The feasibility of milkfish (*Chanos chanos*) aquaculture in Solomon Islands

WorldFish

THE FEASIBILITY OF MILKFISH (*CHANOS CHANOS*) AQUACULTURE IN SOLOMON ISLANDS

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EXECUTIVE SUMMARY

Context

Fish is crucial to food and nutrition security in Solomon Islands, and demand is expected to increase due to a growing population. However, it is projected that current capture fisheries production will not meet this growing demand. Aquaculture has the potential to mitigate the capture fishery shortfall, and the Government of Solomon Islands is prioritizing aquaculture as a solution to meet future food and income needs.

Aquaculture in Solomon Islands is still in early development. Mozambique tilapia (*Oreochromis mossambicus*) is farmed for household consumption, but its prolific reproductive rate and resulting slow growth limit its potential as a commercial aquaculture species. More productive fish species that are not indigenous to Solomon Islands but are successfully farmed overseas could be introduced; however, such a decision needs to take into account the potential ecological or social impacts. For land-based pond aquaculture, the only indigenous species that has been farmed extensively elsewhere is milkfish *(Chanos chanos)*.

Although farming milkfish was never traditionally practiced in Solomon Islands, wild-caught milkfish is a culturally important and favored fish species in some Solomon Islands communities (Shortland Islands and Vella la Vella in Western Province, Kia in Isabel Province, North Malaita in Malaita Province, and Tikopia in Temotu Province). A number of locations are locally well known as places where adult and juvenile milkfish can be found. There are many suitable habitats for milkfish in Solomon Islands, ranging from open seas, coral reefs and estuaries to small, partially enclosed water bodies and mangrove areas. Milkfish are caught by local fishers and sold at urban markets. This familiarity with milkfish has led to ongoing local interest in the aquaculture of milkfish, as evidenced by it being ranked one of the species worth consideration in the National Aquaculture Development Plan (2009–2014).

This report addresses that interest by presenting a feasibility assessment for milkfish farming in Solomon Islands. It synthesizes the current knowledge about milkfish farming and presents results of a 4-year study on the potential for milkfish aquaculture in Solomon Islands. The report includes the following:

- a review of existing knowledge about milkfish in Solomon Islands and the Asia-Pacific region
- analysis of how milkfish seed (juveniles for stocking ponds) could be supplied in Solomon Islands
- a government capacity and hatchery evaluation
- a market analysis
- requirements for adapting milkfish aquaculture technologies for Solomon Islands' conditions, including identifying locally available on-farm and off-farm fertilizer and feed ingredients
- an economic feasibility assessment.

Study findings

This study finds that milkfish farming is technically feasible in Solomon Islands. Milkfish fry are available in some coastal areas of Solomon Islands at certain times of the year, and they can be reared to a harvestable size using locally available resources and technologies. Milkfish can be grown in a range of salinities, from freshwater to seawater. Further, formulated feed can be produced locally, and this local feed can perform as well as imported feed.

However, customary ownership laws governing coastal marine waters pose a potential barrier. All of the sites where milkfish fry occur are on land and seabed that is under customary ownership, meaning the resources (including milkfish fry) belong to someone who has the rights to control their capture and distribution. Considerable negotiation would be required to enable fry collection and distribution within and between provinces. Equally, supply of milkfish fry provides resource owners with a viable business opportunity should milkfish aquaculture develop in Solomon Islands.

Elsewhere in the world the alternative to wild-caught fry is hatchery production of fry. The National Aquaculture Development Plan (2009–2014) states, *"Given the current state of development of aquaculture in Solomon Islands, construction of an additional marine hatchery to support development of the priority commodities is not presently envisaged. Marine hatcheries are expensive to run, are labor intensive and require skilled staff. Elsewhere in the Pacific, government-operated facilities have struggled to provide a return on investment. [The Ministry of Fisheries and Marine Resources] would support private-sector development of small-scale hatcheries"* (MFMR 2009, 43). Accordingly, this study looked only at wild-caught fry.

Economic feasibility

Benefit-cost modeling showed that low-input, subsistence-level milkfish farming, where a proportion of the fish are sold at farm gate, could be economically viable if labor costs are assumed to be zero, the farm is situated close to a natural fry resource, and a dollar value is attributed to the fish eaten by the household. The annual risk of breaking even or making a loss from various commercial milkfish aquaculture scenarios ranged from 28% to 73% with payback periods of at least 3 years, small-scale commercial aquaculture being the least profitable. Payback periods and risks are reduced as the size of the farm increases and economies of scale are sufficient to make operations marginally profitable in the longer term but risky on a yearly basis. Generally, milkfish has a low consumer preference in Solomon Islands, as only a few ethnic groups know and prefer it.

The costs of commercially farming milkfish would be high given the high costs of materials and labor in Solomon Islands. Furthermore, wild-caught fish is currently still able to meet demand; hence the highest possible sale price of milkfish is capped by the price of wild-caught marine fish, with which it competes on the market (it is acknowledged that this may change in a situation where wild-caught fish is not able to meet demand anymore). The high business risks of commercial milkfish farming in Solomon Islands are consistent with observations of milkfish farming in other Pacific Island countries where net losses have been reported. The study found a 73%, 54% and 28% likelihood of making zero profit or a loss in any one year for small, medium and large-scale milkfish aquaculture respectively. Production of milkfish as bait for the tuna fishing industry may be more profitable (FitzGerald 2004), but this option needs to be closely studied (including benefit-cost analysis) and would not directly address the country's fish supply deficit, especially in inland communities.

Despite its low productivity and small maturation size, several characteristics make Mozambique tilapia a more suitable species for subsistence or small-scale aquaculture in Solomon Islands when compared to milkfish. The species breeds readily in freshwater ponds, so fry collection costs that would normally be incurred under milkfish farming, such as the cost of collection equipment, are avoided. Further, because tilapia breeds in freshwater, continuous partial harvests can be done throughout the year. The 4-month production cycle of tilapia is much shorter, so at least three crops per year are achievable, compared to milkfish with a single crop per year (8–9 months production cycle). However, this economic feasibility is only at the small-scale aquaculture level. The strain of Mozambique tilapia present in Solomon Islands would not be suitable for medium- or large-scale commercial aquaculture due to its low productivity and associated high risk of commercial loss in any one year.

Given the finding that milkfish is only suitable for subsistence farming in Solomon Islands (albeit marginally), the authors suggest introducing a more productive strain or species of fish that can meet current household nutrition and income needs in inland areas, as well as future food fish shortfalls across the whole country. The risks of a new fish species or strain, including disease and pest risks, should be fully considered before any such decision.

The nonviability of commercial milkfish aquaculture is concerning. Currently, the high cost of production and competition from capture fisheries (and fish imports) limits its sale price and therefore the profitability of not only milkfish, but perhaps any fish species farmed in Solomon Islands. From a broader national aquaculture development perspective, it is imperative that any species being considered by the government or private sector for aquaculture be thoroughly analyzed for its economics.

The food security benefits of Mozambique tilapia farming at a subsistence level are reflected in the preliminary modeling in this study and uptake of household farming in Malaita and other parts of Solomon Islands. Clearly, any technology improvements in this sector would help improve access to fish, especially in inland parts of the country.

The majority of those who participated in this work were Solomon Islanders, so skills have been acquired and expertise is locally available to do milkfish aquaculture. Milkfish husbandry techniques are simple and can be transferred to other interested farmers. These same skills and familiarity with fish husbandry will be important to the development of aquaculture in Solomon Islands more generally, regardless of the species.

Recommendations

The authors recommend the following:

- Given the unfavorable results of this study's preliminary economic analysis, milkfish aquaculture should not be promoted in Solomon Islands, unless there are contrary findings based on a more thorough economic analysis.
- The Government of Solomon Islands should consider how to develop an alternate aquaculture species, either native to Solomon Islands or introduced.
- Any decision to introduce an aquaculture species or strain new to Solomon Islands should be based on thorough risk analysis, including risks associated with the invasiveness of the species itself and any significant diseases that the fish could have. Any possible new aquaculture species must be evaluated for its economic impacts.
- A broad-based review of the economic feasibility of aquaculture in Pacific Island countries, including detailed economic modeling of a range of country-specific scenarios, should be considered to inform the setting of national and regional policy directions and aid private sector decision-making.

INTRODUCTION

Fish is an important animal source for food and nutrition security in Solomon Islands. Fish consumption is 45.5 kilograms (kg) per person per year in urban areas and 31.2 kg in rural areas (Bell et al. 2009). Fish is important for income generation, contributing an estimated USD 2.8 million annually to local fishers and traders (Brewer 2011). The country is heavily reliant on coastal fisheries for animal-source food; however, as is generally the case for most Melanesian countries, fish are not always available in inland areas (Ahmed et al. 2011).

Demand for fish is projected to increase in Solomon Islands due to a growing population; however, current capture fisheries production levels will not be able to meet this growing demand. The resulting supply-demand gap will be exacerbated by stressors such as destructive fishing practices and climate change affecting inshore coastal ecosystems (Bell et al. 2009; Weeratunge et al. 2011). Aquaculture can mitigate capture fishery shortfalls in Solomon Islands (Bell et al. 2009; Ahmed et al. 2011), and the Government of Solomon Islands is prioritizing it to help meet future food and income needs, especially in areas where access to coastal fisheries is limited and there is no local access to tuna fisheries (MFMR 2009). However, aquaculture in Solomon Islands is in early development and species amenable for simple and broad community-based aquaculture are generally lacking (MFMR 2009). Wild-caught Mozambique tilapia (*Oreochromis mossambicus*), introduced by the British colonial government in the 1950s (Pickering 2009), is an important food source in parts of Guadalcanal, Malaita and Rennell and is the only fish species farmed for household consumption in Solomon Islands (Cleasby et al. 2014). However, the characteristic early onset of sexual maturity, prolific reproductive rate and slow growth of Mozambique tilapia limit its potential as an aquaculture species (Pickering 2009), and it is only recommended for subsistence reasons (Harohau et al. submitted). More productive fish species that are commonly farmed overseas could potentially be introduced to Solomon Islands; however, this would require assessing the environmental and ecological risks (Pickering 2009). The only indigenous species extensively farmed for business in freshwater ponds elsewhere is milkfish (*Chanos chanos*), although mullet does show some future promise (Table 1; Schwarz et al. 2011).

Milkfish is widely cultured for food and to supply the longline fishery bait market, with the main producer countries located in Asia (Nelson and Marygrace 2010). Milkfish is an important food fish from capture fisheries across the Pacific, but efforts to culture milkfish in the South Pacific have had little commercial success (Tanaka et al. 1990; FitzGerald 2004).

Production of milkfish as fishing bait in the Solomon Islands may be commercially viable (FitzGerald 2004), although this would not directly address the country's fish supply deficit, especially in inland communities. Solomon Islands does support a commercial pole and line fishery for tuna that could potentially use locally produced milkfish for bait. However, before any significant investment is made, the economic feasibility needs to be analyzed, including the magnitude and seasonality of demand and the cost of production, distribution and marketing.

This report presents a synthesis of the current knowledge about milkfish farming and the results of a 4-year study on the potential for milkfish aquaculture in Solomon Islands, funded by the Australian Centre for International Agricultural Research (ACIAR). The study was conducted by WorldFish, ACIAR-sponsored Solomon Islands Master of Science candidates from the University of the South Pacific, the Aquaculture Section of the Solomon Islands Ministry of Fisheries and Marine Resources (MFMR), and the Aquaculture Section of the Fisheries and Marine Ecosystems Division of the Secretariat of the Pacific Community. Specialist expertise was provided by two consultants: Mr. John Eric Basco, a milkfish aquaculture expert from the Philippines, provided advice and training on milkfish aquaculture techniques; and Mr. Bill Johnston, an Agricultural Economist from the Department of Agriculture, Fisheries and Forestry, Queensland, Australia, provided expertise and training in conducting cost-benefit analyses.

Species name	Common name	Comments
Lutjanus fuscescens	Freshwater snapper	No aquaculture experience anywhere. Inhabits freshwater and brackish water. Most snappers require a high-protein diet. It is unlikely to be a candidate for food security-oriented aquaculture.
Lutjanus argentimaculatus	Mangrove red snapper	Some hatchery and grow-out technologies available, but feeding habitats and requirement for fish protein make this an unsuitable candidate for food security-oriented aquaculture.
Mesopristes cancellatus	Tapiroid grunter	No Fishbase[1] aquaculture records. Fishbase reports predatory habits, again suggesting unsuitability.
Mesopristes argenteus	Silver grunter	No Fishbase aquaculture records. Fishbase reports predatory habits, again suggesting unsuitability.
Epinephelus cf polystigma	White dotted grouper	Fishbase reports human use in subsistence fisheries, but no aquaculture experience. Feeding habitats and requirement for fish protein make this an unsuitable candidate for food security-oriented aquaculture.
Kuhlia marginata	Dark-margined flagtail	Human food uses, but no known aquaculture use. Insufficient information to assess suitability for aquaculture.
Kuhlia rupestris	Rock flagtail	Human food uses, but no known aquaculture use. Omnivorous. Insufficient information to assess.
Anguilla marmorata	Giant mottled eel	Breeds at sea, and like most eels likely to be difficult to breed. Fishbase reports some aquaculture. Carnivorous feeding habits make this an unsuitable candidate for food security-oriented aquaculture.
Siganus spp.	Rabbit fish	Potentially suitable (marine fish), but trials to date in Solomon Islands have proved unsuccessful. Market uncertain.
Mugil cephalus	Mullet	Farmed widely in extensive ponds, although breeding technologies not well established. Feeds low in food chain (benthos, algae).
Chanos chanos	Milkfish	Widely cultured fish, feeding low in food chain. Important food fish across the Pacific.

Table 1. Preliminary analysis of the suitability of native Solomon Islands species for culture (from David Boseto, unpublished data, presented in Schwarz et al. 2011).

The report includes (i) a review of existing knowledge about milkfish in Solomon Islands and the Asia-Pacific region; (ii) an analysis of how milkfish seed (juveniles for stocking ponds) could be supplied in Solomon Islands; (iii) a government capacity and hatchery evaluation; (iv) a market analysis; (v) requirements for adapting milkfish aquaculture technologies for Solomon Islands' conditions, including identifying locally available on-farm and off-farm fertilizer and feed ingredients; and (iv) an economic feasibility assessment.

The feasibility assessment generally followed the structure presented in Figure 1 (FitzGerald 2004). The study addressed all elements above the dotted line, and the report describes the locally relevant inputs for each box. The inputs to and the outcomes of the feasibility assessment are presented, and the report concludes with recommendations for future steps for the Solomon Islands aquaculture industry.

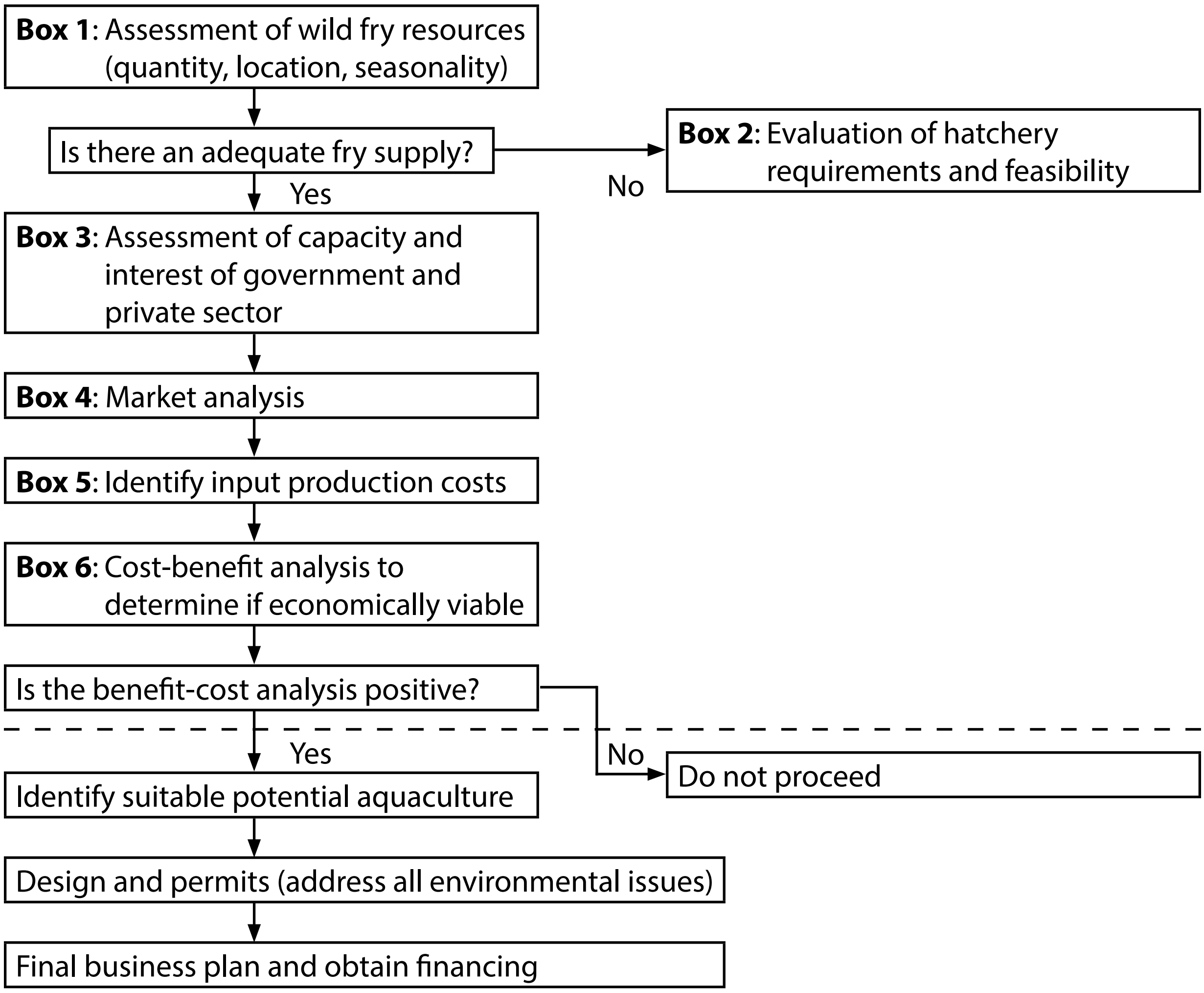


Figure 1. Structure of a feasibility assessment for milkfish aquaculture (FitzGerald 2004).

Milkfish aquaculture in Asia and the Pacific Islands

Milkfish has been cultured in the Philippines, Indonesia and Taiwan for hundreds of years. Production has been steadily increasing since the 1950s (Figure 2), and milkfish continues to be an important aquaculture species, with large investments made since the 1970s by some private investors, aid donors and governments (Nelson and Marygrace 2010).

Rudimentary farming of milkfish in Nauru is documented since the early 1900s with reports of people culturing wild-caught milkfish fry in inland ponds and lakes (Spennemann 2003). Modern aquaculture of milkfish in the Pacific Islands currently occurs in Kiribati (government-funded development project), Fiji (community-based farming) and Palau (a private commercial enterprise), with early development in Tonga and Tuvalu and interest being shown in Solomon Islands.

The following characteristics make milkfish a suitable aquaculture species (Yap et al. 2007) for Solomon Islands:

- euryhaline, so can be farmed in freshwater, brackish water or seawater;
- eurythermal, so can survive water temperatures of 10–40 °C, with an optimum temperature range of 25–30 °C;
- low on the food chain, so can eat microalgae and any other food it is given;
- not piscivorous, so can be polycultured with other fish species and crustaceans;
- not known to be prone to significant diseases;
- fast growing under favorable conditions;
- highly fecund and have longevity in captivity, enabling continuous hatchery production of fry;
- farmed in countries like the Philippines using culture technology that can be easily adapted to Solomon Islands;
- acceptable as a preferred food fish species in several Solomon Islands communities;
- exported by other countries, such as the Philippines, which exports deboned, smoked milkfish products to the United States and European Union.

Milkfish biology and distribution

Milkfish can tolerate a wide range of salinities (0–40 parts per thousand [ppt]) and temperatures (10–40 °C). However, the species only spawns in fully saline waters (35–40 ppt) either in the open sea or near coral reefs (Bagarinao 1991). After fertilization and development, the larval stages begin moving to inshore habitats (mangroves, estuarine areas, inshore coastal areas, etc.), where they can be caught for culture purposes as fry (Bagarinao 1991). Milkfish recruit back into the open sea or coral reefs at the juvenile stage, or they move up rivers as they grow and return to the open sea for spawning when they reach maturity.

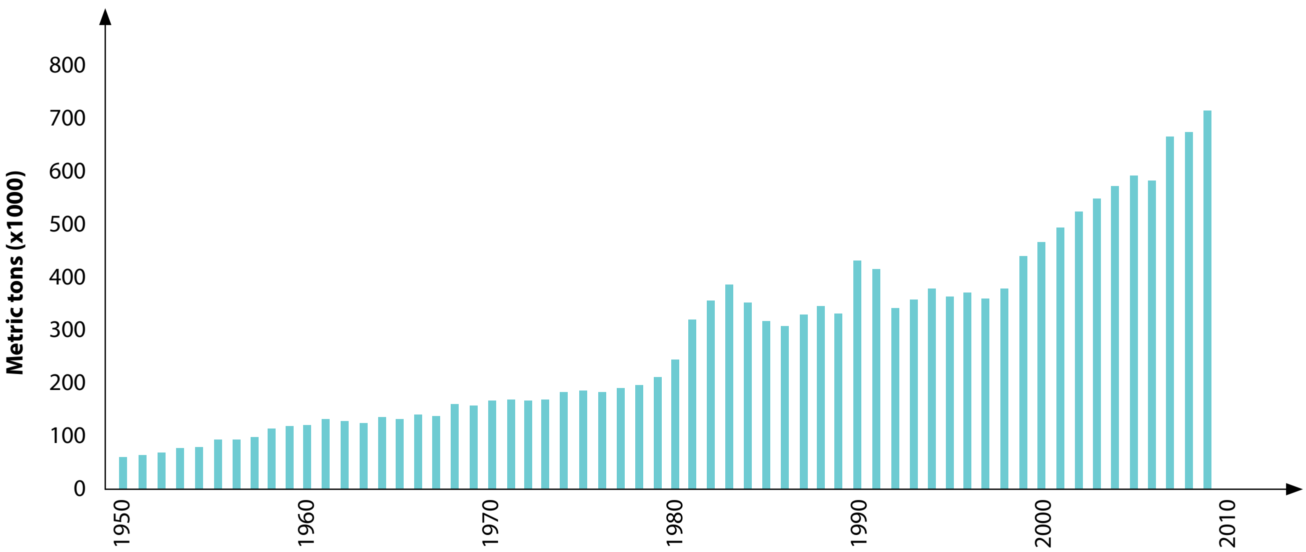
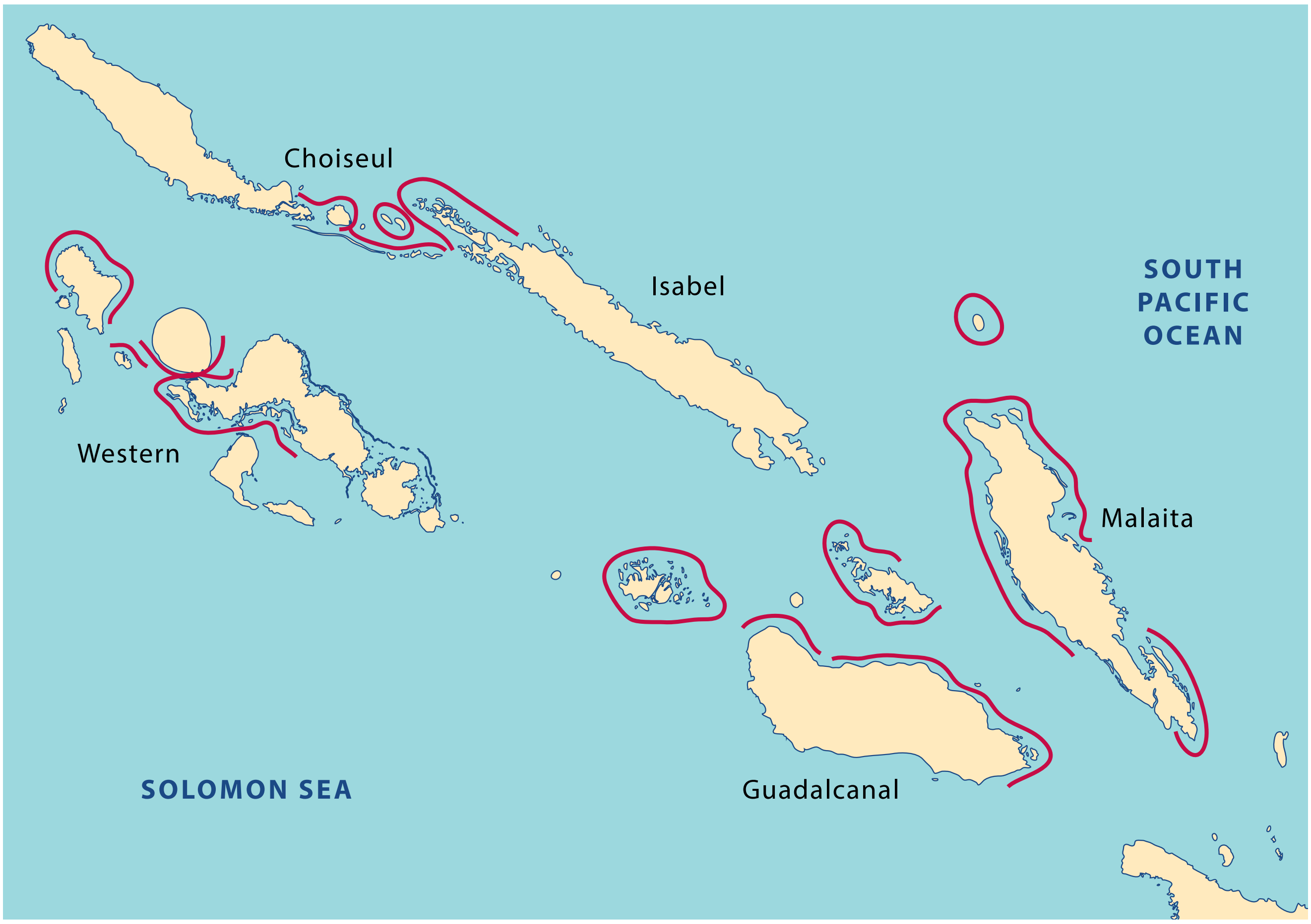


Figure 2. Annual production of milkfish between 1950 and 2010 (Nelson and Marygrace 2010).

Status in Solomon Islands

Solomon Islands falls within the global distribution range of milkfish (Froese and Pauly 2000) and has many suitable habitats for milkfish, ranging from open seas, coral reefs, mangroves and estuaries to small, partially enclosed water bodies that are accessible to the sea. Milkfish are normally caught by local fishers and sold at urban markets. Although milkfish aquaculture was never traditionally practiced in Solomon Islands, wild-caught milkfish is a culturally important and favored fish species in some communities (Shortland, Vella la Vella, Kia in Isabel, Dai Island, North Malaita and Tikopia). Locations where the authors are aware from local knowledge that milkfish fry occur are shown on the map in Figure 3. It is not expected that this map is exhaustive.



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Location where milkfish fry are reported to occur

Note: There are no currently recorded locations in three of the provinces within the known milkfish range.

Figure 3. Map showing locations where milkfish fry are known to occur.

REVIEW

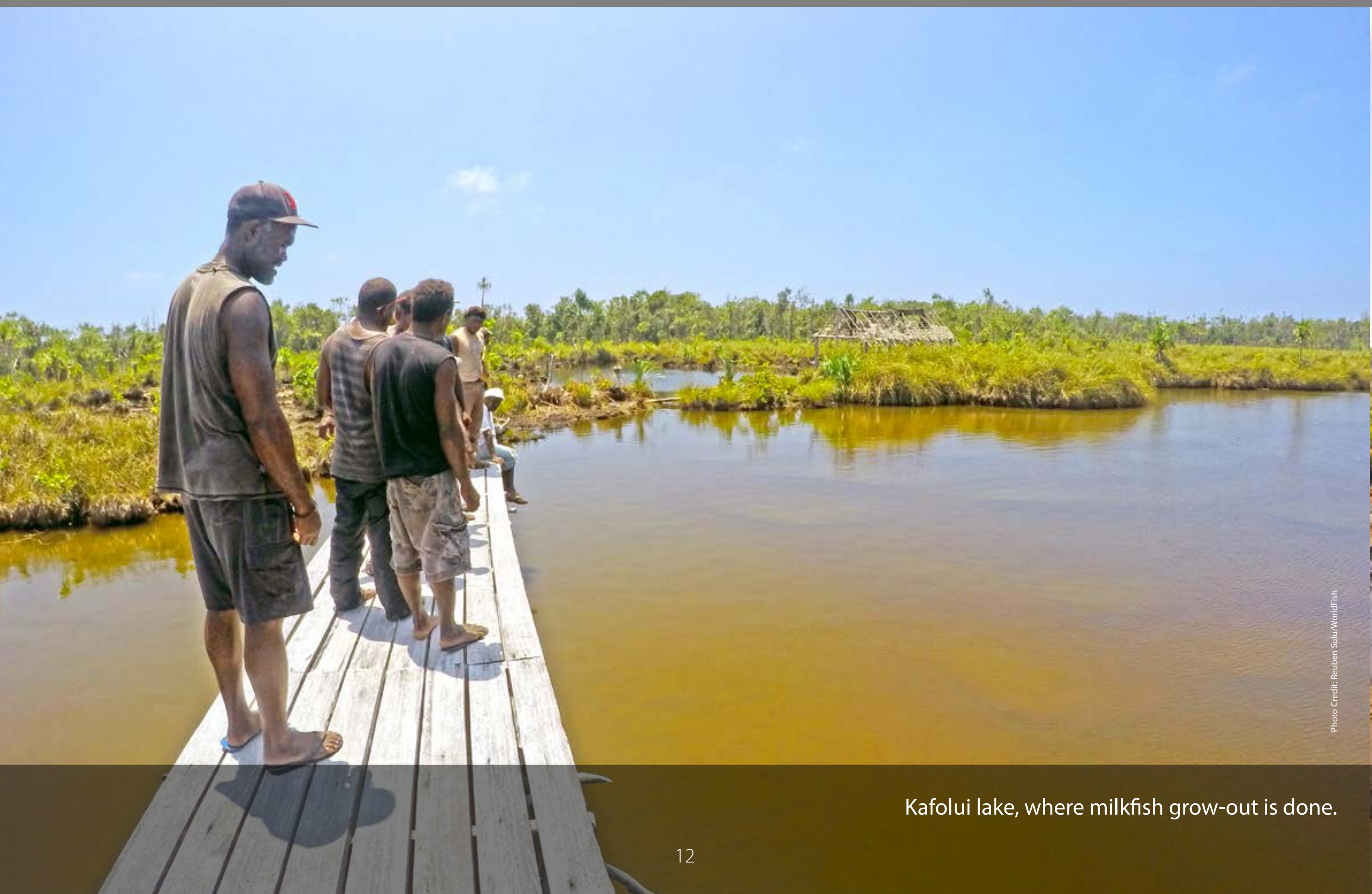
Case study: Dai Island

Dai is a small, flat, coralline island that is approximately 7 kilometers (km) by 2.5 km. Located 45.5 km from the northern tip of the Malaita mainland (Figure 4), it has been associated with milkfish as long as anyone on the island can remember. Milkfish has always been an important part of the Dai culture and diet and has been termed *"ia inito'o"* (fish of status and prestige) for its important role in traditional food systems. Milkfish fry naturally collect within the mangrove wetland systems that stretch for about 1.5 km on the southeast end of the island. Historically, stone weirs (which still exist) were constructed to partition the different parts of the area to ease catching of milkfish when they reach harvestable sizes. Milkfish also occur in two of the large lakes on the island that open to the sea.

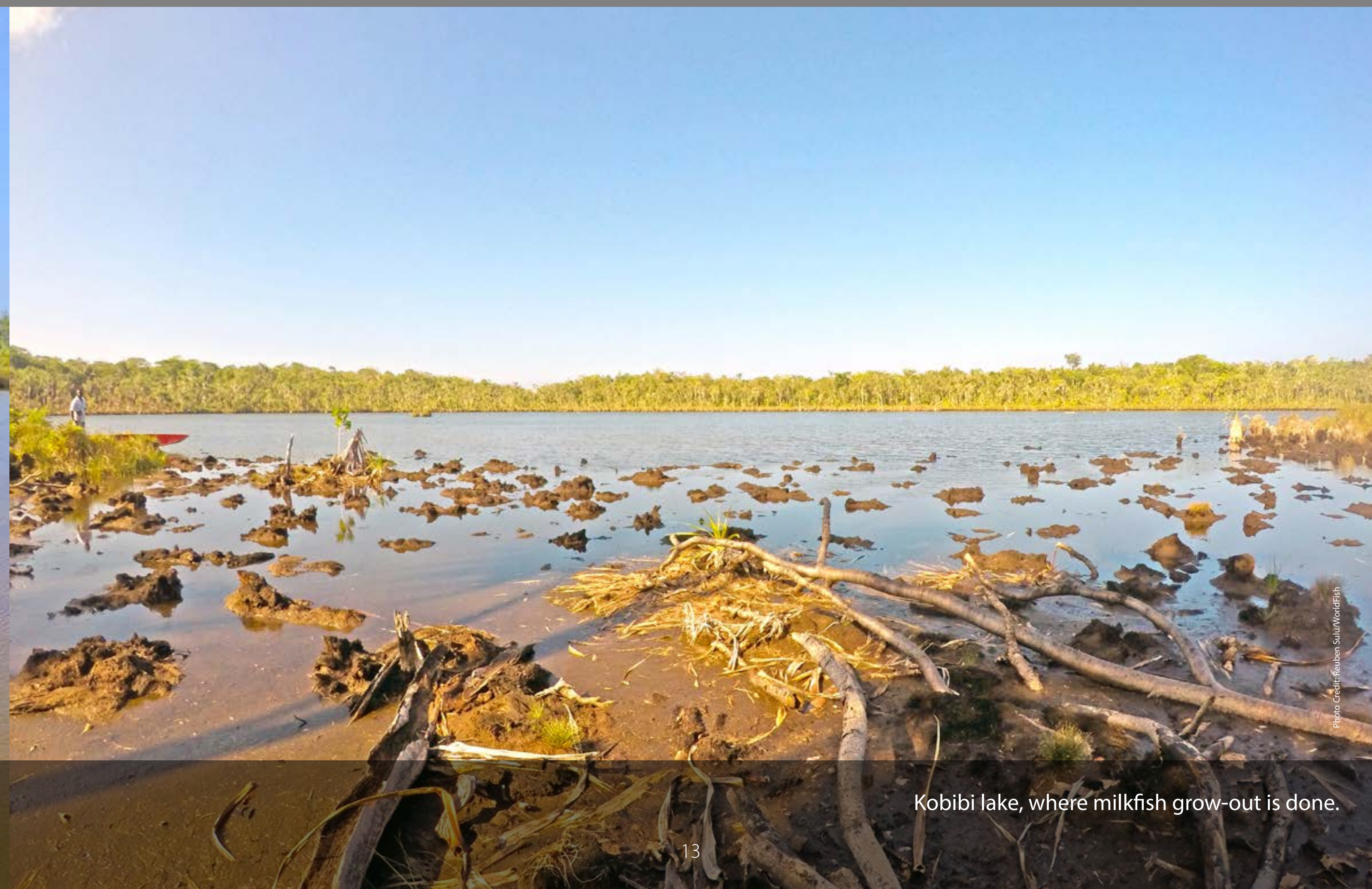
Efforts to commercially farm milkfish began in 2012. Milkfish fry were collected from the southeastern end of the island by men, women and older children and transported to Kafolui and Kobibi—two enclosed water bodies that contain freshwater. Kafolui is about 11,200 square meters (m^2). Fry collection and transport using buckets normally begins at 04:00 and continues till 10:00. No feeding is involved in the grow-out system; rather, the milkfish fry depend on natural food supplies within the enclosed water bodies to grow. According to the farmers, between 10,000 and 20,000 milkfish fry are stocked in the enclosed lakes by different individuals every year.

Several difficulties exist in the Dai milkfish farming system. Since natural systems rather than ponds are used for grow-out, management and control over the culture system are very difficult; this includes lack of control over water levels, algal growth and feeding cycles. The inability to partition the water bodies makes individual farmer ownership and claiming of fish within the water bodies very hard. Transportation costs to the market are relatively high. The high perishability of the milkfish also requires some kind of preservation (e.g. either refrigeration or ice to cool the fish during transport, smoking, or some form of salting and drying). Overcoming these challenges could be achieved through careful small business planning and management, helping farmers to secure a small return on sales to the mainland.

Figure 4. Map of Dai indicating milkfish fry collection areas and lakes.



Kafolui lake, where milkfish grow-out is done.



Kobibi lake, where milkfish grow-out is done.

SOLOMON ISLANDS STUDY: SEED AVAILABILITY

This section addresses Box 1 of the feasibility assessment (Figure 1) and is based on research conducted in Solomon Islands between 2012 and 2015.

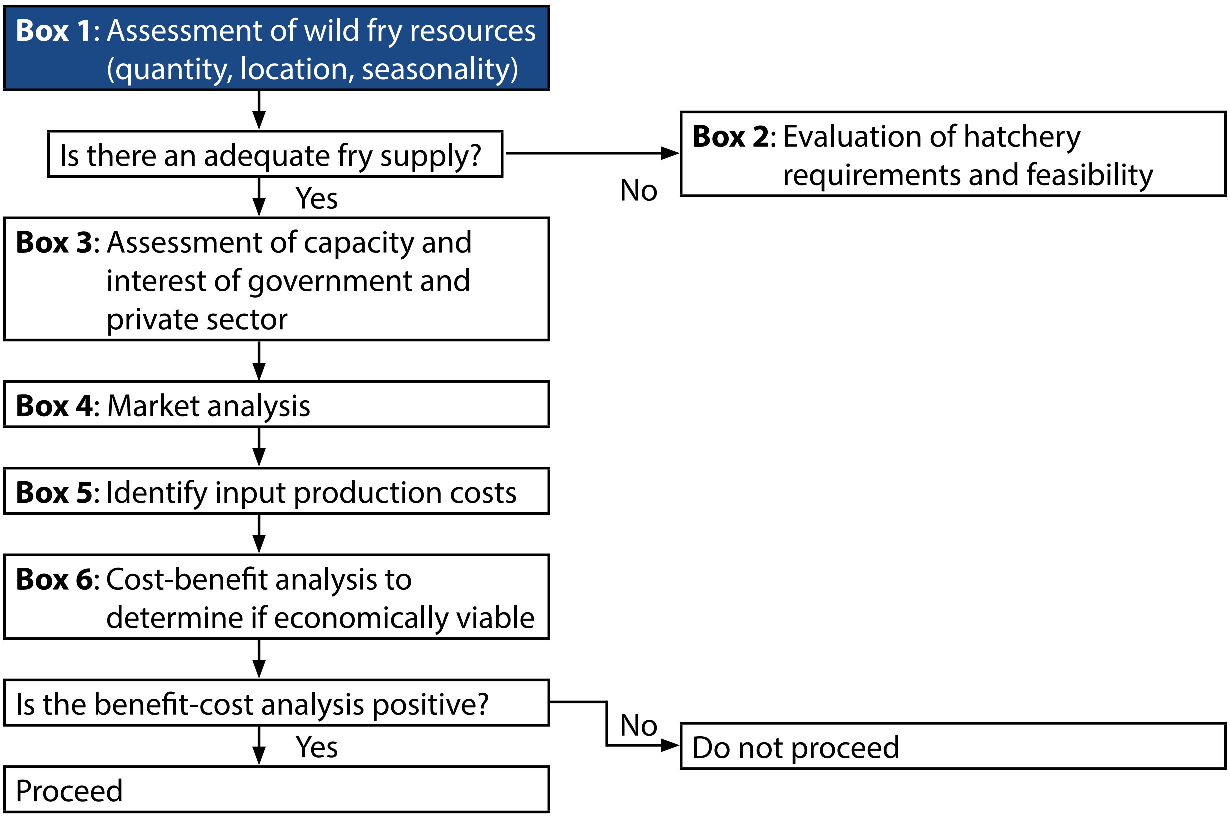
The objective of the availability study on milkfish fry seed was to determine the distribution and abundance of milkfish fry at sites likely to be suitable, based on local knowledge (see Figure 3) and on physical characteristics of sites known to determine suitability elsewhere in the Asia-Pacific region. Fry were also collected from these sites for practical trials from nursery to on-farm grow-out.

Sampling site descriptions

Studies on seed availability were conducted over 1 year at Tenaru River mouth and Alligator Creek mouth in Guadalcanal (Figures 5–7) and at Rarumana in the Western Province (Figures 8–9). One-off opportunistic sampling was also done at the Arnavon Islands, in Manning Strait (Figure 10), and some locations on the west coast of Malaita (Figure 11). The Malaita locations were chosen for their ease of access and proximity to a large number of existing Mozambique tilapia farmers, some of whom had expressed an interest in farming milkfish.

Tenaru River mouth, Guadalcanal
Tenaru River mouth (Figure 5) is about 15 km east of Honiara City. At the river mouth where sampling was done, the maximum water depth is about 3 meters (m) and the maximum width about 20 m. The zone just outside the river mouth where the oncoming waves break is shallow due to sediment that collects there from wave action, which pushes the sediment back into the river mouth.

There are several settlements on the coast near the river. The river mouth is frequented by fishers from a fishing village in Honiara, who reported it as a good fishing ground and location to target the seasonal arrival of *mamamu* (glass-stage fish fry that migrate into the river mouth).



Alligator Creek mouth, Guadalcanal

The Alligator Creek mouth (Figure 6) is about 10 km from Honiara City, located at the coastal end of the Honiara International Airport runway, and is about 3.5 km west of the Tenaru River mouth. The maximum depth where sampling was done is less than 2 m and the maximum width is about 20 m. Unlike Tenaru River, which has a main channel that extends well inland, the Alligator Creek mouth only extends for a short distance inland, after which it is fed by small streams and possibly subsurface water sources. Alligator Creek always contains water and floods during heavy rain. Sampling was conducted within the creek mouth pool and along about 200 m of the eastern coastline of the creek mouth.

Figure 5. Aerial view of the Tenaru River mouth. South is on the top of the picture and west is to the right. Sampling areas are marked in red.

Figure 6. Aerial view of Alligator Creek mouth. South is on the top and west is to the right of the picture. Sampling areas are marked in red.

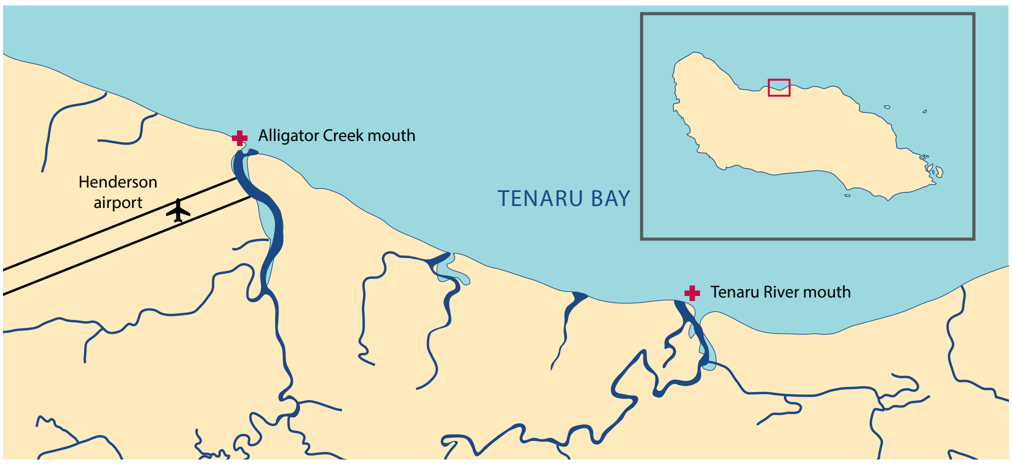


Figure 7. Map showing Alligator Creek mouth and Tenaru River mouth, Guadalcanal.

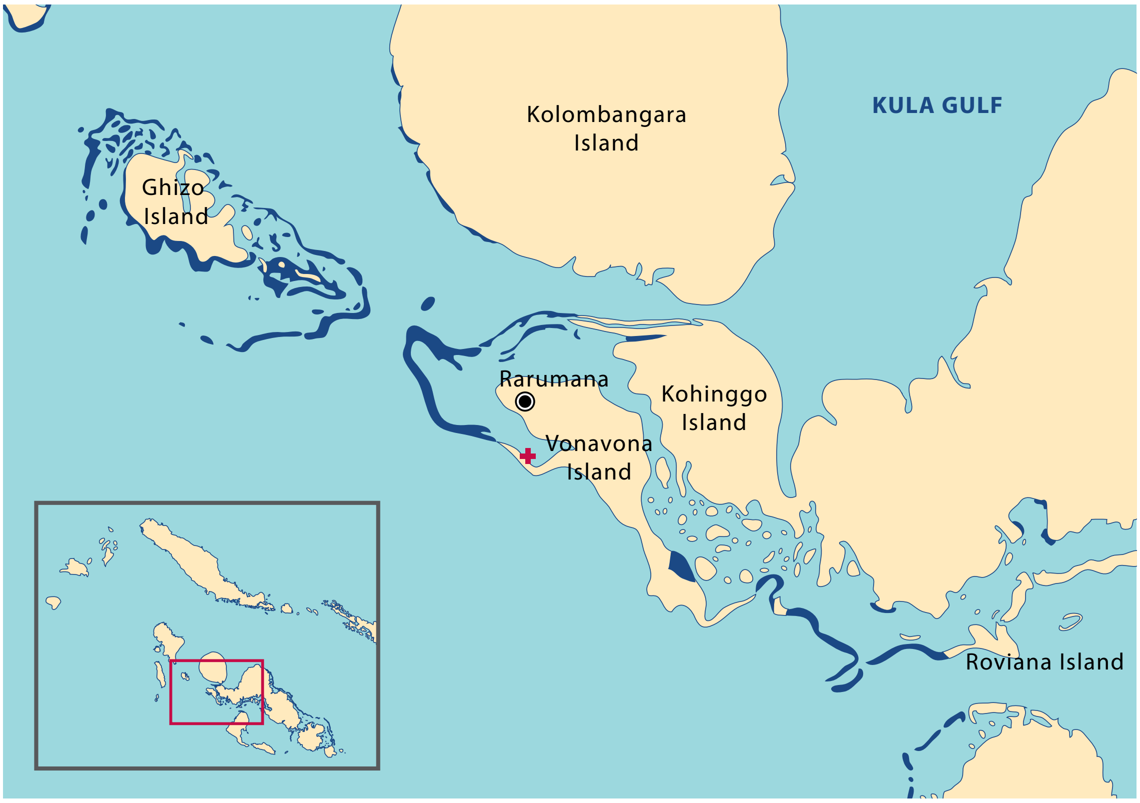
Rarumana, Western Province

The Rarumana sampling site is within a sheltered embayment on Vonavona Island (Figures 8 and 9). It is enclosed by the Vonavona mainland on the northern side and by thin island extensions of the mainland on the southern side of the embayment. The area contains mangroves and seagrass beds. There is a large opening to the open sea on the northwestern side of the embayment with a small shallow outlet opening on the southern side. The main benthic substrate in the area is sand. Sampling was conducted in the shallow areas of the southern side of the embayment, at shin to waist depth at the location marked in the aerial photo in Figure 8.

Arnavon

The Arnavon marine conservation area, which is situated in the Manning Strait between Isabel and Choiseul, consists of three small uninhabited islands and surrounding coral reef areas (Figure 10). Sampling was conducted within a 500-m stretch of an embayment that also served as an opening to an enclosed water body within Kerehikapa Island. The main substrate within the sampling area was fine carbonate sand.

Figure 8. Aerial view of the sampling site at Rarumana. South is at the top of the picture and west is to the right. The sampling area is marked in red.



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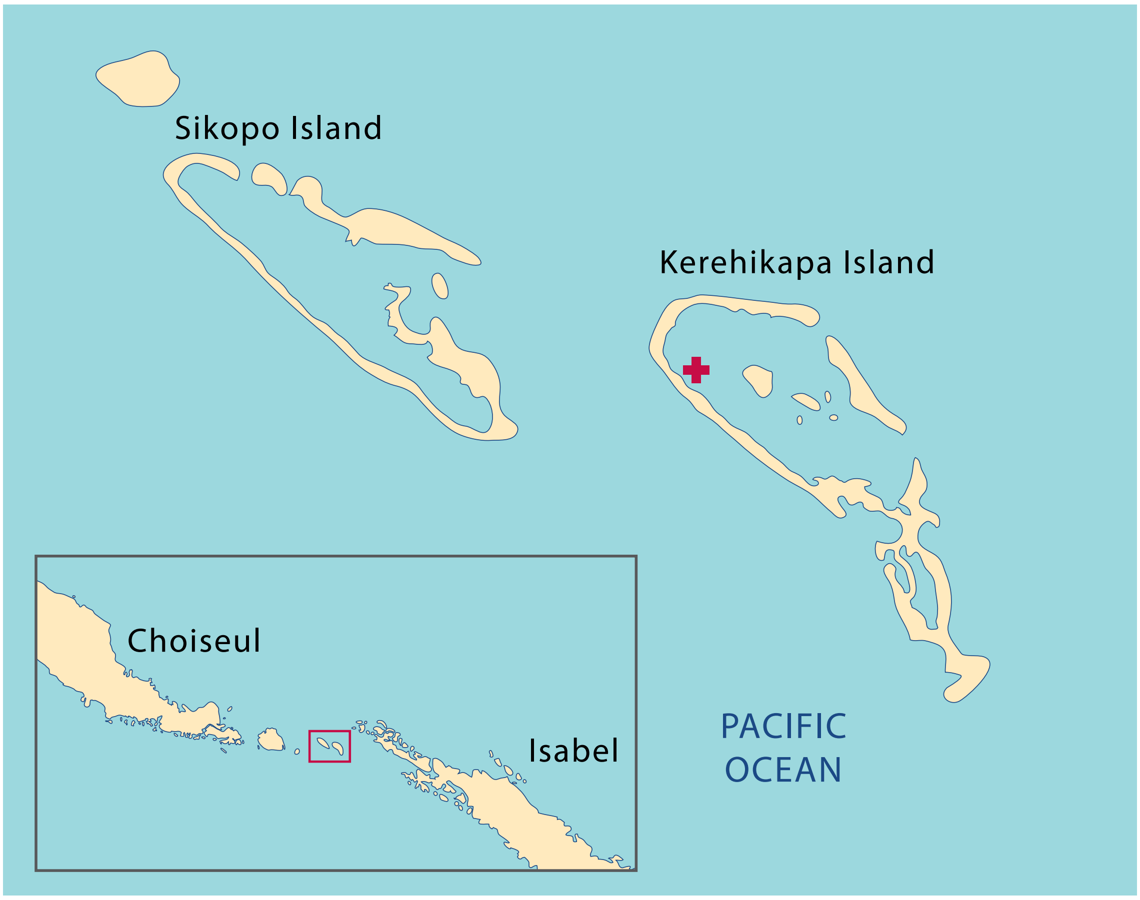
✚ Milkfish collection site

■ Reef

Figure 9. Milkfish sampling location at Rarumana, Western Province.



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✚ Milkfish sampling site

Figure 10. Milkfish sampling location at the Arnavon Islands, Manning Strait.

Malaita sampling locations

Bakofu seafront

The sampling site was located within a bay, along the beach from the mouth of the Taeloa River and two stream outlets (Figure 11). The benthic substrate at the site was a mixture of white and black sand and gravel.

Alota'a beach

Alota'a beach is located in Lilisiana village just outside Auki town (Figure 11). The area is a fringing reef that contains seagrass. The benthic substrate at the site consists of sand on the shoreline and a mixture of sand and rubble on the reef.

Radefasu and Nanao

Radefasu and Nanao river mouths are very close to each other (Figure 11). Both locations contain mangroves and are sheltered by an adjacent barrier reef that also contains mangroves. The substrate at both locations is a mix of mud, sand and pebbles.

Sampling methods

Based on work in the Philippines, Kumagai (1984) reports that milkfish fry were generally more abundant during the new moon and full moon phases due to increased spawning activity in the quarter moon phases. Sampling was therefore conducted during these times in both the Guadalcanal and Western Province sites. Besides the moon phase, time of day, tide state, sea condition, wind and current direction, seawater temperature, salinity, and turbidity were also evaluated as potential predictors of fry availability. With respect to time of day, sampling was initially done in the early mornings; however, this was changed following advice (Eric Basco, personal communication) that it would be appropriate to sample at any time during daylight hours, provided sampling coincided with flood and high tide when abundance is expected to be higher than at low and ebb tides (Kumagai 1984).

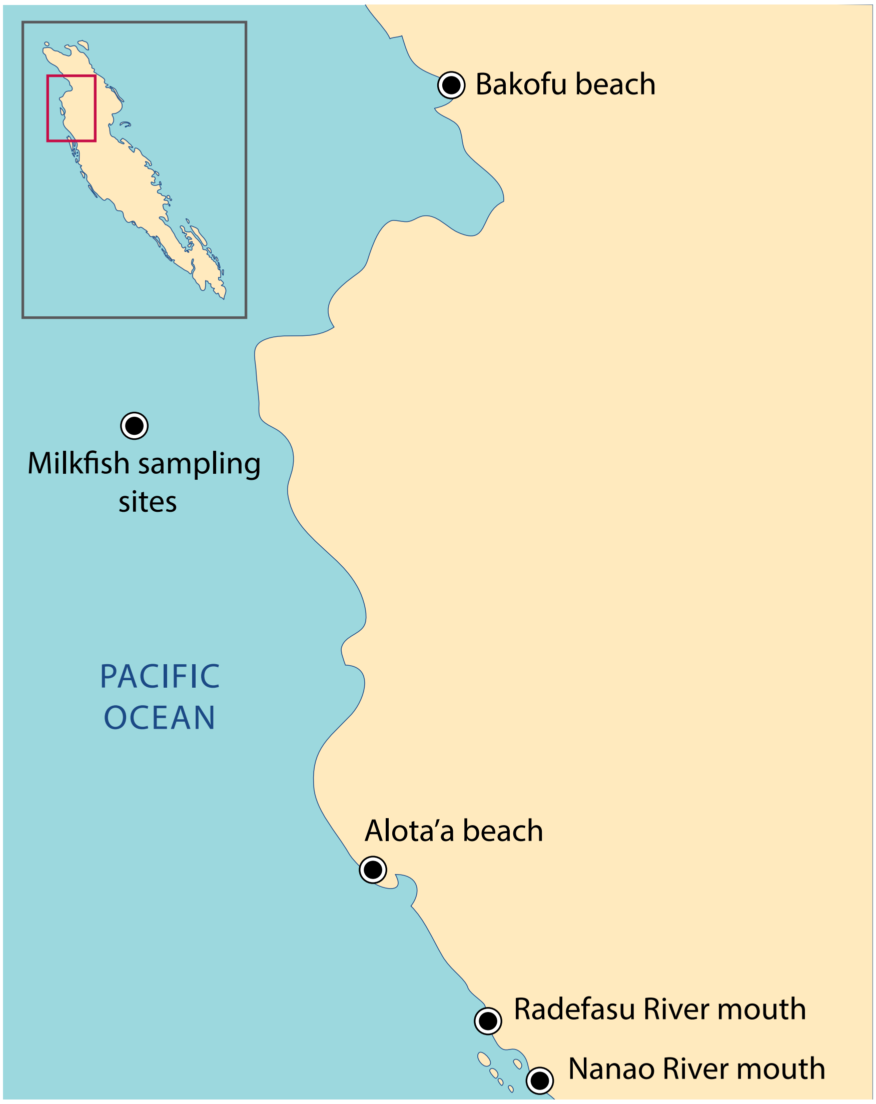


Figure 11. Milkfish sampling locations at Malaita.

In Guadalcanal, milkfish fry sampling was conducted approximately twice monthly during March 2012–July 2013. Two methods were used. A seine net was used in locations where milkfish fry were in groups or schools on the shallow bank of the river or creek mouth or around logs; that is, places where a dozer net could not be used. A dozer net was used along the shoreline in shin-to-waist-deep water where there were no obstructions like logs. The dozer net was pushed along the shoreline, stopping about every 5 minutes to check for, scoop out and count the milkfish fry present. Each sampling session involved pushing the dozer net repeatedly up and down the same stretch of the coast for about an hour. The total milkfish obtained for the day were counted and recorded at the end of the sampling.

Sampling methods used at Rarumana and the Arnavon Islands varied slightly. Sampling at Rarumana was conducted during October 2012–November 2013. A 1-km stretch of surf zone was sampled using a dozer net. The dozer net was stopped at 20-m intervals to empty the net and record the total number of milkfish fry obtained for the 50 data points, representing the full 1-km sample area. Sampling at Arnavon was done from 26 to 28 March 2013. The same method was used; however, only a 0.5-km track was sampled, representing 25 data points. For both Rarumana and Arnavon, during the data collection process, the two water parameters most relevant to milkfish fry abundance (temperature and salinity) were measured by thermometer and refractometer, respectively. The water depth was measured with a meter rule and the distances from the shoreline to the dozer net estimated by eye. Weather conditions (such as wind and current directions, sea and sky conditions) and water turbidity were also recorded on each sampling day. Similar to Rarumana and the Arnavon Islands, milkfish sampling at Malaita used the dozer net method. In Malaita, however, sampling was conducted on only two occasions in May and June in 2014 and 2015, months that are proven in Western Province to be the most likely months to find fry.

Photo credit: Tim Pickering, WorldFish

Using a seine net to catch a school of milkfish fry from under a log at Tenaru River mouth.

Statistical analysis

The median and mode were calculated using the continuous probability distribution method instead of discrete values. This was appropriate for this data set because it has a skewed distribution with many zeros.

Shapiro-Wilks and Kolmogorov-Smirnov tests were used to test for normality of data for Rarumana and Arnavon, while the Fligner-Killen and Bartlett's test was used to test for homogeneity of variance. Since data for both locations was non-normal and non-homogenous, the data was transformed using the Box Cox (Box and Cox 1964) method ($\lambda = 0.3$ and shift = 0 for Rarumana data and $\lambda = 0$ and shift = 1 for Arnavon data) to satisfy parametric model assumptions. One-way analysis of variance (ANOVA) was used to compare milkfish abundance between different factor levels for each condition (e.g. for moon phase—new moon and full moon), while a two-way ANOVA was used to analyze interaction between two conditions (e.g. tide condition and time of day or temperature and turbidity).

When milkfish fry sampling was carried out simultaneously at Rarumana and Arnavon (26–28 March 2013), a Welch two sample t-test was used to compare abundance between the locations for this time period. Differences were considered significant at $p < 0.05$.

Statistical analysis for the Guadalcanal data was conducted differently, as the data contained many events where no milkfish fry were collected (excess zero counts). The data was non-normally distributed and variance was non-homogenous. The Generalized Linear Model (GLM) with a negative binomial distribution best fitted the data; hence the Guadalcanal data was analyzed using the GLM method (with negative binomial distribution). Differences were considered significant at $p < 0.05$.

No statistical analysis was done for Bakofu, Alota'a, Radefasu or Nanao, as only opportunistic sampling to determine the presence of milkfish was done at these locations rather than long-term sampling.

Photo Credit: Tim Pickering/WorldFish

Sampling with a dozer net at Rarumana.

Results of the seed availability study

Milkfish fry abundance: Guadalcanal

At the Guadalcanal sites, milkfish fry catch varied between 0 and 641 fry per sampling day during the 1-year sampling period (Figure 12), with peak periods during the first half of the year (January–May). There were a lot of trips where no milkfish fry were caught.

Milkfish fry catch was significantly affected by moon phases such that there were greater chances of increased milkfish fry catch during the new moon than during the full moon (Table 2). Tidal conditions (Table 2) did not affect the number of milkfish fry caught at any moon phase.

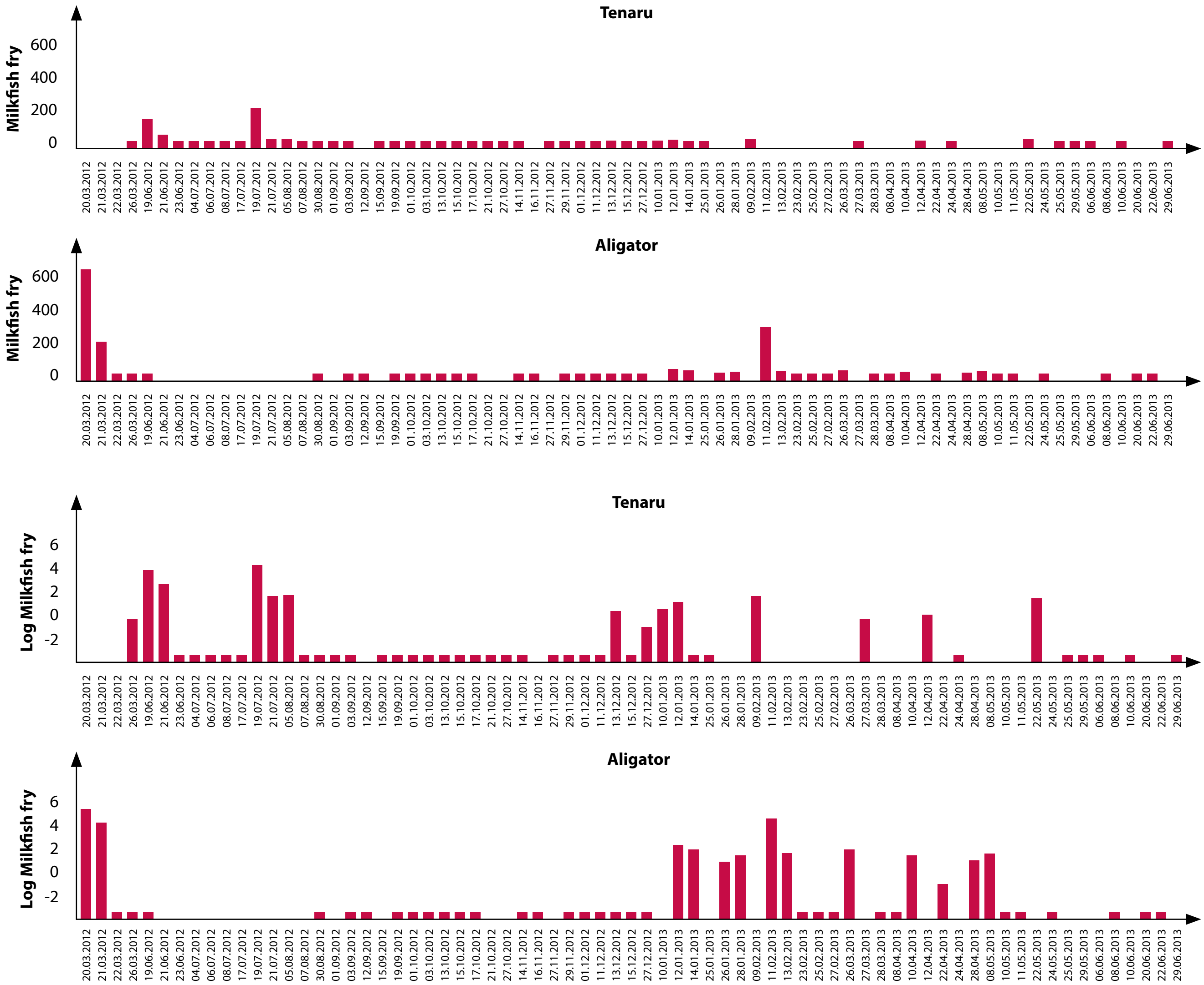


Figure 12. Plot of milkfish fry caught at Guadalcanal locations. The horizontal axis shows the dates of sampling, while the vertical axis shows number of fry as an absolute value (top panel) and log transformed (bottom panel) to better reveal the data trends.

Condition		Trips	Zeros	Mean	Median	Mode	Minimum	Maximum
Moon phase	Full moon	42	33	1.8	0	0.1	0	20
	New moon	48	30	34.3	0	0	0	641
Tide condition	Falling	36	28	16.9	0	1.6	0	205
	Rising	54	35	20.6	0	0	0	641

Table 2. Summary of milkfish fry catch for different moon phases and tide conditions at Guadalcanal locations.

Milkfish fry abundance: Rarumana, Western Province

In Rarumana, milkfish fry catch varied between 7 and 517 fry per sampling day during the 1-year sampling period (Figure 13) with peak periods between April and May. Table 3 summarizes milkfish fry catch during the new moon and full moon phases and other environmental conditions. The mean, mode and median indicate that catch at new moon is higher than during the full moon phase. However, these differences were not statistically significant, nor were there any significant differences in milkfish fry abundance for particular sampling days during a moon phase (e.g. 2 days before full moon, on full moon day and 2 days after full moon).

Significance testing on whether time of the day (AM or PM) affected milkfish fry abundance revealed that there is no difference in milkfish fry abundance between sampling done in the morning or afternoon (Table 3). Similarly, there was no significant effect of tidal condition, sky condition, wind or current direction (Table 3), indicating that milkfish can be collected at Rarumana at any time during a new moon or full moon period (a period = 2 days before and after the moon state).

There was no significant correlation between salinity, temperature or water turbidity and the abundance of milkfish. There was, however, an interactive effect between temperature and turbidity (Figure 14), meaning that higher numbers of milkfish fry were caught at low temperatures during "not turbid" conditions than at high-temperature turbid conditions. There was also an interactive effect of temperature and salinity, with the highest number of milkfish fry caught during low temperature–low salinity conditions (Figure 15).

Milkfish fry abundance: Arnavon, Manning Strait

The number of milkfish fry caught at Arnavon during the 3 days of sampling varied between 2 and 37 milkfish fry per day. More milkfish fry were caught in the morning (AM) than in the afternoon (PM) and during the flood tide than the rising tide (Table 4). Time of day had an interactive effect with tidal conditions; more milkfish fry were caught at the morning flood tide than at the afternoon rising tide.

Milkfish fry abundance: Malaita

No milkfish fry were obtained from the Radefasu River mouth (sampled in May 2014) or Nanao River mouth (sampled in May 2014 and June 2015). Fifteen milkfish fry were caught at the Alota'a seafront in May 2014 and 31 milkfish fry were caught during the second sampling period (3 May–9 June 2015). Sampling at Bakofu in September 2014 yielded no fry (which is consistent with the results from Guadalcanal and Western Province for that time of year), although fry of tarpon (*Megalops cyprinoides*), which bears some resemblance to milkfish, and other species were seen. A total of 53 milkfish fry were collected during the second sampling period (9 May–28 June 2015) at this site.

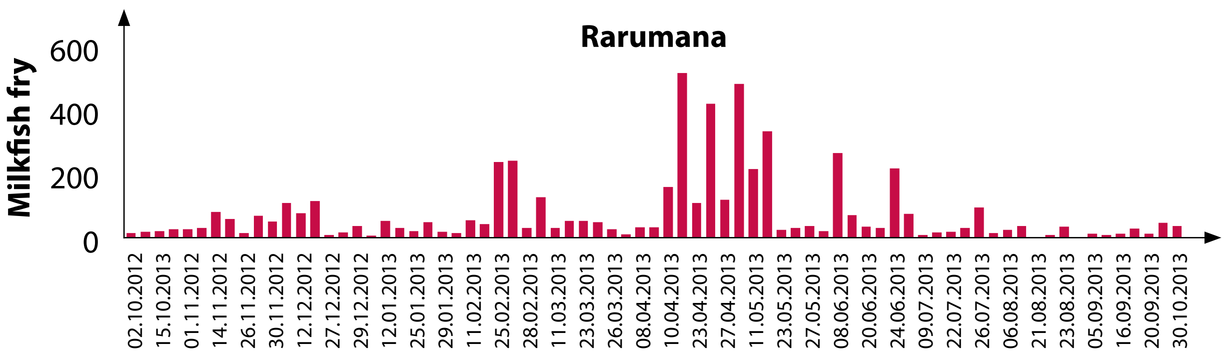


Figure 13. Milkfish fry catch at Rarumana, October 2012 to October 2013.

Condition		Trips	Mean	Median	Mode	Minimum	Maximum
Moon phase	Full moon	37	62.1	31.0	25.0	8	422
	New moon	35	92.7	42.0	28.9	7	517
Specific days in the phase	2 days before new moon	11	85.0	31.0	22.8	7	483
	New moon	12	83.4	53.5	34.8	8	266
	2 days after new moon	12	109.8	47.0	36.9	8	517
	2 days before full moon	12	45.8	19.5	16.0	8	237
	Full moon	11	88.5	31.0	29.5	16	422
	2 days after full moon	13	56.0	34.0	30.7	13	218
Time of day	AM	29	96.1	34.0	26.56	8	483
	PM	43	64.1	33.0	24.0	7	517
Tidal condition	Rising	28	99.1	34.0	28.5	8	483
	Falling	44	63.9	32.0	23.0	7	517
Sky condition	Overcast	27	94.3	33.0	26.0	8	517
	Rain	11	81.0	37.0	31.7	8	241
	Sunny	34	62.0	33.5	26.9	7	335
Wind direction	None	16	118.8	34.0	32.7	15	517
	Northwest	16	95.0	50.0	35.0	8	483
	North	6	47.0	32.0	24.1	7	110
	Northeast	3	28.7	20.0	18.5	17	49
	East	6	84.5	72.5	31.4	8	218
	Southeast	17	57.5	20.0	18.1	8	266
	South	4	27.8	26.0	25.6	8	51
	Southwest	4	40.0	37.5	33.1	27	58
Current direction	None	24	88.8	32.0	26.0	8	517
	Northwest	21	78.2	36.0	25.8	8	422
	North	3	41.3	49.0	53.34	17	58
	Northeast	2	255.5	255.5	28.9	28	483
	East	4	32.3	36.0		15	54
	Southeast	7	85.7	52.0	40.5	19	241
	South	7	30.7	25.0	44.2	7	69
	Southwest	1	110.0	110.0	17.0	110	110
	West	3	23.7	24.0	25.3	20	27

Table 3. Summary of milkfish fry catch (numbers of fry) at Rarumana under different environmental conditions.

Condition		Trips	Mean	Median	Mode	Minimum	Maximum
Time of day	AM	4	14	8.5	6.2	2	37
	PM	4	8.3	3	2.1	0	27
Tide condition	Flood	4	19.5	19	11.2	3	37
	Rising	4	2.8	2.5	2.3	0	6
Combination of time of day and tide conditions	AM – Flood	2	24	24	11.1	11	37
	AM – Rising	2	15	12	3.1	3	27
	PM – Flood	2	4	4	2	2	6
	PM – Rising	2	1.5	1.5	0.0	0	3

Table 4. Number of milkfish fry caught at different times of the day at Arnavon.

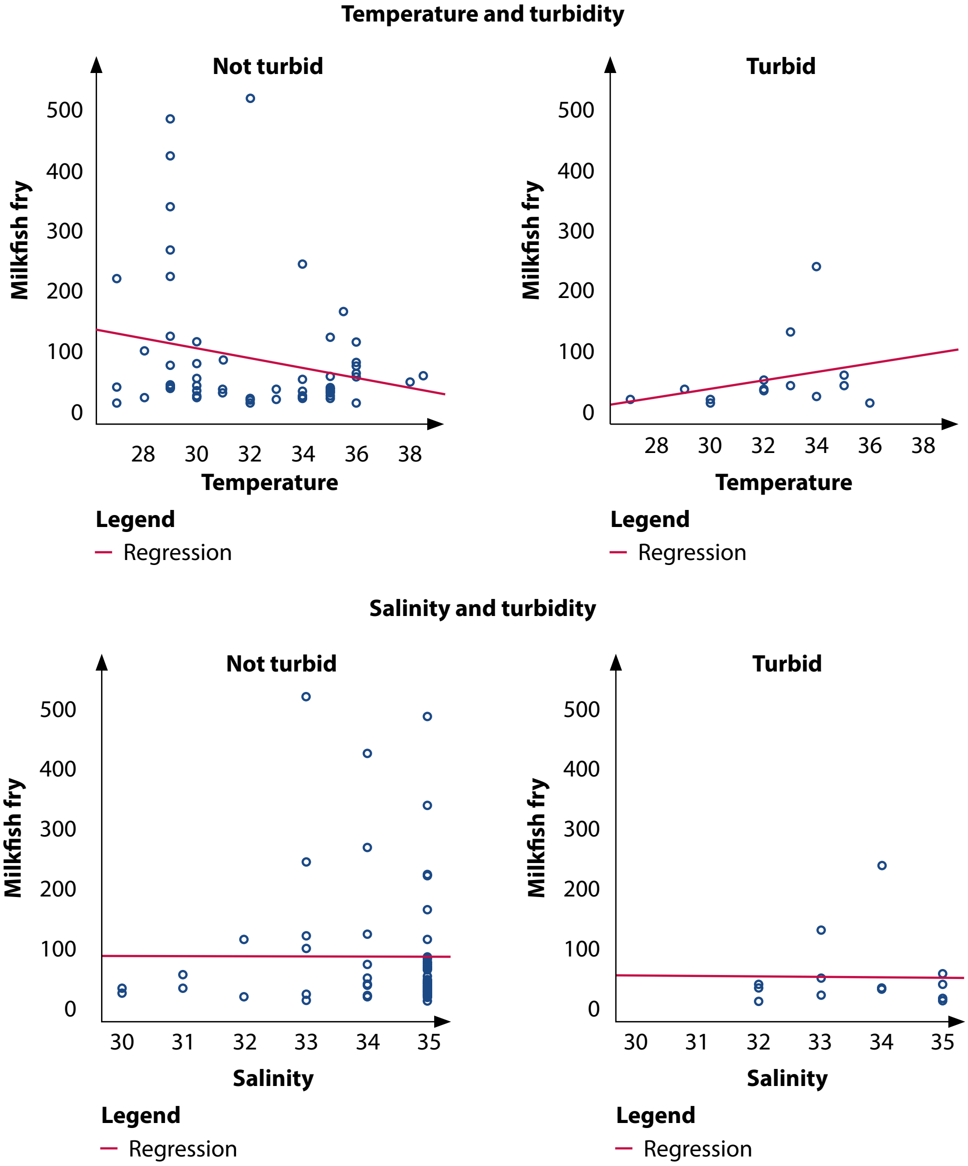


Figure 14. Number of milkfish fry caught at different temperature-turbidity and salinity-turbidity conditions.

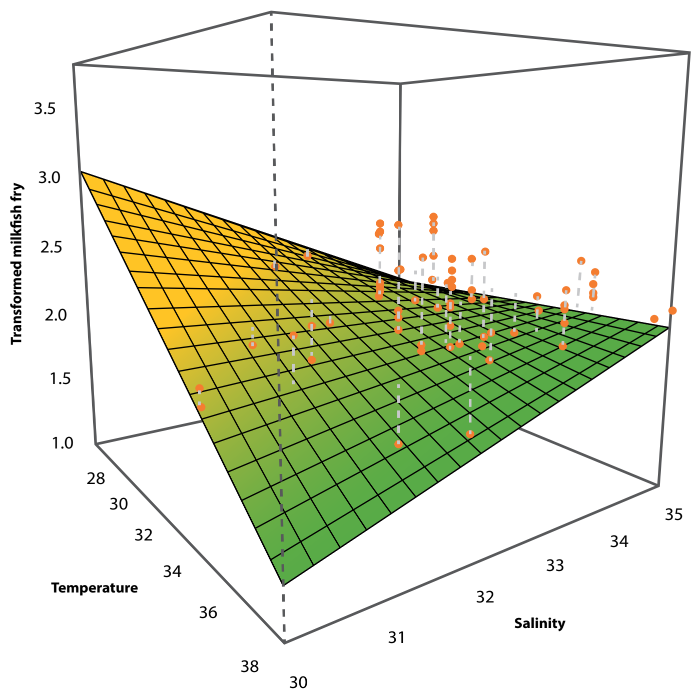


Figure 15. 3-D plot of Box Cox transformed number of milkfish fry caught under different temperature and salinity conditions at Rarumana.

Summary of seed (fry) availability

The results show that there are clearly some locations in Solomon Islands where fry can be sourced from suitable shorelines for subsequent grow-out. In this study, the highest numbers of fry were collected from Rarumana and Alligator Creek, while at other sites abundance was not high enough to support supply to aquaculture. Only a subset of likely suitable sites in the whole of Solomon Islands (Figure 3) were sampled; but the findings suggest that the most suitable sites are coastal areas near mangroves, seagrass beds and estuarine habitats, with the first half of the year (January–June) being the best time to collect milkfish fry.

Even in sites where fry is abundant, there are some local constraints to accessing commercially available quantities of fry that were investigated further. The sites where milkfish fry occur are generally on land and seabed that is under customary ownership, meaning that accessing the resources (including milkfish fry) depends on those who have the rights to control access and distribution. During the land-based trials at Nusatupe it was made clear by the Rarumana resource owners that considerable negotiation would be required to enable fry to be sold to others and/or shipped out of the province. Similarly, residents of Dai Island in Malaita expressed that they do not wish to sell their milkfish fry to anyone, but rather wish to keep them for their own aquaculture purposes. Negotiations had to be undertaken with resource owners in Guadalcanal and Malaita before fry sampling was conducted. Therefore, the supply of fry for any future enterprises will depend on the owners of the resource being willing to engage in supply as a viable and sustainable business opportunity for them and to develop effective relationships with buyers. A possible model for the supply of milkfish fry is proposed in Figure 16.

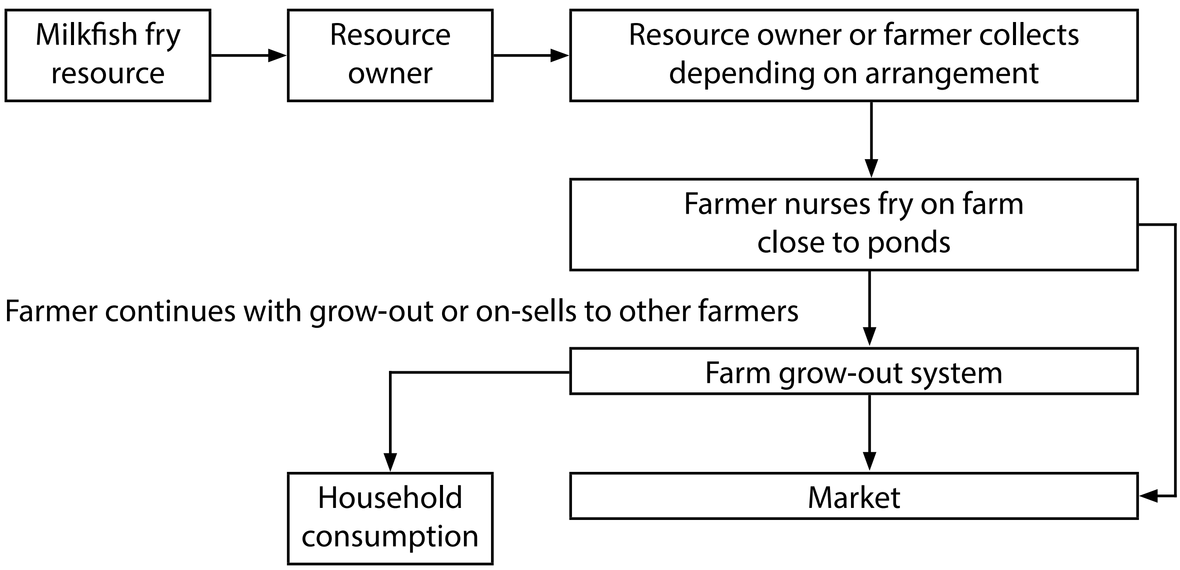


Figure 16. Possible model for the sourcing of milkfish fry supply from the wild for aquaculture purposes.

HATCHERY EVALUATION

The alternate option to wild-caught fry is hatchery-produced fry (Box 2, feasibility assessment, Figure 1) either imported from overseas or produced in Solomon Islands. A 2011 desk analysis of the comparative advantages and risks of developing a milkfish aquaculture industry in Solomon Islands (Schwarz et al. 2011) addressed the possibility of hatchery production of fry, and the relevant points are summarized here.

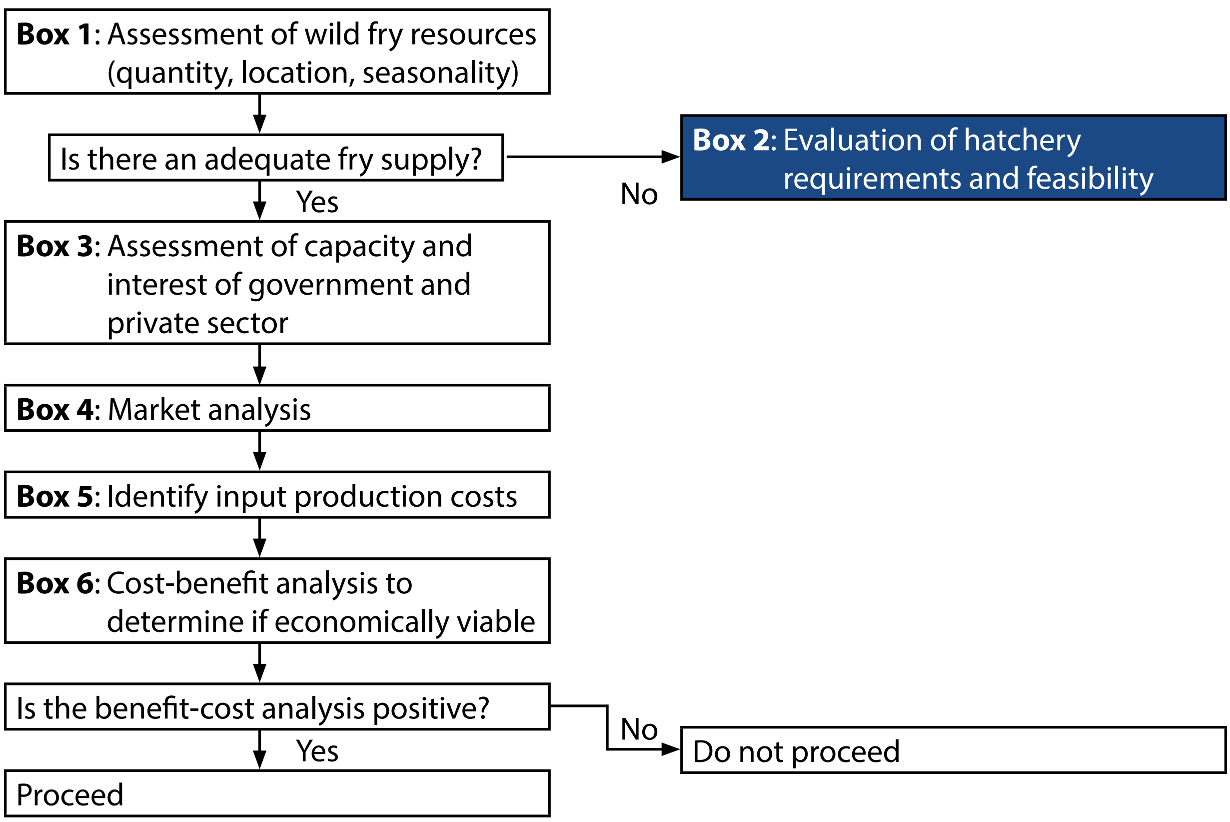
Advantages

- Milkfish broodstock is available from the wild and could be developed as a future possible source of hatchery-bred fry for large-scale seed production.
- A continuous supply of seed stock can be guaranteed from hatchery technology.
- Local feed ingredients are available in the country and feed technology from other countries could be adapted.

Disadvantages

- MFMR lacks staff trained in identifying, collecting, holding and culture of milkfish fry.
- There is a lack of technical skills in aquaculture.
- It takes 4 to 5 years to develop suitable broodstock after a hatchery is developed, meaning that there remains a reliance on wild-caught fry to continue operations in the interim.
- There are limited resources for infrastructure development (hatchery and related infrastructure).
- Land must belong to the government or be secured before establishing an aquaculture facility.
- Maintaining a hatchery requires guaranteed budget support.

The Solomon Islands MFMR National Aquaculture Development Plan states, "Given the current state of development of aquaculture in Solomon Islands, construction of an additional marine hatchery to support development of the priority commodities is not presently envisaged. Marine hatcheries are expensive to run, are labor intensive and require skilled staff. Elsewhere in the Pacific, government-operated facilities have struggled to provide a return on investment. MFMR would support private-sector development of small-scale hatcheries" (MFMR 2009, 43).

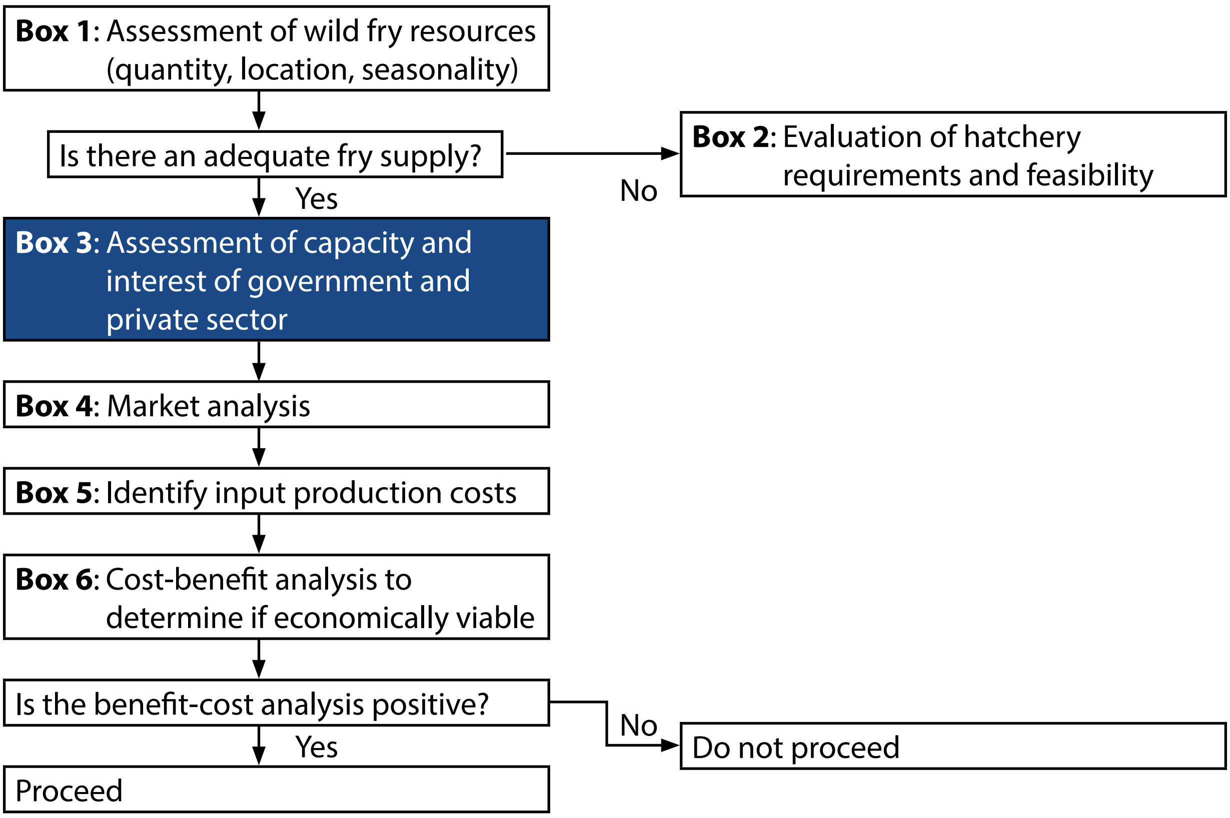


GOVERNMENT AND PRIVATE SECTOR CAPACITY

The feasibility assessment considers government and private sector capacity to support the industry (Box 3, feasibility assessment, Figure 1).

Milkfish appear on the list of aquaculture commodities prioritized in the MFMR National Aquaculture Development Plan 2009–2014 (MFMR 2009). They rank 13th out of 17 and are assessed as being able to make a medium impact, with a medium feasibility rating. At the time the plan was developed, there was no experience within MFMR or any nongovernmental organizations (NGOs) in Solomon Islands to initiate or support milkfish aquaculture; the Secretariat of the Pacific Community was an important source of regional knowledge.

The research in this report was done after the release of the National Aquaculture Development Plan. The majority of those who participated were Solomon Islanders, so skills have been acquired and expertise is currently available locally to do milkfish aquaculture. This includes government officers, researchers, NGO staff and farmers. The milkfish husbandry techniques that have been developed (see section on inputs for growth of milkfish in Solomon Islands) are simple and can be transferred to other interested farmers.



The study in this report recognizes that for inland aquaculture to make a significant contribution to Solomon Islands' economy and food security, both public and private investments at a range of scales will be required. Private investors at the scale of interested local fish farmers have been most involved in studies to date. Besides involvement in the research, they have contributed their perspectives to project meetings and to MFMR-facilitated workshops (provincial fisheries officers' annual meetings and revision of the National Aquaculture Development Plan). At the local business level, discussions have not progressed beyond statements of future interest, given that understanding of possible commercial opportunities is still limited. Should conditions improve for a commercial aquaculture industry to become a reality, further investment to engage local businesses will be required.

At the time of study and the time of writing, the most persistent interest in farming fish was (and continues to be) expressed by smallholder farmers who currently farm Mozambique tilapia and who were directly involved in the research described in the section on inputs for growth of milkfish in Solomon Islands.

Photo Credit: Reuben Sulu/WorldFish

Milkfish fry collection area within the mangrove wetland on the southeastern end of Dai Island. Stone weirs are used to partition the area to ease catching of milkfish when they reach harvestable sizes.

LOCAL MARKET ANALYSIS

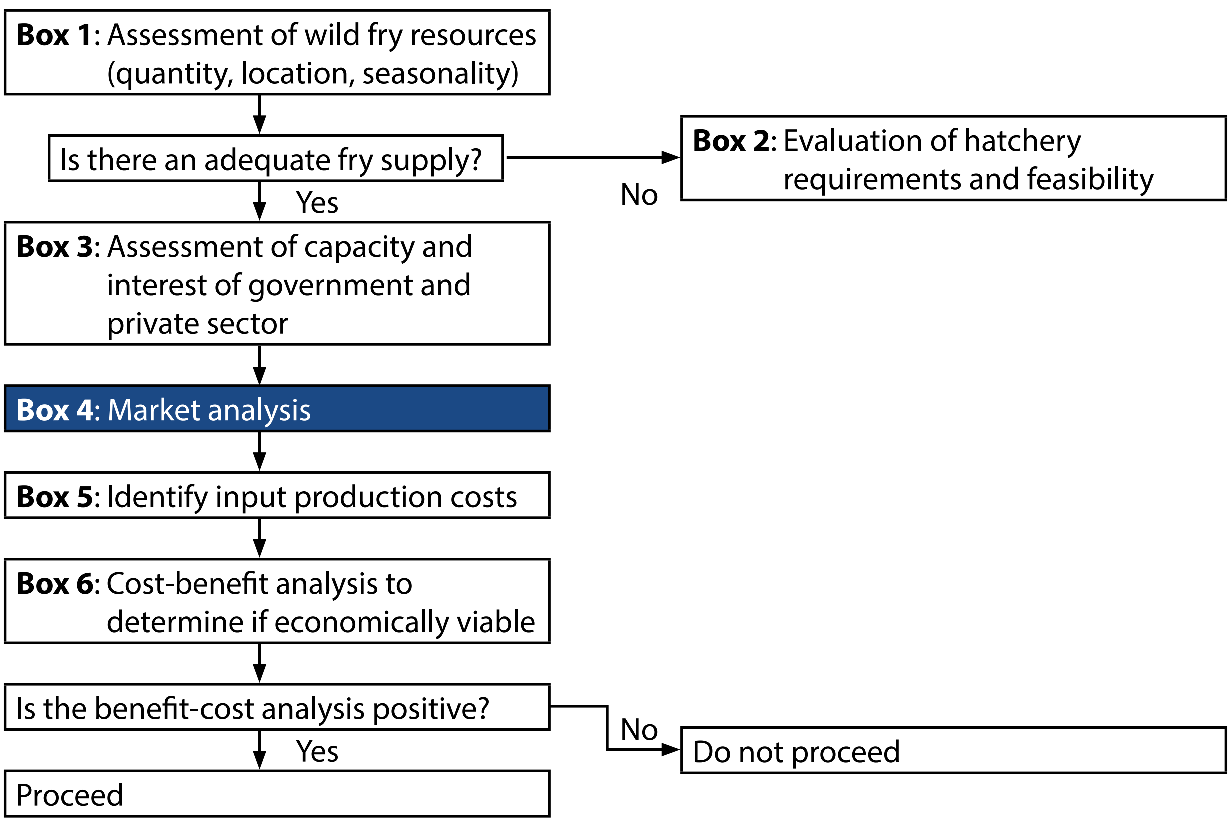
Understanding consumer acceptance is essential in evaluating the viability of any new production species, regardless of whether it is being farmed for household consumption or for sale. This section of the study contributes to Box 4 of the feasibility assessment (Figure 1).

A market survey was done in Honiara to determine the general acceptance and marketability of milkfish. The survey was passive in nature, as it relied on interviews with vendors (retailers) who were normally selling milkfish as part of their daily business, as opposed to a direct survey of buyers or consumers to actively determine customer choice in selection of milkfish over other fish species.

Market surveys were conducted at Honiara fish markets twice a week between September 2012 and August 2013. These were the Maromaro fish market opposite the WorldFish office; the fish market opposite Solomon Islands National University (SINU) Kukum campus; the fishing village market; the central market in the center of Honiara; and the White River market at the western end of Honiara town. The surveys were not random, as the surveyors actively sought vendors selling milkfish. Vendor details were recorded and each was asked about the following:

- location where milkfish were caught;
- fishing method used to catch milkfish;
- date and time they arrived with the fish at the market;
- the selling price of milkfish;
- how the selling price compared to price of other fish (particularly reef fish);
- whether milkfish was selling faster or slower than other fish;
- who their main customers were.

The total length and weight of milkfish were measured, and the quantity of milkfish in the cooler boxes recorded—these measurements were not taken if the vendor was busy with customers or the milkfish were at the bottom of the cooler boxes (under other fish). The fish families most abundant in the cooler boxes were also estimated. This was later used to generate a frequency graph of the most abundant fish families (%) at the market over the survey period.



Market survey

A total of 152 vendors (33 females and 119 males) were interviewed in 75 survey days over a year. Sixteen interviews were done at the Maromaro fish market, 5 at SINU Kukum campus market, 6 at the fishing village market, 112 at the central market and 13 at White River market. The number of interviews varied between one and eight vendors per day (two vendors on average), depending on the number of vendors available and how busy they were when the market was visited.

The six most abundant fish families at the Honiara markets (based on abundance estimates) were Lutjanidae, Lethrinidae, Scaridae, Haemulidae, Acanthuridae and Serranidae (Figure 17).

Salt fish[2] (comprising mostly Scombridae) obtained from industrial fishing boats was also usually available at the Honiara central market and fishing village market, with significant increases when fishing boats came into port to do transshipment to mother ships. Milkfish (Chanidae) was seen relatively infrequently, comprising less than 1% of fish available at Honiara markets.

Milkfish availability, pricing and selling rate

Milkfish was available at the market on 17 of the 75 survey days and was supplied mostly from Russell Islands, followed by Marau (Guadalcanal), Nggela, Marovo (Western Province), Kia (Isabel) and Lau Lagoon (Malaita). Twenty-five vendors were identified who were selling milkfish during the survey period; 19 were willing to be interviewed, while 6 could not be interviewed, as they were busy with customers. Seventeen vendors (90% of respondents who sold milkfish) reported that milkfish sells at the same price as other reef fish, which was between SBD 24/kg and 40/kg (mean price was SBD 32/kg).[3] One vendor said that he was selling milkfish at a price lower than other fish (respondent also stated milkfish sells slower than other types of fish being sold); the price he was selling other fish was SBD 40/kg, while milkfish was being sold at SBD 30/kg. One vendor stated that he was selling milkfish at a price higher than other fish (although he stated that it sells slower than other types of fish). He normally sells his fish at SBD 32/kg (regardless of the size of individual fish); however, he did not disclose the higher price at which he

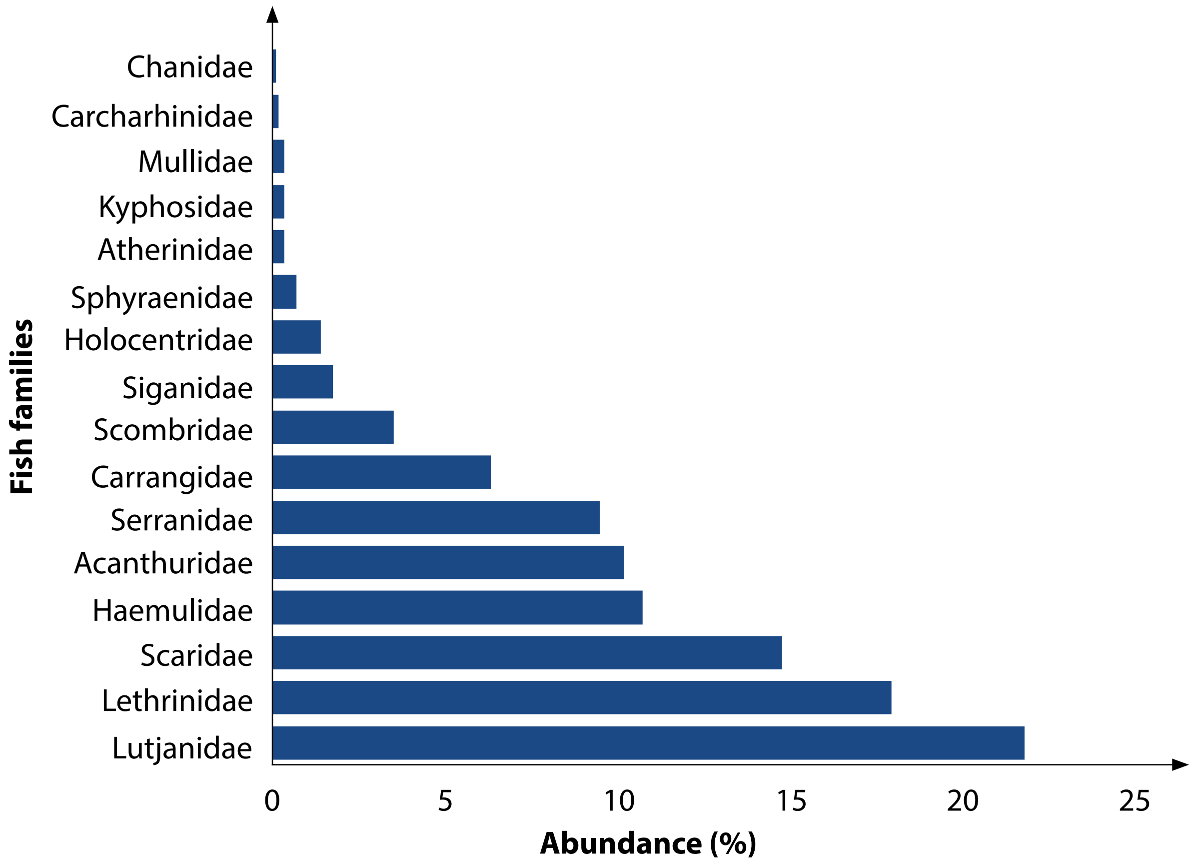


Figure 17. Abundance of fish families at the Honiara fish markets (does not include brine-treated frozen fish—locally called salt fish and obtained from commercial tuna fishing boats).

normally sells to customers who prefer milkfish. Among all the markets surveyed, the price of the fish in general normally declines the longer they are at the market. Vendors reported that higher prices would normally be charged on arrival but be reduced by 10%–15% either in the afternoon or on the next day. In some cases the oversupply of fish at the markets results in selling for lower prices on arrival at the market.

Fourteen vendors responded that milkfish was selling slower than other fish, three vendors reported that it was selling faster than other fish, and two vendors responded that milkfish was selling at the same rate as other fish.

The size range of milkfish observed during the survey was 13–93 centimeters (cm) in total length (mean: 68 cm). On two occasions milkfish of size 40–50 cm dominated as the main fish type (more than 80%) of two cooler boxes from Russell Islands; estimated total fish weight for each of these cooler boxes was approximately 95 kg.

According to milkfish vendors, the ethnic groups that normally buy milkfish are those from North Malaita, Tikopia, Western Province, Isabel and Guadalcanal, as well as Asians and Kiribati Solomon Islanders.

Summary of market analysis

Milkfish (Chanidae) availability at fish markets in Honiara is generally low compared to other fish families. Survey results indicate that the main supply to the Honiara market comes from Russell Islands, mostly by people from Lau Lagoon who reside in Russell Islands. The price at which milkfish sells at Honiara markets is generally the same as for other fish families; however, the rate at which it sells is generally slower, indicating that milkfish may be at the lower end of buyer preference.

Brief interviews with some buyers at the Honiara markets indicate that people were generally aware of milkfish and know about it. According to a fish buyer from Nggela, one of the reasons he chooses not to buy milkfish was because of the "intertwined and intricate embedding of the bones within the flesh, which makes eating the fish difficult," while a buyer from Areare (Malaita) stated that milkfish was generally not consumed by his tribe due to traditional tribal beliefs (other people in Areare, however, do consume it). Despite what seems to be a generally low acceptance of the fish (based on selling rate), there is clearly a niche market for it, especially among certain Solomon Islands ethnic groups and some of the resident Asian population. The perception of a woman from Isabel (Kia) and another from Malaita (Lau Lagoon) was that milkfish was a preferred fish due to its distinct flavor and oily taste that is normally not present in other fish types; their preferred fish size was 35 cm total length and bigger (as the boniness was a greater issue with smaller fish). A Malaita inland fish farmer, who had previously never tasted milkfish, commented after consuming fish from the pond used in an on-farm trial that milkfish had a distinct delicious oily flavor and bones were not an issue, as they were fairly manageable: "The bones were quite soft after cooking in the stone oven (*motu*) so it was not a problem."

The general conclusions from the market survey were the following:

- Milkfish is less common in local fish markets compared to other reef fish types.
- The size of milkfish at the Honiara markets ranged from 13 to 93 cm in total length.
- Milkfish in general sells at the same price as other fish but appears to sell at a much slower rate.
- The main source of milkfish supply to the Honiara market is Russell Islands, with some coming from Nggela, Marovo (Western Province), Marau (Guadalcanal), Kia (Isabel) and Lau Lagoon in Malaita.

INPUTS FOR GROWTH OF MILKFISH IN SOLOMON ISLANDS

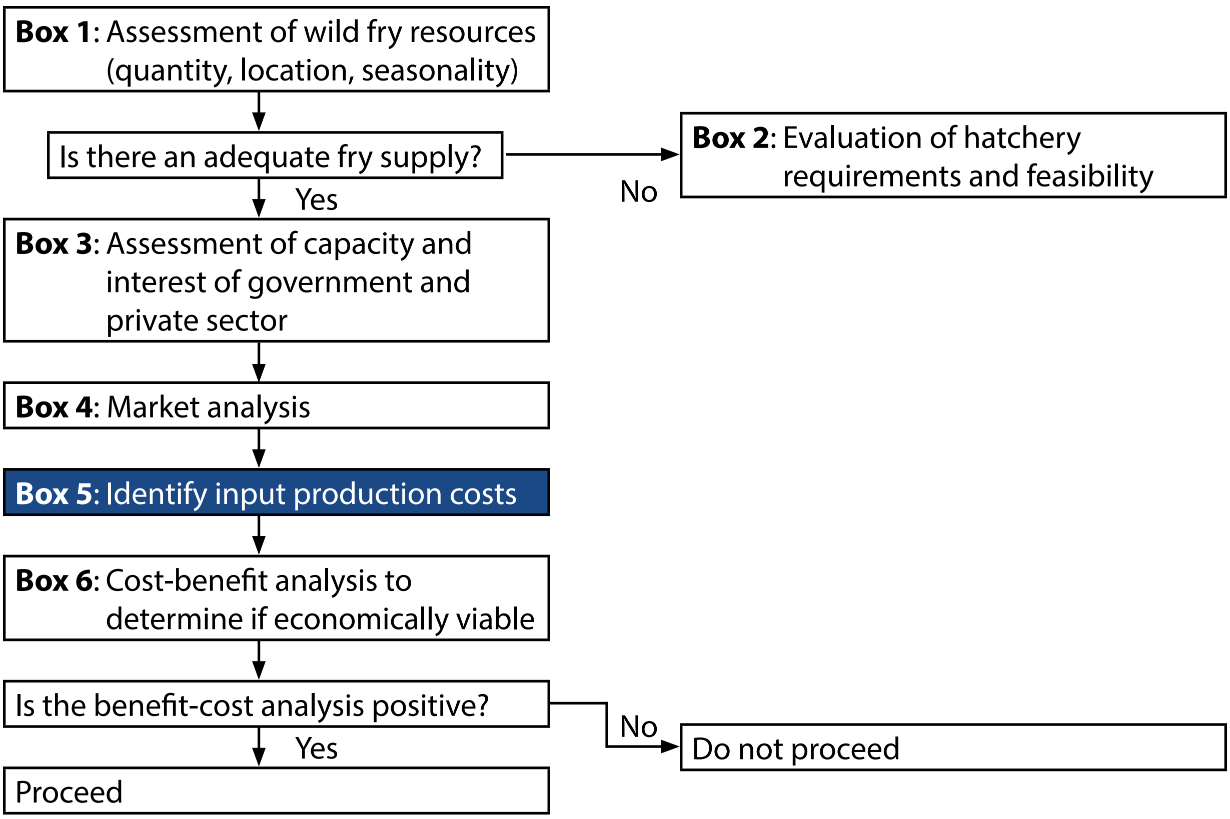
This section of the report is based on trials conducted in Solomon Islands between 2012 and 2014. It covers the nursery phase for wild-caught fry and the growth of fingerlings in land-based tanks, followed by the grow-out in farmer ponds. The results provide contextualized input costs for Box 5 of the feasibility assessment (Figure 1) and the enterprise-level economic analysis of milkfish aquaculture.

Growth trials in land-based tanks

Methods: Fingerling feed

Nursery husbandry was carried out at Nusatupe Research Station and at MFMR in Honiara. Capacity in the WorldFish and MFMR technical teams for growing milkfish through the nursery stage was built through hands-on training by Eric Basco (a milkfish consultant from the Philippines). Milkfish fry (10–15 millimeters [mm] total length) were nursed for 2–3 weeks in small basins (5 liters) and fed egg yolk (Lim et al. 2002) until they were fully developed and reached a total length of ≥ 19 mm. Fully developed milkfish that attained a total body length of ≥19 mm were transferred either to experimental tanks or into large (20 metric tons) stunting tanks (35 ppt) where they were stocked at high densities and fed a locally formulated feed at below optimum levels to stunt or slow growth (Bombeo-Tuburan and Gerochi 1988), a technique used to maintain fish until they can be transferred to farms for grow-out trials. Some milkfish fingerlings kept in stunting tanks at Nusatupe were later used in on-farm trials in Gizo, while those in stunting tanks in Honiara were used for on-farm grow-out trials in Malaita.

The key determinants of growth[4] of fish include environmental conditions (e.g. water quality) and the quality and quantity of feed. At Nusatupe, growth trials on milkfish were conducted to test the performance of two variations of a locally formulated feed against a commercial tilapia feed imported from Fiji and under different salinities. All three feeds contained 30% crude protein content (Table 5), calculated from published values from previous ACIAR-funded aquaculture feed projects[5] and other literature (Bautista et al. 1994; Gonzalez and Allan 2007).



Three replicates were set up for each treatment in a three-by-three design. A total of 30 fingerlings were randomly selected, measured and stocked in each tank containing 300 liters of water; all tanks used for the experiment were similar in type and dimensions. Stocking was done for all tanks on the same day. Feeding was done four times daily (at 07:00, 11:00, 14:00 and 16:30) for the duration of the experiment. The daily feeding rate for each tank was calculated as 10% of average fish body weight for a particular tank. Tank water was changed every 3 to 7 days depending on the water quality and water availability; water change was normally done for all tanks at the same time. A salinity of 20 ppt was maintained in all experimental tanks. Water temperature and salinity were monitored daily. The length and weight of fish were measured on days 0, 21, 49, 70, 97, 118 and 142. Fish mortality occurred during the course of the experiment; hence the total number of milkfish at the end of the experiment was less than the number at the beginning of the experiment. Growth differences between fish fed the different feed types were analyzed using ANOVA. Differences were considered significant at $p < 0.05$.

Results: Fingerling feed

All three feeds effected positive growth for milkfish over the experiment period (Figures 18 and 19). Although feed 2 appeared to produce the highest mean total length and weight, followed by feed 1 and then feed 3 (Table 5), these apparent differences were not statistically significant.

Methods: Effects of salinity on growth

The experimental design was an unbalanced one, with three tanks at a salinity of 0 ppt, two tanks at 20 ppt and one tank at 35 ppt. About 100 fingerlings were measured and stocked in each tank containing 2000 liters of water; all tanks were similar in type and dimensions. All the tanks were stocked on the same day and fed the same type of feed (feed 1) four times daily (at 7:00, 11:00, 14:00 and 16:30) for the duration of the experiment. The daily feeding rate for each tank was calculated at 10% of average body weight of the fish in each tank. Tank water was changed every 3 to 7 days depending on the water quality and water availability; water change was normally done for all tanks at the same time. The length and weight of individual fish from each tank were measured for a subset of 30–32 milkfish on day 0 and approximately every 30 days thereafter, with the last measurement on day 124.

Results: Effects of salinity on growth

Milkfish demonstrated similar growth patterns at three different salinities (Figures 20–21 and Table 7). The highest growth rate occurred at 20 ppt, followed by 35 ppt and then 0 ppt, although these differences were not statistically significant. The lack of sufficient replicates as a possible reason for not detecting a statistically significant difference is acknowledged.

From the land-based tanks, attention moved to on-farm grow-out trials. There were two objectives of the farm grow-out trials: (i) to test fingerling survival during transport under local conditions and (ii) to test milkfish aquaculture under local farmer conditions using local feeds. The fish that had been retained in the stunting tanks were used for these trials.

Feed 1: Local ingredients with coconut oil retained		Feed 2: Local ingredients without coconut oil		Feed 3: Imported Fiji feed
Fish meal	44.1%	Fish meal	44.1%	Commercial tilapia imported from Fiji, which is corn based and has 30% crude protein content
Freshly grated coconut with oil retained	14.7%	Copra meal (oil has been extracted)	14.7%	
Rice bran	27.5%	Rice bran	27.5%	
Wheat flour	13.7%	Wheat flour	13.7%	

Table 5. Composition of feeds tested for growth performance.

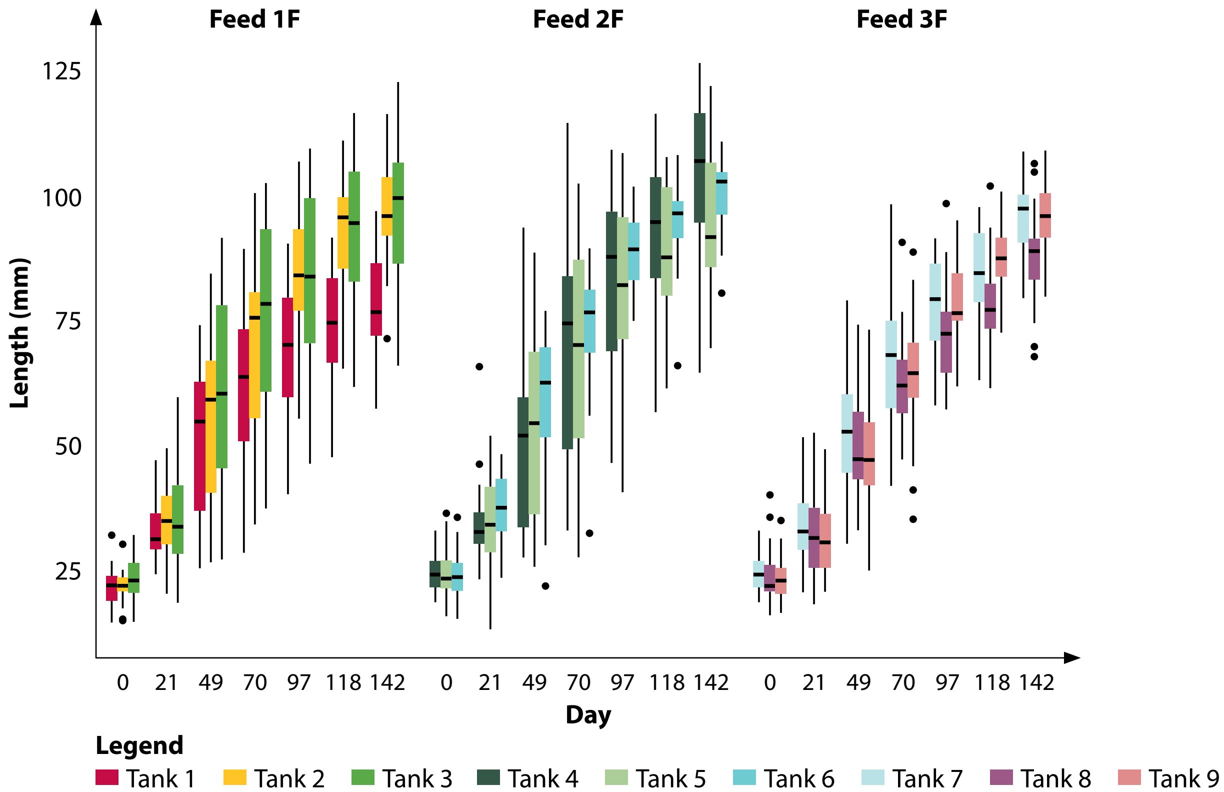


Figure 18. Box plot of milkfish fry growth, as total length, over 142 days.

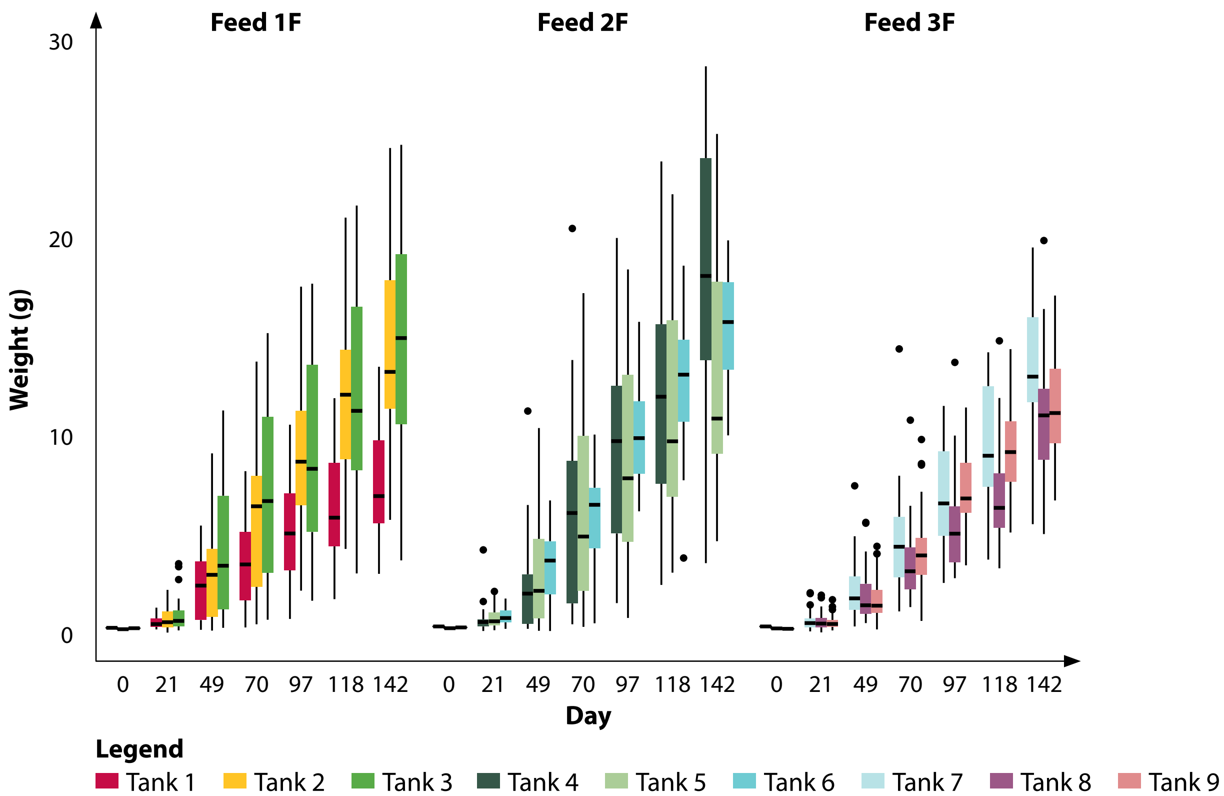


Figure 19. Box plot of milkfish fry growth as weight (grams [g]) over 142 days.

Feed 1: Local ingredients with coconut oil retained		**Feed 2: Local ingredients without coconut oil**		**Feed 3: Imported Fiji feed**	
Initial mean length (mm)	Final mean length (mm)	Initial mean length (mm)	Final mean length (mm)	Initial mean length (mm)	Final mean length (mm)
22.1	88.3	24.1	98.3	23.6	61.4
Initial mean weight (g)	Final mean weight (g)	Initial mean weight (g)	Final mean weight (g)	Initial mean weight (g)	Final mean weight (g)
0.25	11.4	0.3	15.12	0.3	11.9
Mean daily change in length (mm/day)		Mean daily change in length (mm/day)		Mean daily change in length (mm/day)	
	0.5	0.6			0.3
Mean daily change in weight (g/day)		Mean daily change in weight (g/day)		Mean daily change in weight (g/day)	
	0.1	0.1		0.1	

Table 6. Changes in mean length and weight of milkfish fed three different feeds over 142 days.

0 ppt		**20 ppt**		**35 ppt**	
Initial mean length (mm)	Final mean length (mm)	Initial mean length (mm)	Final mean length (mm)	Initial mean length (mm)	Final mean length (mm)
25.8	101.2	21.7	119.2	18.5	105.8
Initial mean weight (g)	Final mean weight (g)	Initial mean weight (g)	Final mean weight (g)	Initial mean weight (g)	Final mean weight (g)
0.6	16.0	0.3	36.1	0.3	18.3
Mean daily change in length (mm/day)		Mean daily change in length (mm/day)		Mean daily change in length (mm/day)	
0.6		0.8		0.7	
Mean daily change in weight (g/day)		Mean daily change in weight (g/day)		Mean daily change in weight (g/day)	
0.1		0.3		0.1	

Table 7. Changes in mean length and mean weight of milkfish under different salinities over 124 days.

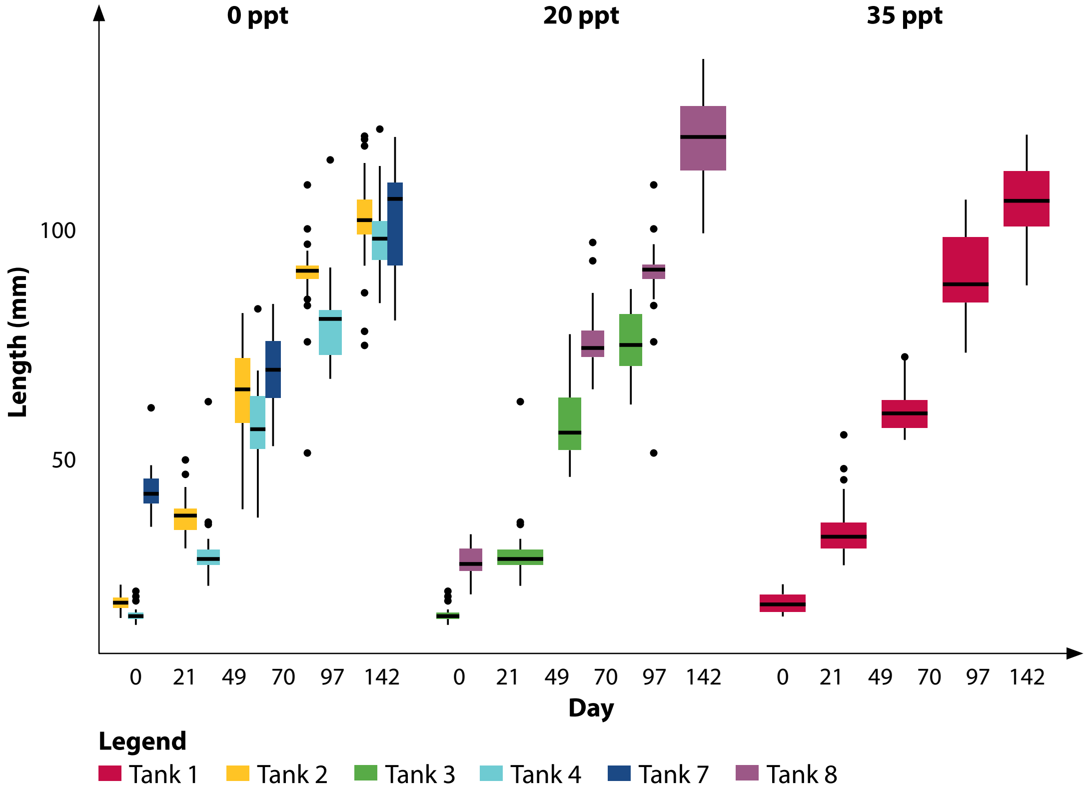


Figure 20. Box plot showing changes in milkfish total length (mm) in different salinity levels over 124 days.

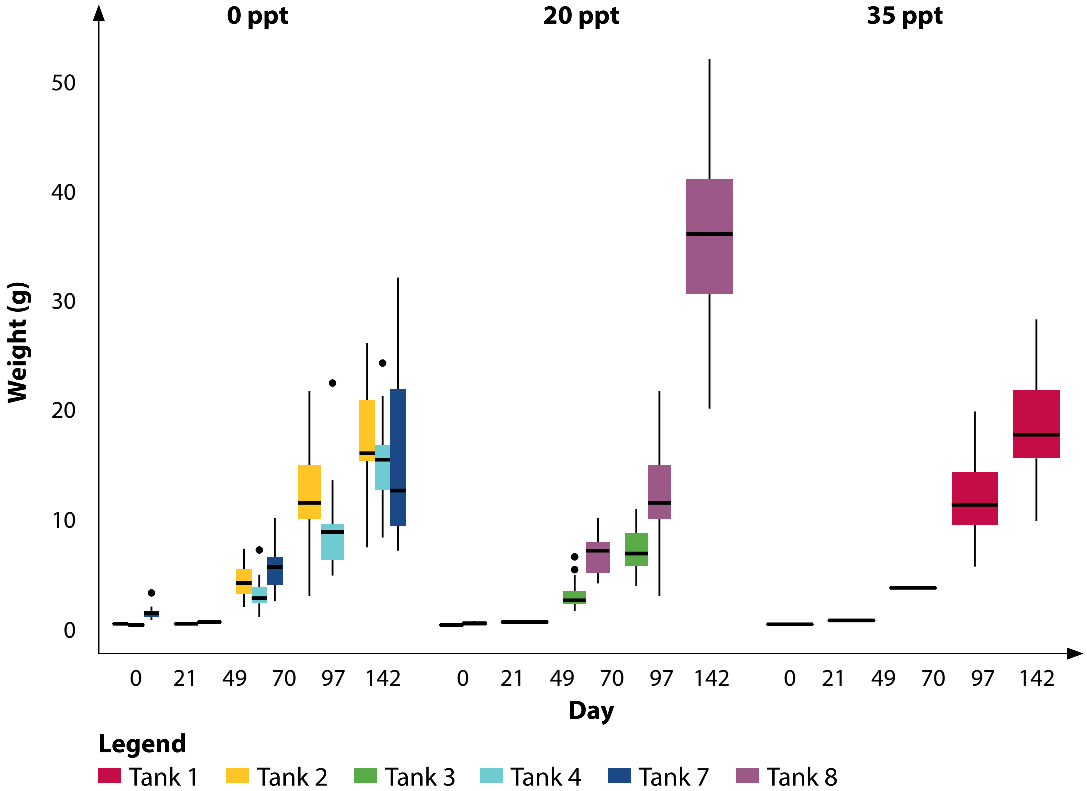


Figure 21. Box plot showing changes in milkfish weight (g) in different salinity levels over 124 days.

Fingerling transportation

Transportation time for fingerlings within the geographical range of the project varied from less than an hour in the case of fingerling shipment from Nusatupe Research Station to Gizo (hence no need for aeration) to several hours when fingerlings were transported from Honiara to Malaita (self-contained underwater breathing apparatus [scuba] tanks, which contain 21% oxygen, were used for aeration in this case).

Nusatupe to Gizo
Preparation began many weeks prior to transportation. Since most of the ponds designated for stocking were freshwater ponds, milkfish were slowly acclimatized to freshwater before transportation. Salinity was gradually lowered from 20 ppt in the stunting tanks to 0 ppt before transportation. As the travel time to Gizo was only 30 minutes, fingerlings were packed in plastic containers for transport. At the pond, the fish were acclimatized and placed into *hapa* nets, where they were left for observation for 3 days before being released. No fish mortalities occurred during fingerling transfer from Nusatupe to Gizo.

Honiara to Malaita
Preparation began several weeks before transportation. Salinity was gradually lowered from 20 ppt to 0 ppt and feeding was stopped 24 hours before transportation to minimize fish waste and associated degradation of water quality during transport. The size of fingerlings transported ranged from 60 to 80 mm.

On the day of transportation packing was done early in the morning, 2 hours before the ship departed for the approximately 5-hour journey from Honiara to Malaita. Fish were packed at a density of four pieces per liter in 2-liter plastic bags (i.e. eight pieces per plastic bag). The bags were aerated with a scuba tank (oxygen content 21%) and packed with ice in polystyrene boxes, which were sealed and transported to a fast inter-island vessel. Monitoring was done every 30 minutes and the bags were re-aerated if the fish showed signs of respiratory stress. Mortality for the first transfer was 4% and 17% for the second (Table 8). A likely contributing factor to a higher mortality in the second transfer was that no ice was used to cool the fish during the transfer—average air temperature in Solomon Islands ranges from 28 to 30 °C.

Farm grow-out

Grow-out trials were done with three local farmers in Malaita who were farming Mozambique tilapia in Anamose, Barasioro and Ura. One pond on each farmer's land was stocked with milkfish. Initially it was proposed to monitor growth every 80 days for up to 12 months. Logistics and farmer availability, however, did not allow us to keep to this schedule. Furthermore, growth monitoring at each farm was reduced after the second monitoring caused mortality from handling stress. The results presented here are from the two monitoring occasions. The farmer at Anamose fed his fish pig feed (mill run) mixed with scraped coconut and some salt (pounded together and then sun dried). The farmers at Barasioro and Ura both used mainly grated coconut and termites (Table 9).

Growth rates of fish at the three sites varied (Table 10) between 0.01 g/day and 1.1 g/day. Milkfish were subsequently harvested and consumed by the farmers at Barasioro and Ura, who stated that the final total length of the milkfish at harvest was between 30 and 38 cm (about 500 g), 9 months after stocking. The pond at Anamose produced the lowest growth, as the farmer was polyculturing milkfish with Mozambique tilapia and a significant increase in the Mozambique tilapia population over the monitoring period appeared to result in intense competition with milkfish for food. Milkfish in the Anamose pond remained stunted and had still not been harvested as of the time of writing.

Packing of fingerlings into plastic bags.

When filling a bag with water, ample space is allowed for aeration.

Aeration using a scuba tank (oxygen content 21%).

Sealing and packing into polystyrene boxes.

Packing with ice (frozen water bottle) in between plastic bags containing fish.

Re-aeration on arrival at Auki before transporting to farmers' ponds.

Date of transfer	Total fingerlings transported (pieces)	Duration of transportation from packing to release in ponds (hours)	Number of fingerlings dead	Mortality rate (%)
1 July 2013	128	7	5	4
24 July 2013	128	7	22	17

Table 8. Details of fingerling transfer from packing to release in ponds.

Farmer	Location	Pond dimensions in meters (length x width x depth)	Number of fingerlings stocked	Fingerling size range at stocking (mm)	Feed used
A	Anamose	10 x 8 x 1.5	173	50–70	Pig feed mixed with scraped coconut and some salt
B	Barasioro	10 x 10 x 1.5	34	60–80	Scraped coconut and termites
C	Ura	8 x 5 x 1.5	44	60–80	Scraped coconut and termites

Table 9. Details of stocking at farmers' ponds.

Date	Total fingerlings in pond	Days since initial stocking	Average body length (mm)	Average body weight (g)	Growth rate (g/day)
Anamose					
1 July 2013	44	0	70	4.5	-
5 November 2013	173[6]	127	112.4	11	0.05
19 Feb 2014	173	233	123.3	20	0.01
Barasioro					
24 July 2013	34	0	80	4.5	-
31 October 2013	29	99	242	112	1.1
19 February 2014	29	210	247	110	0.5
Ura					
24 July 2013	44	0	80	4.5	-
31 October 2013	25	99	232.5	104	1.0

Table 10. Milkfish growth data for the different ponds at different monitoring dates.

ENTERPRISE-LEVEL ECONOMIC ANALYSIS OF MILKFISH AQUACULTURE

Trials of wild milkfish fry collection, nursery rearing and grow-out in earthen ponds showed that milkfish aquaculture in Solomon Islands is technically possible. However, active uptake at subsistence or commercial levels depends on farmer confidence of net benefit or profit. Business modeling was conducted to determine the economic viability of milkfish farming at an enterprise level (Box 6, feasibility assessment, Figure 1). Importantly, the fry collection and farming trials provided reliable, locally relevant information on which to base the modeling, meaning that there is relatively high confidence in the resulting model outputs.

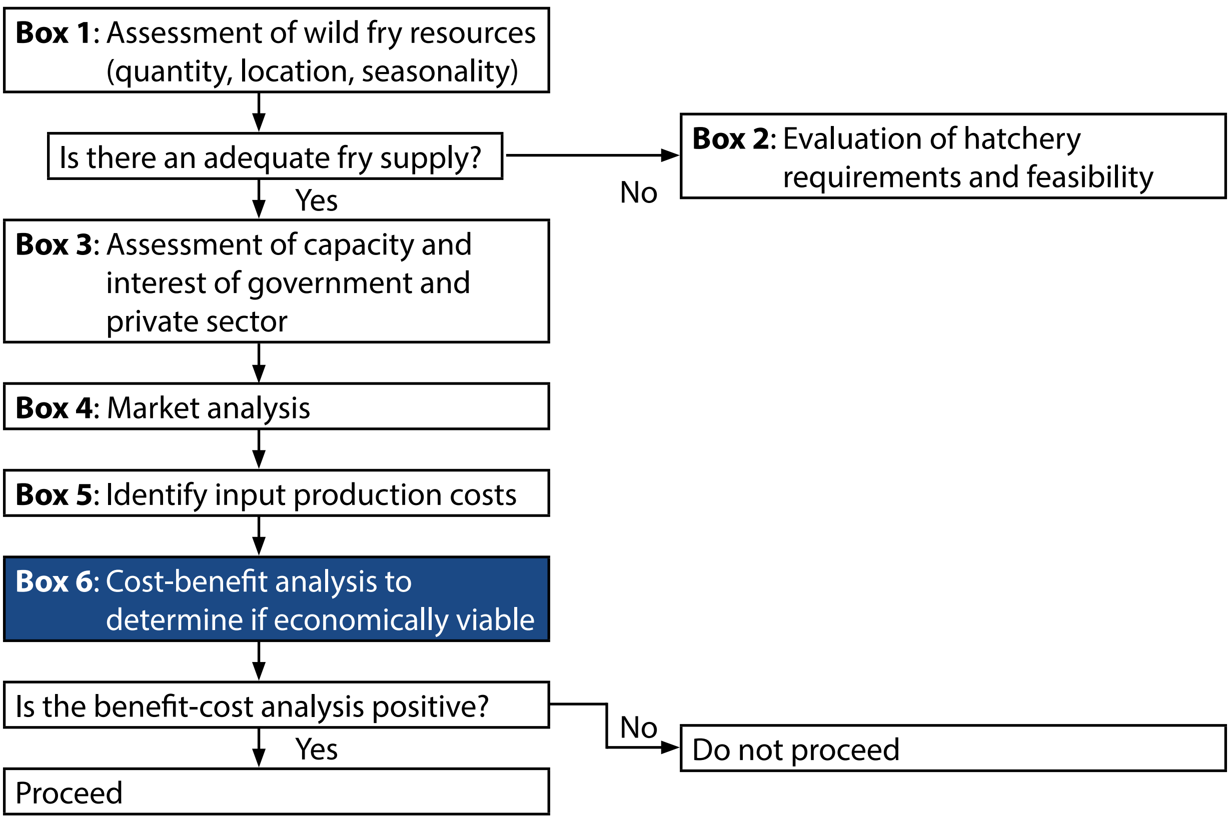
A number of farming scenarios were modeled, ranging from household-level subsistence farming to small-, medium- and large-scale commercial milkfish farming. Subsistence Mozambique tilapia (*Oreochromis mossambicus*) farming (as currently practiced in Solomon Islands) and small-scale commercial Mozambique tilapia farming were also modeled for comparison. Although not a commercially productive species, Mozambique tilapia is commonly cultured at a small-scale subsistence level in some parts of Solomon Islands.

In selecting the scenarios, some key factors likely to affect economic viability were explored, including the following:

- the commercial or subsistence nature of the farming activity;
- the size of the farm (pond area);
- the distance to the fry resource;
- whether the farmer had to pay to access that fry resource.

Of the several scenarios modeled, four milkfish farming scenarios and two Mozambique tilapia farming scenarios are reported:

- subsistence milkfish aquaculture
- small-scale commercial milkfish aquaculture
- medium-scale commercial milkfish aquaculture
- intensive large-scale commercial milkfish aquaculture
- subsistence Mozambique tilapia aquaculture
- small-scale commercial Mozambique tilapia aquaculture.



Economic analysis method

A spreadsheet-based benefit-cost analysis modeling tool developed by Bill Johnston[7] was used to assess the economic feasibility of farming operations. The model used discounted[8] cash flow analysis to determine the following economic parameters:

- annual gross revenue
- annual cost of production
- average cost per kg of fish produced
- revenue per kg of fish produced
- net present value[9]
- annual return
- internal rate of return
- benefit-cost ratio
- payback period.

Within the annual cost of production, the model outputs included the cost structure in terms of the cost of purchasing or collecting fry, nursery feed, farm labor, fuel and energy, repairs and maintenance, other operating costs, marketing costs, and the cost of capital. The model assumed a farming cycle of 1 year (12 months) from fry collection through harvesting for a total farming period of 20 years and used a real discount rate of 5% to calculate the net present value. The model also applied Monte-Carlo simulation to determine the probability of making a profit (and the risk of making a loss) for production and fish price, based on expert judgment.

Model inputs for the various scenarios were largely informed by the small-scale milkfish farming trials in this report and assumptions based on experiences of milkfish aquaculture in Palau and the Philippines.

All dollar values reported are in Solomon Island dollars (SBD).

Modeling was initially conducted during a 2-day workshop with participants from MFMR and WorldFish. The models were refined and updated with more accurate input data after the workshop.

Farming scenarios and assumptions

Scenario 1: Small-scale subsistence milkfish farm

This scenario was based on a household farm situated close to a wild milkfish fry resource where the farmer collects fry after paying the resource owner. Following collection, fry are nursed in buckets or small ponds of 1 m^2 for about a month to fingerling size before being transferred to two earthen ponds, which are 54 m^2. Farming is primarily for household consumption, with 20% of harvest being sold at the farm gate.

Labor costs were considered zero, as members of the household would do farm work. Two family members would need to work for 2 hours per day for 270 days (9-month production cycle) for grow-out, as well as one person for 1 hour per day for a month during the nursery phase, plus time taken for fry collection. No opportunity costs were applied to these times, as it was assumed that alternative employment opportunities would be scarce.

Feed costs were also assumed to be zero, as the fish would rely on natural food from a fertilized pond, household scraps and other readily available feeds around the farm such as termites. A relatively high food conversion ratio was applied to calculate growth rates and associated farm production.

The 80% of fish consumed by the household was attributed a replacement value based on cost of fish purchase from the market.

A full list of modeling input values is provided in Appendix 1.

Scenario 2: Small-scale commercial milkfish farm

The small-scale commercial milkfish farm scenario is similar to the subsistence farm scenario in that it has the same pond dimensions, is located close to the fry resource, the farmer has access to fry from that resource, and the farm uses the same fry collection, nursery and grow-out methods as scenario 1. However, given its fully commercial nature (where all production is sold at farm gate), it was assumed that the farm would use commercial feed and use external paid labor in addition to the free family labor. A full list of modeling input values is provided in Appendix 2.

Scenario 3: Medium-scale commercial milkfish farm

This scenario was based on a farm situated close to where wild milkfish fry can be collected by the farmer after paying the resource owner. The farm has six earthen ponds, each 100 m^2 in size. As before, after collection, fry are nursed in buckets or small ponds for about a month to fingerling size before being transferred to the earthen ponds. The farm uses commercial feeds and extensive external labor. Family labor also needs to be paid for. Stocking of ponds would be staggered through the year to manage the increased demands for fry collection and transport of harvested fish to market.

It was assumed that all products would be sold at a local market approximately 10 km away (as opposed to selling at the farm gate as per the previous scenarios). A full list of assumptions and input values is provided in Appendix 3.

Scenario 4: Large-scale commercial milkfish farm

This scenario is based on the currently disused aquaculture site at Ruaniu (west of Honiara) that was previously used for prawn farming. There are ten 1-hectare-sized ponds. It was assumed the site would be rehabilitated and used for commercial milkfish farming. It was also assumed that the farm would rely on purchasing fry from overseas commercial hatcheries in Taiwan or Indonesia (given the large numbers of seed needed for stocking) and a workforce of professional farm staff and casual labor. Although there would be considerable savings in terms of start-up costs given the use of an existing pond infrastructure, there would be a considerable capital outlay of over SBD 3 million. A full list of modeling input values and assumptions is provided in Appendix 4.

Scenario 5: Small-scale subsistence Mozambique tilapia farm

The Mozambique tilapia subsistence farming scenario was based on a household farm with two earthen ponds, each 54 m^2 in size (as applied to the small-scale milkfish farm scenario). Labor costs were considered free and opportunity costs of household labor were not taken into consideration.

Juveniles would normally be collected from streams or purchased from another farmer (typically about 10 pieces for SBD 10) and allowed to breed to populate the ponds. For modeling, it was assumed that each pond would be partially harvested every 4 months, although current practices suggest that in reality there would be more frequent harvests of smaller amounts of fish. Since Mozambique tilapia characteristically has early onset of sexual maturity and a prolific reproductive rate, restocking would not be required until after 3 years, when the pond would need to be emptied, dried and repaired before restocking. Farming is primarily for subsistence purposes, with only 20% of harvest sold at farm gate. Where fish are sold, selling price is SBD 1 a piece for a 12-g fish. A full list of modeling input values is provided in Appendix 5.

Scenario 6: Small-scale commercial Mozambique tilapia farm

For the small-scale commercial tilapia farm scenario, the pond sizes were assumed to be the same as for the subsistence tilapia farm. However, based on what is currently practiced by some farmers, it was assumed that mono-sex culture (males are separated to enable fast growth) was practiced, some outside labor was hired to dig ponds, and additional capital costs were incurred in purchasing tools and equipment. Juvenile tilapia would be collected from streams or otherwise about 10 fish purchased from other farmers. Farming would be geared toward income generation through sales at farm gate, with only 20% of harvest retained for family consumption. Selling price was modeled at SBD 1 a piece for a 12-g fish. A full list of modeling input values is provided in Appendix 6.

Economic modeling results

Scenario 1: Small-scale subsistence milkfish farm

A small-scale subsistence milkfish farm would produce 65 kg of fish annually at a cost of SBD 820. The total annual gross revenue at SBD 30/kg would be SBD 1634, and the average production cost per kilogram of fish would be SBD 13.71 (see Figure 22 for distribution of production costs). As a business enterprise, this farm would have a benefit-cost ratio of 1.99 (for every dollar spent, SBD 1.99 will be derived in return). Given the minimal capital expenditure, the payback period would be 2 years, during which the cumulative cash flow would be negative (Figure 23). There would be a positive discounted cumulative cash flow from the third year onwards.

The net present value of the operation would be SBD 10,137 with an annual return of SBD 813. Risk analysis revealed there to be an 11% chance of making zero profit or a loss in any one year (Figure 24).

Scenario 2: Small-scale commercial milkfish farm
A small-scale commercial milkfish farm would produce 65 kg of fish annually at a cost of SBD 1704. The total annual gross revenue at SBD 30/kg would be SBD 1795, and the average production cost per kilogram would be SBD 28.48 (see Figure 25 for distribution of production costs). As an enterprise, this farm would have a benefit-cost ratio of 1.05 and a payback period of 17 years (Figure 26).

The net present value of the operation would be SBD 1135 with an annual return of SBD 91. Risk analysis revealed that there is a 73% chance of making zero profit or a loss in any one year (Figure 27).

Scenario 3: Medium-scale commercial milkfish farm
A medium-scale commercial milkfish farm would produce 332 kg of fish annually at a cost of SBD 8828. The total annual gross revenue at SBD 30/kg would be SBD 9975, and the average production cost per kilogram of fish would be SBD 26.55 (see Figure 28 for distribution of production costs). As an enterprise, this farm would have a benefit-cost ratio of 1.13 and a payback period of 11 years (Figure 29).
The net present value of the operation would be SBD 14,294 with an annual return of SBD 1147. Risk analysis revealed that there would be a 54% chance of making zero profit or a loss in any one year (Figure 30).

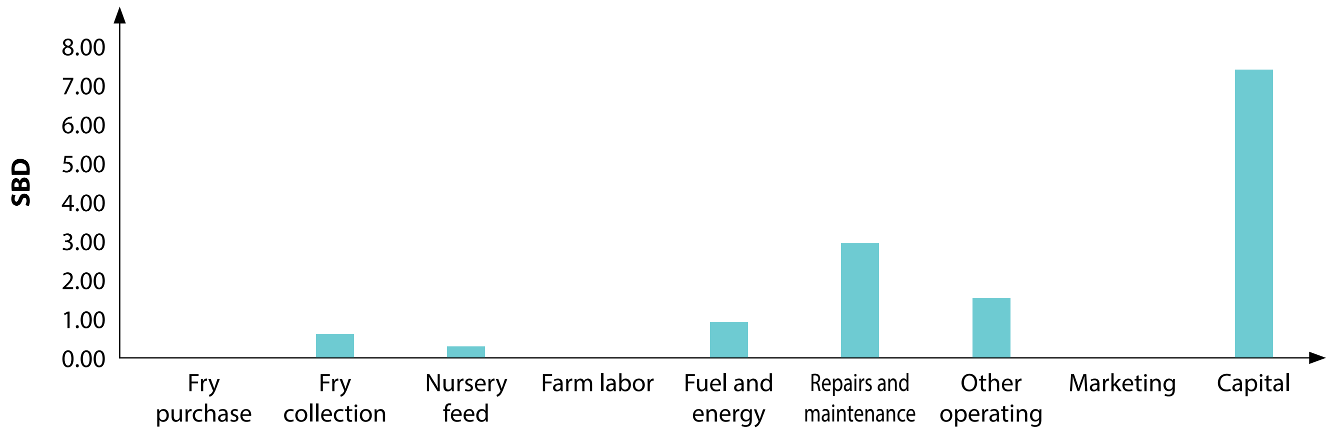


Figure 22. Distribution costs of producing 1 kg of milkfish in subsistence aquaculture scenario.

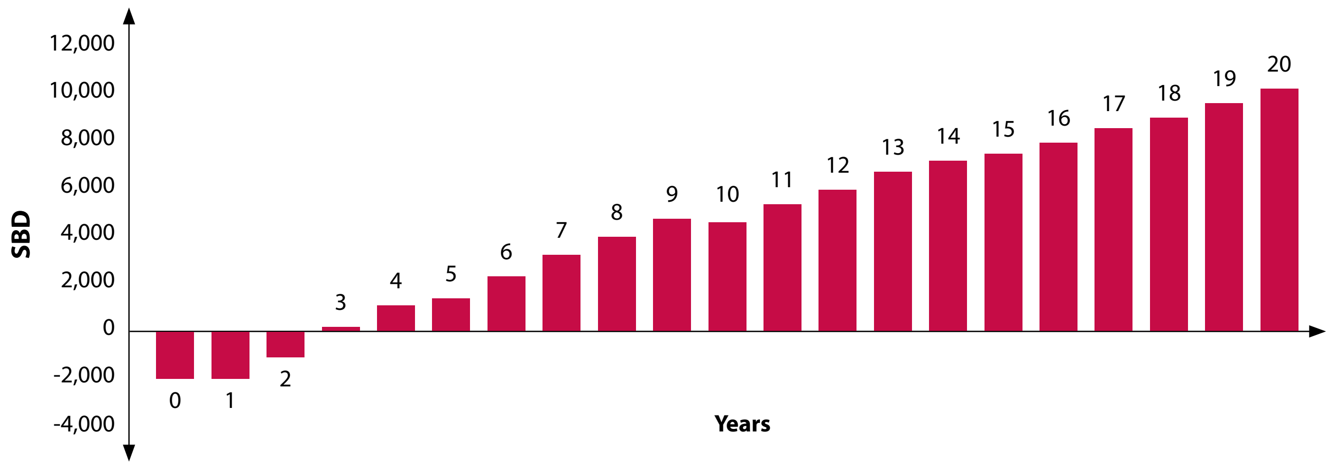


Figure 23. Discounted cumulative cash flow of a two-pond (108 m^2) subsistence milkfish aquaculture venture.

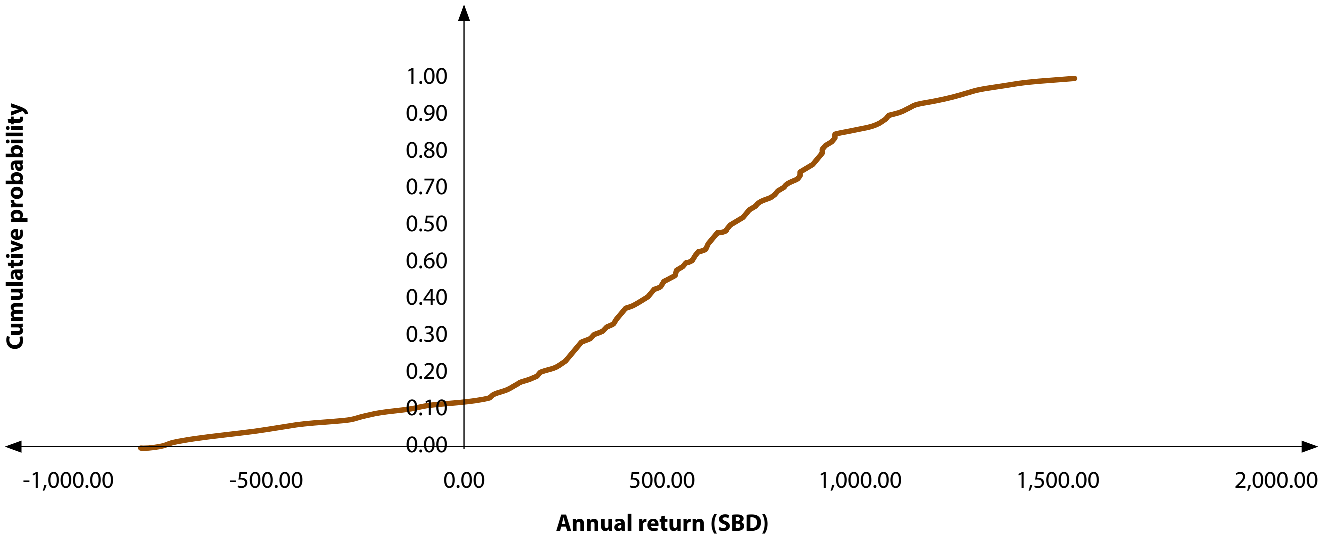


Figure 24. Cumulative probability distribution of risk analysis for subsistence aquaculture of milkfish.

Figure 25. Distribution cost of producing 1 kg of milkfish under a small-scale commercial aquaculture scenario.

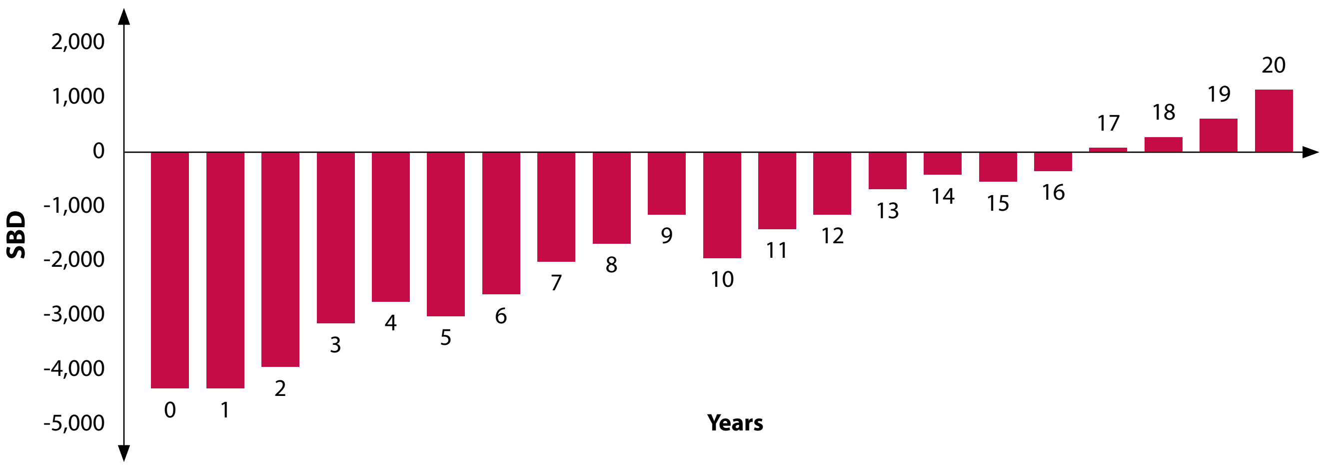


Figure 26. Discounted cumulative cash flow for small-scale commercial milkfish aquaculture scenario.

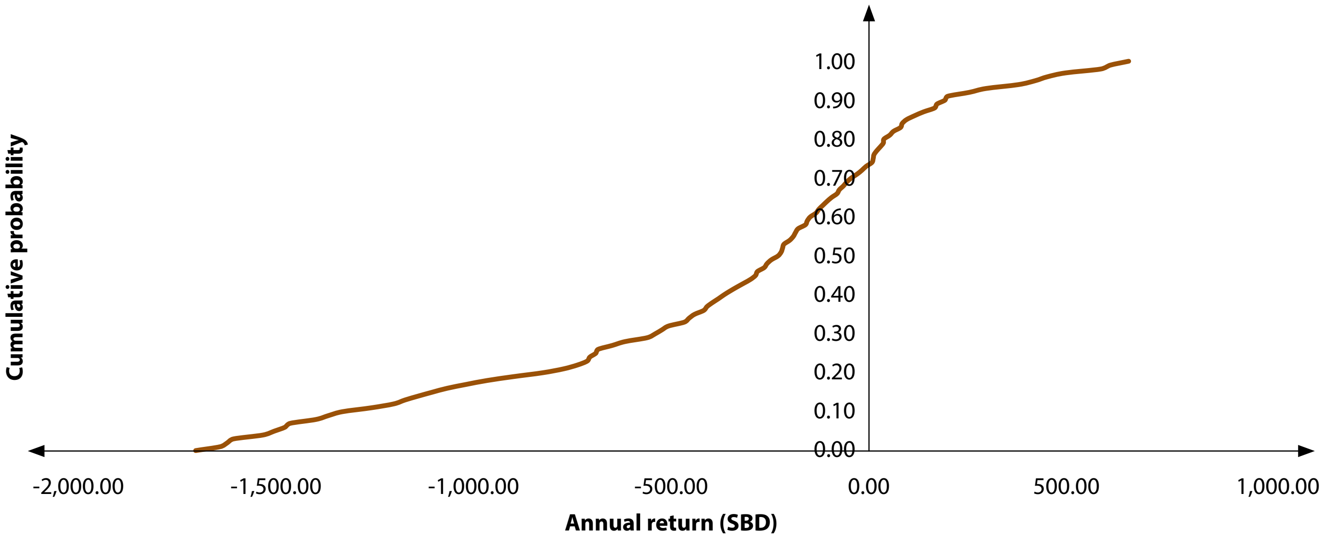


Figure 27. Cumulative probability distribution of risk analysis for small-scale commercial milkfish aquaculture.

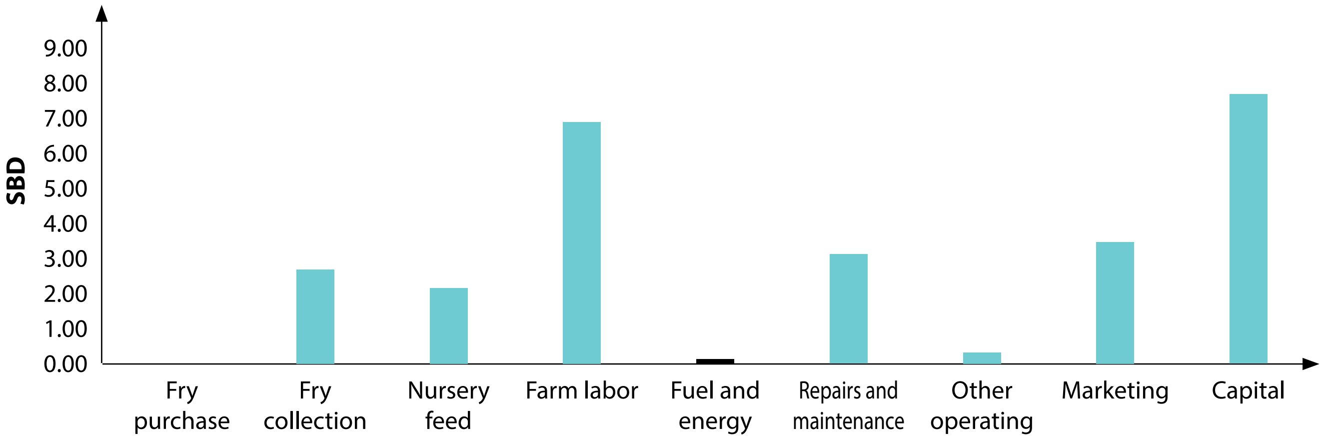


Figure 28. Cost structure of producing 1 kg of milkfish under a medium-scale commercial aquaculture scenario.

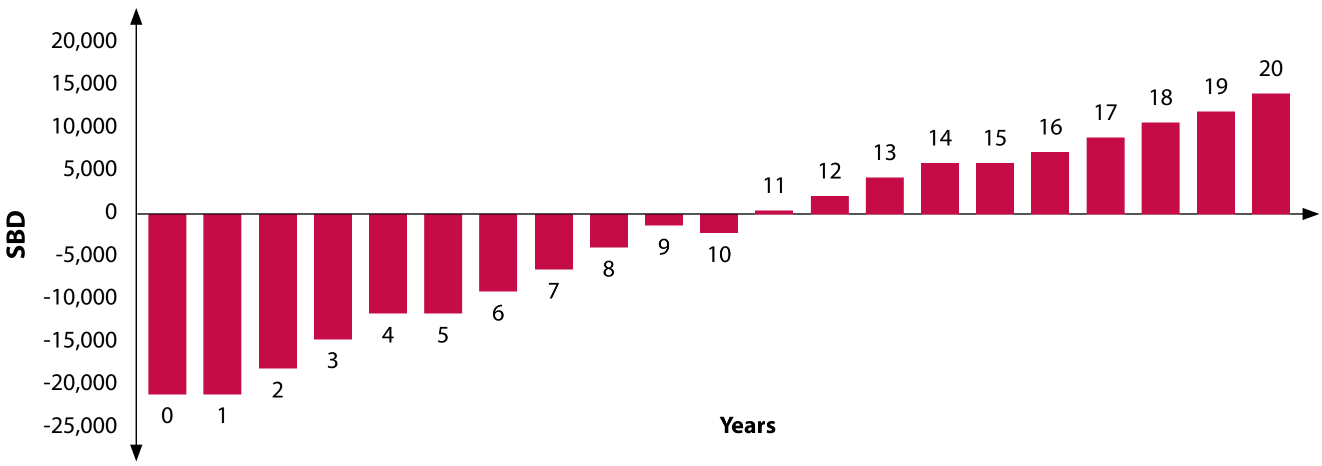


Figure 29. Discounted cash flow of a medium-scale commercial milkfish aquaculture venture.

Scenario 4: Large-scale commercial milkfish farm

A large-scale intensive commercial milkfish farm would have an annual production of 1.7 metric tons at a production cost of SBD 3.6 million. The total annual gross revenue at SBD 30/kg would be SBD 5.1 million. The average production cost per kilogram of fish would be SBD 21.41 (see Figure 31 for distribution of production costs). As an enterprise, this farm would have a benefit-cost ratio of 1.4. Given that the modeling assumed no significant pond-building costs, the payback period would be 2 years, during which the cumulative cash flow would be negative (Figure 32). Cumulative cash flow would be positive from year 3 onwards.

The net present value of the operation would be SBD 19.6 million with an annual return of SBD 1.5 million. Risk analysis revealed that there would be a 28% chance of making zero profit or a loss in any one year (Figure 33).

Scenario 5: Small-scale subsistence Mozambique tilapia farm

A small-scale subsistence Mozambique tilapia farm would produce 12 kg of fish annually at a cost of SBD 311. The total annual gross revenue (at the current market price of SBD 1 for a 12-g fish, which converts to SBD 83/kg) would be SBD 1021. The average production cost of a 12-g fish would be SBD 0.31, which converts to SBD 25.83/kg (see Figure 34 for distribution of production costs). As an enterprise, this farm would have a benefit-cost ratio of 3.28. The payback period would be 1 year, during which the cumulative cash flow would be negative (Figure 35). Cumulative cash flow would be positive from year 2 onwards.

The net present value of the operation would be SBD 8843 with an annual return of SBD 710. Risk analysis revealed that there would be a 10% chance of making zero profit or a loss in any one year (Figure 36).

Scenario 6: Small-scale commercial Mozambique tilapia farm

A small-scale commercial Mozambique tilapia farm would produce 12 kg of fish annually at a cost of SBD 806. The total annual gross revenue (at the current market price of SBD 1 for a 12-g fish, which converts to SBD 83/kg) would be SBD 984. The average production cost of a 12-g fish would be SBD 0.80, which converts to SBD 66.67/kg (see Figure 37 for distribution of production costs). As an enterprise, this farm would have a benefit-cost ratio of 1.22 and a payback period of 7 years, during which the cumulative cash flow would be negative (Figure 38). Cumulative cash flow would be positive from year 8 onwards.

The net present value of the operation would be SBD 2210 with an annual return of SBD 177. Risk analysis revealed that there would be a 10% chance of making zero profit or a loss in any one year (Figure 39).

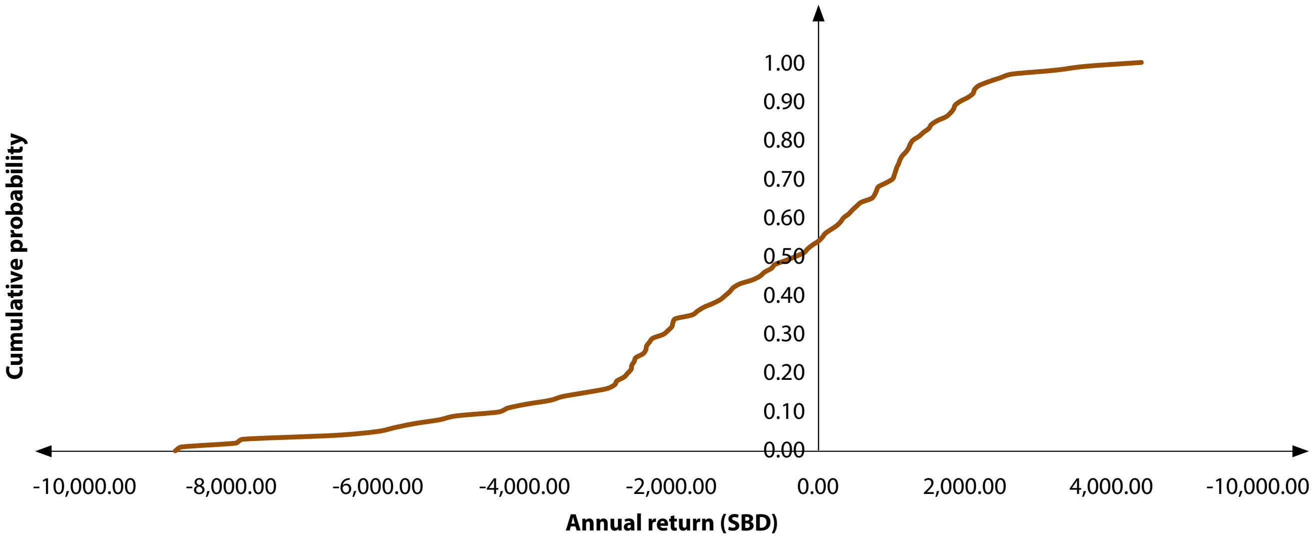


Figure 30. Cumulative probability distribution of the risk analysis for medium commercial-scale aquaculture of milkfish.

Figure 31. Distribution costs of producing 1 kg of milkfish under intensive commercial aquaculture.

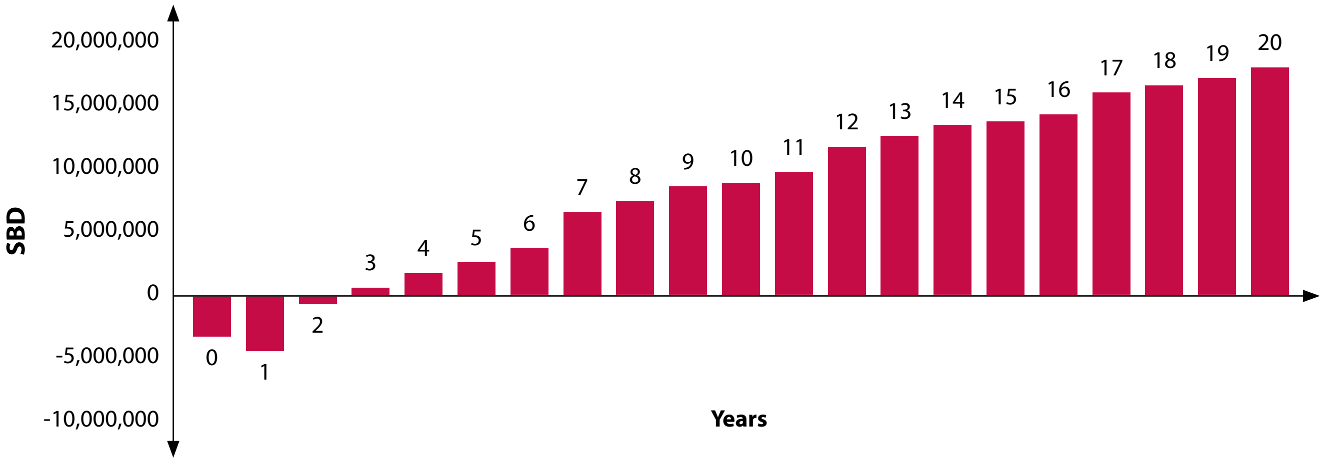


Figure 32. Discounted cumulative cash flow of milkfish aquaculture under an intensive commercial aquaculture scenario.

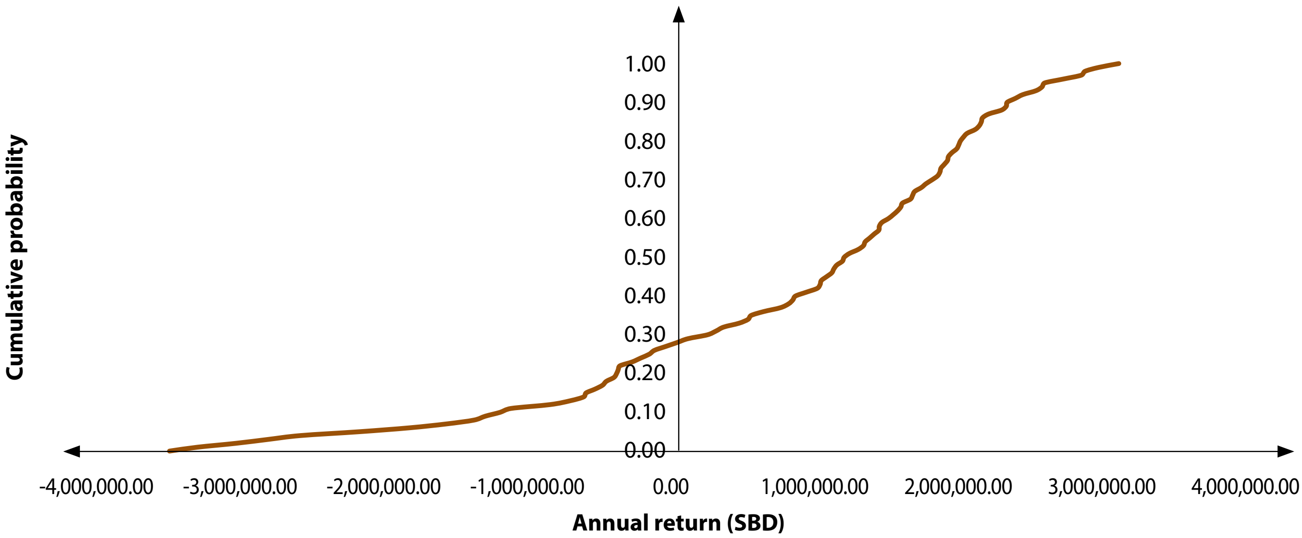


Figure 33. Cumulative probability of risks of an intensive commercial aquaculture scenario.

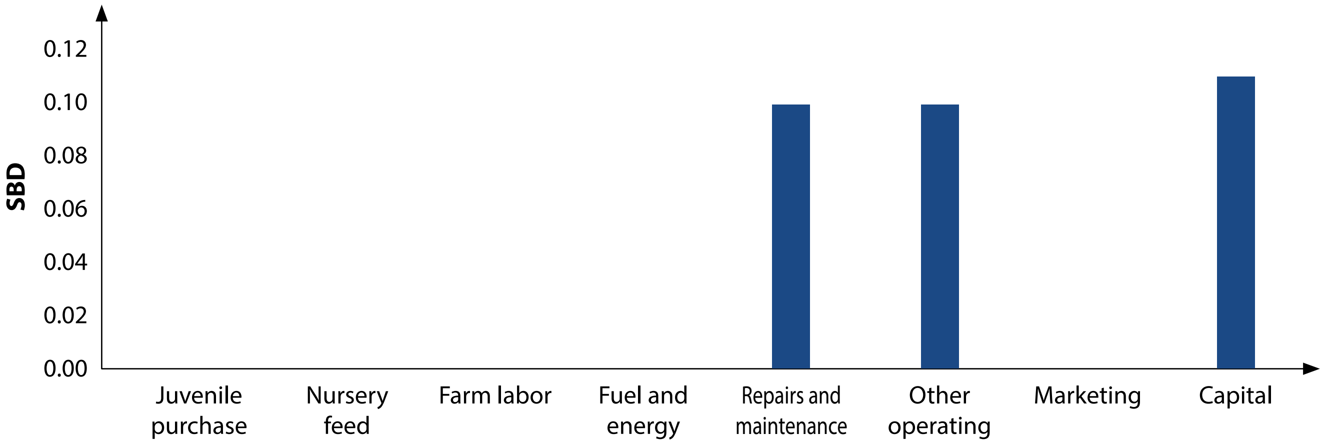


Figure 34. Distribution costs of producing 1 kg of Mozambique tilapia under a small-scale subsistence aquaculture scenario.

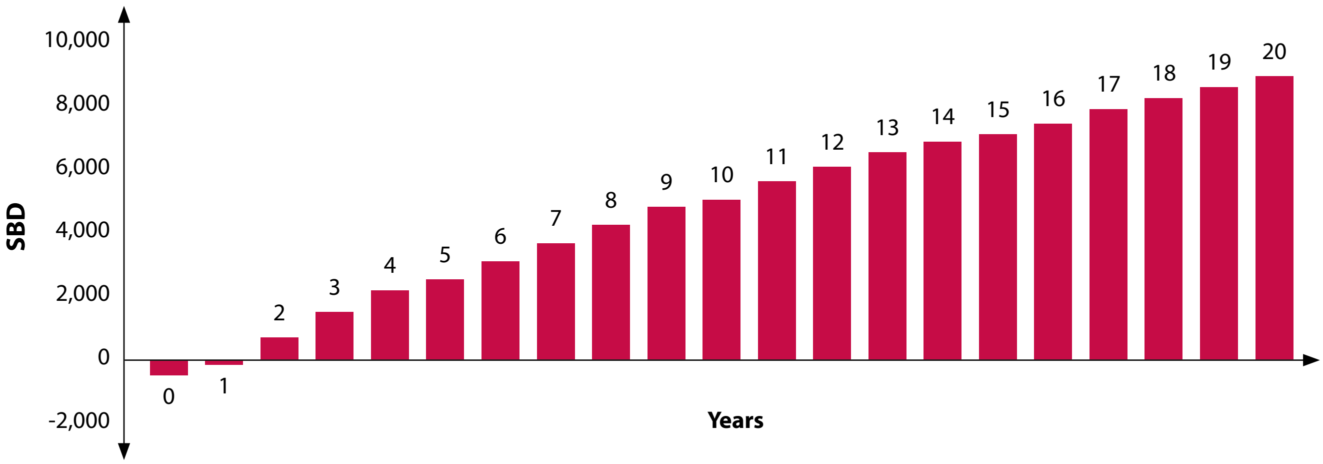


Figure 35. Discounted cumulative cash flow for a subsistence tilapia aquaculture undertaking.

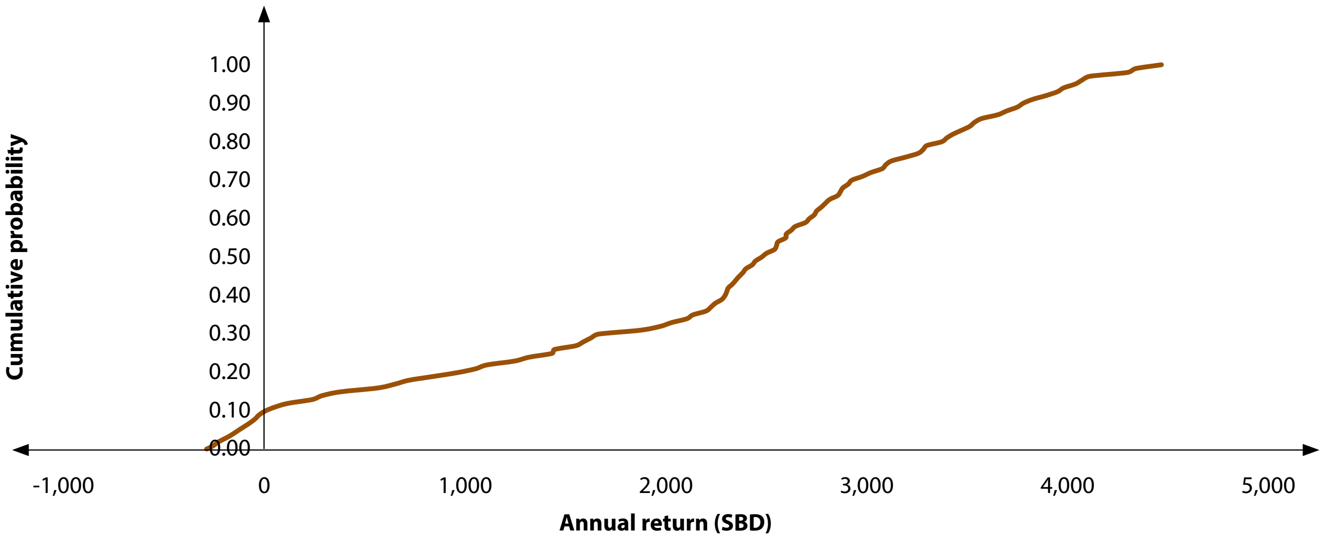


Figure 36. Cumulative probability of risks of a subsistence aquaculture undertaking.

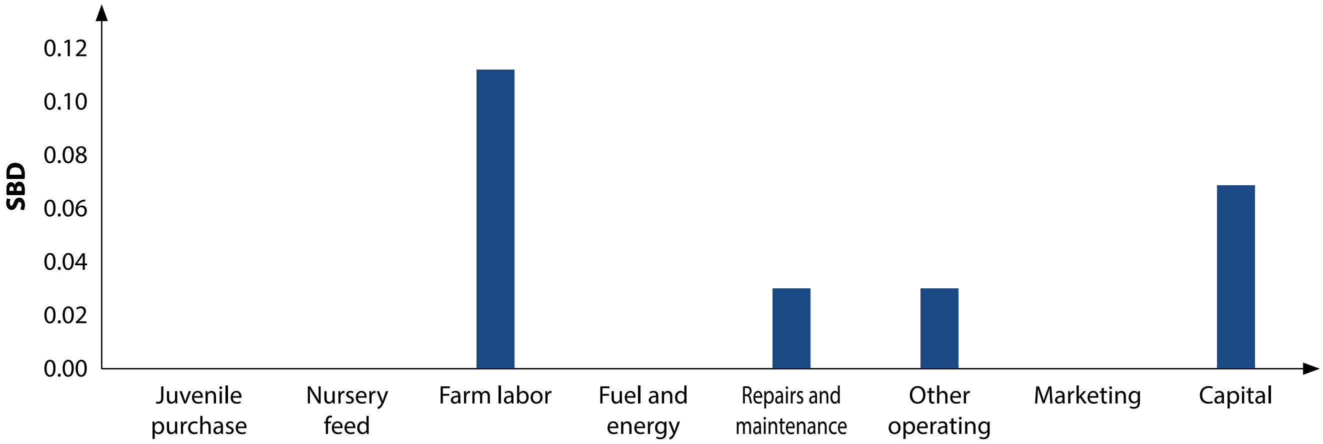


Figure 37. Distribution costs of producing 1 kg of Mozambique tilapia under a small-scale aquaculture scenario.

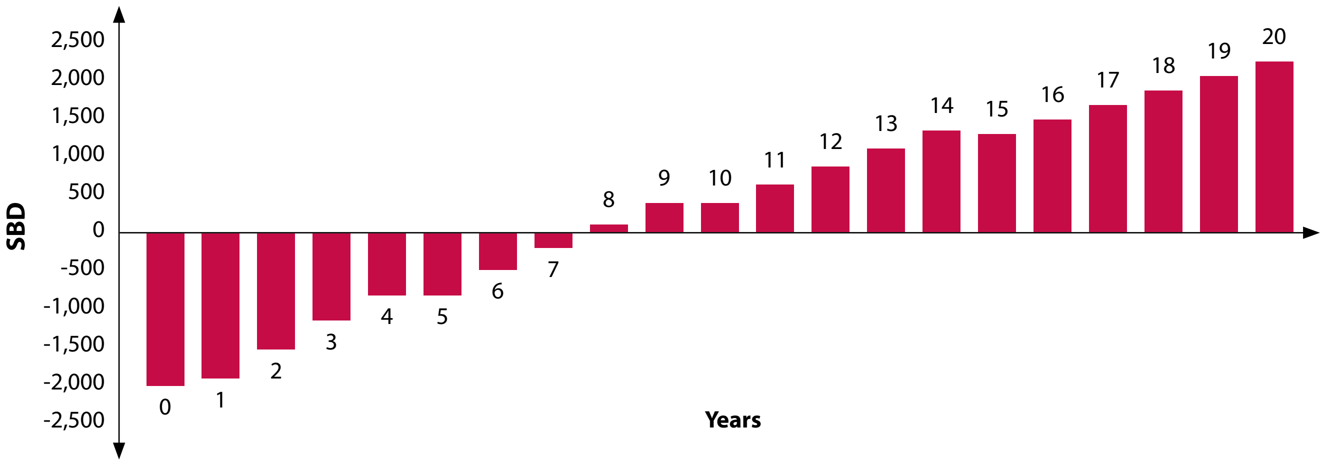


Figure 38. Cumulative cash flow for a small-scale commercial tilapia aquaculture undertaking.

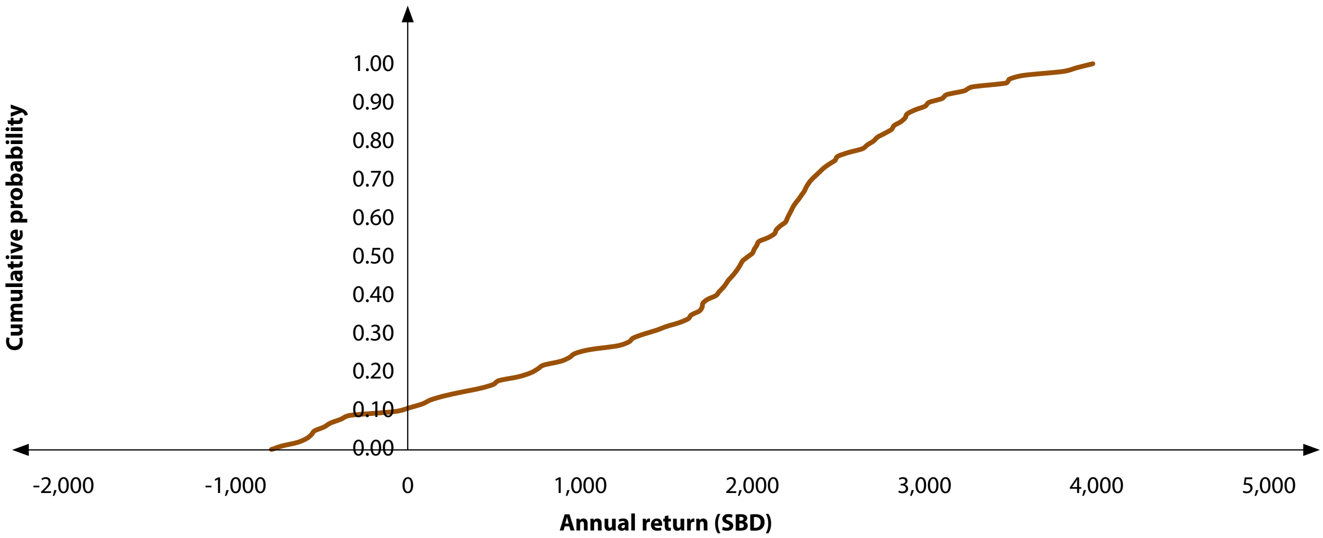


Figure 39. Cumulative probability of risks of small-scale commercial tilapia aquaculture.

FEASIBILITY ASSESSMENT AND CONCLUSIONS

This study has shown that milkfish farming is technically feasible in Solomon Islands. Milkfish fry are available from some coastal areas of Solomon Islands at certain times of the year, and they can be reared to a harvestable size using locally available resources and technologies. Further, milkfish can be grown in a range of salinities, from freshwater to seawater. It has also been demonstrated that formulated feed can be produced locally and could perform equally as well as imported feed.

There are some barriers, however. Milkfish fry may not necessarily be available at the quantities required from accessible locations to support widespread subsistence or commercial-level aquaculture. Customary ownership laws governing coastal marine waters also pose a potential barrier to a technically feasible opportunity. All of the sites where milkfish fry occur are on land and seabed that is under customary ownership, meaning that the resources (including milkfish fry) belong to someone who has the rights to control their capture and distribution. Considerable negotiation would be required to enable fry collection and distribution within and between provinces. Equally, supply of milkfish fry could represent a viable business opportunity for resource owners.

Modeling showed that low-input subsistence milkfish farming, where a proportion of the fish are sold at farm gate, could be economically viable—that is, if labor costs are assumed to be zero (i.e. if all work is undertaken by household members and the opportunity cost of this time is disregarded), the farm is situated close to a natural fry resource, and a dollar value is attributed to the fish eaten by the household. Leaving aside potential difficulties in ready access to fry resources, the benefit-cost ratio and production costs of such a subsistence milkfish farm compares well with subsistence farming of Mozambique tilapia (Table 11). However, this would not be the case if the farm is distant from the fry resource (as transport costs would be prohibitive) or if the opportunity cost of labor is taken into consideration.

Modeling also showed that the risk of breaking even or making a loss from commercial aquaculture ranged from 28% to 73% with payback periods of at least 3 years, small-scale commercial aquaculture being the least profitable. Payback periods and risks are reduced as the size of the farm increases and economies of scale are sufficient to make operations marginally profitable.

The net present value model used for economic modeling is linear and assumed a stable fish price with continuous absorption by the market as productivity increases. That is, no account was taken of the potential for decreasing sale price of milkfish in a market oversupplied by one or several medium- or large-scale commercial fish farms. Importantly, milkfish has a low consumer preference generally in Solomon Islands, as only a few ethnic groups know of and prefer it.

The costs of farming milkfish commercially would be high given the high costs of materials and labor in Solomon Islands. Furthermore, the upper limit of milkfish sale price is capped by the prices of wild-caught marine fish with which it competes on the market. Observations in Kiribati where milkfish is well known and preferred has shown that milkfish aquaculture has saturated the "milkfish as food" market and it is difficult to compete pricewise against wild-caught fishery products (FitzGerald 2004). It is quite likely that any significant level of milkfish aquaculture in Solomon Islands will follow a similar pattern, given the small niche market that it currently holds, against the diverse range of readily available capture fishery products. Given this low preference, the high capital investment required, and the low and uncertain profitability (due to fish price volatility and limited market demand), it is unlikely that there would be commercial interest in large-, medium- or small-scale commercial milkfish aquaculture in Solomon Islands.

The high business risks of commercial milkfish farming in Solomon Islands (73%, 54% and 28% likelihood of making zero profit or a loss in any one year for small-, medium- and large-scale milkfish aquaculture, respectively; see Table 11) are consistent with observations of milkfish farming in other Pacific Island countries. FitzGerald (2004) cites several reports stating that the government milkfish farm in Tarawa, Kiribati, which had been in operation for 25 years (as of 2004), is reported to perform below expectations and continues to make a net loss despite early optimism. Pickering et al. (2012) report a net financial loss in a semicommercial milkfish farm in Fiji, in part because half of the harvested fish were distributed free to local villagers. The report concludes that the operation could be profitable if operated on a fully commercial basis, although this modeling did not take into consideration the cost of labor.

Despite its low productivity and small maturation size, several characteristics make Mozambique tilapia a more suitable species for subsistence or small-scale aquaculture in Solomon Islands when compared to milkfish. The species breeds readily in freshwater ponds, so fry collection costs (which include costs for collection equipment) that would normally be incurred under milkfish farming are avoided. Furthermore, because tilapia breeds readily in freshwater, continuous partial harvests can be done throughout the year. The production cycle (4 months) of tilapia is much shorter, so at least three crops per year are achievable, compared to milkfish with a single crop per year (8–9 month production cycle). However, this feasibility is only at the small-scale aquaculture level. The strain of Mozambique tilapia present in Solomon Islands would not be suitable for medium- or large-scale commercial aquaculture due to its low productivity and associated high risk of commercial loss in any one year.

Photo Credit: Reuben Sulu/WorldFish

Milkfish grow-out area at Kafolui lake, Dai Island.

Given the indications from this study that in Solomon Islands milkfish is only suitable for subsistence farming (albeit marginally), consideration should be given to the introduction of a more productive strain or species of fish that can meet current household nutrition and income needs in inland areas, as well as future food fish shortfalls in the country in general. The risks associated with any new fish species or strain, including disease and pest risks, would need to be considered and managed before introduction.

The findings about the nonviability of commercial milkfish aquaculture are concerning because of the implications for other species. The high cost of production and competition from capture fisheries (and fish imports) would limit sale price and therefore profitability of not only milkfish, but perhaps any fish species farmed in Solomon Islands. Therefore, from a broader national aquaculture development perspective, it is imperative that any species being considered by the government or the private sector for aquaculture be subjected to thorough economic analysis.

The food security benefits of Mozambique tilapia farming at a subsistence level are supported by the preliminary modeling in this study and are reflected in the uptake of household farming in Malaita and other parts of Solomon Islands. Clearly, any technology improvements that can be achieved in this sector would only improve access to fish, especially in inland parts of the country.

The majority of those who participated in this work were Solomon Islanders, so skills have been acquired and expertise is locally available to do milkfish aquaculture. Milkfish husbandry techniques are simple and can be readily transferred to other interested farmers. These same skills and familiarity with fish husbandry will be important to the development of aquaculture in Solomon Islands more generally, regardless of the species.

Photo Credit: Reuben Sulu/WorldFish

Don Bosco Rural Training Center pond, Tetere, Guadalcanal.

Venture type	Net present value (SBD)	Internal rate of return (%)	Annual return (SBD)	Payback period (years)	Fish production costs (SBD /kg)	Benefit-cost ratio	Risk of loss per annum (%)
Subsistence milkfish aquaculture	10,137	38.92	813	3	13.71	1.99	11
Small-scale commercial milkfish aquaculture	1,135	7.49	91	17	28.48	1.05	73
Medium-scale commercial milkfish aquaculture	14,294	11.27	1,147	11	26.55	1.13	54
Intensive large-scale commercial milkfish aquaculture	19,581,261	42.02	1,460,174	3	21.41	1.4	28
Subsistence Mozambique tilapia aquaculture	8,843	123.79	710	2	25.83	3.28	10
Small-scale commercial Mozambique tilapia aquaculture	2,210	15.02	177	8	66.67	1.22	10

Table 11. Summary of the economic characteristics of the different aquaculture venture types.

RECOMMENDATIONS

- Given the unfavorable results of this study's preliminary economic analysis, milkfish aquaculture should not be promoted in Solomon Islands, unless there are contrary findings based on a more thorough economic analysis.
- The Government of Solomon Islands should consider developing an alternative aquaculture species, either native to Solomon Islands or introduced.
- Any decision to introduce an aquaculture species or strain new to Solomon Islands should be based on thorough risk analysis, including risks associated with the invasiveness of the species itself and any significant diseases that the fish could harbor.
- Any new aquaculture species being considered must be subjected to rigorous economic analysis.

NOTES

1 www.fishbase.org

2 Brine frozen fish (mostly Scombridae: skip jack tuna, yellow fin tuna and rainbow runners) obtained from commercial tuna fishing boats that come into port to transship to mother boats.

3 At time of study, SBD 1.00 = USD 0.13.

4 "Growth" is defined as advancement in development and positive change in size over time.

5 ACIAR mini project MS1007: Pacific islands aquaculture feed ingredients inventory; FIS/2001/034: Inland pond aquaculture in PNG; FIS/2001/083: Inland aquaculture in PNG: Improving fingerling supply and fish nutrition for smallholder farms.

6 An additional 129 fingerlings were added to this pond on 24 July 2013.

7 Principal Agricultural Economist, Department of Agriculture, Fisheries and Forestry, Queensland, Australia.

8 Discounting reduces future costs or benefits to an equivalent in today's currency value—the net present value.

9 $NPV\,(i,N) = \sum_{t=0}^{N} \frac{R_t}{(1-i)t'}$, where *NPV* is the net present value (SBD); R_t is the net cash flow (cash inflow – cash outflow) at time *t*; *t* is the time period of cash flow (1 year); *i* is the discount rate (the rate of return that could be earned on an investment – the opportunity cost of the capital): 0.08; and *N* is the total number of periods: 20 years.

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APPENDIX 1

Scenario 1: Summary of input and outcome values for modeling the economics of a small-scale subsistence milkfish farm

Description	Value	Source or explanation
Number of ponds	2	Typical number owned by farmers in Solomon Islands
Average length of ponds (m)	10	Typical pond size in Solomon Islands
Average width of ponds (m)	5.4	
Average depth of ponds (m)	1.5	
Number of aerators per pond	0	
Pond surface area (m²)	54	
Average pond volume (m³)	81	
Water required per pond (kL)	0.08	
Total water required (kL)	0.16	
Total pond area (m²)	108	
Production parameters		
Stocking juveniles		
Stocking density (juveniles/m²)	2	One juvenile/m² in this study but consultant advised that this can be increased to 2 juveniles/m² if husbandry is good.
Juveniles stocked	254	
Grow-out parameters		
Start month (1 to 12)	5	Production cycle starts every May since this is the peak period for fry collection.
Grow-out period (months)	9	Grow-out can be achieved in 4–8 months (if well managed). Assumption of 9 months made based on farmer practice observed during this study (1 month for fry to fingerling and 8 months for grow-out).
Nonproduction period per year (months)	3	Assumption that there is only one cycle (9 months) per year. Thus, 3 months were allocated for pond preparation (drying, liming, etc.) for the next cycle.
Death rate during grow-out (%)	15	Reasonable assumption, although the current study did indicate higher mortality, which is likely to improve with experience.
Expected weight at harvest (kg)	0.3	Ideal market or harvest size
Juveniles required		
Number of juveniles required per crop	299	
Death rate of fry to juvenile stage (%)	25	Some fry loss expected due to poor handling, predation, poor hygiene, or salinity or temperature shock.
Number of fry required	399	
Cost of fry (if purchased rather than caught by owner)	SBD 0	
Cost of fry purchase per crop	SBD 0	
Feed		
Feed conversion ratio (kg feed: kg fish)	3.0	Fish fed entirely on household food scraps
Kilograms of feed required per cycle	194	
% of feed substituted by re-use of household scraps	100	Fish fed entirely on household food scraps
Total feed purchased	0	
Cost of feed per kilogram	SBD 0	
Total cost of purchased feed per cycle	SBD 0	
Harvest		
Number of fish at start of crop cycle	254	
Number of fish at end of crop cycle	216	
Weight of fish available for sale per crop (kg)	65	

APPENDIX 1

Description	Value	Source or explanation
Sales		
Percentage of harvest to be sold	20	20% of fish sold, 80% for household consumption
Weight of harvest to be sold (kg)	13	
Sale price of fish	SBD 30	Based on market survey
Revenue per cycle (less travel cost)	SBD 389	
Fish retained for family consumption	52	
Retained fish represents how many meals?	46	
What is the cost of the average family meal component replaced by the harvested fish?	SBD 30	
Value of meals replaced by fish	SBD 1,380	
Total value of commercial sales and meal replacements	SBD 1,769	
Fry requirements		
Captured fry required per crop	399	
Months required for collection	2	Collection can be done within months of the period of peak abundance.
Collection equipment		
Buckets (2 @ SBD 118 each)	SBD 236	Two buckets are sufficient for fry collection, storage and nursery.
Scooping bowls (2 @ SBD 10 each)	SBD 20	2 scooping bowls for fry collection
Scooping nets (@ SBD 20 each)	SBD 20	Cost based on using mosquito netting.
Dozer net (net only @ SBD 700)	SBD 700	Dozer netting for fry collection would need to be obtained from Palau since materials are not available in Solomon Islands.
Dozer bamboo (@ SBD 0)	SBD 0	Cost based on assumption that bamboo is readily available in rural areas, as is typically the case.
Access cost		
Fry collection visits to fill crop cycle requirements	2	Assumption that two fry collection trips would be required per culture cycle to allow for an additional trip in the event few or no fry are caught, as was regularly experienced during the trial
Payment per fry for access (per piece)	SBD 0.10	Assumption made that the farmer does not have access rights to the fry collection grounds under customary marine tenure arrangements
Fry required per visit	199	
Access cost per visit	SBD 19.93	
Total access cost per cycle	SBD 39.86	
Additional collection costs		
Boat hire per trip	SBD 0	Assumption that the farmer has ready physical access to the fry collection site
Distance (km) travelled to collection site (return)	4	Assumption that the farm is close to the collection site
Fuel usage rate to travel to fry collection site (liters per 100 km)	0	Not applicable
Cost per liter of fuel	SBD 0	Not applicable
Fuel cost per trip	SBD 0	
Total fuel cost per crop cycle	SBD 0	
Collection labor		
Number of people required	2	Assumption that only family members are involved in fry collection
Cost of labor per day	SBD 0	Assumption that family members provide unpaid labor
Labor cost for fry collection per trip	SBD 0	
Total labor cost for fry collection per cycle	SBD 0	

APPENDIX 1

Description	Value	Source or explanation
Nursery		
Nursery parameters		
Length of nursery phase (weeks)	4	
Length of yolk feeding (weeks)	1	Based on the current study, the fry are fed boiled egg yolk for the first week.
Length of algae and ground feed phase (weeks)	3	Based on the current study, algae and ground pellet feed were used for 3 weeks after the first week on egg yolk.
Nursery equipment		
Cost of ponds, *hapas* or tanks required (@ SBD 50 each)	SBD 0	Assumption that a small pond (1 m x 1 m) beside the grow-out pond would be dug for nursery and holding purposes
Other nursery equipment	SBD 0	
Feeding cost		
Cost of egg yolk for feed per 100 fry	SBD 5	Based on the current study, the fry are fed egg yolk for the first week of the nursery period.
Number of fry in nursery	399	
Cost of egg yolk feeding	SBD 19.93	
Cost of ground pellet feed and algae per 100 fry per week	SBD 0	Chicken manure is accounted for separately in the modeling.
Total cost of ground pellet feed and algae	SBD 0	
Total feeding cost for nursery phase (per cycle)	SBD 19.93	
Nursery labor		
Number of people required to tend nursery	1	Assumption that household member(s) would do this work
Cost of labor per day	SBD 0	Assumption that household member(s) would be unpaid
Total days required over nursery phase	2	Assumption of a time input of approximately 1 hour per day for a month
Total labor cost for fry collection per cycle	SBD 0	
Farm labor		
Fry collection labor		
Cost of fry collection labor	SBD 0	
Cost of nursery labor	SBD 0	
Family labor – grow-out		
Total number of family laborers	2	Assumption that two family members work unpaid for 2 hours per day for 270 days (9-month production cycle) for free
Estimated number of days per family labor unit	15	
Total cost of family labor per day	SBD 0	
Total cost of family labor	SBD 0	
Hired labor – grow-out		
Total number of hired laborers	0	Not applicable. Assumption made that all work would be done by unpaid family members.
Estimated number of days per hired labor	0	
Total cost of hired labor per day	SBD 0	
Total cost of hired labor	SBD 0	
Total farm labor cost (per cycle)	SBD 0	
Farm operating expenditure		
Fuel and energy		
Cost of fuel and oil (other than fry collection trips)	SBD 60	General fuel use expense—this cost item allows for unforeseen fuel needs.
Repairs and maintenance		
Repairs and maintenance	SBD 191	Assumption of 5% of capital cost
Miscellaneous items		
Manure for fertilizing ponds	SBD 100	2 x 50-kg bag manure @ SBD 50 each
Total farm operating expenses	SBD 351	

APPENDIX 1

Description	Value	Source or explanation
Marketing		
Market – Own vehicle		
Trips to market per cycle	0	Not applicable, as most local farmers do not own private vehicles and harvested fish (20%) would be sold at farm gate or roadside.
Distance (km) travelled to market (return)	20	
Fuel usage rate to travel to market (liters per 100 km)	0	
Cost per liter of fuel	SBD 0	
Fuel cost per trip	SBD 0	
Total fuel cost to market	SBD 0	
Market – Public transport		
Freight to market (return) – full SBD 40 or empty SBD 20	SBD 0	Not applicable, since the harvest (20%) will only be sold at farm gate or roadside.
Truck fare to market (return)	SBD 0	
Total public transport cost	SBD 0	
Marketing costs		
Ice for travel of product to market	SBD 0	Not applicable, since the harvest (20%) will only be sold at farm gate or roadside.
Total marketing costs	SBD 0	
Capital items		
Land and buildings		
Sheds or similar	SBD 0	Not required
Pond construction		
Pond earthworks	SBD 0	Assumption that the farmer and household members would build ponds at no cost
Pond infrastructure	SBD 0	Assumed that bamboo (which is readily available in rural areas) can be used for pond inlet and outlet pipes instead of PVC pipes, which are too expensive for households to purchase.
Other capital		
Tools and equipment	SBD 1,000	Based on approximate price at hardware stores in Honiara
Other	SBD 0	
Capital outlay for establishment	SBD 1,976	
Risk analysis: Selling price/kg		
Minimum	SBD 25/kg	Based on Honiara market price
Poor	SBD 20/kg	Based on Honiara market price
Average	SBD 30/kg	Based on Honiara market price
Good	SBD 35/kg	Based on Honiara market price
Maximum	SBD 40/kg	Based on Honiara market price

APPENDIX 2

Scenario 2: Summary of input and outcome values for small-scale commercial milkfish farm

Description	Value	Source or explanation
Number of ponds	2	Typical number owned by farmers in Solomon Islands
Average length of ponds (m)	10	Typical pond size in Solomon Islands
Average width of ponds (m)	5.4	
Average depth of ponds (m)	1.5	
Pond surface area (m^2)	54	
Average pond volume (m^3)	81	
Water required per pond (kL)	0.08	
Total water required (kL)	0.16	
Total pond area	108	
Production parameters		
Stocking juveniles		
Stocking density (juveniles/m^2)	2	Ponds were stocked at 1 juvenile/m^2 in this study but consultant advised that this can be increased to 2 juveniles/m^2 with good husbandry.
Juveniles stocked	254	
Grow-out parameters		
Start month (1 to 12)	5	Production cycle starts every May since this is the peak period for fry collection.
Grow-out period (months)	9	Grow-out typically takes 4–8 months (if well managed) but 9 months used based on farmer practice observed during the current study (1 month for fry to fingerling and 8 months for grow-out).
Nonproduction period per year (months)	3	There is one culture cycle (9 months) per year. Three months are allocated for pond preparation (drying, liming, etc.) for next cycle.
Death rate during grow-out (%)	15	Although the current study did indicate a slightly higher rate than 15%, it is assumed survival would improve with husbandry experience.
Expected weight at harvest (kg)	0.30	Ideal market or harvestable size
Juveniles required		
Number of juveniles required per crop	299	
Death rate of fry to juvenile stage (%)	25	Some fry may die due to poor handling techniques, the presence of predators, dirty facilities, and salinity or temperature shock.
Number of fry required	399	
Feed		
Feed conversion ratio (kg feed: kg fish)	2.0	Commercial feed will be used.
Kilograms of feed required per cycle	130	
% of feed substituted by re-use of household scraps	100	Only household scraps and other locally available feed will be used.
Total feed purchased (kg)	0	
Cost of feed per kilogram	SBD 0	
Total cost of purchased feed per cycle	SBD 0	
Harvest		
Number of fish at start of crop cycle	254	
Number of fish at end of crop cycle	216	
Weight of fish available for sale per crop (kg)	65	

APPENDIX 2

Description	Value	Source or explanation
Sales		
Percentage of harvest to be sold	100	Income generation
Weight of harvest to be sold (kg)	65	
Sale price of fish	SBD 30	Based on market survey
Revenue per cycle (less travel cost)	SBD 1,944	
Fish retained for family consumption	0	
Retained fish represents how many meals?	0	
What is the cost of the average family meal replaced by the fish?	SBD 0	
Value of meals replaced by fish	SBD 0	
Total value of commercial sales and meal replacements	SBD 1,944	
Fry collection		
Fry requirements		
Captured fry required per crop	399	
Months required for collection	2	Collection can be done within months of the peak period since large quantity will be available.
Collection equipment		
Buckets (@ SBD 118 each)	SBD 236	Two are sufficient for fry collection, storage and nursery for such scale.
Scooping bowls (@ SBD 10 each)	SBD 20	Two scooping bowls or even one are sufficient for fry collection.
Scooping nets	SBD 50	Mosquito net can be used thus cost will be around SBD 50
Dozer net (net only @ SBD 700)	SBD 700	For fry collection and have to get from outside (Palau) since materials are not available in the country
Dozer bamboo (@ SBD 50)	SBD 50	Bamboo is available in rural areas.
Access cost		
Fry collection visits to fill crop cycle requirements	2	Two trips per cycle for fry collection (one backup trip in case of bad luck during first trip)
Payment per fry for access (per piece)	SBD 0.10	Other people might own the fry collection ground (customary marine tenure).
Fry required per visit	199	
Access cost per visit	SBD 19.93	
Total access cost per cycle	SBD 39.86	
Additional collection costs		
Boat hire per trip	SBD 0	Assumed ready access to collection site
Distance (km) travelled to collection site (return)	4	Collection sites are assumed close to the farm site.
Fuel usage rate to travel to fry collection site (liters per 100 km)	0	Not applicable
Cost per liter of fuel	SBD 0	Not applicable
Fuel cost per trip	SBD 0	
Total fuel cost per crop cycle	SBD 0	
Collection labor		
Number of people required	2	Normally needs three, but if experienced only required two.
Cost of labor per day	SBD 50	Based on village daily labor wage @ SBD 50 per person
Labor cost for fry collection per trip	SBD 100	
Total labor cost for fry collection per cycle	SBD 200	

APPENDIX 2

Description	Value	Source or explanation
Nursery		
Nursery parameters		
Length of nursery phase (weeks)	4	
Length of yolk feeding (weeks)	1	Based on current study, the fry were fed with boiled egg yolk for the first week.
Length of algae and ground feed phase (weeks)	3	Based on current study, algae and ground feed were used for 3 weeks after the use of boiled egg yolk on the first week.
Nursery equipment		
Cost of ponds, *hapas* or tanks required (@ SBD 50 each)	SBD 50	For nursery and storage
Other nursery equipment	SBD 0	
Feeding cost		
Cost of egg yolk feeding per 100 fry	SBD 5	Based on current study—for the first week of nursery period
Number of fry in nursery	399	
Cost of egg yolk feeding	SBD 19.93	
Cost of ground feed and algae per 100 fry (per week)	SBD 10	Based on current study—for the whole nursery period
Total ground feed and algae cost	SBD 119.58	
Total feeding cost for nursery phase (per cycle)	SBD 139.52	
Nursery labor		
Number of people required to tend nursery	1	Require one person to care (feeding, cleaning and water exchange if required) for the fish (fry to fingerling) to avoid mass mortality
Cost of labor per day	SBD 25	Based on Solomon Islands minimum wage—using 1–2 hours per day for each day of the nursing period
Total days required over nursery phase	2	Spent only about 1–2 hours per day over a month
Total labor cost for fry collection per cycle	SBD 50	
Farm labor		
Fry collection and nursery labor		
Cost of fry collection labor	SBD 200	
Cost of nursery labor	SBD 50	
Family labor – Grow-out		
Total number of family laborers	1	One family member will work 1 hour per day for 270 days (9-month production cycle). Total number of hours will be 270. Each working day is a total of 8 hours, so converting to working days (270/8) will come to a total of 33.75 days. Labor will be provided for free by family members.
Estimated number of days per family labor unit	33.75	
Total cost of family labor per day	SBD 0	
Total cost of family labor	0	
Hired labor – Grow-out		
Total number of hired laborers	0	Not applicable. Most work will be done by family members (family labor).
Estimated number of days per hired labor unit	0	
Total cost of hired labor per day	SBD 0	
Total cost of hired labor	SBD 0	
Total farm labor cost (per cycle)	SBD 250	
Farm operating expenditure		
Fuel and energy		
Cost of fuel and oil (other than fry collection trips)	SBD 60	General fuel use expense—this element allows for unforeseen fuel needs.
Repairs and maintenance		
Repairs and maintenance	SBD 291	5% of capital cost as a guide
Miscellaneous items		
Manure x 2 – fertilizing ponds	SBD 100	2 x 50-kg bag manure @ SBD 50 each
Total farm operating expenses	SBD 451	

APPENDIX 2

Description	Value	Source or explanation
Marketing		
Market – Own vehicle		
Market costs	0	Sales will be at the farm gate so no market costs are incurred.
Capital items		
Land and buildings		
Sheds or similar	SBD 500	Build with bush materials. The farmers will provide their own materials.
Labor accommodation	SBD 0	
Pond construction		
Pond earthworks (2 ponds @ SBD 750 each)	SBD 1,500	Based on two people working (digging) for 3 weeks @ SBD 750 each
Pond infrastructure (i.e. pipes)	SBD 0	Bamboo, which is available in rural areas, can be used instead of PVC pipe, which is quite expensive for farmers to purchase.
Harvesting and processing equipment (i.e. gill net)	SBD 20	
Other	SBD 0	
Other capital		
Tools and equipment	SBD 1,000	Based on average selling price at hardware stores in Honiara
Other	SBD 0	
Capital outlay for establishment	**SBD 4,326**	
Risk analysis selling price/kg		
Minimum	SBD 25/kg	Based on Honiara market price
Poor	SBD 20/kg	Based on Honiara market price
Average	SBD 30/kg	Based on Honiara market price
Good	SBD 35/kg	Based on Honiara market price
Maximum	SBD 40/kg	Based on Honiara market price

APPENDIX 2

APPENDIX 3

Scenario 3: Summary of input and outcome values for medium-scale commercial milkfish farm

Description	Value	Source or explanation
Number of ponds	6	Assumed by authors
Average length of ponds (m)	10	Reasonable pond size the farmer can construct manually
Average width of ponds (m)	10	
Average depth of ponds (m)	1.5	
Number of aerators per pond	0	
Pond surface area (m^2)	100	
Average pond volume (m^3)	150	
Water required per pond (kL)	0.15	
Total water required (kL)	0.90	
Total ponded area (m^2)	600	
Production parameters		
Stocking juveniles		
Stocking density (juveniles/m^2)	2	Based on current study—normally 1 juvenile/m^2 but consultant advised that this can be increased to 2 juveniles/m^2 if husbandry is good
Juveniles stocked	1,412	
Grow-out parameters		
Start month (1 to 12)	5	Production cycle starts every May since this is the peak period for fry collection.
Grow-out period (months)	9	Usually it takes 4–8 months (if well managed) but we used 9 months based on farmer practice observed during the current study (fry to fingerling = 1 month, grow-out = 8 months).
Nonproduction period per year (months)	3	There is only one cycle (9 months) per year. Thus, 3 months will be allocated for pond preparation (drying, liming, etc.) for next cycle.
Death rate during grow-out (%)	15	Reasonable assumption, although the current study did indicate a slightly higher rate—this is likely to improve with experience.
Expected weight at harvest (kg)	0.30	Ideal market or harvestable size
Juveniles required		
Number of juveniles required per crop	1,661	
Death rate of fry to juvenile stage (%)	25	Some fry may die due to poor handling techniques, the presence of predators, dirty facilities, and salinity or temperature shocks.
Number of fry required	2,215	
Cost of fry (if purchased rather than caught by owner)	SBD 0	
Cost of fry purchase per crop	SBD 0	
Feed		
Feed conversion ratio (kg feed: kg fish)	1.5	Commercial feed will be used.
Kilograms of feed required per cycle	540	
% of feed substituted by re-use of household scraps	0	Only commercial feed will be used.
Total feed purchased	540	
Cost of feed per kilogram	SBD 6.50	Based on current feed study
Total cost of purchased feed per cycle	SBD 3,510	
Harvest		
Number of fish at start of crop cycle	1,412	
Number of fish at end of crop cycle	1,200	
Weight of fish available for sale per crop (kg)	360	

APPENDIX 3

Description	Value	Source or explanation
Sales		
Percentage of harvest to be sold	100	Income generation
Weight of harvest to be sold (kg)	360	
Sale price of fish	SBD 30	
Revenue per cycle (less travel cost)	SBD 10,800	
What is the cost of the average family meal replaced by the fish?	SBD 0	
Value of meals replaced by fish	SBD 0	
Total value of commercial sales and meal replacements	SBD 10,800	
Fry collection		
Fry requirements		
Captured fry required per crop	2,215	
Months required for collection	2	Collection can be done within months of the peak period since large numbers will be available.
Collection equipment		
Buckets (@ SBD 118 each)	SBD 472	To cover fry collection, storage and nursery
Scooping bowls (@ SBD 10 each)	SBD 30	Three people will do fry collection.
Scooping nets (@ SBD 200 each)	SBD 200	
Dozer net (net only @ SBD 700)	SBD 700	For fry collection and have to get from overseas since materials are not available in the country
Dozer bamboo (@ SBD 50)	SBD 50	For dozer net frame
Access cost		
Fry collection visits to fill crop cycle requirements	5	Five trips per cycle for fry collection (one backup in case of bad luck on first trip)
Payment per fry for access (per piece)	SBD 0.10	Other people might own the fry collection ground (customary marine tenure).
Fry required per visit	443	
Access cost per visit	SBD 44.29	
Total access cost per cycle	SBD 221.45	
Additional collection costs		
Boat hire per trip	SBD 0	Assumed ready access to collection site
Distance (km) travelled to collection site (return)	4	Collection sites are assumed to be close to the farm site.
Fuel usage rate to travel to fry collection site (liters per 100 km)	0	Not applicable
Cost per liter of fuel	SBD 10	Not applicable
Fuel cost per trip	SBD 0	
Total fuel cost per crop cycle	SBD 0	
Collection labor		
Number of people required	3	One person for pushing the net, and the other two helping in scooping and sorting the milkfish fry from other fish fry
Cost of labor per day	SBD 50	Based on village daily labor wage of SBD 50 per person
Labor cost for fry collection per trip	SBD 150	
Total labor cost for fry collection per cycle	SBD 750	
Nursery		
Nursery parameters		
Length of nursery phase (weeks)	4	
Length of yolk feeding (weeks)	1	Based on current study, the fry were fed with boiled egg yolk for the first week.
Length of algae and ground feed phase (weeks)	3	Based on current study, algae and ground feed were used for the next 3 weeks.
Nursery equipment		
Cost of ponds, *hapas* or tanks required (@ SBD 50 each)	SBD 100	For nursery and storage
Other nursery equipment	SBD 0	

APPENDIX 3

Description	Value	Source or explanation
Feeding cost		
Cost of egg yolk feeding per 100 fry	SBD 5	Based on current study—for the first week of nursery period
Number of fry in nursery	2,215	
Cost of egg yolk feeding	SBD 110.73	
Cost of ground feed and algae per 100 fry (per week)	SBD 10	Based on current study—for the whole nursery period
Total ground feed and algae cost	SBD 664.36	
Total feeding cost for nursery phase (per cycle)	SBD 775.09	
Nursery labor		
Number of people required to tend nursery	1	Require one person to care (feeding, cleaning and water exchange if required) for the fish (fry to fingerling) to avoid mass mortality
Cost of labor per day	SBD 25	Based on minimum wage—using 1–2 hours per day for each day of the nursing period
Total days required over nursery phase	2	Spent only about 1–2 hours per day over a month
Total labor cost for fry collection per cycle	SBD 50	
Farm labor		
Fry collection and nursery labor		
Cost of fry collection labor	SBD 750	
Cost of nursery labor	SBD 50	
Family labor – grow-out		
Total number of family laborers	1	One family member will work 2 hours per day for 270 days (9-month production cycle). Total number of hours will be 270 x 2 = 540. Each working day is a total of 8 hours so converting to working days (540/8) will come to a total of 67.5 days per person. A labor rate of SBD 25 per day was used as per minimum labor rate.
Estimated number of days per family labor unit	67.5	
Total cost of family labor per day	SBD 0	
Total cost of family labor	SBD 1,688	
Hired labor – grow-out		
Total number of hired laborers	0	Not applicable. Most work will be done by family members (family labor).
Estimated number of days per hired labor unit	0	
Total cost of hired labor per day	SBD 0	
Total cost of hired labor	SBD 0	
Total farm labor cost (per cycle)	SBD 2,488	
Farm operating expenditure		
Fuel and energy		
Cost of fuel and oil (other than fry collection trips)	SBD 60	General fuel use expense—this element allows for unforeseen fuel needs.
Repairs and maintenance		
Repairs and maintenance	SBD 1,121	5% of capital cost as a guide
Other farm operating expenses		
Annual rents or leases paid	SBD 0	
Government fees and charges	SBD 0	
Other fees and charges	SBD 0	
Accounting and legal expenses	SBD 0	
Skills training	SBD 0	
Office expenses	SBD 0	
Phone	SBD 0	
Travel (related to business)	SBD 0	
Vehicle or boat registrations	SBD 0	
Insurance (boat, vehicle and infrastructure)	SBD 0	
Miscellaneous items		
Manure x 2 – fertilizing ponds	SBD 100	2 x 50-kg bag manure @ SBD 50 each
Total farm operating expenses	SBD 1,281	

Description	Value	Source or explanation
Market – Own vehicle		Not applicable as most local farmers do not have a private vehicle, thus public transportation will be the main form of travelling to the market.
Trips to market per cycle	3	Public transportation system will be used.
Distance (km) travelled to market (return)	20	
Fuel usage rate to travel to market (liters per 100 km)	0	
Cost per liter of fuel	SBD 0	
Fuel cost per trip	SBD 0	
Total fuel cost to market	SBD 0	
Market – Public transport		
Freight to market (return) – full SBD 40 or empty SBD 20	SBD 180	Freight for transporting the fish to the market @ SBD 40 for full esky and SBD 20 for empty esky on return for three trips
Truck fare to market (return)	SBD 240	Two people @ SBD 40 each for three trips
Total public transport cost	SBD 420	
Market costs		
Ice for travel of product to market	SBD 300	Require six pieces for preserving the fish for 6 selling days
Market fee	SBD 240	6 selling days @ SBD 40 per day
Food for market stay	SBD 300	Meals for 6 selling days for two people
Total marketing costs	SBD 840	
Capital items		
Land and buildings		
Land	SBD 0	
Sheds or similar	SBD 500	Build with bush materials. The farmers will provide their own materials.
Labor accommodation	SBD 0	
Pond construction		
Pond earthworks (2 ponds @ SBD 750 each)	SBD 9,000	Based on 12 people working (digging) for 3 weeks @ SBD 50 each
Pond infrastructure (i.e. pipes)	SBD 6,000	Twelve pipes (2–4 inches) for six ponds: one for inlet and one for outlet for each pond. Based on average selling price at hardware stores in Honiara
Jetties or walkways	SBD 0	
Aerators	SBD 0	
Pond exclusion nets or barriers (toads)	SBD 0	
Fry collection		
Esky (cooler boxes)	SBD 3,000	Require 2 eskies for the harvest
Other	SBD 0	
Other capital		
Tools and equipment	SBD 1,000	Based on average selling price at hardware stores in Honiara
Other	SBD 0	
Capital outlay for establishment	**SBD 20,922**	
Risk analysis selling price/kg		
Minimum	SBD 25/kg	Based on Honiara market price
Poor	SBD 20/kg	Based on Honiara market price
Average	SBD 30/kg	Based on Honiara market price
Good	SBD 35/kg	Based on Honiara market price
Maximum	SBD 40/kg	Based on Honiara market price

APPENDIX 3

APPENDIX 4

Scenario 4: Summary of input and outcome values for large-scale commercial milkfish farm

General farm parameters		
Description	**Input value**	**Source or explanation**
Total farm area (ha)	20	Based on the abandoned Ruaniu prawn farm site
Ponded area (ha)	10	Use only 10 ponds @ 1 ha each
Pond dimensions and requirements		
Average length of ponds (m)	100	Standard pond size at the Ruaniu site
Average width of ponds (m)	100	
Average depth of ponds (m)	1.5	
Number of complete water exchanges per crop	5	Regular water exchange helps remove waste and ammonia produced by the fish, and supplies oxygen.
Number of aerators per pond	6	Pond size is quite big; thus, require six to maintain dissolved oxygen in the pond at optimum levels, especially at night and early morning.
Number of nursery ponds	4	Require four to cater to 10-ha ponds
Pond surface area (ha)	1	
Number of ponds available	10	
Average pond volume (m^3)	15,000	
Water exchange per pond per day (%)	25	
Water exchange per pond each cycle (ML)	900	
Water usage per production cycle (ML)	9,000	
Fish production		
Production parameters		
Stocking density (kg/m^3 of pond water)	1	Assumed
Biomass per pond (kg)	15,000	
Farm productivity (kg)	150,000	
Grow-out parameters		
Grow-out period (months)	8	Based on experience in Palau
Pond dry-out period (months)	2	2 months to dry or repair ponds between crops (in case of bad weather)
Date fish are stocked	April	Stocking in April
Expected weight at harvest (kg)	0.35	Ideal marketable size
Death rate during grow-out (%)	30	Based on current study and literature
Number of fingerlings purchased per crop	612,245	
Number of fish remaining at harvest	428,571	
Fry cost		
Size of fry purchased (mm)	15	Average size collected from wild or hatchery
Cost of fry per mm	SBD 0.01	
Fry cost per crop cycle	SBD 91,837	
Grower feeds		
Feed conversion ratio (kg feed: kg fish)	1.20	Quality commercial feed will be used.
Cost of feed delivered (per metric ton)	SBD 10,000	Estimate
Weight of individual fish at harvest	0.35	
Total feed requirement over crop cycle (kg)	SBD 155,965	
Total cost of feed per cycle	SBD 1,559,649	

APPENDIX 4

General farm parameters				
Description	**Input value**		**Source or explanation**	
Nursery parameters				
Nursery feed parameters				
Length of fish stocked into nursery (mm)	15			
Weight of fish stocked into nursery (g)	0.05			
Length of fish harvested from nursery (mm)	88		Based on current study and literature	
Weight of fish harvested from nursery (g)	9.04			
Nursery food conversion ratio for juveniles	1.00		Quality commercial feed will be used.	
Nursery feed consumed per crop cycle (kg)	5,503			
Starter feeds	**Feeding rate (%)**	**Feed used (kg)**	**Price per kg (landed)**	**Cost/cycle**
Crumble	20	1,101	SBD 15	SBD 16,509
1-mm start	40	2,201	SBD 12	SBD 26,415
2-mm start	40	2,201	SBD 12	SBD 26,415
Total nursery feed cost				SBD 69,340
Processing and packaging				
Fish sold – 150,000 kg				
Chilled whole				
Weight of fish per package (kg)	18			
Gross weight of packaging (kg)	21			
Cost per package (each)	SBD 24			
Kilograms of ice per package	3			
Cost of ice (SBD/kg)	1.20			
Number of plastic liners per package	0			
Cost of each plastic liner	SBD 0			
Label or logo	SBD 1.20			
Cost of packing tape (SBD/roll)	6			
Number of packages per tape roll	20			
Total cost per box or bulk bin per cycle	SBD 29.10 x 150,000 kg		SBD 242,500	
Sale price – Revenue per crop cycle				
Expected price per kilogram chilled	SBD 30		Based on market survey	
Freight and marketing				
Freight cost (SBD/kg)	0.50			
Total cost of freight	SBD 87,500			
Market fee (per package or box)	SBD 5			
Commissions (%)	0			
Total marketing costs	SBD 129,166.67			

APPENDIX 4

Farm labor			
Permanent and part-time employees	**% full-time employee**	**Weekly salary**	**Explanations**
Skilled 1	1.0	SBD 1,500	Require three skilled and experienced personnel to manage operations. The weekly salary varies among the three personnel depending on rank.
Skilled 2	1.0	SBD 1,000	
Skilled 3	1.0	SBD 1,000	
Laborer 1	1.0	SBD 400	Require seven laborers to help the skilled personnel to care for the operations, with each paid SBD 400 weekly based on the country minimum wage (SBD 3.20 per hour)
Laborer 2	1.0	SBD 400	
Laborer 3	1.0	SBD 400	
Laborer 4	1.0	SBD 400	
Laborer 5	1.0	SBD 400	
Laborer 6	1.0	SBD 400	
Laborer 7	1.0	SBD 400	
Owner, operator or manager average (weekly)	1.0	SBD 2,000	Require a manager to oversee the operation
Farm operating expenses			
Description		**Input value**	**Explanations**
Diesel		SBD 200,000	Electricity (power) supply does not reach the farm site, thus a generator will be required (20,000 liters diesel @ SBD 20/liter for generator).
Engine oil (10%)		SBD 60,000	Require 2,000 liters @ SBD 30/liter for generator
Repairs and maintenance		SBD 100,000	Due to scale of operation (all assets)
Electricity		SBD 0	
Accounting and legal		SBD 0	
Administrative expenses		SBD 10,000	
Phone (domestic and mobile)		SBD 6,000	Based on SBD 20 per day
Travel (related to business)		SBD 2,000	Most traveling to town by own vehicle
Vehicle registrations		SBD 1,600	Based on the country's regulation
Vehicle insurance		SBD 1,600	Based on the country's regulation
Farm insurance		SBD 0	
Council rates and licenses		SBD 2,093	Based on similar kinds of business under the Honiara City Council
Chemicals (cleaning)		SBD 5,000	
Equipment leases			
Land and building leases		SBD 10,000	The land is owned by someone, thus it has to be leased.
Total farm operating expenses		SBD 398,700	

APPENDIX 4

Other capital				
Capital item	**No. of items**	**Cost of items**	**Total cost**	**Explanation**
Land and buildings				
Sheds and office	1	SBD 200,000	SBD 200,000	Staff have to stay close to the farm. The cost is based on the average cost for a two-bedroom house in Solomon Islands.
Staff accommodation	1	SBD 200,000	SBD 200,000	Staff have to stay close to the farm. The cost is based on the average cost for a two-bedroom house in Solomon Islands.
Processing room	1	SBD 300,000	SBD 300,000	Since it is a commercial operation, processing and cold rooms are required.
Cold room	1	SBD 250,000	SBD 250,000	
Other	0	SBD 0	SBD 0	
Electricity connection	-	SBD 0	SBD 0	
Vehicles and machinery				
Utilities	2	SBD 200,000	SBD 400,000	Two vehicles are required, with one on standby on farm site in case of emergency
Motorbikes	0	SBD 0	SBD 0	
Tractor (second hand)	0	SBD 0	SBD 0	
Mower or slasher	2	SBD 1,500	SBD 3,000	Two are required with one for backup
Commercial feed thrower to disperse feed into ponds	1	SBD 10,000	SBD 10,000	
Pond-related expenditure				
Pond construction (per pond)	10	SBD 5,000	SBD 50,000	The site was an abandoned prawn farm and the ponds (20 x 1 ha each) were already constructed but need minor repair and maintenance.
Pond piping and infrastructure (per pond)	10	SBD 0	SBD 0	
Pond electricity connection (per pond)	10	SBD 0	SBD 0	
Aerators	60	SBD 6,000	SBD 360,000	Intensive scale, thus require more aerators
Nursery ponds and infrastructure	4	SBD 15,000	SBD 60,000	The site was an abandoned prawn farm and the ponds (20 x 1 ha each) were already constructed but need minor repair and maintenance.
Moorings and walkways	10	SBD 1,000	SBD 10,000	The site was an abandoned prawn farm and the ponds (20 x 1 ha each) were already constructed but need minor repair and maintenance.
Other infrastructure and equipment				
Generator	2	SBD 375,000		Require two with one for backup. The cost is based on selling price by the local dealers.
Pumps	2	SBD 150,000		Require two with one for backup. The cost is based on selling price by local dealers.
Feeding equipment	1	SBD 5,000		Assumed
Water monitoring equipment	1	SBD 20,000		Good to have because at higher biomass, holding capacity is influenced more by water quality
Harvesting equipment	1	SBD 5,500		Assumed
Fish grading machine	0	SBD 0		Assumed
Processing equipment	-	SBD 0		Assumed
Ice machine	1	SBD 120,000		Require only one large ice machine
Net and pond cleaning equipment	-	SBD 0		Assumed
Workshop tools and equipment	-	SBD 20,000		Assumed
Miscellaneous items	-	SBD 5,000		Assumed
Other capital items	0	SBD 0		Assumed
Total capital outlay				
Risk analysis selling price/kg				
Minimum	SBD 25/kg	Based on Honiara market price		
Poor	SBD 20/kg	Based on Honiara market price		
Average	SBD 30/kg	Based on Honiara market price		
Good	SBD 35/kg	Based on Honiara market price		
Maximum	SBD 40/kg	Based on Honiara market price		

APPENDIX 4

APPENDIX 5

Scenario 5: Summary of inputs and outcome values for small-scale subsistence Mozambique tilapia farm

Description	Value	Source or explanation
Number of ponds	2	Average number owned by farmers in Solomon Islands
Average length of ponds (m)	10	Typical pond size in Solomon Islands
Average width of ponds (m)	5.4	
Average depth of ponds (m)	1.5	
Number of aerators per pond	0	
Pond surface area (m^2)	54	
Average pond volume (m^3)	81	
Water required per pond (kL)	0.08	
Total water required (kL)	0.16	
Total ponded area (m^2)	108	
Production parameters		
Stocking frequency (years)	3	Mozambique tilapia reproduces easily in ponds so next stocking will be in 3 years when ponds are dried and maintained. Current experience shows that farmers can use a pond for up to 3 years.
Stocking density (juveniles/m^2)	8	Current stocking density used by farmers whom we work with in central Malaita
Juveniles stocked	864	
Growth parameters		
Start month (1–12)	1	Farming does not depend on fry availability so can start any time of the year.
Grow-out period (months)	4	Mozambique tilapia are normally ready to be harvested after 4 months of culture.
Expected weight at harvest (g)	12	Based on average weight of farmers' harvests
Juveniles required		
Juvenile cost	0	Juveniles are normally obtained from streams so they are free
Total cost of juveniles	0	
Feed conversion ratio (kg food: kg fish)	4.0	This is quite high as feed used will be mostly household leftovers, termites, scraped coconut and some local plants.
Kg of feed required per cycle	41	Mozambique tilapia relies heavily on algae so as long as ponds are well greened only minimal feed input will be required.
Cost of feed per kg	0	Household leftovers and food scraps will be used to feed the fish.
Total cost of feed purchased per cycle	0	Based on current experience with farmers
Percentage of fish stocked that will be harvested each cycle	40	Based on partial harvests undertaken by farmers
Number of fish harvested per cycle	346	
Weight of fish harvested (kg) per cycle	4.15	
Percentage of fish sold for commercial gain	20	
Sale price of fish	SBD 1/piece for 12-g fish	Based on current price among farmers
Revenue per cycle	SBD 69	
Number of fish retained for family consumption	276	
Retained fish represents how many meals	14	
Cost of average family meal replaced by the fish	SBD 20	
Value of meals replaced by fish	SBD 80	
Total value of commercial sales and meal replacements	SBD 349	

APPENDIX 5

Description	Value	Source or explanation
Farm labor		
Total number of family laborers	2	
Estimated number of days per family labor unit	15	
Total cost of family labor per day	SBD 0	Farmer will provide own labor so considered free.
Total cost of family labor per cycle	SBD 0	
Additional operating expenses		
Repairs and maintenance	SBD 100	
Manure	SBD 100	
Marketing costs	SBD 0	Most fish will be for family consumption. Any selling will only be at farm gate.
Capital expenses		
Pond earthworks	SBD 0	Farmer will undertake work himself so valued as free.
Harvesting equipment	SBD 20	Mosquito net will be used to catch fish.
Tools and equipment	SBD 500	Based on cost of shovels and spades when implementing the project
Total capital outlay for establishment	SBD 520	

APPENDIX 5

APPENDIX 6

Scenario 6: Summary of inputs and outcome values for small-scale commercial Mozambique tilapia farm

Description	Value	Source
Number of ponds	2	Average number owned by farmers in Solomon Islands
Average length of ponds (m)	10	Typical pond size in Solomon Islands
Average width of ponds (m)	5.4	
Average depth of ponds (m)	1.5	
Number of aerators per pond	0	
Pond surface area (m^2)	54	
Average pond volume (m^3)	81	
Water required per pond (kL)	0.08	
Total water required (kL)	0.16	
Total ponded area (m^2)	108	
Production parameters		
Stocking frequency (years)	3	Mozambique tilapia reproduces easily in ponds so next stocking will be in 3 years when ponds are dried and maintained. Current experience shows that farmers can use a pond for up to 3 years.
Stocking density (juveniles/m^2)	8	Current stocking density used by farmers whom we work with in central Malaita
Juveniles stocked	864	
Growth parameters		
Start month (1–12)	1	Farming does not depend on fry availability so can start any time of the year.
Grow-out period (months)	4	Mozambique tilapia are normally ready to be harvested after 4 months of culture.
Expected weight at harvest (g)	12	Based on average weight of farmers' harvests
Juveniles required		
Juvenile cost	0	Juveniles are normally obtained from streams so they are free.
Total cost of juveniles	0	
Feed conversion ratio (kg food: kg fish)	4.0	Only household food scraps and leftovers will be used.
Kg of feed required per cycle	41	Mozambique tilapia relies heavily on algae so as long as ponds are well greened only minimal feed input will be required.
Cost of feed per kg	0	
Total cost of feed purchased per cycle	0	
Percentage of fish stocked that will be harvested each cycle	40	Based on partial harvests undertaken by farmers
Number of fish harvested	346	
Weight of fish harvested per cycle (kg)	4.15	
Percentage of fish sold for commercial gain	80	
Sale price of fish	SBD 1/piece for 12-g fish	Based on current price among farmers
Revenue per cycle	SBD 276	
Number of fish retained for family consumption	69	
Retained fish represents how many meals	3	
Cost of average family meal replaced by the fish	SBD 20	
Value of meals replaced by fish	SBD 60	
Total value of commercial sales and meal replacements	SBD 336	

APPENDIX 6

Description	Value	Source
Farm labor		
Total number of family laborers	1	
Estimated number of days per family labor unit	15	Each family member will spend 1 hour per day for 4 months (120 days). Total hours are 120. Each working day is 8 hours so total working days will be 120/8, which comes to 15 days.
Total cost of family labor per day	SBD 25	Based on current minimum labor rate
Total cost of family labor per cycle	SBD 375	
Additional operating expenses		
Repairs and maintenance	SBD 100	
Manure	SBD 100	
Marketing expenses	SBD 0	Fish will be sold at farm gate so no costs incurred.
Capital expenses		
Pond earthworks	SBD 1,500	SBD 750 to manually construct a pond
Harvesting equipment	SBD 20	Mosquito net will be used to catch fish.
Tools and equipment	SBD 500	Based on cost of shovels and spades when implementing the project
Total capital outlay for establishment	SBD 2,020	

APPENDIX 6

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