American Samoa Aquaculture Feasibility Study

Lalolagi o le Sami Tank Farm Mural, by artists William P. Faga, Jr., Niuafolau Pua, Vaimili Tyrell, Duffy Hudson, Raymond Keleti, Puataunofo Tofaeono, Faitoto'aetasiolefaleomavaega Nick King, Su'a Wilson Fitiao (Tufuga ta Tatau), Sekio Fuapopo and Regina Meredith-Fitiao.

Prepared for the American Samoa Coastal Zone Management Program

Department of Commerce

Findings and Recommendations

Conducted by:

Maria Haws, Ph.D. Professor, Pacific Aquaculture and Coastal Resources Center, University of Hawaii Hilo
haws@hawaii.edu

Hope Helg, Microalgae Culture Manager, Pacific Aquaculture and Coastal Resources Center, University of Hawaii Hilo
helg@hawaii.edu

David Nisbet, Owner and CEO, Goose Point Oyster Company Inc., Inc., Nisbet Oyster Inc. and Hawaiian Shellfish LLC
dave@goosepoint.com

Background and Purpose

The American Samoa Coast Zone Management Program (ASCZMP) of the Department of Commerce (DOC) funded a feasibility study of aquaculture opportunities for American Samoa in recognition of the economic potential of this activity. American Samoa has a long history of pilot aquaculture efforts which sets the stage for future development, as well as close ties to Samoa where aquaculture development has flourished. The Pacific Islands in general have many forms of aquaculture that provide a basis for transfer to American Samoa. Thus, potential to establish diverse types of aquaculture is clearly possible.

Among the most favorable factors that make aquaculture an appealing option are: 1) good freshwater resources; 2) some protected bays; 3) diverse species with potential for aquaculture; 4) need to reduce reliance on imported protein sources; 4) educated population and presence of technical specialists; and 5) availability of fish meal. Despite the known potential, there are obstacles to aquaculture development that must be overcome before progress can be made.

The specialists for this work were Dr. Maria Haws and Ms. Hope Helg of the Pacific Aquaculture and Coastal Resources Center (PACRC), University of Hawaii Hilo. They were assisted in the work by Mr. David Nisbet, President and CEO of Goose Point Oyster Company and Hawaiian Shellfish LLC, who served on a *pro bono* basis. Mr. Nisbet was included in the team due to his experience developing aquaculture businesses and a hatchery, as well as for his expertise in financing for agriculture and aquaculture. The ASCZMP points of contact were Ms. Gina Faiga-Naseri, Mr. Tony Langkilde and Mr. Jonathan Brown during the visit. During the contracting process, Ms. Sandra Lutu and Ms. Reinette Thompson-Niko acted as the points of contact and provided invaluable assistance to the consultants. Additional assistance was provided by Dr. Darren Okimoto (Associate Director and Extension Leader), University of Hawaii Sea Grant Program, formerly Sea Grant Extension Agent at ASCC), Ms. Kelley Tagarino (ASCC) Sea Grant Program) and Mr. Francis Leiato (ASCC Land Grant Program).

Fact finding schedule

Monday, Nov. 4, 2019

Specialists traveled from Hilo, Hawaii to Pago Pago.

Tuesday, Nov. 5, 2019

The specialists met with Gina Faiga-Naseri, Tony Langkilde and Jonathan Brown after an initial introductory meeting with Director Keniseli Lafaele. Director Keniseli informed the consultants of the goal to develop aquaculture as an important activity for economic benefits on a scale that could eventually rival the tuna canning plants. The importance of the wetlands was also discussed.

The Director has also been the point of contact for the consulting company, Lynker Technology, which has recently received a Sea Grant award for a similar aquaculture feasibility study. Dr. Haws had a telephone discussion with Sarah Pautzke who is the lead on the Lynker study, about possibilities of collaboration prior to visiting American Samoa. Since the visit to American Samoa, Dr. Haws and Ms. Pautzke have spoken several times to share information so that the upcoming study avoids duplication of effort.

The consultants and the DOC team spent about three hours discussing the history of aquaculture, current efforts and opportunities, and priorities for aquaculture development. The group agreed that there were three desired outcomes for aquaculture development, including increasing food production, income and employment (not necessarily in that order). The potential for aquaculture to be used for conservation and environmental purposes was also discussed. The ASCZMP personnel also introduced the idea of considering how to utilize the wetlands for aquaculture. Some of the team also met briefly with Tony Tiaui (GIS Technician) of DOC.

In the afternoon, the specialists and DOC personnel met with Kelley Tagarino and Francis Leito of the American Samoa Community College. Dr. Darren Okimoto (UH Sea Grant) had arranged a conference call with Ms. Tagarino and Mr. Leito for an exchange of ideas prior to the visit. During the meeting on November 5, 2019, the ASCC instructors discussed their educational work and their efforts in developing and promoting tilapia culture. Ms. Tagarino later emailed important documents related to the work with tilapia. She also discussed a proposal that she and Dr. Haws had worked on to culture Manila clams. The concept was based on some clam shells that came from Samoa, although the species identification was not certain.

On the way back to town, the team passed some women selling Nu'uuli Pala Lagoon clams on the roadside and interviewed the women (Figure 1). The clams had been collected from this lagoon and were being sold for $10 a basket. Some of the clams were later opened by the consultants and the shells were well filled with meat. This indicates that the lagoon may be a good growing area for bivalves, but sanitation there is questionable. This clam species may be a candidate for aquaculture since it is predisposed environmentally to the area as well as having apparently high glycogen content. Culture may be done similar to Manila clams with broadcast seeding into the mud sediment with a protective predator netting covering the newly seeded area.

Figure 1. Women and children selling clams harvested from the Nu`uuli Pala Lagoon. The clams are a Psammobidae clam, possibly *Asaphis violascens* (Willan 1993). The clams had high levels of glycogen making them “fat”, indicating the lagoon has good growing conditions for this species. Shellfish sanitation will be an issue for areas near settlements.

Wednesday, Nov. 6, 2019

The team made a site visit to Aoa and Aunu`u island (Figure 2).

The village of Aoa is on the northeast side of the island. It has a large wetland area in the middle of the village. The wetland is experiencing a considerable amount of encroachment by houses and agriculture. The team met one woman who had built her house in the wetland area and she said it was subject to repeated flooding. Several such houses were observed, some elevated in a precarious fashion on cinder blocks. The wetland area has a large number of invasive plant species and litter. Some of the invasive trees were identified as *fau, Hibiscus tiliaceus.*

A large, worn oyster shell was found on that beach that appeared to be from a Pacific Oyster. The mayor did not know if this shell was from local stock, although he said that large oysters used to exist in the area. It might have been discarded from purchased oysters. Since Pacific Oysters have been introduced to nearly all Pacific Islands at some point, it might be worth searching for them in estuarine areas to determine if relic populations still exist.

Aoa village has a relatively calm Northern exposure. It may be a candidate for testing the growth and conditioning of Pacific oyster seed using floating bag culture on a tethered single anchor pivot system (see discussion below).

Figure 2. Aoa Village (left) has a relatively calm bay which may be a good site for aquaculture. It can be seen that the central wetland area is being surrounded by houses and this could impact the ecological services provided by the wetland. Aunu`u island (right) is a location where two species of seaweed are gathered. Seaweed culture may have potential there.

The team then traveled to Aunu`u where they met with Mayor Setefano Opapo and other village leaders. The community leaders emphasized that they hoped that some concrete results would come from the study and that they would be informed of the results. Mayor Opapo took the DOC team on a walk along the beach where seaweed (*limu*) is harvested and then into the extensive wetland area where traditional agriculture is still practiced. The latter area could potentially be used for freshwater aquaculture. Several species of fish were observed including some tilapia. The fact that American Samoa still has such extensive agriculture is positive since it is much easier to train farmers in aquaculture as they are accustomed to the concept of caring for a crop on a regular basis.

On the ocean side of the island is an area where seaweed is harvested. There are two types of *limu* that the villagers use. The first is *limu fuafua* (*Caulerpa racemosa*), called seagrapes in English. The Mayor said this species could be sold for around $10 USD for a small bag, but that it had a short shelf life of 2 days and could not be refrigerated. The other species was referred to as a brown species (noting the color, not the taxonomic division) with long leaves, but no one knew the scientific or English name. It was said that this species was tough and had to be cooked prior to eating. The Mayor also said that the seaweeds appeared seasonally and that people from the main island would come to harvest it but had to ask permission first. The team was unable to obtain a specimen of the brown seaweed, but it may be *Halymenia durvillei* (*limu mumu*) and which is reported to be consumed (Skelton 2003). Although there is an ASPA wastewater outfall on this beach (150 ft long), the Mayor did not feel that it was affecting the seaweed as the seaweed had been there before the line was installed. The team was interested in this since an outbreak of bubble algae had been reported in Ofu and this could be related to excess nutrients.

The Mayor also said that their coastal resources could be protected from poachers. He also mentioned that a seawall may be built to control coastal erosion.

Although it is not recommended that a hatchery be built without further assessment and study, Aunu`u island may be a possible site given that water quality is likely to be good. If it is indeed possible to prevent poaching and theft, then grow out sites could be established around the island as part of a future hatchery effort. It is also not so remote that hatchery specialists would find it difficult to work there. The northern side of the island where the seawall may be built is a possible location since it is calmer than the ocean side of the island.

Thursday, Nov. 7, 2019

The team visited Leone and Maloata (Figures 3, 4). In Leone the team met with Ms. Andra Samoa, a member of the House of Representatives for the village of Leone. She continues to work as a villager leader and was teaching a sewing class for women when the team arrived. Ms. Samoa took the team on a walking tour, which included the Healing Garden, a memorial to the victims of the 2009 tsunami. Leone was one of the most affected areas of that disaster. The team was also taken to view a freshwater spring with a man-made rock pool, and it was reported that several other springs existed. This availability of freshwater indicates that fish culture could be conducted.

Ms. Samoa also mentioned that the village had participated in a project growing coral on artificial substrates with the intent of restoring corals that were damaged in the tsunami with some success. This project was facilitated by Dr. Tusi Avegalio of the University of Hawaii Manoa. Ms. Samoa also mentioned a project from U.S. Fish and Wildlife for mangrove and wetland conservation. The amount of mangrove area has been reduced from 41 acres to about 12. This is a serious concern given the importance of wetlands as nursery sites for marine organism, their role in protecting terrestrial areas and for traditional agriculture.

Leone has a small embayment at the mouth of the stream coming from the wetland area that might be a good site to capture small marine or estuarine fish for growout in other areas. Although the coast line near Leone is shallow and subject to wave action, this may be a potential site for aquaculture of corals or seaweed that can be grown in these types of locations.

Figure 3. The Leone Healing Garden (left) and one of several springs (right). Tsunamis remain a major threat to the islands and this should be kept in mind when planning aquaculture. The abundance of freshwater is a good indicator for the possibility of expanding tilapia culture.

The team then drove to Maloata, a village on the northwest side of the island. The intent was to meet with Peter Gurr, who was not there at the time the team arrived. The team was able speak with his son, Tamiano Gurr, and viewed the flower and hydroponic culture areas. There was also a very large concrete structure that was comprised of several very large tanks. This structure had been built by the senior Mr. Gurr's sister but was later damaged in the tsunami.

Possible uses of this structure were later discussed with Mr. Peter Gurr (see below). Mr. Tamiano Gurr also said that poaching could be a problem with aquaculture in open water as there were organized groups that would travel by boat between sites at night, dropping off divers to collect marine resources, then picking them up again.

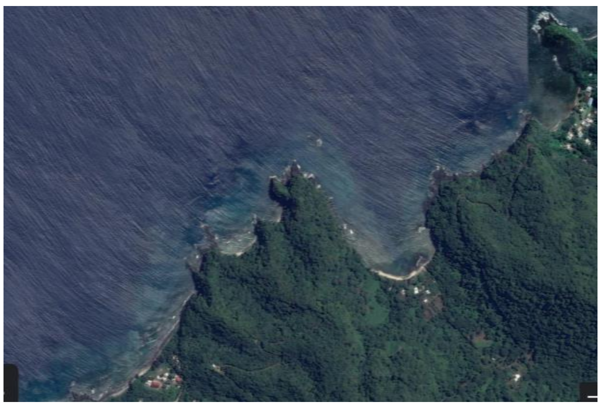

Figure 4. Maloata village (left) has a deep embayment were aquaculture may be a possibility. The owner of the property has four large cement tanks that were intended for fish culture but which were not put into commission after the pumps were damaged in the 2009 tsunami. The tanks have potential to be used in a number of ways (see below).

A meeting was also held with Domingo Ochavillo, Director of the Department of Marine and Wildlife Resources. Mr. Ochavillo provided information on the background of aquaculture and fisheries issue and clarified certain issues such as the ability to obtain permits and construct seawater intakes. He also mentioned that there were plans to import giant clams to restart this activity. He later sent the team the application form for research activities that may be related to aquaculture.

Friday, Nov. 8, 2019

The team went to Masefau and drove along both sides of the wetlands that are in the center of the town. Observations were made of the bay. The bay seems to be a promising site for aquaculture because it is large, relatively calm and because the villagers said they are able to control fishing and gathering by non-residents. There are no boats in the village, however, which might be required if they were to start aquaculture activities.

In the afternoon, the team visited the Nu`uuli Pala Lagoon. This included meeting with Representative Mark Atafua at Lion's Park. Mr. Atafua indicated interest in developing aquaculture in the area and also mentioned impacts on the wetlands.

The team also made some observations in the intertidal area of the lagoon. There are at least two different species of oysters in the area. They are most likely a *Saccostrea* oyster species (Figure 5). Mr. Atafua said that it is mainly Filipinos that gather them, and it was easy to see where oysters had been pried off the rocks. The abundance of the oysters on the rocks suggests this might be a good site to collect wild oyster spat, although the lagoon water is probably too contaminated with fecal coliform and possibly heavy metals to use as a growout site.

Figure 5. Several species of bivalves set on a rock in the Nu`uuli Pala Lagoon, including at least two species of *Saccostrea oyster* and *Isognomon* spp. (left). One of the *Saccostrea* oyster specimens attached to a small rock. This oyster was in spawning condition (right).

The team then visited Mr. Solomona Tuisivi who is developing a site within the mangrove area that will be an ecotourism and educational site. He is conducting a small pilot study using mangrove crabs and has interest in raising mussels. He said that mullet and trevally are common in the estuary. He thought it would be relatively easy to protect the area from poachers, at least the area near his property.

The Nu`uuli Pala Lagoon is the largest wetland area in American Samoa. Residential areas and industrial activities have already encroached on it. Rubbish and other wastes such batteries and appliances were mentioned as problems for the lagoon. The area was the site of aquaculture efforts in the past and could do so in the future. However, preventing more encroachment and cleaning up sources of pollutants would be important in terms of allowing it to continue to provide ecological services that support aquaculture and fisheries.

The team then went with Mr. Brown to look for the site of the old giant clam hatchery that had been located between the airport and Freddie's beach (Tagarino, Itano, pers. comm.). Although the team was in the general area, they were unable to find the exact site.

In the late afternoon, the team attended the weigh-in for the Sanctuary fishing tournament and had an opportunity to meet other stakeholders in natural resource management such as Dustin Snow (fish exporter) and Mike Marsek (NOAA).

Saturday, Nov. 9, 2019

Haws, Nisbet and Brown returned to Masefau to conduct a rapid snorkel survey of the lagoon after obtaining permission from the chief. The marine resources appear to be in relatively good shape with a number of large fish that did not exhibit much fear. Several species of colorful corals were also observed that might be candidates for aquaculture for the ornamental trade. Bivalves such as giant clams and oysters might also be cultured.

The team also visited the National Park where some large, giant clams were observed. This is a positive sign that some wild stock may still exist that could be used to restart giant clam culture.

In the evening, Haws and Nisbet attended the closing sanctuary fishing tournament events and met other residents who shared information.

Sunday, Nov. 11, 2019

Haws and Nisbet attended an afternoon event with Tony Langkilde which included the owner of Tisa's Barefoot Bar and had a chance to meet other residents who provided more information on fisheries and related matters.

Monday, Nov. 12, 2019

This was Veteran’s Day. The team spent most of the morning working on the draft report. They then met Tony Langkilde at the Nu`uuli lagoon to meet with Mr. Peter Gurr. They discussed his agriculture endeavors and got a fuller description of the concrete structure that had been originally intended for moi culture. Mr. Gurr said there had been pumps to fill it with seawater, but these were damaged by the tsunami and the effort was then discontinued.

The team then discussed the possibility of using the large tank structure for scaling up tilapia culture since Mr. Gurr mentioned that tilapia were in demand, and were sometimes ordered in large numbers for events such as funerals. Mr. Gurr’s large concrete tank structure could be used in several ways.

Since the tank structure is next to a stream, it could be filled with freshwater without using pumps in order to culture tilapia or other freshwater fish. The tanks are fairly large though, and it would make management easier if they could be partitioned. This facility might serve to produce large numbers of tilapia fingerlings, which could then be sold to other local producers. This could be a way to increase both the number of tilapia producers and improve the quality of the tilapia if improved strains were used and if only male fingerlings were distributed.

Another option would be to use the large tanks as reservoirs for seawater which could then be distributed to smaller, more easily managed tanks for marine or brackish water fish. If solar-powered pumps were used only during the day, this would significantly reduce the operational costs and avoid the need for batteries. For example, mullet fingerlings could be captured from the wild and grown out in tanks at this site.

The other issue discussed was the possibility to manufacture fish and livestock feed using fishmeal from the canning plants. Local manufacture of feeds can build on the experiences of the ASCC staff in making tilapia feed, as fish meal is readily available. Mr. Gurr had also used fishmeal to make poultry feed with some success and was considering entering into large scale manufacture. One obstacle for scaling up feed production is the availability of a carbohydrate source.

Mr. Gurr also told the team about hosting sea cucumber expert, Mr. Masahiro Ito several years ago. Mr. Ito is an internationally recognized sea cucumber culture specialist and recently authored a manual on hatchery production of sea cucumbers (Ito 2018). Mr. Ito apparently thought that there was potential for sea cucumber production, including in the Nu`uuli Pala Lagoon, particularly since most Samoans do not eat sea cucumber and this would prevent problems with theft.

After the meeting with Mr. Gurr, the team visited the Nu`uuli lagoon to re-examine the site during low tide.

The Hawaii-based team then departed that evening for Honolulu.

Findings and recommendations

American Samoa is similar to the rest of the world in terms of aquaculture development since the potential far exceeds the realization of this potential. Generally aquaculture development in any location is limited by common constraints and unless these are addressed, aquaculture development will be stymied. However, current conditions are favorable to start aquaculture development in several forms, but small-scale farming and aquaculture for conservation or environmental purposes are the most likely types to be successful at this time.

There are three basic forms in which American Samoa can pursue aquaculture:

Small-scale farming by individuals or community-based groups-pilot projects and small-scale farming are feasible at this time assuming that the responsible agencies and the private sector can work together to provide support and resources.

Large-scale commercial farming-this is far less feasible under current conditions since infrastructure, services, policy framework and investment are not immediately available. However, small-scale efforts can help set the stage for larger efforts in the near future.

Aquaculture for conservation and environmental purposes-some forms of this may be feasible and could go hand-in-hand with small-scale farming efforts. For example, using bivalves for water quality purposes or coral culture for restoration could be coupled with small scale farming at the community level.

In order for aquaculture pilot projects or small-scale efforts to be successful, the following would be needed:

- Species that can be cultured with the least amount of technical capacity, fewest and least expensive inputs, and which provide benefits to the stakeholders in a timely fashion. Initially it is best to avoid forms of aquaculture where capital and operational costs are high and where external sources of goods are required as these factors increase the likelihood of failure. It is also rare for communities to have the patience to engage in efforts where benefits take a long time to accrue, or where the benefits are not concomitant with the effort or time required. Stakeholders also compare how the benefits from aquaculture compare to other opportunities they have with other activities.
- Dedicated technical assistance for a minimum of three to five years for each project is required. Generally longer-term support is needed. This assistance is best delivered by local extension agents that have sufficient resources and expertise to render technical support. Local extension agents can be supported by non-resident specialists as needed. For example, there are researchers and extension specialists who work with all of the

species mentioned in this report in the Pacific Region, and their expertise can be tapped by local specialists.

- It is important to conduct an economic analysis of costs and benefits prior to choosing which type of aquaculture to support and at what scale. The market must also be considered.
- Willingness of the stakeholders (e.g. villagers) to "own" the initial pilot efforts and to take responsibility for the execution of the work is also extremely important.
- The government must be willing to provide three to five years of technical support as well as some of the initial financing, although contributions from stakeholders (e.g. part of the financing, labor) should be required in order to avoid over dependence on government financial support.
- Long-term capacity needs to be built through educational and training opportunities so reliance on external specialists is reduced.
- Since aquaculture is a multi-disciplinary and multi-sectoral activity that ranges from natural resource management to financing and marketing topics, it is necessary for multiple agencies to coordinate closely to support new efforts.

A basic SWOT analysis was conducted in order to determine which species and culture systems might be most appropriate in the short-term.

SWOT ANALYSIS FOR AQUACULTURE IN AMERICAN SAMOA

Strengths	Weaknesses	Opportunities	Threats
Well-educated population Many retired veterans with technical and leadership skills Village leaders have some control over resource use Prior experiences with different forms of aquaculture Educational and technical capacity present at the American Samoa Community College , DMWR and other agencies Training opportunities in other countries Diverse aquatic resources Population has interest in fishing and maritime activities Good prospective sites such as the northern bays	Infrastructure for aquaculture (e.g. hatcheries) is non-existent Insufficient technical expertise for aquaculture aside from DMWR and ASCC. Factors which caused failure for past projects still exist: • Lack of compliance with regulations • Theft and poaching • Scarcity of financing Few small boats Regulatory framework and permitting process are not clear for all types of aquaculture	High demand and imports for seafood and protein Export opportunities to Samoa and other countries Several species that can be cultured without a hatchery Existing marine science and aquaculture courses at ASCC to build local capacity Presence of NOAA and other U.S. federal agencies that support aquaculture Agencies and expert personnel that can support aquaculture Proven track record with small-scale tilapia culture and local feed manufacture Experiences in Samoa and other Pacific islands can be transferred without reinventing the wheel	Tsunamis and storms Southern coast is rough with narrow coastal shelf Water pollution Poaching and theft affected past aquaculture production and management of marine resources Economic dependency on U.S. economy Restrictive or unclarified regulation and permitting Damage to wetlands may affect fisheries/aquaculture resources Lack of financing

Assessment of Species, Culture Systems and Sites

American Samoa is fortunate in having a large number of marine, estuarine and freshwater species with potential for aquaculture. Most of these species, as well as their culture systems, have been developed elsewhere in the Pacific Region, so re-inventing the wheel is not necessary. Lessons learned from other areas can be readily transferred. A network of technical and extension specialists also exists in the region and these specialists can be tapped to support local efforts. American Samoa also has diverse sites where one or more species can be cultured. However, it is important to carefully match species and their culture systems with appropriate sites. Poor site selection is a major cause of failure for aquaculture. It is also important to work closely with private sector or community members who are responsible for new projects so that role and responsibilities of each stakeholder group are clearly understood and carried out.

The stakeholders the team spoke with consistently mentioned the possibility of theft as a major reason that aquaculture could fail.

It was also noted that there are few small boats due to the tsunami. Most open-water sites would require the use of small boats, although they do not necessarily need to be motorized. In the calmer bays, some sites could be accessed on foot. The DOC has a project to build an improved model of an alia. These boats could also be used for aquaculture.

The following is a discussion of the species, culture systems and sites that have the highest degree of feasibility under current conditions in American Samoa.

Much of this analysis is based on prioritizing species that can be cultured without investing in hatcheries, or which would require minimal investment for infrastructure. The reason for this criterion is that for most species, hatchery production requires the ability to culture large volumes of microalgae, which is an expensive and technically exacting activity. Moreover, even simple hatcheries are expensive to build and maintain, and must be staffed with highly trained personnel.

This is not to say that hatcheries should not be included in longer term development goals, only that this must be planned carefully and stable funding needs to be assured. There is a long history of regional hatcheries failing due to inconsistent technical and financial support. Additionally, if hatcheries are to be built, capacity building and education must go along with this to ensure that there are qualified staff available. The simplest forms of aquaculture can proceed in the short-term without the expense and complications of building a hatchery.

Tilapia

The term “tilapia” refers to a wide range of cichlid fish species in the genera *Oreochromis*, *Sarotherodon* and *Tilapia*. Each species, as well as hybrids between species, have unique characteristics that must be evaluated in the context of the local situation. There is great variation in their feeding and reproductive habits, as well as salinity tolerance. Tilapia have become one of the most common freshwater species for aquaculture on a global basis due to their rapid growth, tolerance of extreme environmental conditions and ease of reproduction. Some tilapia species can benefit from fertilizing the pond which produces an algal bloom and zooplankton which the fish can eat. This can greatly reduce the amount of feed required. Despite being one of the easiest fish to culture, caution is indicated because there is a requirement for some degree of technical expertise

American Samoa imports a large amount of frozen fish which could possibly be replaced by local tilapia production. Non-fillet frozen fish represented 14.8% of $123M AS imports in 2017. Tagarino (2019) reports that wholesalers sell approximately 225,600 pounds of tilapia per year, representing an increase of 58,600 pounds per year since 2004. The retail price is $1.86 per pound, a $0.48 per pound increase since 2004. This makes tilapia more expensive than chicken. If farmers use the locally-produced fish feed made by ASCC, tilapia farming can be profitable. Some farmers may obtain higher prices through direct sales.

Many locations in American Samoa are classified as “food deserts” (Asifoa-Lagai 2012) where limited access to locally-produced, healthy foods leads to an over dependence on imported, nutrition-poor foods. More tilapia production in the villages, for example by school or women’s groups, could help provide locally-sourced protein. Fish culture is also an excellent educational activity for school children.

The Sea Grant and Land Grant programs at the ASCC have a long-standing effort to develop and promote tilapia culture. This included developing the capability to manufacture local feeds on a small-scale. This feed is produced through ASCC procuring the fish meal and the farmer provides the starch and oil. ASCC has the equipment for small-scale feed manufacture. Kelley Tagarino and Francis Leito were helpful in providing background information on their work. They have data showing that the combination of reducing feed costs along with increased retail prices are at the point where tilapia culture can be economically feasible. Given the initial success of this work, tilapia culture is ready for expansion and could become a significant source of food and income. Additionally, even small-scale production can be important as a local food sources. Many countries have school-based food production programs including fish culture, which can provide a steady source of food for school children.

Tilapia culture could be another way to take advantage of the freshwater resources of American Samoa. Particularly in the case of villages which surround wetlands, freshwater could be extracted to support tilapia culture. This is best done by diverting a limited amount of water from the upland areas to supply ponds built outside of the wetlands, rather than siting ponds in the wetlands. Wetland areas are generally poor sites for ponds due to flooding and because ponds built in low-lying areas cannot be drained. The latter is particularly important for tilapia farming as these species tend to breed prolifically in ponds and exceed the carrying capacity. The ponds must be periodically drained and dried to get rid of the overabundance of small fish. In any case, if tilapia farming is expanded, it may be important to calculate a water budget for the farming area to avoid creating competition for freshwater between residents and fish farmers.

Based on the information provided by the ASCC staff and observations made by the DOC and consultant teams, the following actions are needed to support expanded tilapia culture:

- A steady supply of tilapia fingerlings with good genetics can increase growth rates and potentially the appearance and marketability of the product if red strains of tilapia are used.
- Production efficiency can be increased if all male strains, sex reversal or hand sexing can be implemented. Male tilapia grow faster than females. Reducing or eliminating the number of females also limits over population of the ponds by thousands of small tilapia which leads to slower growth and stunting.
- Extension personnel are essential to help farmers become self-sufficient. While the Land Grant and Sea Grant programs at the ASCC currently provide technical assistance, more support for them would be helpful and could help kick start larger-scale fish farming.
- The local fish feed production has served as an important proof of concept that fish feed can be locally produced. This program requires financial support and could be expanded. A steady supply of a carbohydrate source is needed since using local sources is preferable to purchasing flour (although the latter clearly works).
- Proper siting and construction of ponds is important. Poor site selection and pond design can make it difficult or impossible to manage a pond effectively. There is a tendency to build ponds in existing depressions or low-lying areas since this reduces the labor requirement. However, tilapia culture depends on the ability to drain and dry ponds to eliminate the over-production of small tilapia. Once ponds are dried, they should be cleaned and lime is often added to adjust the soil pH. This increases primary production once the pond is filled again. Primary production in ponds serves as an additional food sources for tilapia and reduce the amount of feed needed. A survey of suitable sites near villages that have interest in tilapia farming could identify adequate locations, including areas near, but not in wetlands, where an adequate water supply could be sourced.
- Involving groups such as children and elders that may need supplement protein sources should be considered. School ponds can be a good source of food as well as a way to teach basic science.

Seaweed (*limu*)

A review of the literature finds that three species are consumed in American Samoa: *Caulerpa racemosa*; *Caulerpa* spp. and *Halymenia durvillei*. The Samoan name for *Caulerpa* (Seagrapes in English) is reported as *limu fuafua* and *H. durvillei* may be *limu mumu* (Skelton 2003). It appears from local interviews that consumption of seaweed has been reduced or forgotten in recent years and among the youth. Seaweeds are a relatively easy/low cost species group to culture, provide high levels of nutrition and feeding is not required.

There may be another 20 or so species which could potentially be consumed. For example, *Grateloupia filicina*, *Codium mamillosum* and *Asparagopsis taxiformis* are present. These species were traditionally consumed by Hawaiians and continued to be prized although collection from the wild is increasingly difficult as many coastal areas in Hawaii have seen the seaweed populations decline. *A. taxiformis* (*limu kohu* in Hawaiian) is the most highly valued seaweed in Hawaii with the price being around $20 per pound. This species has not yet been successfully produced in commercial aquaculture but *G. filicina* and several *Codium* species can be reared through vegetative propagation.

During the visit to Aunu`u, the residents reported harvesting a green and a brown seaweed. The green seaweed is most likely one of the *Caulerpa* species. The “brown” seaweed was not identified, but residents said that it was cooked, then eaten with coconut cream. None of the three Samoan specialists involved in the interview had heard of this latter species nor the practice of cooking a seaweed. The “brown” seaweed may be *H. durvillei*, which is in the Division Rhodophyta (red seaweeds). The villagers said that both species appear seasonally on the exposed, southern part of the island. The prices for the green seaweed was reported to be $10 for a small bundle. Residents of Masefau also reported that seaweed used to be gathered and consumed but said that this was no longer done.

Seaweed culture could have potential for American Samoa as it generally requires little technology and can provide both healthy food and income. Methods have been developed for *Caulerpa* and experiments are being conducted in the Philippines with *H. durvillei* (Figure 6). The latter is not usually cultured for food, but rather for as a source of the red pigment r-phycoerythrin and other nutraceuticals such as a lambda-carrageenan-like polysaccharide (Santiañez et al 2016). Both substances have high value, but confirmation with buyers would be needed before deciding to produce this species for its secondary compounds.

Researchers at UHH are conducting research on culture methods for *Caulerpa*, and the results can be shared with interested parties.

 

Figure 6. *Halymenia durvillei* (*limu mumu*) a red seaweed which has potential for aquaculture (left). Source: Skelton, 2003. Experiments with *Caulerpa* at UHH show that it ready attaches to many types of substrate meaning that it can be transplanted and grown in areas where it may not be found naturally. Source: M. Haws

Two non-native species are reported as having been introduced for culture for the carrageenan industry, *Eucheuma* spp. and *Kappaphycus* spp., but populations of these species are not reported as having persisted. These species are among the most commonly cultured in the world, but re-introduction is not recommended as they have the potential to become invasive and global prices are low.

Small-scale seaweed production is common in countries such as the Philippines, Indonesia, Fiji and Tanzania but may be less feasible in the other Pacific Islands as in most cases, seaweed prices are low, and residents may have more lucrative opportunities. Given that the price of this international commodity is so low, if American Samoa stakeholders decide that seaweed culture may be an option, only the higher priced species that can be sold for food or exported should be considered.

Additionally, caution should be taken to avoid importing seaweeds as there are many areas with seaweed diseases. Climate change impacts such as increased sea surface temperatures may also impact seaweed culture. This happened in the case of Tanzania where seaweed began to suffer from the "ice-ice" disease which bleached the seaweeds. It then became important to choose sites where the water was cooler to reduce the incidence of "ice-ice" disease (Haws, pers obs.). Thus site selection is important when considering seaweed culture.

Giant Clams

Giant clams (Tridacnids) have a long history in American Samoa.   It is believed that the native species are *Tridacna maxima*, *T. squamosa* and *Hippopus hippopus*. The first two have been persistently present, although the latter is believed to have been re-introduced to aquaculture after local stocks were depleted. Other species such as *T. gigas* and *T. derasa* were also introduced for aquaculture.

Around 1986, DMWR personnel visited Palau to learn spawning methods and *T. derasa* was imported for the first time. The introduced *T. derasa* clams were around 4 inches in length and were housed at the Waikiki Aquarium during the transhipment. Initially the clams were kept in the borrow pit area near Coconut Point, Nu`uuli. They were later moved to Alofau. There were problems with poaching and the remaining clams were put at Taema Bank at about 65 feet, but these were also stolen (David Itano, pers. comm. to Kelley Tagarino).

In 1989, a second project was started with funds from the Center for Tropical and Subtropical Aquaculture (CTSA) for *T. derasa*, followed by a third in 1991 for *H. hippopus*. *T. gigas* was also introduced at this time. A small hatchery was built and several full-time personnel were hired over the years in which the various projects were executed. Trials to test growth rates and survival with the various species were conducted at Nu`uuli, Ofu and Alafau (Bell 1993). The latter report details eleven introductions of different species from 1986 to 1991.

The DMWR operated a giant clam hatchery in the 1990's near the airport for several years and at least three farms operated for some time. In 2004, an effort was made to build a hatchery at Alao with Chief Ava Hunkin, although this facility did not come fully into operation (Figure 7). One of the main issues with this site was the difficulty of installing a seawater intake line due to the wave action on that area of coast. Mr. Simon Ellis, Director of the Marine and Environmental Research Institute of Pohnpei (MERIP) was the lead trainer for this effort and could serve as a resource person in the future. At that time, there were also plans to begin culturing soft corals at the small hatchery but this did not take place as the hatchery effort was discontinued.

Figure 7. Spawning tanks at Alao from an effort to develop a giant clam hatchery (left). Chief Ava Hunkin injecting a giant clam with serotonin during the training (right). Source: Ellis, 2004.

The current status of the various giant clam species at the present time is not entirely clear. Some specimens were viewed in one area of the national park and villagers reported that some clams are present, but not abundant. Giant clams are a valuable resource and their populations are easily decimated by overfishing. While the methods for aquaculture production have been developed and are relatively simple, very few hatcheries survive without government support. Farming efforts are often cut short by poaching. The length of time needed to obtain a clam large enough to eat is 3-5 years and this may discourage farmers as well. Some success in production of smaller sized clams (~2 inches) for the ornamental trade has been achieved in areas such as Pohnpei and the Republic of the Marshall Islands.

An economic analysis conducted in 1993 (Leung et al. 1993) estimated that the small-scale production system in use for *T. derasa* in American Samoa resulted in a cost of $0.76 for a 1-year-old clam and $3.40 for a 2-year old clam. Costs would no doubt be higher using current values but increasing the scale of the farming could also lower it. There were only a few thousand clams being grown at that time. The authors concluded, however, that if all parts of a clam are saleable (meat and shells), profitable clam farming could be possible.

Although giant clam farming has been demonstrated to be biologically feasible, many countries have had their giant clam trials halted by problems with theft, including the past efforts in American Samoa. Unless mechanisms are in place to prevent this, it is unlikely that giant clam farming will be feasible. It would also be important to determine the market potential for clams as ornamental specimens and the prices for the various product (e.g. shells, meat). Giant clams can also help with tourism development. Giant clam "circles" (large clams aggregated in shallow areas) have been popular tourist attractions in Kosrae and Palau in the past. Some wild giant clams do exist in protected areas in American Samoa, but unless better means of protecting both the wild and farmed clams are found, aquaculture production may not be a viable option (Figure 8).

Figure 8. A rare wild giant clam in a protected spot on Tutuila. This clam is probably a *T. derasa* (left). Giant clams (*Tridacna gigas*) in the Solomon Islands illustrating their value as a possible

tourist attraction if they can be protected. Aggregating the clams also improves reproductive success if stock enhancement is the aim (right). Source: Teitlebaum and Friedman, 2008.

Although giant clam hatcheries are among the simplest types of hatcheries to build and manage, even these minimum costs to build and operate a small facility may not be merited unless the theft problem is dealt with. As an example of the costs involved for even a very small hatchery effort, the pilot hatchery that was started in Alao was backed with about $50,000 in grant funds and would have had around $1,000 per month operational costs, excluding labor (Ellis, per. comm. 2019).

One possibility would be to select one or more villages as pilot sites, and support these with technical services and law enforcement to enable villagers to test clam growout. Giant clams are produced in large numbers in other countries' hatcheries, particularly *H. hippopus* (Figure 9). Small specimens could be imported for initial growout trials to determine if the social conditions exist to avoid theft. *H. hippopus* is native to American Samoa and is relatively fast growing, so it is a candidate for food production. It would not be highly suitable for the marine ornamental trade as it tends not to have bright coloration as do *T. derasa* and *T. maxima*, but this also helps it to avoid theft to some degree. If food production and reef restocking are the goals for new efforts with giant clams, then this species would be appropriate.

Figure 9. Bear Paw giant clams (*Hippopus hippopus*) being produced in the thousands by Martin Selch, who operates a private business at the National FSM Hatchery located in Kosrae. Clams could potentially be imported from Kosrae for pilot projects and as future broodstock. Source: Martin Selch.

A great deal of marketing research and liaising with international buyers would be needed to enter the field of ornamental clam production, so this is not recommended until the research can be done. Also, the other regional hatcheries which produce ornamental clams are most likely close to saturating the market.

Other bivalves (oysters, clams, mussels)

Bivalves other than giant clams may be possible culture candidates if they can be obtained through spat collection, or from other hatcheries. Production of bivalve larvae and spat requires a hatchery with the capability to produce large amounts of several species of microalgae culture, which requires technical expertise and incurs high costs. A bivalve hatchery would require several years to develop and significant investment.

Dr. John Glude first assessed the potential for shellfish aquaculture in 1971. He observed that there were two clam species that supported a small fishery, *Gafrarium tumidum* and *Lioconcha lorenziana* (Glude 1972; Uwate et al. 1984). These species were not observed during this study. Dr. Glude also conducted a few trials transplanting the local oyster (*Saccostrea glomerata*) from the Nu`uuli Pala Lagoon to other areas with some success. He recommended following up on the trials. This recommendation is still valid. *Saccostrea* oyster species are cultured in several areas, including in Australia.

Aside from the clam species mentioned in Glude's report, there are other bivalves which may be a possibility for aquaculture. The tuagane clam seems to be relative abundant in some lagoons. This is a Psammobiidae clam (sunrise clam), most likely an *Asaphis* species.

At least two species of oysters were observed attached to rocks in the Nu'uli lagoon. These appear to be *Saccostrea* species based on the structure of the shells. A large oyster shell which appeared to be from a Pacific oyster (*Crassostrea gigas*) was found on the Aoa beach. The latter species appears to have been introduced at least once from Washington State (Chew 1990). Whether this shell was from a past introduction or was discarded from purchased seafood is unclear.

There are two ways in which juvenile bivalves can be obtained for culture without the need for a local hatchery.

One immediate possibility is to import a limited number of Pacific Oyster spat (juveniles) from a Hawaii hatchery to test in a few sites such as Masefau. The ideal location would have a protected bay and a village with the capacity to protect the oysters from poaching. The Hawaii shellfish hatcheries (including the PACRC at UHH) sell certified disease-free spat, so introduction of diseases is not a high risk. Also, if triploid spat are used, the possibility of reproduction is nil, thus preventing establishment of non-native oyster populations in the wild. Triploid oysters have three sets of chromosomes which makes them sterile. These can be purchased from the Hawaii hatcheries. Oyster spat also has the advantage of being relatively inexpensive. One thousand 2 mm spat cost around $15. Most of the Hawaii hatcheries also produce Manila clam seed.

A second low-cost option which does not involve much technology is wild spat collection. This can be used to obtain species that are not produced in hatcheries. For example, the oysters observed in the lagoon could most likely be collected using collectors made from materials such as various forms of plastic, wooden stakes, coconut shells and husks, etc. (Haws 2002, Haws and Ellis 2004). In general, only bivalves which attach though cementing themselves, or by attachment by byssal threads can be collected in this way. See some of the examples of inexpensive, easy to use spat collectors are shown in Figure 10.

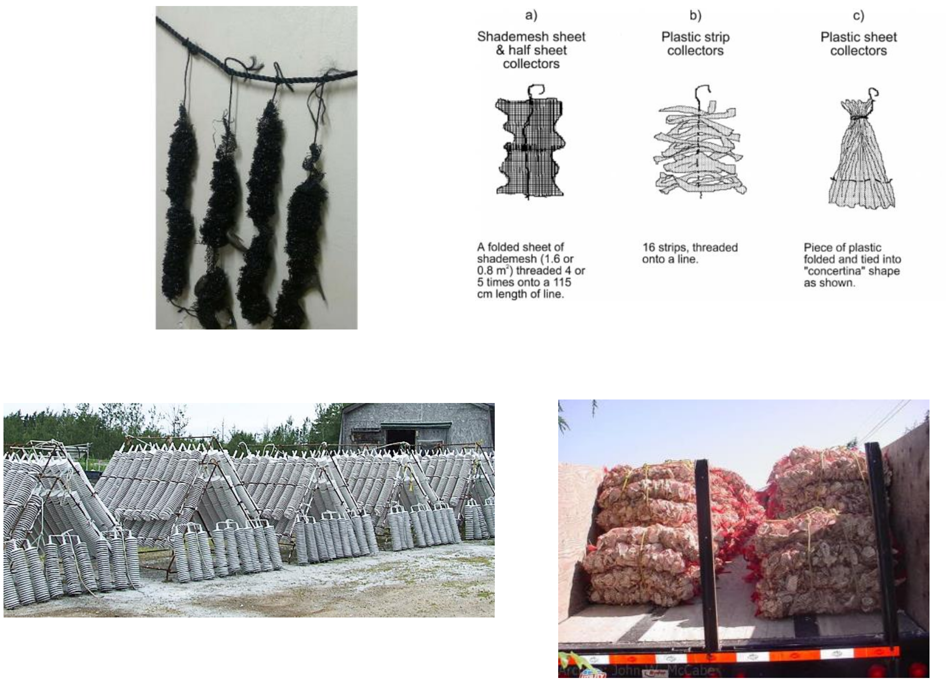

Figure 10. Spat collectors made from different materials. Nearly any material can be used for spat collection, but materials that are dark, offer spaces to hide from predators or have high calcium content usually work well. From top left to bottom right are: shade cloth collectors for pearl oysters or mussels, a variety of other materials, plastic collectors used in Korea and oyster shells used in Washington.

Oysters can be cultured using a wide variety of cages and systems, but for the calmer bays in American Samoa, floating cages might be appropriate as they make handling and cleaning easy. One such type is shown in Figure 11.

Figure 11. One type of floating bag system used for oyster culture which consists of a mesh bag attached to floats. In these photographs, the oyster cages have been flipped up to expose them to sunlight which reduces fouling. After a drying period, the cage is flipped over again so that the oysters are submerged. Source: Go Deep Shellfish Aquaculture.

One critical aspect of shellfish production is sanitation. Filter-feeding bivalves accumulate bacteria and viruses from the water and thus can be unsafe to eat. Shellfish sanitation involves regular water testing in the growing area. This would need to be done at each growout site to evaluate the levels of total and fecal coliform bacteria. These bacteria are the most commonly used indicators for shellfish sanitation. For bivalves such as giant clams where only the muscle is consumed, routine water testing may not be necessary.

However, it would need to be determined whether U.S. regulations related to shellfish sanitation are applicable if the shellfish are intended only for local consumption and not for export. The Food and Drug Administration (FDA) and individual state agencies are responsible for shellfish sanitation in the U.S. Even if FDA shellfish sanitation regulations are not required in American Samoa, analogous regulations and monitoring would still be needed to avoid the possibility of shellfish-borne diseases which can be deadly.

If it is decided that spat collection is an option to pursue, the spat could be collected in nearly any site (e.g. Nu`uuli Pala Lagoon) even if the water quality is poor, then moved to a cleaner site for growout. Generally spat need to be transferred to cleaner waters before they reach a size of 20 mm. The only exception may be if heavy metals were present in the collection area and were detectable in the spat. In this case, it would not be possible to use these spat.

Filter-feeding bivalves can also be use for water quality mitigation purposes, but this would require that people are prevented from stealing or eating them.

Pearl culture may be another option, but a hatchery would most likely be needed. Mr. Peter Williams, a well-known pearl farmer from Manihiki, Cook Islands, conducted surveys in Samoa and American Samoa in the mid-2000's (Williams pers. comm). He was only able to find a few scattered specimens which makes spat collection unlikely.

Coral and live rock

Corals may be cultured for the marine ornamental trade or for conservation purposes such as restoration or to create artificial reefs for coastal protection. There are several coral farms in the USAPI, which include MERIP, Marshall Islands Mariculture Farm (MIMF) and Aquaculture Kosrae. These farms culture a variety of marine ornamentals such as giant clams, corals and fish in order to be able to offer a variety of species to buyers which prefer to buy as much as possible from one supplier. During the snorkel survey at Masefau, several species of brightly colored corals were observed that may be potential culture candidates (Figure 12). Aside from bright coloration, the species has to be easy to fragment and grow, look attractive under aquarium lights and be able to survive transportation. The candidate species should also be unique and not one that is readily available from other regions. Soft corals can also be grown and are in demand for aquaria.

Figure 12. Examples of brightly colored corals found at Masefau that might be candidates for culture. Other factors such as the appearance under aquarium lights, ability to survive shipping and price would need to be evaluated for each species.

One company which buys only cultured products is Ocean, Reefs and Aquarium (ORA, orafarm.com). This company has a facility in the Marshall Islands and buys products from other areas such as Pohnpei and Kosrae. Some examples of hard and soft corals sold by ORA or produced at MERIP are shown in Figure 13. MERIP provides technical support to about 20 small-scale farmers in Pohnpei to produce hard and soft corals. MERIP also plays a key role by handling the sales, shipping and permitting tasks. A similar model of partnership between small-scale private farmers and a non-profit agency could be developed in American Samoa. It is important to work directly with buyers from the beginning of a project as they have precise specifications for the various types of coral and how they are cultured and shipped.

Figure 13. Corals from Pohnpei, some of which are purchased by ORA for sale in the U.S. The center photograph shows a soft coral being cut into pieces for culture. The photograph on the right shows hard corals being grown on an artificial substrate that is supplied by ORA. The use of an artificial substrate makes it clear that the specimen is cultured which helps pass inspections. The plug also fits nicely into mesh, as well as being easy to place in an aquarium. Sources: ORA and MERIP.

Coral culture is generally done through breaking off small pieces from wild coral (fragmentation), attaching the fragment to a substrate where it grows into a small coral specimen. These are then shipped to buyers who redistribute to retail outlets. Although this sounds simple, establishing coral culture as a viable enterprise is not just a question of being able to grow the coral, it is critical to be able to communicate and coordinate closely with the buyers. Also, most buyers prefer to buy multiple species from a single seller, which is one of the factors of success for the farms in Micronesia since most of them offer giant clams, corals, fish and other ornamentals.

Live rock is a product used in seawater aquaria and is in high demand since most seawater aquaria require many pounds of it. It is used in aquaria as a biological filter, to introduce new organisms and for decoration. Live rock is produced by putting suitable substrate “base rock” in the aquatic environment and allowing it to be colonized naturally by marine organisms such as coralline algae, coral and small animals. The substrate can be natural or artificial, but usually attempts are made to use a light weight substrate to reduce shipping costs. Old, bleached coral can be used as well as mixtures of cement and other materials. As long as the substrate is placed in areas where it will not impact the reef, this can be a highly sustainable activity. Care must also be taken that the live rock harvested is actually cultured, and that live coral is not being harvested under the guise of producing live rock.

To start live rock production, a pilot would be needed to test different sites to determine in which area the colonization of the base rock results in the most attractive assortment of organisms.

Mangrove crab

Mud crab culture is a topic which invokes a high degree of interest due to the high demand and prices wherever crab species are found. This form of aquaculture is practiced in locations in South East Asia and Africa. Some of the technology has been transferred to Palau by Dr. Miguel delos Santos who is from the Philippines. The most common form of mud crab culture is done by capturing juvenile crabs in wetland areas, then growing them either in net pens in the wetland, or in land-based tanks. Either system requires that large amounts of fish be used to feed the crabs, which can be problematic since the fish creates waste and water quality problems in the wetland areas. Also, feeding fish to crabs may compete with the use of fish for human consumption. Net pen structures built in a wetland area may also cause impacts. Given these issues, promoting mud crab culture is not recommended. Instead, managing the crab catch in a sustainable fashion is a more desirable route, as well as protecting the wetland area in which crabs breed and grow.

Marine Fish

Production of marine fish generally requires a sophisticated hatchery and highly trained personnel. Even with hatchery infrastructure in place, it may take 2-3 years before a marine fish hatchery is functional due to the need to obtain and condition fish broodstock. In the case of marine fish species that have not been cultured before, research may also be necessary to work out the required hatchery protocols. Until such a hatchery exists in American Samoa, there are other options for culturing marine or brackish water fish: 1) work with hatcheries in other areas to buy fish fingerlings for stocking; or 2) use capture-based methods to obtain stock for local species.

Hawaii would seem to be a natural place to obtain hatchery produced fish, yet the State is now suffering from a lack of fish fingerlings. The Oceanic Institute (OI) of Hawaii Pacific University has the capability to produce several species of marine fish (moi, mullet, coral grouper) but any effort with them would have to be fully funded as they usually do not sell fingerlings. OI works with researchers in Palau to research methods for producing coral grouper and potentially a similar collaborative arrangement could be made with an American Samoa agency.

The PACRC has a new marine fish hatchery, but fingerlings may not be available until mid-2020. Either option will be expensive given shipping costs. Also, caution is indicated in bringing in fish from other regions, even if the species in question is found locally, since there is risk of diseases. Unless genetic studies have been done which show that the fish from the hatchery locale is genetically similar to the population in American Samoa, there is also a risk of impacting local fish genetics.

A simpler and much less expensive option is to stock aquaculture operations using juvenile fish that are captured locally. There are several methods for doing this (Figure 14). Juvenile fish can be collected from nursery areas, e.g. wetlands. Mullet may be a good candidate for this. Another method involves capturing fish as the larval fish begin to settle out on reef or sea grass areas.

This method is currently being tested in Pohnpei, FSM, by Simon Ellis. Mr. Ellis and his team at the Marine and Environmental Research of Pohnpei (MERIP) have developed methods using specially designed nets to capture rabbitfish larvae as they settle out into seagrass areas. The fish are then kept in tanks until they are large enough to transfer to floating net pens in a lagoon.

This method can be environmentally friendly since only a very small percentage of the fish population are captured. Generally it is habitat availability which limits fish recruitment, not the number of fry that settle in reef areas. Most juvenile fish will die from predation before becoming mature. It may be possible to develop similar methods for species in American Samoa, although this would require research to determine in which locations and seasons the various fish species can be caught. Specialists from the DMWR may need to conduct studies to determine how many fingerlings could be removed without affecting the fisheries stock. Care must also be taken not to disturb the habitat in which the capture takes place.

It is also necessary to determine where the grow out phase of fish farming could take place. American Samoa offers some complications due to the high energy nature of its coast line. Although net pen engineering has advanced to the point where cages can be located the open ocean, these operations are costly and complex to manage. Smaller net pens may be feasible in some of the calmer, more protected areas such as Masefau, Aoa or Afono. Even some of the Pago Pago harbor may be useable for net pens, although water quality would need to be assessed first. Land-based grow out facilities may also be a future possibility, but again, these are expensive to build and manage.

Figure 14. Using small push nets to capture milkfish fry in Bali (left), source: Clyde Tamaru. Nets used in Pohnpei (center) to capture larval rabbitfish as they settle in seagrass areas and floating net pens for grow out (right). Source: Simon Ellis.

Education and Extension Capacity

American Samoa is fortunate in having numerous specialists in fisheries management, marine science and related fields at institutions such as the American Samoa Community College, DMWR, and U.S. agencies such as NOAA. For example, Kelley Tagarino and Francis Leito, along with their predecessors, were able to start a small-scale tilapia farming industry and manufacture fish feed using local ingredients. One deficit, however, is the lack of dedicated aquaculture extension agents with experience culturing multiple species and with resources to train and assist aquaculture stakeholders.

In order to advance with either pilot projects or further assessment, at least one highly qualified aquaculture extension agent would need to be hired and placed at one of the agencies.

It would also be desirable to begin building future capacity by providing resources to the ASCC for undergraduate education in aquaculture and possibly through scholarships to four-year and graduate educational institutions in the region. Incentives to attract recent graduates back to American Samoa may also need to be provided. Currently trained aquaculture specialists are in high demand in Hawaii and other regions, and salaries tend to be relatively high even for new graduates if they have hands-on experience.

Another model that has worked in other countries a working group model where a multi-institutional group made up of local and external specialists work collaboratively to develop and possibly implement small-scale projects as well as to work on other crucial aspects of aquaculture such as policy development and financing.

Wetlands and aquaculture

The consultants were asked to consider the possibility of using wetlands to support aquaculture development. American Samoa is fortunate in having extensive wetland areas ranging from mangroves to freshwater stream habitats. These areas provide ecological services including serving as nursery, breeding and roosting sites for many aquatic and terrestrial species. They also serve as sites for traditional agriculture and help protect the coast lines. Many wetlands have been permanently altered or impacted including the largest wetland area, the Nu`uuli Pala Lagoon (Volk 1993). It is vitally important to protect wetlands of all types so they can continue to serve these purposes. When wetlands are lost, fisheries decline and the coastline is more vulnerable to storms.

Wetlands generally do not make good sites in which to practice aquaculture. For example, if ponds are built in wetland areas, they are usually difficult to drain which makes it hard to harvest and manage to pond. Net pens or other enclosures can be installed in wetland areas, but feeding fish or crabs that may be held in these can create problems with water pollution.

The best way to utilized wetlands to benefit aquaculture and fisheries is to protect them. They can however, be used as sites to collect limited numbers of fish or bivalves for aquaculture. Wetlands also play a valuable role in retaining freshwater. Some water can be extracted from some types of wetlands to support ponds built outside the wetland, but care must be taken to not divert so much water that the function of the wetland is affected.

Summary and next steps

American Samoa is well-positioned to begin planning and development of small-scale pilot projects for a selected number of species identified during this study.

The most feasible opportunities for small-scale aquaculture development are, by species: tilapia, giant clams, bivalves that can be obtained through spat collection, seaweed and corals. Marine fish that can be collected from the wild as juveniles or fingerlings as a source for fish farms could also be considered. Other options may be possible in the future, but these would require investment in infrastructure such as hatcheries, as well as having a team of highly qualified technical personnel. One tremendous advantage for American Samoa is the availability of fish meal for making aquatic feeds.

Each of the options presented in the report will require further study and discovery of key facts, but it may be possible to do this fairly quickly. For example, given the abundance of experience with giant clams in American Samoa and elsewhere in the Pacific, the biological feasibility is not in question, but issues such as the logistics for importing or collecting broodstock clams, permits, identifying the best sites, how to work with communities and how to prevent poaching would need more definition.

Other important steps can also be taken. For example, any aquaculture development activity needs oversight and technical support. This could be done in several ways. Specialists from different agencies could team up in working groups to develop and support pilot projects. Or, funding could be sought to hire a dedicated extension agent to oversee and guide development of one or a few pilot projects, although this person would need support from various agencies. This may require inter-agency agreements that clearly outline roles and responsibilities for each participating entity.

Each option also requires careful study of market opportunities as well as an analysis of the costs.

Opportunities to build capacity for aquaculture can be increased through support to ASCC which is has marine science and aquaculture educational opportunities. The question is how to support students to obtain advanced degrees, gain hands-on experience and then return to American

Samoa to work in the field. Scholarships and internships could be beneficial in allowing more students to obtain relevant degrees, but jobs need to be available to them after graduation.

Community and private sector involvement are also important. Projects which are entirely executed by government agencies often do not survive. The ideal situation is one in which the government works hand-in-hand with private sector or community partners, with the end goal of the non-governmental partner eventually taking full control over the work. Profitability must also be a goal as grants or subsidies are most effective as seed money, but eventually the activity must pay for itself.

In conclusion, the possibilities of re-starting aquaculture development in American Samoa are good, particularly if private and public sector partners can work together to provide support and overcome challenges together.

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