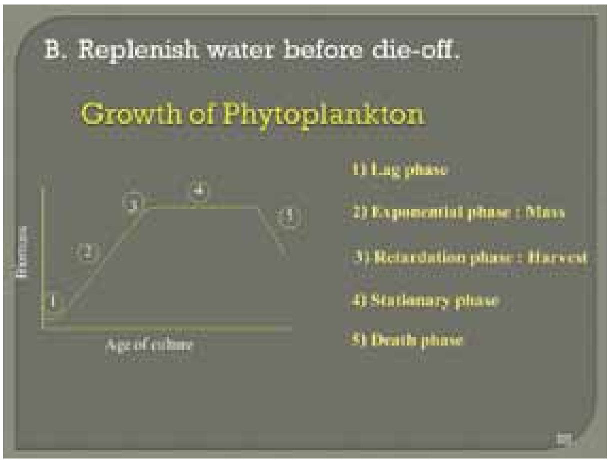

Figure 18. The farm manager's job is to keep the pond's phytoplankton population in the growth phases (2 and 3) by carefully exchanging seawater and adding new fertilizer

Milkfish will grow faster if supplementary feed is added. The known nutritional requirements of milkfish are shown in Table 2.

Table 2. Milkfish nutritional requirements (source: SEAFDEC AQD 1994)

Nutrient	Requirement
Protein	40% for fry
	30%–40% for juveniles
	44% protein:energy
Essential Amino Acid	%
Arginine	5.2
Histidine	2
Ileucine	4
Leucine	5.1
Lysine	4
Methionine + Cystine	2.5(cys, 0.8)
Phenylalanine + Tyrosine	4.2(tyr, 1.0)
Threonine	4.5
Tryptophan	0.6
Valine	3.6
Lipid	7%–10%
Essential Fatty Acids	1–1.5% n–3 polyunsaturated fatty acid
Carbohydrates	25%
Digestible Energy	2500–3500 kcal/kg

Abbreviation: SEAFDEC AQD Southeast Asia Fisheries Development Center Aquaculture Department

When adding supplementary feed, it is necessary to calculate the Daily Feed Ration (DFR) to avoid losing money through over-feeding.

Worked example of DFR:

- the pond was stocked with 10,000 fry;
- the Average Body Weight (ABW) of the fish is now 2 g each;
- the recommended feed rate for this size of fish is 4% of their ABW per day.

Computation:

$$\text{Biomass of fish} = \frac{10{,}000 \times 2\text{ g}}{1{,}000} = 20\text{ kg}$$

Daily Feed Ration DFR = Biomass × Feed Rate
= 20 kg × 4%
= 0.8 kg or 800 g

A sample of at least 30 fish should be caught and weighed every 2 weeks, and the new ABW used to re-calculate the DFR as the fish grow older and increase in size.

The milkfish will also be eating benthic algae ('lab-lab') and can consume 60% of their ABW per day. This means that 20 kg of fish fingerlings can eat 20% × 60% = 12 kg of 'lab-lab' each day. Juveniles can consume 25% of body weight.

When feeding juvenile milkfish in hapa or in nursery ponds, use these points as your guide:

- feed to satiation, not just by computation. Start with a computed ration (as above) but adjust it by increasing or decreasing the feed ration until there is always just a little bit of feed still remaining 2–3 hours after feeding (which means that fish have stopped taking any more feed);
- to find out whether fish have reached satiation after 2–3 hours, monitor their feeding using the feed-tray technique to check for remaining crumbs;
- milkfish have a digestion time of 5 hours and they feed mainly in the day time, so the suggested feeding times are 0700 hours, 1100 hours, and 1500 hours;
- normally the amount of feed given for fish to reach satiation from three feeds per day will add up to about 5% of ABW per day;
- the protein content of the feed given should be around 24%;
- check the hapa for predatory fish and remove them, or for holes made by crabs and patch them.

For bigger farms, an efficient way to ensure fish are fed to satiation is to install 'self-feeders', or 'demand-feeders', whereby fish are able to feed themselves when they are hungry.

Table 3. Recommended feed formulations

Ingredients	24% Protein	31% Protein
Fishmeal	10.8	16.1
Soybean Meal	23.8	35.7
Cassava leaf meal	13	13
Rice bran	27.9	17.4
Rice hull	15.5	8.4
Cod liver oil	2	2.2
Soybean oil	2	2.2
Breadflour	5	5
Proximate Analysis (Dry Matter Basis)	24	30.5
Crude protein	11.4	11.2
Crude fat	43.5	39.9
Nitrogen-free extract	43.5	39.9
Crude fibre	11.2	9.1
Ash	9.9	9.3
Metabolizable energy (kcal/kg)	3,726	3,824

The most typical means of supplementary feeding is to formulate for 24% protein and follow a feeding rate of 5% of total fish biomass each day.

Alternative feed ingredients:

- dried fishmeal
- trash fish
- breadcrumbs
- rice bran
- rice hull
- cassava meal
- copra meal

The farm manager or trusted deputy should be living on or right next to the farm, because:

- pond water quality parameters are dynamic so need constant monitoring;
- troubleshooting and adjustment of pond conditions must be prompt;
- night time is the best time for changing the water.

Good record-keeping of pond water quality observations and adjustments, and feed calculations, is vital to monitor fish performance and to estimate costs for your budgeting purposes.

Three techniques can be used to harvest the fish – total harvest after drainage, partial harvest by swimming against the current, or partial harvest by gill netting.

Total harvest means picking up fish by hand from the pond bottom mud after all pond water has been drained out. It results in poor quality due to muddy taste and to flesh getting too hot in the sun, so market value is lower.

Gill netting is the same method as used in wild-capture fishing. It leaves fish with marks on their bodies, which also lowers market value.

Swim against current and seine netting – this uses the behavioural tendency for milkfish to swim up-current. Letting water into the pond encourages fish to swim near the inlet gate where they can be scooped and seined. This maintains fish quality, and price.

Mark Rowel Napulan
Assistant Section Manager
Charoen Pokphand Foods Phil. Corp.

2.5. Best practices for making smoked milkfish

The steps involved in smoking and packing of milkfish for human consumption are shown in Figure 19.

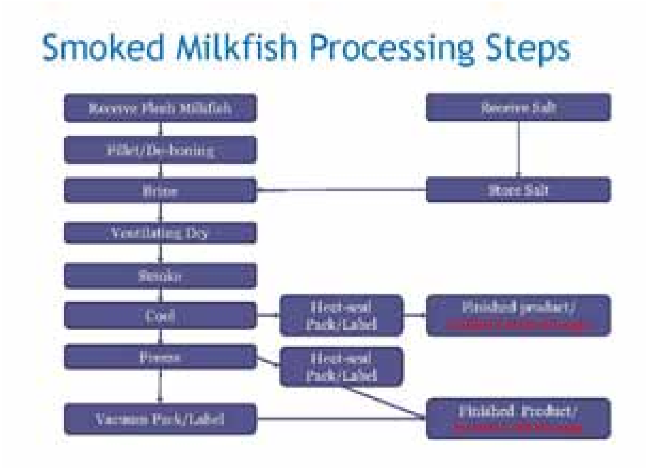

Figure 19. Smoking steps

Smoked fish is good, but:

- fish smoked without proper salting and cooking can result in food poisoning;
- most food poisoning bacteria can and will grow under the conditions normally found in the preparation and storage of smoked fish;
- *Clostridium botulinum* is the most harmful of these bacteria.

A Food Safety Hazard is any biological, chemical or physical property that may cause a food to be unsafe for consumption.

Pathogens vs Spoilage Organisms:

- biological hazards are caused by pathogens;
- pathogens are microorganisms that result in a potential health hazard;
- spoilage organisms are not biological hazards. They may affect quality but not safety. Examples are yeasts and molds.

Some facts about pathogens:

- some pathogens can grow inside a vacuum pack;
- some pathogens can grow in 10% brine;
- some pathogens can grow in a refrigerator;
- some pathogens can produce toxin before spoilage;
- some pathogens cannot be sterilized in normal boiling;
- some toxins cannot be inactivated in normal boiling;
- pathogens cannot be sterilized in the frozen cold storage.

Bacterial food-borne pathogens include:

- *Salmonella* spp.
- *Clostridium botulinum*
- *Staphylococcus aureus*
- *Yersinia enterocolitica*
- *Listeria monocytogenes*
- *Vibrio spp.*
- *Escherichia coli* O157:H7
- *Clostridium perfringens*
- *Campylobacter* spp.
- *Shigella spp.*
- *Aeromonas hydrophila*
- *Streptococcus*

The characteristics of some pathogens make them capable of posing a hazard in smoked milkfish. These pathogens, and some means of control, are described below.

Clostridium botulinum

- sporeforming, toxigenic;
- present in soil, and marine sediment;
- affects vegetables, seafood;
- anaerobic;
- no growth below pH 4.6;
- spores are extremely heat resistant;
- some types are non-proteolytic.

Control

- difficult to 'keep it out';
- correct retort process will destroy spores;
- control growth (germination) by means of pH, Aw, temperature, inhibitor.

Staphylococcus aureus

- non-sporeforming, toxigenic;
- found in human skin nasal passages;
- resistant to high salt;
- cells killed by mild heat;
- enterotoxin is very heat stable.

Control

- prevent contamination through proper hygiene, exclusion of food handlers with boils, or abscesses;
- cells are destroyed by normal cooking, but the enterotoxin is not;
- proper refrigeration/hot holding prevent growth.

Listeria monocytogenes

- non-sporeforming, infectious;
- present in animals, humans, the environment;
- low pH prevents growth;
- survives dehydration and freezing;
- grows at refrigeration temperatures.

Control

- may be difficult to 'keep it out';
- destroyed by mild heat;
- environmental monitoring in RTE* areas;
- ingredient specifications;
- avoid recontamination of RTE foods;
- prevent growth.

*ready-to-eat, e.g., salads, sandwiches

Chemical hazards: top eight food allergens:

peanuts	milk
tree nuts	egg
soybeans	fish
wheat	crustaceans (such as prawn, crab)

A Critical Control Point (CCP) is a step at which control can applied and is essential to prevent or eliminate a food safety hazard or reduce it to an acceptable level. The steps involved in smoking and packing milkfish are shown for the Heat Seal Packing method in Figure 20, and for Vacuum Packing in Figure 21. The hazards involved, and the CCPs that can be identified, are shown in Tables 4 and 5.

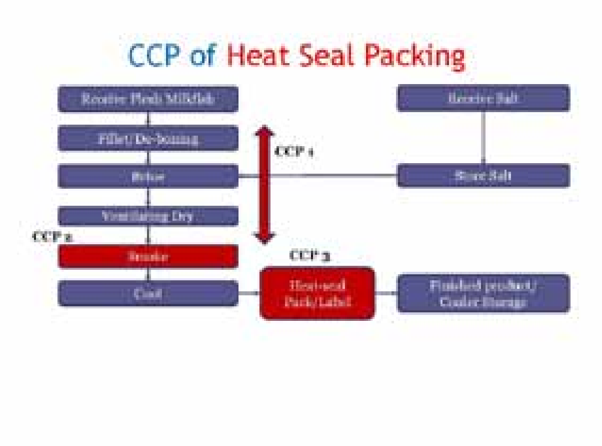

Figure 20. CCP of Heat Seal Packing

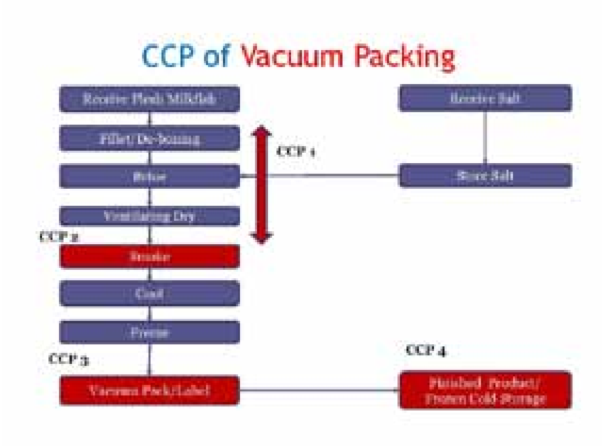

Figure 21. CCP of Vacuum Packing

Table 4. Hazard Analysis of Heat Seal Packing (see Figure 20)

Processing Step	Biological, chemical, and physical food hazards	Significant (Yes or No)	Justify the decision	Control measure(s)	Critical Control Point? (Yes or No)
Fillet – Smoke	Pathogen growth – temperature abuse	Yes	Pathogens such as enterotoxin producing *S. aureus* could grow if time/temperature abuse occurs	Time control less than three hours	Yes CCP 1
Smoke	Pathogen growth – temperature abuse	Yes	Pathogens could be present on raw milkfish	Cook to internal temp. of at least 63° for 17 min to kill pathogens	Yes CCP 2
Heat seal pack & label	Food allergens	Yes	Milkfish are a major food allergen	Labels applied at this step must contain the market name 'Milkfish'	Yes CCP3

Table 5. Hazard Analysis of Vacuum Packing (see Figure 21)

Processing Step	Biological, chemical, and physical food hazards	Significant (Yes or No)	Justify the decision	Control measure(s)	Critical Control Point? (Yes or No)
Fillet – Smoke	Pathogen growth – temperature abuse	Yes	Pathogens such as enterotoxin producing *S. aureus* could grow if time/temperature abuse occurs	Time control less than three hours	Yes CCP 1
Smoke	Pathogen growth – temperature abuse	Yes	Pathogens could be present on raw milkfish	Cook to internal temp. of at least 63° for 17 min to kill pathogens	Yes CCP 2
Vacuum pack & label	Food allergens	Yes	Milkfish are a major food allergen	Labels applied at this step must contain the market name 'Milkfish'	Yes CCP3
Finished frozen cold storage	*C. botulinum* toxin	Yes	*C. botulinum* toxin could form in finished product which is in a reduced oxygen package	Store production in cooler at temperature at 3.3°C or below to provide a hurdle to growth for *C. botulinum*	Yes CCP4

The CCPs identified in these tables can be seen highlighted on the diagrams for the smoking steps shown in Figures 20 and 21. Looking at these diagrams, we can see that the hazards of smoking of milkfish, and their control, can be summarized as follows:

- three common ingredients in all fish-smoking recipes are salt, smoke, and heat;
- this indicates that salt and heat are important for safety, and explains the basic techniques for preparing delicious smoked fish with absolute safety;
- frozen or refrigerated storage is important for all smoked fish.

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JICA Senior Volunteer
USP

2.6. Economics of milkfish farming in Fiji

The Vitawa Pilot Project has been producing milkfish at a scale that is meaningful for analysis of the economic viability of milkfish capture-based aquaculture in Fiji (see Figure 22).

Figure 22. Vitawa sales

The target is to harvest milkfish from the main pond at Vitawa village at a frequency of three times per year. In practice there have been some events of mass mortality due to unusual weather patterns in 2010 and 2011, respectively (both excessive drought and excessive rain occurred during this period). Under these conditions, the actual production of milkfish during this period is that shown in Table 6.

Table 6. Production of milkfish at Vitawa 2010–2011

Harvest date	Weight of fish (kg)
December 2010	413
March 2011	217 (harvested due to mass mortality)
April 2011	274
June 2011	311
TOTAL	**1215 kg**

The pond area is 0.76 ha and the grow-out period was for 17 months, producing 4311 pieces at 200–300 g weight. We can calculate from these data that the production per unit area was 1128 kg $ha^{-1} yr^{-1}$. In the Philippines, milkfish production is on average 761 kg ha^{-1} yr^{-1} and ranges from 266 to 1429 kg ha^{-1} yr^{-1}, so that production at Vitawa compares well with figures for Southeast Asian production.

Half of the fish produced were sold, and the other half distributed among the households within the village. The farm gate price of milkfish at Vitawa is FJD 7.00 per kg, for example to the Nauru community in Suva, or within the village the fish is sold at FJD 5.00 per kg. If the average price can be assumed to be FJD 6.00, then the income from the project to date is worth FJD 4117.

Table 7. Production expenses at Vitawa

Item	Amount used	Cost
Pellet feed \$1.20 kg^{-1}	1393 kg	FJD 1425
Manure @ \$3.00 per 17 kg bag	346 bags (= 6200kg)	FJD 1254
Lime	480 kg	FJD 423
Miscellaneous (fry & feed transportation, operation costs, etc)		FJD 2669
TOTAL		**FJD 5771**

When production expenses are taken into account (Table 7) we can see that the project made a loss of FJD 1600 during this production period. However there were potential earnings of FJD 7290 gross and profit of FJD 1519 net, if all 1215 kg of the fish produced had been sold for cash.

This economic model does not include the cost of wages, because labour was provided by volunteers among the village youth. Three to four staff worked from 10 a.m. to 4 p.m. daily to maintain the farm, which in Fiji would represent a cost of FJD 15 per person per day.

The costs of running the Vitawa pilot project can be reduced by:

1. Reducing the level of manure from 6 tonnes ha^{-1} to 3 tonnes ha^{-1}, which is a level more typical of that used in Southeast Asia. The high level applied at Vitawa was used to try and restore both bottom algae and phytoplankton blooms lost by unusual weather. Normally, manure is only effectively given when the water is both sunny and brackish, and is not effective when there is heavy rain or when salinity is quite high. Inorganic NPK fertilizer is more effective than manure if water is very salty (30 ppt or above). Pond water depth can also be lowered to increase penetration of available sunlight.
2. Reducing the level of supplementary feed given. Food Conversion Ratio (FCR) at Vitawa in this production period was 1.15:1, while in Southeast Asia it is more typically 0.8:1. Extra pellet feed had to be given to compensate for the poor algae and plankton blooms caused by unusual weather, however at 0.8:1 this cost would have been reduced from FJD 1425 to FJD 855.
3. Increasing the survival of the milkfish fry stocked into the ponds. Only 4311 fish were harvested from a total of 20,000 fingerlings stocked. This is a survival rate of about 20%, yet 80% survival should be possible. Fine-tuning of fry collection, handling systems and remove of predators when sorting fry is needed to eliminate sources of stress from rough handling and mortality by predation, and to increase survival to more than 50%.
4. Increasing the pond area to make the farm into a more economic unit. The same labour and fry collection fixed-costs would apply to a farm two or even three times larger than the present farm.
5. Increasing stock density of fish. During this trial the fish stock density was 0.55 fish m^{-2}, however this could be increased to 1 fish m^{-2} with no reduction in survival or growth performance.

The conclusion drawn from this analysis is that the Vitawa Pilot Project is economically viable. However, there is scope for fine-tuning fry collection and pond management techniques to reduce costs, increase production, and thereby further improve viability.

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Fisheries and Aquaculture International Co. Ltd

3. Status of milkfish aquaculture in the Pacific Islands

Cook Islands

Policies
There is no specific policy on aquaculture of milkfish.

National status
A lot of requests are received about milkfish, particularly from outer islands where people ask about the possibility of rearing fry in natural pools or lakes for local consumption and, more recently, the prospect of supplying tuna longliners based in Cook Islands with bait. There has been a pilot project at Titikaveka on Rarotonga for milkfish and Pacific oyster polyculture. However, the milkfish fingerlings (25–50 mm size) had to be air-freighted from Northern Cook Islands at great expense, and during the trial they all died. Manihiki Island is one place where traditionally fingerlings have been stocked into natural pools to graze on benthic algae, and in this way up to 300 kg of fish per harvest could be produced, and used for special occasions. The price paid for milkfish locally is around NZD 7–10 kg^{-1}.

In the early 1990s, milkfish fry were collected in Manihiki and transported to Mitiaro with the assistance of the Food and Agriculture Organization of the United Nations and a UN Volunteer. Fry were stocked in mosquito net cages and fed with mashed pig pellet. Fish were stocked into the Mitiaro Lagoon and grew to 8–10 cm in size. One year later the large-sized fish were harvested by the Mitiaro community with high appreciation.

Advantages and constraints
Milkfish fingerlings are seasonally abundant in the Northern Cook Islands group, but are not known to occur in great numbers in the Southern Cook Islands. Conversely, the greatest demand for milkfish and the best scope for grow-out are in the Southern Cook Islands. It is a more popular fish for eating among locals than tilapia, the latter being consumed mainly by expatriate Filipinos and Fijians. Cook Islands tuna boats import between NZD 50,000–100,000 worth of tuna bait annually.

Future aspirations
It will be interesting to conduct surveys to find out if milkfish fry can also be harvested for pond stocking in the islands of the Southern Group such as Aitutaki.

Fiji

Policies

Fiji has a Freshwater Aquaculture Policy, and legislation to support aquaculture is in an advanced stage of preparation. There is no specific policy on milkfish aquaculture, however it is written into the MoFF Corporate Plan and government is supporting these activities.

National status

Fiji MoFF is supporting milkfish initiatives including the Pilot Project at Vitawa village, and intends to extend project outcomes to other districts. In the past, MoFF officers have conducted milkfish fry surveys, and under the Commodity Development Framework (CDF) programme a milkfish farm was constructed to supply the tuna bait market (and later closed due to on-site technical problems such as soil type and water pH).

Constraints and advantages

Wild fry are available and abundant for several months of the year. Coastal sites are available for pond construction. But skills and experience in capture and husbandry are lacking. Milkfish are a low value fish in Fiji.

Future aspirations

The future goal is to expand this activity up to a commercial level for food security and for livelihoods.

French Polynesia

Policies

There are no written plans in place to develop milkfish aquaculture, but a synthesis of milkfish research and development is in preparation, for which ministerial approval will be sought. There is no current milkfish farming activity. As a result of past research by the Fisheries Department, 4 years of data are available on milkfish fry collections in French Polynesia, and 3 years of data from trials on pond grow-out using chicken pellet as feed.

National status

Milkfish have no status at the moment, but are considered suitable for the far-flung isolated islands of the Tuamotu Group. Rangiroa and Niau atolls are potential sites for milkfish aquaculture. There are plans to conduct further fry collection survey in other atolls like Arutua and Aratika, using the channel collection method, and to revive old ponds on Rangiroa for a pilot grow-out trial.

Constraints and advantages

So far, there has been no review and analysis of earlier scientific results to establish the basis for moving forward from here. Travel to and within the Tuamotu Group is expensive. Milkfish are a popular fish for human consumption in the Tuamotu Group, though not in Tahiti where they are considered too bony unless served raw (for example, as *Salade Tahitienne).*

Future aspirations

Milkfish are a different and alternative marine finfish option to the batfish *Platax*. Milkfish are more hardy and lower in production cost (though also lower in value). The goal would be to culture the fish in a low-cost way for food security in isolated atolls.

Kiribati

Policies
Milkfish are a nationally important fish for human consumption, and the subject of government and bilateral donor collaboration in research and development.

National status
The Eco-farm near the airport has an extensive area of tidally flushed ponds (see Figure 23) for low-density culture of milkfish using fry and fingerlings captured in North Tarawa. Natural fry availability has been insufficient to keep the farm stocked at commercial levels, however. Recognizing this, 5 years ago Taiwan ROC joined the Department of Fisheries to set up a broodstock maturation and hatchery facility for milkfish near Parliament in South Tarawa (see Figure 24). Wild captured juveniles were reared in cement tanks and fed on locally made pellet feed for the last 5 years to grow them up to breeding size. These fish spawned for the first time in the tanks during 2012.

Figure 23. Milkfish grow-out ponds at the Eco Farm near Tarawa's airport

Figure 24. Milkfish broodstock ponds at the South Tarawa hatchery operated as a collaboration by Kiribati Fisheries and Taiwan ROC

Advantages and disadvantages
Milkfish fry can be captured in Gilberts Group lagoons but it is not so easy to get them in really big numbers for commercial culture. Successful maturation and spawning of milkfish were achieved on Tarawa during 2012, and a first batch of hatchery-reared juveniles has now been produced. A tuna bait market exists in Tarawa because foreign tuna longliners are based there and land fish there. Golden Ocean Ltd from Fiji has constructed a tuna loining plant which will produce fish waste (e.g. saw meat) suitable for use as a milkfish feed ingredient. Milkfish are a popular food item. Airline passengers departing overseas often purchase smoked milkfish from the Eco-farm to take with them as gifts for relatives living overseas.

Future aspirations
The goal is to scale up hatchery production of milkfish to fully utilize the Eco-farm ponds and grow-out fish both for food and for tuna bait.

Nauru

Policies
Milkfish are a nationally important fish in Nauru and there is a past practice of traditional culture of this fish.

National status
Milkfish are culturally important and are a 'must' for special functions like weddings. It is a traditional activity to culture milkfish in Nauru, in pools and in the Buada Lagoon where 32 families have rights to harvest. A typical backyard pool might be stocked with 400 fry of which 200 can survive to harvest size of 300–400 g. In recent years this practice has declined due to competition with feral tilapia and due to a decline in availability of milkfish fry or fingerlings in the wild for capture and stocking. In 2001 a Taiwanese project stocked three 10 × 30 m ponds and harvested 3500 fish of 700–900 g. Milkfish are imported, for example from Guam, and fetch AUD 10 kg^{-1} at a size of around 1 fish per kg.

Advantages and constraints
Milkfish are greatly appreciated by Nauruans and are traditionally an important fish species. There is a history of milkfish aquaculture in Nauru. Ponds and pools of about 10 × 30 m are available, filled by ground-water seepage with salinity that fluctuates from 10 ppt to 20 ppt depending upon rainfall. Continuation of milkfish farming nowadays depends on importing milkfish fry from Kiribati, however currently there are no direct flights available.

Future aspirations
Nauru Department of Fisheries intend to build and equip a nursery facility to obtain milkfish fry either locally for from overseas, then rear them to fingerling size and make them available to owners of ponds or water bodies suitable for grow-out.

Palau

Policies
Milkfish are listed as a priority commodity for aquaculture in the Palau's aquaculture policy document.

National status
Palau has three milkfish farms – the Ngatpang State Milkfish Farm (NSMF) (see Figure 25), the Shallum Etpison Palau Aquaculture (SEPA) (see Figure 26), and the Melwert Tmetuchel Airai Fish Farm (MTAFF) – importing fry from hatcheries in Taiwan or the Philippines for grow-out to supply both fresh fish to the public and bait fish for the tuna long-line fishery. Three finfish hatcheries – the Palau Mariculture Demonstration Center (PMDC), the Palau Community College's Cooperative Research and Extension (PCC/CRE), and the Ngaraberas Association Rabbitfish Hatchery (NARH) – have been established for other fish species, and now plan to play a role in supporting the milkfish industry. Milkfish are increasing in popularity as a food fish, especially for special occasions like weddings.

The SEPA farm has a 1000 m^2 pond for growing milkfish fry brought in from the Philippines to fingerling size then transferred to sea cages for grow-out. In 2009 SEPA was producing 1350 kg per month, and the fish were sold for USD $4 per kg for whole fish and USD $7.77 per kg for boned fish. The company intends to start a hatchery, so are rearing some fish up to breeding size in a cage, which will take 5–7 years. Palau Community College already holds broodstock fish that are now about 5 years old.

Figure 25. Ngatpang State Farm

Figure 26. SEPA Farm

Constraints and advantages

All fry are currently imported from Taiwan, and feed is also imported. Local markets are available and there is unmet demand for two product forms: (i) food, and (ii) bait. Milkfish hatcheries will come on stream during 2012. Fry do appear to be available in coastal waters but their potential for collection and on-growing has not been assessed. Palau has little land area available for grow-out ponds, so the practice is to nurse them to a size where they can be transferred for grow-out in sea cages. Peleliu does have pools cut off from the sea by construction of a Japanese road. Palau has established infrastructure and experience for milkfish grow-out, but attracting farm staff is difficult because aquaculture is not a popular career choice for young Palauans.

Future aspirations

To lower production costs and improve margins by establishing a local source of fry; the milkfish aquaculture industry in Palau is expanding and seems to have a good future.

Papua New Guinea

Policies

PNG has a National Aquaculture Development Policy but no specific policies on milkfish aquaculture.

National status

There is some small-scale milkfish farming activity, for example a natural inlet is being stocked with wild-captured fry in Central Province near Port Moresby. A survey of fry availability in other parts of Central Province is planned. It is a popular fish for eating, and there is a high-value market with Asians in Port Moresby. Kavieng, Morobe and Trobriand Islands are other places with potential.

Constraints and advantages

There are good local markets for milkfish in PNG. Lae supermarkets sell milkfish imported from Philippines for PGK 15.00 per kg. However there is little local knowledge and experience of fry collection places and times, or pond grow-out techniques.

Future aspirations

Many coastal people will be interested in the possibility of capturing and growing milkfish for their own consumption, and for livelihood opportunities by selling it in Port Moresby where there is a general scarcity of fresh fish.

Solomon Islands

Policies
Solomon Island aquaculture policy documents identify milkfish as an indigenous fish species worthy of investigation as an alternative to tilapia which is an introduced species.

National status
Milkfish are eaten and appreciated in Solomon Islands, where there is a general scarcity of fish in peri-urban areas. Milkfish are a high-status fish in some areas, for example in Kia and other parts of Isabel province. Milkfish fry collection and grow-out in ponds are currently being evaluated as part of an Australian Centre for International Agricultural Research funded Inland Aquaculture project being implemented by the Ministry of Fisheries and Marine Resources, Worldfish, and SPC. Dai Island and Arnavon Islands are areas reputed to be hotspots of milkfish recruitment.

Advantages and constraints
Milkfish are in demand by local people. There are anecdotal reports about natural recruitment that could be sufficient for capture-based culture, and options to do this are now being evaluated. The main constraint is that milkfish aquaculture in Solomon Islands is at a trial evaluation phase. Not enough knowledge or experience is yet available about milkfish in Solomon Islands to justify construction of farms.

Future aspirations
The goal is first to complete the evaluation of potential for capture-based culture of milkfish in Solomon Islands, and then make a decision about whether it is worthwhile to scale up this activity.

Tonga

Policies
There is a general aquaculture development policy document, but no policies specifically about milkfish aquaculture.

National status
There is currently no farming activity, but the potential for fry collection has been remarked upon. A milkfish research and development project funded by FAO is about to start in Tonga. A natural lake in Namuka Island has been surveyed by an FAO consultant and found suitable for milkfish grow-out. A hatchery facility exists on Tongatapu and could be used to breed milkfish if necessary.

Constraints and advantages
Tonga lacks infrastructure for culture systems like ponds or cages. There is no knowledge as yet about fry availability or seasonality. Because milkfish are a popular fish for eating, local demand exists. One advantage is that milkfish aquaculture is a development activity about which there do not appear to be any environmental concerns.

Future aspirations
Tonga's aspirations are to get some milkfish aquaculture underway as a pilot project to learn the techniques and to provide food security for participating communities. Any commercial market for milkfish in Tonga can be developed later on.

Tuvalu

Policies
Tuvalu has identified milkfish as a priority commodity for development of aquaculture.

National status
Taiwan is supporting a capture-based culture project on Funafuti atoll in a cement tank system (three tanks of 2.5 × 2.5 m and one tank of 12 × 4 m), using local feed ingredients (banana, coconut, breadfruit) mixed with imported fish meal to make a supplementary feed. Cage culture in Funafuti lagoon did not produce very good results, but a community trial of cage culture on Vaitupu atoll has produced 700 pieces of 900 g size and 30 cm length from one cage in 9 months. Cement tank culture on Funafuti can produce 25–30 cm fish in 10 months. Fry are captured near mangrove using dozer net. The price of milkfish in Funafuti is AUD 5.00 kg^{-1}.

Advantages and constraints
Milkfish fry are available, particularly near mangroves, but meeting targets for fry stocking into nursery tanks for cage grow-out is difficult. Feed formulated from local ingredients has proven more expensive than imported pellet feed, once the cost of labour to gather and prepare feed ingredients is taken into account.

Future aspirations
The goal is to complete the pilot projects on milkfish aquaculture in Funafuti and Vaitapu, and evaluate them for scale-up potential. Consideration will be given to rearing fish up to broodstock size (5 years) and spawning them, if capture of wild fry proves to be insufficient.

Vanuatu

Policies
Milkfish farming development is a medium ranked priority for Vanuatu.

National status
There is no farming activity on milkfish at the moment, and no current plans to carry out any research and development. There is a history of collecting seasonal shoals of fingerlings and small juveniles for food in some places, such as Tanna Island.

Advantages and constraints
There is a market for milkfish for domestic consumption, and a possible market for use as tuna bait for the vessels based in Vanuatu. Because reef fish are now very expensive, on Efate Island lower-income households will appreciate any increase in availability of milkfish. For example, the price of tilapia 4 or 5 years ago was VT 450 kg^{-1} but has now risen to VT 600–750.

Future aspirations
There are no immediate plans to develop milkfish aquaculture, because there is no knowledge available on fry or fingerling collection sites or their seasonality of abundance in Vanuatu.

4. Practical sessions

4.1. Bulldozer net or 'fry-dozer' frame construction

Figure 27. Cutting a slot for an end peg in the bamboo beam.

Figure 28. Lashing an end peg to the main beams.

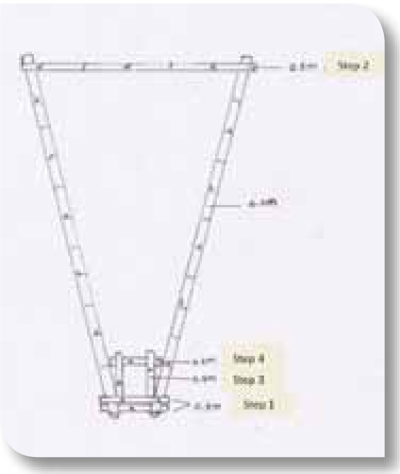

Figure 29. Layout and dimensions of the bamboo frame for the bulldozer net.

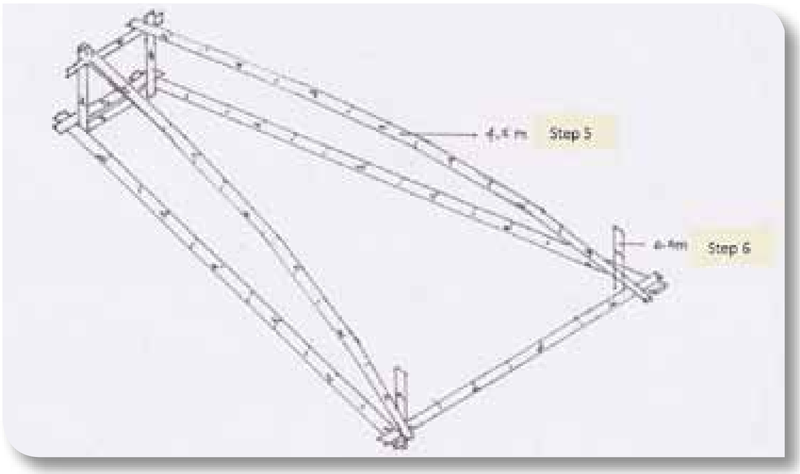

Figure 30. The completed frame for the bulldozer net.

Figure 31. Detail of the end pegs and their lashings.

Figure 32. An alternative style of construction, using 100% bamboo (no timber). Strips of car tyre inner-tube instead of rope for lashing enables much faster assembly and disassembly for carrying the bulldozer net to different sites in a vehicle or boat.

4.2. Bulldozer net mesh construction

Figure 33. The special needle and thread used for sewing the mesh of the bulldozer net.

Figure 34. Laying out the mesh material ready for cutting to shape.

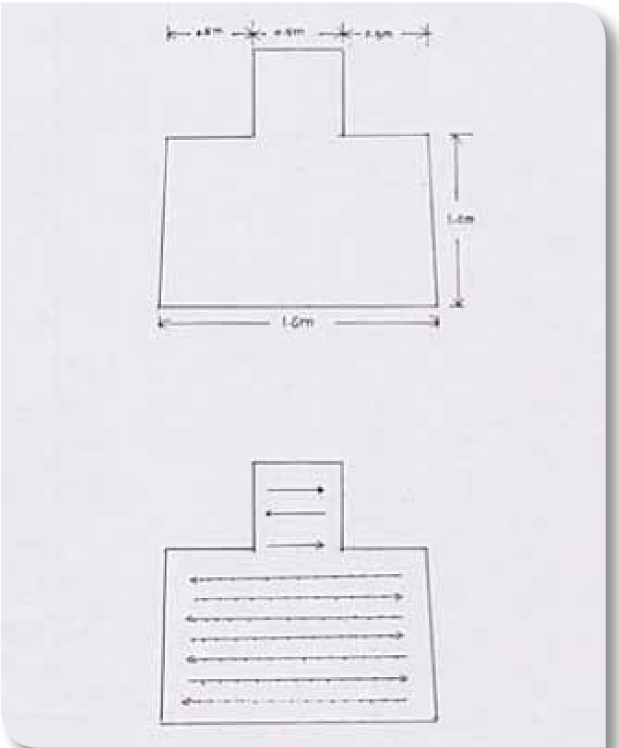

Figure 35. Pattern and dimensions of mesh to be cut out for the cod-end of the bulldozer net.

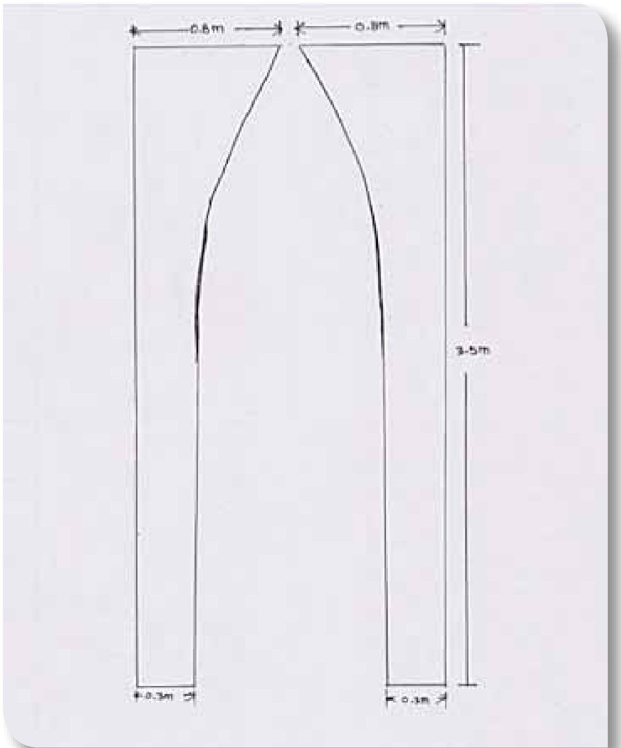

Figure 36. Pattern and dimensions of mesh to be cut out for the wings of the bulldozer net.

Figure 37. Measuring out the shape and dimensions of the cod-end.

Figure 38. Cutting out the mesh for the bulldozer net's cod-end.

Figure 39. Re-inforcing the double-layer cod-end with additional seams. The double layer of mesh reduces the pressure of water current forcing fry up against the net, thus reducing injury and mortality.

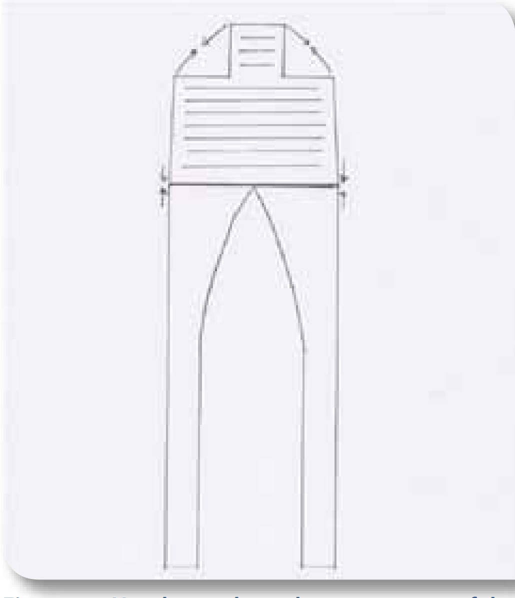

Figure 40. Hand-sew along the two corners of the cod-end's rear edge to make it into a box shape. Sew the two wings of mesh onto the front edge of the cod-end, as shown here.

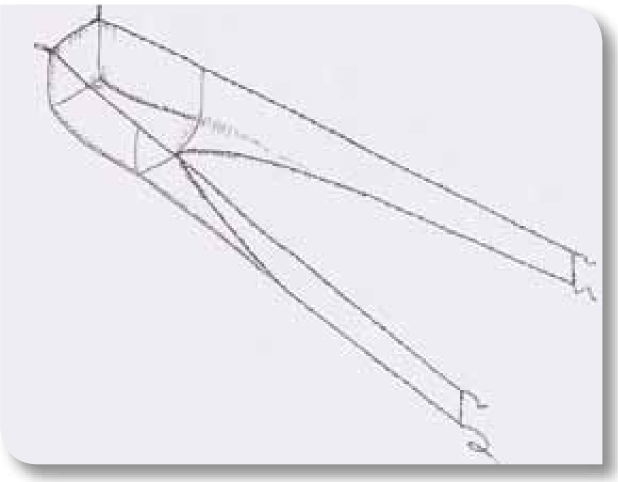

Figure 41. Diagrammatic overview of the completed net

Figure 42. Making the wings of the net, with rope edging added to string the net to the frame.

Figure 43. Adding rope edging for stringing the net onto the bamboo frame.

Figure 44. Completed net, with wings added to the cod-end bag.

4.3. Bulldozer net deployment

Figure 45. Stringing the net to the bamboo frame.

Figure 46. Lashing the wings to the frame at the front end of the net.

Figure 47. Lashing the cod-end to the rear of the bamboo frame.

Figure 48. The bulldozer net ready for deployment.

Figure 49. The bulldozer net in operation, being pushed slowly along a sandy beach on a rising tide.

Figure 50. Stop every 20–50 m or so to check the cod-end for milkfish fry, and remove debris.

Figure 51. Keep the captured fry in a basin, but transfer them as soon as possible to a large container with aeration for transport to the milkfish farm.

Figure 52. Milkfish fry have two dark spots for the eyes, followed by a middle spot for the air bladder, and can often show a fainter grey spot for the caudal fin. Recognition is based upon seeing these three dark spots; two spots close together at one end, one spot in the middle, and a lesser spot at the other end, combined with a characteristic darting swimming motion, and a strong tendency to swim into the current when water is swirled in the basin. Size will be in the range of 10 to 17mm long.

4.4. Seine net deployment

Figure 53. Push net being used to catch fingerlings in tidal pools of mangrove areas at low tide.

Figure 54. Milkfish fingerling caught by push net method.

Figure 55. Tidal pools in mangrove area, where milkfish fingerlings accumulate at low tide.

Figure 56. A fine-mesh seine net with cod-end bag sewn into the centre of the net.

Figure 57. A fine-mesh seine net being used to capture milkfish fingerlings in a shallow pool at low tide.

Figure 58.Use a basin to carefully transfer fingerlings into a bucket. The milkfish need to be kept swimming in water at all times. Bringing them out of water to touch the net or your fingers will cause scale damage or other injury that will lead to mortality.

Figure 59. A coarse mesh seine net, suitable for catching larger sizes of fingerlings in deeper pools.

Figure 60. A catch of fingerlings in the seine net.

Figure 61. Fingerlings being carefully removed to a bucket of water aerated by a battery-powered portable aerator.

Figure 62. Fingerlings of milkfish ready for transfer to a bucket of water.

4.5. Acclimation and transport of fingerlings

Figure 63. Clean seawater from the capture pool is used to fill a tub, to hold the catch each time that the net is emptied of fish.

Figure 64. The seawater in the fish-holding tub should be measured for salinity, because different pools may have different salinity and yet the fish from these pools will later need acclimation to the seawater in a single big transportation tank.

Figure 65. Using a hydrometer type of salinity tester.

Figure 66. Fingerlings in the tub may need to be acclimated by slow mixing with water from the transportation tank.

Figure 67. During transportation, the water in the tank needs to be kept aerated with bubbles from air stones.

Figure 68. Installing air stones on plastic hose into the transportation tank.

Figure 69. A 12 V portable aerator can be used to provide air bubbles, by connecting it to the vehicle's battery.

Figure 70. Milkfish fingerlings inside the transportation tank.

Figure 71. A tank containing 9000 fish, ready to be delivered to the milkfish farm.

4.6. Sorting and counting fingerlings

Figure 72. At the farm in a shady spot, fingerlings can be scooped out of the transportation tank using a soft-mesh dip net and held for sorting and counting in a plastic tub with aeration provided by an air stone and battery-powered aerator.

Figure 73. Milkfish fingerlings in the tub ready for sorting.

Figure 74. A close-up of live milkfish fingerlings.

Figure 75. A milkfish fingerling, characterized by forked tail, single dorsal fin, and small mouth.

Figure 76. Predatory fish that can easily be confused with milkfish (at bottom of photo) during sorting include the tarpon *Megalops cyprinoides* (middle) and ten-pounder *Elops machnata* (above), which can be distinguished by their different body shape and especially by their larger mouth gape.

Figure 77. Larger size and darker colour is another way to recognize a ten-pounder among milkfish fingerlings during sorting.

Figure 78. During transport from the catching site to the farm, a milkfish fingerling had already been swallowed whole by this ten-pounder.

Figure 79. After milkfish fingerlings have been sorted from other pest species and counted, they can be acclimated to pond water and then transferred to a nursery hapa net.

Figure 80. Let live fish swim out of the bucket into the hapa, leaving dead ones behind in the bucket. If dead fish are left inside the hapa, then crabs in the pond will want to chew through the net to get at them.

4.7. Pond design and layout

Figure 81. This site of back-mangrove salt pan has been identified as suitable for development into a milkfish farm. A natural channel brings tidal flushing with seawater.

Figure 82. First, check the water level in the supply channel at high tide, and again at low tide. This will determine the depth of excavation to construct ponds that can be filled without pumping, but can also be drained out dry.

Figure 83. Measure out the site, to enable decisions to be made about the size and location of ponds, dykes and drainage channels.

Figure 84. To find out if the pond bottom soil can hold water without leaking, dig a hole to obtain some soil and form it into a ball.

Figure 85. Drop the ball to the ground from head height. If it shatters or crumbles, the soil is too sandy to be water tight. If it stays together, as shown, the clay content is sufficient to stop water leaking out.

Figure 86. Another leak test can be performed by digging a hole down to where the bottom will be. Fill the hole with some water and mark its level. If the water drains out within a couple of hours, then the soil is too sandy.

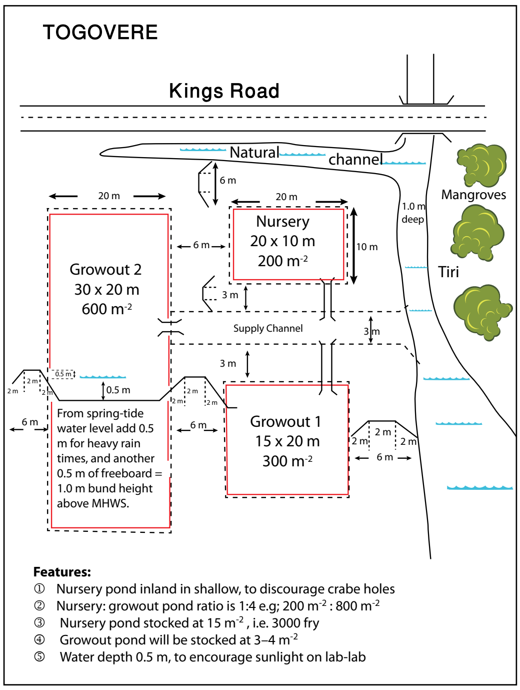

Figure 87. Based upon the on-site measurements, make a site plan for the ponds to guide the digger operator. Allow sufficient space between each pond for the dyke walls, and for drainage channels, according to the dimensions shown here.

4.8. Nursery pond preparation

Figure 88. A nursery pond of size suitable for growing fingerlings up to juvenile stage.

Figure 89. The pond must be drained out completely by digging channels, to eliminate pest fish and to make liming more effective.

Figure 90. In acidic soil types, the pond should be limed with approximately 100 $g.m^{-2}$ of agricultural lime to raise the pH to one more favourable for phytoplankton and fish growth.

Figure 91. Once limed, the pond is next fertilized with 200 $g.m^{-2}$ of chicken manure, and then left to stand for a few days so that the lime can interact with the pond bottom sediment.

Figure 92. After water has been filled and a plankton bloom has started to form, the pond can be stocked with fingerlings.

4.9. Pond water quality

Figure 93. How to make a secchi disk for measuring the pond's plankton bloom.

Figure 94. Measuring pond water salinity using a refractometer.

Figure 95. The secchi disk in use, measuring the concentration of phytoplankton in the water.

Figure 96. This is a nice healthy colour for pond water, and is the result of the plankton bloom being maintained in the 'exponential' phase of growth (see Figure 18) by careful management of water replenishment and fertilization with manure.

4.10. Moving fish between ponds

Figure 97. To move fish into bigger ponds with more natural food as they grow larger, they can be made to swim by themselves. Here, 3000 fish of 200 g size need to be moved from Grow-out Pond 2 to Grow-out Pond 3. Netting them out of GP2 will cause stress and mortality.

Figure 98. Milkfish have a natural tendency to swim into the current. During high tide, let GP3 fill up as much as possible. During low tide, let GP2 drain down low. At night, open the sluice gates of GP2 and 3 and close the gate to the main channel, so that water flows out of GP3 into GP2.

Figure 99. With water flowing from GP3 back into GP2 via the central channel, milkfish will move by themselves out of GP2 and swim up-current into GP3 without stress or damage.

Figure 100. The same technique can be used to move fish out of ponds and into the end of the drainage channel, where it is much easier to seine them by net once they are concentrated into a group.

Figure 101. Milkfish harvested from the farm.

Figure 102. Farming milkfish is very satisfying.

4.11. De-boning and smoking of milkfish

Figure 103. A wood-fired fish smoker.

Figure 105. Tools needed for the milkfish de-boning process. Milkfish are a bony fish, but there is a quick procedure for removing bones before smoking.

Figure 104. The work area, ready for preparing fish for the smoker.

Figure 106. Ready to start preparation of milkfish for smoking.

Figure 107. Remove scales from the outside of the fish.

Figure 108. Cut the fish to open it out into a 'butterfly'.

Figure 109. Remove the fish guts.

Figure 110. Slice away the biggest of the intra-muscular bones with a sharp knife.

Figure 111. The fine bones can be pulled out using strong tweezers.

Figure 112. A butterflied and de-boned milkfish, ready for salting.

Figure 113. Milkfish are soaked in a brine bath, at about 45 g of sea-salt per litre.

Figure 114. The fish are removed after 30 minutes, blotted with a paper towel to remove excess brine solution, and left to dry off.

Figure 115. The fish have been placed on a rack after brining, to drain dry again.

Fiigure 116. The fish are now ready for smoking.

Figure 117. Milkfish being loaded into the fish smoker.

Figure 118. These fish, being somewhat small, were left in the smoker for 4 hours. Larger fish can be smoked for longer. The target temperature is 60°C.

Figure 119. When smoking is complete, the trays are removed and the fish are allowed a period of time to cool down.

Figure 120. Smoked and cooled milkfish, ready for packing.

Figure 121. A vacuum-packing heat sealer machine.

Figure 122. Using the vacuum packer to suck air out of the plastic bag containing the smoked milkfish, then to seal the bag to make it airtight and prevent entry of bacteria.

Figure 123. A milkfish vacuum-sealed into a plastic bag.

Figure 124. Commercially available smoked milkfish grown and packed in the Phillipines.

4.12. Harvest and icing of fresh chilled milkfish

Figure 125. Fish harvested by seine net (see Figure 86) can be collected up in a plastic laundry basket.

Figure 126. As soon as possible, the fish should be washed in clean water to remove any mud.

Figure 127. Weigh the fish, but also count them, to calculate the average body weight (ABW) of the harvest.

Figure 128. As soon as possible, pack the fish in ice to chill them and preserve freshness.

Figure 129. The correct way to arrange the milkfish in the ice-box to maintain their shape and attractive appearance.

Figure 130. Selling milkfish fresh, direct from the farm. Keep records of your harvest in weight (kg) sold and price per kg, so that you can budget your funds to start a new pond cycle of milkfish grow-out.

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