Final report on the

Komodo Fish Culture Project

A pilot project to establish a multi-species reef fish hatchery in Loh Mbongi and village-based grow-out farms in communities surrounding Komodo National Park, West Flores, Indonesia

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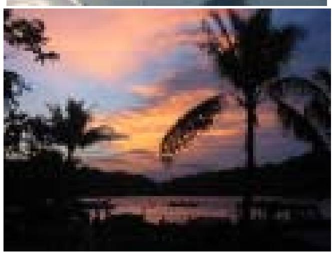

Report from The Nature Conservancy, Coral Triangle Center in collaboration with the Komodo National Park authority

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Executive summary

The Nature Conservancy's Komodo Fish Culture Project started in 1997, and was concluded in June 2005 with the transfer of the project to a fish culture company. The project aims to establish a grouper culture industry in the Komodo area (West Flores, Indonesia). After trials to source fingerlings from the wild, the Komodo project established a hatchery to produce fingerlings for grow-out in community-operated fish cages.

The main objectives of the Komodo Fish Culture Project are:

- to contribute to the transformation of the live reef fish market from unsustainable, capture-based to sustainable, culture-based
- to develop sustainable fish culture of high-quality reef fish as an alternative to non-sustainable fishing practices in and around Komodo National Park.
- to provide a vehicle for outreach activities in the Komodo area, targeting local fishing communities and government agencies

The Komodo Fish Culture Project is a pilot project with a planned maximum capacity of 25 tons of fish of marketable size. This pilot project is the predecessor for a commercial fish culture business within the Komodo area, with a potential capacity of well over 200 tons of reef fish per year. This business will have a triple bottom line: profitable, socially responsible and environmentally sound. The modus operandi is that a central hatchery in the Komodo area provides inputs (fingerlings, know-how, feed, materials) to satellite fish farms deployed at nearby villages. The pilot project worked towards the development of models for technical implementation, for business development, for community involvement, for governance at the enterprise level (best practices) and for governance at the institutional / governmental level (carrying capacity studies, licensing of fish culture operations).

Starting in 1997, The Nature Conservancy explored models for the development of a fish culture industry, and it was concluded that hatchery production of fingerlings from captive broodstock has less negative impact on the environment than sourcing fingerlings from the wild. A preliminary business plan compiled by experts in 1999 showed that hatchery-based grow-out of fingerlings is economically viable. A study conducted in the framework of an MSc project of Rhode Island University showed that local communities and the local fish traders were likely to adopt fish culture once economic viability is proven.

The pilot project involves local communities in the grow-out of estuary grouper *Epinephelus coioides*, mouse grouper *Cromileptes altivelis*, tiger grouper *Epinephelus fuscoguttatus* and mangrove jack *Lutjanus argentimaculatus*, to be marketed as live product to the Hong Kong - based live reef fish trade. Fingerlings are being produced from captive broodstock in a hatchery situated at Loh Mbongi (ca. 6 km North of Labuan Bajo).

The fish culture project has approximately 3 tonnes of broodstock, which are kept in floating cages near the hatchery site at Loh Mbongi. The completed hatchery facility has a maximum production capacity of around 100,000 juvenile fish per annum, and includes facilities for the culture of algae, rotifers and *Artemia* to support this level of production. Full operational capability of the hatchery was reached by March 2003. The first batch of eggs transferred to the hatchery was of estuary grouper, collected during the night of 6 March 2003. These were hatched on 7th March 2003 and by December 2003 had been transferred to the first of two community-based grow-out units. These fish were harvested on 12th June 2004, and 500kg exported live to Hong Kong. Since that time, a further seven commercial-sized batches of fish have been transferred to grow-out units from the hatchery facility at Loh Mbongi, including one of mouse grouper, one of tiger grouper and five of mangrove jack.

The fish culture project created partnerships with institutes that have the necessary know-how. The main partners for technical support of the Komodo fish culture project are the Gondol Research Institute for Mariculture (Bali, Indonesia), the Department of Primary Industries, Queensland (Australia) and the Network of Aquaculture Centers in Asia (based in Bangkok, Thailand).

As part of the up-scaling phase, The Nature Conservancy planned to conduct a carrying capacity, best practices and institutional governance study. This study will determine safe environmental limits to future fish farm development and this study will also determine which regulatory instruments can be used to keep the industry within these limits. In that framework, a carrying capacity workshop, coordinated by the Network of Aquaculture Centers in the Asia-Pacific (NACA), was held in Labuan Bajo in January 2003. This workshop resulted in a workplan for this study.

The Community Outreach team of The Nature Conservancy's Komodo Field Office assisted with the extension of the Fish Culture Project to local communities, and negotiations with target villages, as well as installation of the first grow-units, was underway by September 2003. Final negotiations leading to the installation of the first grow-out unit, at the village of Warloka, took place during December 2003, and the cage unit was stocked with the first production batches produced by the hatchery at Loh Mbongi. The second grow-out unit was installed at the village of Menjaga during June 2004..

By the end of the planned duration of the pilot project, the hatchery had been successfully constructed, operated and staffed, batches of fish of all species held as broodstock by the project had been successfully reared to market-size, two community grow-out units had been successfully installed and operated, and a model for collaboration with the relevant local communities developed and refined. Furthermore, a total of 24 students from Sape Fisheries High School, Sumbawa, had completed residential training courses of between 1 and 2 months at the hatchery facility at Loh Mbongi, and many other trainees, local, national and foreign, had received training or work experience of some sort at the facility.

However, challenges and constraints were encountered as the pilot project developed. The successful production of marine fish juveniles, particularly grouper, proved much more problematic than expected. The viral disease VNN proved to be a major constraint to the reliable and predictable production of grouper juveniles, and the target yearly production of 100,000 juveniles was never achieved. Furthermore, only two of the planned four community-based grow out units were installed, due to the lower production of juveniles achieved by the hatchery.

The eventual aim for the Komodo Fish Culture Project is its transformation into a viable triple bottom line business that is replicated elsewhere in Indonesia and beyond. A first step towards the establishment of this industry is the transformation of the Komodo fish culture project into an economically viable fish culture business, namely one with a production capacity of at least 200 tons per year. To succeed, this process must be business driven, and The Nature Conservancy has been exploring partnerships and mechanisms for business development. A number of consortia of private investors have shown interest in investing in the further development of this enterprise, and by June 2005 negotiations with the chosen investor, PT Karamba, had been completed. Actual transfer of the facility took place on June 30, 2005.

1. Introduction

The Komodo fish culture project was originally implemented as part of The Nature Conservancy's Komodo marine conservation program, though its significance now goes beyond the Komodo area. Komodo National Park (Eastern Indonesia, Fig. 1) is widely recognized as an exceptional storehouse of both terrestrial and marine biodiversity of global significance. Komodo National Park was established as a National Park in 1980, and declared a UNESCO Man and Biosphere Reserve and a World Heritage Site in 1986. Famous as the last remaining habitat of the Komodo dragon (*Varanus komodoensis*), the Park also harbors more than 1000 fish species, about 260 species of reef-building corals, sea turtles, manta rays and 14 species of whales and dolphins. Close to 3,300 people live within Park boundaries, and approximately 17,000 people live around the Park. The main threats to the marine ecosystems of the Park are destructive fishing methods (blast fishing, fishing with poison, etc.), and over-exploitation.

To abate these threats The Nature Conservancy's Coral Triangle Center has been implementing a marine conservation program together with the Indonesian Park authority since 1996. The objective of this program is to establish a marine reserve that (1) ensures long-term protection of the natural community structure, habitat and species of the coastal and marine ecosystems within and around Komodo National Park, and (2) protects a portion of the exploited reef fish stock to enhance fisheries in the traditional use zones inside the Park and in the waters surrounding the Park. The components of the conservation program are Park planning & financing, community awareness & education, surveillance, monitoring & research and alternative livelihood development. The purpose of the alternative livelihood projects is to provide coastal people with sustainable alternatives to reef fishing. The projects that are currently implemented focus on seaweed farming, pelagic fishing and fish culture. Together, they accounted for around 25% of the total budget for The Conservancy's marine conservation program in Komodo. The fish culture project is the most capital intensive of the alternative livelihood projects.

The main objectives of the Komodo Fish Culture Project are:

- to contribute to the transformation of the live reef fish market from unsustainable, capture-based to sustainable, culture-based activities.
- to develop sustainable fish culture of high-quality reef fish as an alternative to non-sustainable fishing practices in and around Komodo National Park.
- to provide a vehicle for outreach activities in the Komodo area, targeting local fishing communities and government agencies

Currently, the live reef fish trade is rapidly depleting the Indo-Pacific stocks of Napoleon wrasse (*Cheilinus undulatus*) and groupers (*Serranidae*). The Komodo fish culture project demonstrates that the culture of groupers can be done in a sustainable and environmentally sound manner.

Fish culture consultants who visited the Komodo area in 1997 reported that the Komodo area was very suitable for the deployment of fish cages: water quality was excellent, there was little rainfall, and there were many locations that were sheltered from storms and waves. Also, a marketing channel for wild-caught live food fish was already in place, and local communities had already some experience with keeping wild-caught fish in cages. Therefore, it was considered relatively easy to involve local communities in the grow-out phase. However, one of the main bottlenecks was found to be the availability of grouper fingerlings, the 'seed' for the culture enterprise.

Starting in 1997, a method to obtain fingerlings from the wild was tested in the Komodo area with the assistance of Philippine consultants. This method, *gango*, has already been used extensively in the Philippines. After one year of field trials in the Komodo area, it was concluded that *gango* puts additional fishing pressure on the wild stocks, both those of groupers and those of non-target fish. Therefore, it was decided not to implement *gango* but to produce fingerlings from captive broodstock.

Species cultured in the Komodo fish culture are estuary grouper *Epinephelus coioides*, mouse grouper *Cromileptes altivelis*, tiger grouper *Epinephelus fuscoguttatus*, sea bass *Lates calcarifer* and mangrove jack *Lutjanus argentimaculatus*, whereof especially the grouper species can be marketed as live product to the Hong Kong-based live reef fish trade. Fingerlings are being produced from captive broodstock in a hatchery situated in Loh Mbongi (6 km North of Labuan Bajo). The pilot project aimed to produce up to 25 tonnes of live fish annually, to be realized over 3-4 harvests per year per grow-out unit. A grow-out unit consists of a complex of 16 floating cages, varying in size between 9 and 25 m^2 surface area . In the pilot phase, 4 grow-out units were originally planned for deployment near the villages that are participating. The produced volume would consist of a mix of the five species of broodstock presently secured. This multi-species approach reduces risks related to species-specific vulnerability to disease and to fluctuation in consumer preference and price. The species composition of the first batch of fingerlings has depended on hatchery practicalities, as this batch was used for training in grow-out in village-based fish farms rather than for the generation of revenue. Plans for the pilot phase (i.e. production capacity of up to 25 tonnes annually) envisaged ‘employing’ up to 20 villagers on a full-time basis, with many more being trained in grow-out techniques. Once economic viability and environmental sustainability have been demonstrated, a carrying capacity analysis is planned, to determine the optimal production capacity.

The project is based on full-cycle culture, meaning that impacts on wild stocks are minimal. A full cycle comprises spawning of captive broodstock, collection of fertilized eggs, larvae rearing, fingerling production, grow-out in sea cages, and marketing. A full cycle takes 11 to 22 months, depending on the species. The individual body weight of marketable fish varies between 0.4 and 1.2 kg, depending on the current market preference and on the species. The project has aimed to grow out fish to an individual body weight of 0.5 kg. The fish are fed primarily on a diet of commercial pelleted feeds, with some supplementation with fresh fish when appropriate. Feed costs in the region of US$1000 per tonne, which at a feed conversion ratio of 1.7 results in a feeding cost of US$1.70 per kg of produced fish. Considering that grouper may fetch between 5 and 35 US$ per kg and that feed costs comprise the major part of the total costs for producing fish, there appears to be a good prospect for business development (see Chapter 8).

***Figure 1**. Indonesia with location of Komodo National Park.*

2. Hatchery construction

On December 21, 2000, The Tahija Foundation donated 150,000 m^2 of land in Loh Mbonghi to The Nature Conservancy for the purpose of construction of the hatchery (Fig. 2). Working from the 'Strategy and Action Plan' of July 2001, a blueprint for the hatchery was prepared by the fish culture team in cooperation with a local engineering company (CV Teksas) and with expert consultation from staff at the Gondol Research Institute for Mariculture. By April 2002 the contract with the Master Contractor (CV Bumi Cakra Persada) was signed and construction commenced.

The bulk of the hatchery planning and construction phase of the project was overseen by the original mariculture manager Dr. Phillip Arumugam. His position was taken over by Trevor Meyer from September 2002 onwards.

By March 2003 construction was completed and the hatchery was operational (Fig. 3 - 7). The hatchery at Loh Mbongi was officially inaugurated in July 2003 by the Minister of Fisheries and Marine Affairs, Prof. Dr. Rokhmin Dahuri. This event was attended by senior local government officials and key stakeholders.

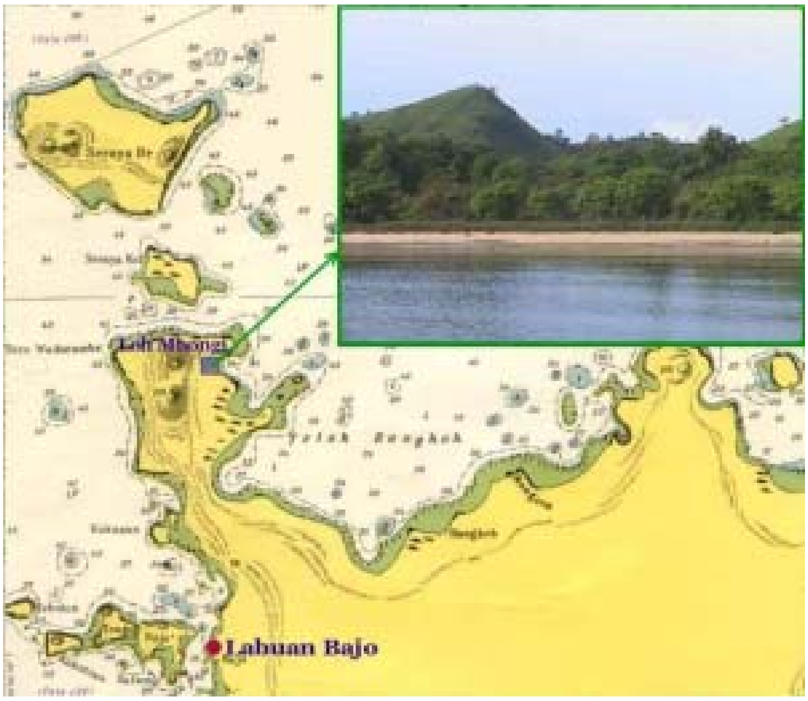

Figure 2. *Loh Mbongi, situated on the peninsular North of Labuan Bajo, West Flores, Indonesia.*

Experts from the Gondol Research Institute for Mariculture (GRIM) have visited the construction site on a number of occasions: The Director of GRIM, Dr Adi Hanafi, visited the site on April 4 2002 and Mr Agus Priyono carried out an assessment of the mariculture complex during the period 29 July - 5 August 2002, and made a follow-up visit in mid-October. Dr. Fris Johnny and Mr. Dedi carried out a technical support visit in August 2003. Technical support visits were carried out by Dr. Fris Johnny and Mr. Dedi in August 2003, and by Dr. Eri Sutiadi in October 2004.

Two representatives of the engineering company and the master contractor visited the Gondol Research Institute of Mariculture to get first-hand insights on hatchery construction. The study trip took place on 3-5 June 2002.

Environmental impact assessments (UKL / UPL), as required under Indonesian law, have been completed and were approved by the District Planning Agency (BAPPEDALDA). In March 2002, the approval was followed by a letter of recommendation of the Bupati (District Head) of the District Manggarai. The environmental impact assessments were carried out by Universitas Nusa Cendana (UNDANA) of Kupang, Nusa Tenggara Timur.

3. Details of hatchery design

The design of the hatchery is consistent with production methods developed specifically for grouper culture in Indonesia, with an emphasis on a simple, sturdy and reliable design easily constructed with locally-available materials and compatible with local environmental conditions. For example, production tanks are constructed of concrete, which is much cheaper to install than the fibre-glass tanks more popular in European hatcheries. Production methods are also geared towards low cost and simplicity, with a minimal need for costly and imported components and materials. For example, algal culture tanks are large (10 cubic metres) and open to the elements, relying on natural sunlight for propagation and cultured using low cost industrial-grade fertilizers. This results in a low cost and simple system, but one which is prone to occasional catastrophic stock crashes due to contamination by way of competing algae and other micro-organisms. However, in such a remote location as Komodo, a high productivity but high cost, complex production system would almost certainly prove unworkable under ambient conditions.

3.1 Water Supply system

The seawater supply to the hatchery is drawn up a pair of 4-inch pipes by way of three Electra E100-20 centrifugal pumps, rated at 10 horse-power and 7.5kW, housed in a dedicated pump-house, sited on the beach approximately 3m from the shoreline during high water. Each pump has a specified pumping capacity of 25-125 cubic metres per hour, and with the existing set-up has been measured at approximately 40 cubic metres per hour. Only one pump is used at any one time, with two being operated at 12 hour intervals. A third pump acts as a back-up. The seawater intakes are approximately 90m from the pump house, fitted to a sub-sea frame with a minimum depth of 4m at low water, and 3m above the seabed. The intakes are fitted with bronze and plastic non-return valves.

The seawater pumps have proved sturdy and reliable, with no breakdowns experienced in 3 years of constant service. Water quality at Loh Mbongi is variable, with occasional high quantities of plankton and fine ‘debris’ reducing water visibility to 5m on occasion. The occasional storm from an easterly direction will reduce visibility still further due to fine sediment load.

The pump house is powered by its own dedicated 15kW electrical generator, located in the generator house in the centre of the facility.

The water pumps transfer water almost immediately to a pair of fibre-glass sand filters, each rates at 25 cubic metres per hour. These operate at a slight pressure of 1.5 bar, and produce clear water on almost all occasions. Each is fitted with a single variable valve allowing back-flushing and all possible variations of water flow. These sand filters actually replaced the original sand filters – two huge mild steel structures with a basic but complex valve system allowing back-flushing. After 2 years of service, these steel filters had corroded significantly, with dissolved and particulate iron entering the hatchery, and were cause for concern with respect to water quality and therefore fish health. Consequently, they were replaced with the fibre-glass filters.

The supply line to the hatchery and live feed production facility from the seawater pumps is by way of a flow-through arrangement through a system of 4-inch pvc piping. There is no seawater reservoir located between the pumps and the production tanks, and consequently no gravity-fed emergency water supply to the hatchery. Previously, the steel sand filters were large enough to act as desaturation tanks, and so allow the removal of any gases supersaturated during their passage through the pumps. Their replacement with the smaller, high-pressure fibre-glass filters necessitated the fitting of simple desaturation columns to all production tanks.

The distance from the seawater pumps to the hatchery facility is around 100m, with a very slight uphill gradient.

By an arrangement of valves, seawater can be directed throughout the hatchery, with major branches passing to the live food production facility, the larval rearing section and the nursery section. Once having passed through the hatchery, the seawater is collected in concrete drainage channels and directed to a system of simple settlement ponds, each of approximately 200 square metres, where any particulate material is allowed to settle out of suspension, and which also act as natural biological filters, and thus remove any nitrogenous compounds which may be present in the effluent. The current arrangement of four ponds is large enough to consume the waste of a fully up-scaled hatchery of 1 million juveniles per year capacity, and so is under-utilized at present.

Once having passed through the settlement tanks, the hatchery effluent then passes through the natural mangrove forest at Loh Mbongi, before passing back into the sea.

3.2 Live food facility

The live food facility is designed to produce sufficient quantities of single-celled algae, rotifers and artemia for the production of 100,000 grouper juveniles per annum. The production tanks are backed up by a laboratory, in which master cultures are maintained and sub-cultured under optimum conditions.

The laboratory itself is equipped with the necessary equipment, including glassware, counting equipment, microscopes, autoclave, a refrigerator, etc. to allow aseptic techniques to be used to culture algae and rotifers from master cultures. The lab is equipped with lighting and an air conditioner to maintain a temperature of around 20C for starter cultures. Algal and rotifer productivity can be monitored by way of specialized counting equipment.

Within the laboratory, algal cultures of 1 litre and 3 litres are produced under sterile conditions, prior to transfer to larger cultures maintained outdoors. In addition, the master cultures of rotifers are maintained in 1 litre and 5 litre volumes.

Glass aquaria are used to produce intermediate culture volumes of algae, of 100 litres. Fibre-glass circular tanks are used, of volumes 500 litres, 1000 litres and 1500 litres, for both algal and rotifer cultures. These tanks are relatively light in weight, and portable, allowing their movement around the facility as and when required, although a housing has been constructed for rotifer production, to shield the rotifer cultures from the elements (sun and rain).

The largest culture volumes consist of concrete 9000 litre tanks, arranged in 1 group of 4 and 1 group of 5. These tanks are constructed of bricks and mortar, together with steel reinforcements on all corners and at certain points in the walls. The bricks are then covered in concrete to produce a smooth even surface. The inside surfaces are made waterproof with light blue acrylic paint. Each tank is fitted with seawater inlets and outlets, and aeration. The tanks are also fitted with flexible piping attached to pumps, to allow the transfer of water, algae etc, between tanks, and from the live food tanks to the hatchery. To some extent the tanks can be used for either algal or rotifer production, according to requirements, but, under normal conditions, 5 tanks (total production volume 45,000 litres) are used for algal production and 4 tanks (36,000 litres) for rotifer production. The 9000 litre tanks are not covered by a roof, and are therefore fully exposed to the elements.

A 1000 litre header tank is mounted on a frame close to the hatchery building. Algal cultures are pumped from the algal production tanks into this header tank, and then fed, by gravity and at slow rates, to the hatchery tanks by way of a system of pipes and valves.

Artemia production is carried out in fibre-glass conical tanks of 100 litre capacity. These tanks are also used for the enrichment of both rotifers and artemia by way of specific soluble live-feed enrichment products.

3.3 Larval rearing and nursery facilities

The hatchery building proper is divided into a larval rearing and a nursery rearing section. The two sections differ in design due to their differing requirements, but both are house under the same roof within the main hatchery building.

The larval rearing section is enclosed, with walls, a roof and closeable doors. Light is provided by fluorescent bulbs suspended above each tank, and natural light can enter the building through sky-lights, covered in opaque corrugated plastic, in the roof. These sky-lights have been further covered with translucent tarpaulins to further control natural lighting within the larval rearing area. The enclosed nature of this section allows close control over ambient environmental conditions – particularly light and temperature. It also seals the facility off from outside adverse influences (contamination, flying debris and insects, unauthorized personnel, etc.).

The larval rearing section is fitted with a row of six square 10-tonne concrete tanks. Tanks are constructed in a similar way to the 9000 litre live food tanks described above, ie of concrete bricks and mortar, reinforced with steel rods, and covered with further layers of concrete. Also, the inner surfaces of the tanks are coated with light blue epoxy paint. Each tank has a surface inlet pipe, and an outlet situated in the bottom corner. A stand-pipe is fitted into the outlet aperture to control water level in the tank. Although relatively simple in design, the tanks are effective.

Each tank is further provided with a supply of air from the electrical blowers, and a direct pipeline from the alga storage and supply tank.

Water temperature is stabilized to some extent by way of insulating sheets of transparent plastic sheeting. During certain months of the year, air temperatures at night can drop to 24-25C, with an accompanying drop of larval rearing tank water to as low as 25-26C.

The nursery rearing section of the hatchery facility is identical to the larval rearing section, save that the room is open to the outside ie has no walls, but remains beneath the roofing of the hatchery building. Nursery rearing does not necessitate such environmental control as the larval rearing area. A similar row of six 10-tonne concrete tanks are available for nursery rearing.

Consequently, total larval rearing volume consists of 60 tonnes, of which each batch of larvae is expected to occupy 30 tonnes (since larval rearing cycles are 50 days, whereas eggs are collected every 30 days). Total nursery rearing volume adds up to 60 tonnes also.

3.4 Broodstock cages

The broodstock are housed in a floating cage facility moored within the bay at Loh Mbongi, approximately 300m offshore, at a depth of 18-24m. This is the third mooring position of these cages. Originally moored close to Pulau Kukusan, near Labuan Bajo, the cages were towed to Loh Mbongi once the land had been secured for hatchery construction, and later relocated further away from the shore to reduce any potential transmission of pathogens between the broodstock and hatchery facilities.

The cage platform itself consists of 4m square cages arranged in groups of four or two, all of which are tied together into a single cage platform. The construction is simple, involving the use of wooden planks tied with rope, using plastic drums as floaters. A total of 24 broodstock cages are employed, together with approximately 10 smaller cages, used for quarantine and other purposes. There is also a working platform, a guard-house and a storage room.

Netting used consists of large-mesh imported knotless netting. Nets require cleaning every 6 weeks or so, to remove fouling organisms such as algae, hydroids, oysters, etc. The nets are typically fitted with a square frame attached to the floor of the net, to provide support and therefore allow the groupers to sit on the bottom without sinking into the net. Nets are typically between 5 and 8 metres in depth.

The moorings used, namely locally-made ‘grapple’-style anchors of 20-30kg weight, are not very effective in the soft sediments over which the cages are moored, and anchors frequently drag significantly during periods of strong winds. The anchors would normally be re-positioned, using lines attached from marker floats down to the anchors, which facilitates the dragging of anchors back into position with the aid of the speedboat and without the requirement of divers. More efficient ‘spade’-style mooring anchors are unavailable locally and expensive to import, and the laying of mooring blocks is impractical with the boats and facilities available to the project. The anchors have since been rein.forced by the addition of small 50-100kg concrete weights with iron bars embedded, which has significantly reduced dragging.

Mooring lines are strengthened and weighted by the addition of ground chain at the junction between the anchors and mooring rope. Because of the very sheltered conditions encountered at the broodstock cage site, cushion floats are not employed, and mooring lines are typically tied directly to the cages.

4. Hatchery construction and design – lessons learned and suggestions for improvement

4.1 Water supply system

With the benefit of hindsight a number of improvements and modifications to the existing hatchery design would be appropriate for any upscaling, or replication, of the marine hatchery.

The Electra E100-20 centrifugal seawater pumps have proved sturdy and reliable, with no breakdowns or significant problems experienced after 3 years of almost constant service.

PVC piping between the sand filters and hatchery building required replacement after 2.5 years of operation, due to the corrosion of the steel sand filters. The pipes were coated inside with a layer of bright orange iron deposit, which was thought to be adversely affecting hatchery water quality. In addition, the corrosion of the sand filters had led to the entry of filter medium into the water supply pipes.

The structural integrity of the PVC piping itself lasted the 3 years of hatchery operation well. Direct exposure to sunlight was reduced where possible by burying the main supply line – this also avoided excessive solar heating of the water supply to the hatchery. Plans had been made to replace the 4 inch pipe supply system with higher quality HDPE piping, but this ultimately proved unnecessary.

The use of mild steel sand filters was a serious flaw in the original design specifications of the hatchery. The cost advantage of their purchase was outweighed by serious water quality problems encountered from the corrosion, with filter medium and iron deposits entering the entire hatchery system, including the larval rearing tanks. Filters attached to larval rearing tank inflows would appear bright orange after just a few hours of water passage.

Attempts were made to line the inner surfaces of the filters with water-proof paint and even fibre-glass, but parts of the filters were sealed and therefore inaccessible. In addition, the piping and valve system of the filters were also constructed of steel, and had also corroded. The one advantage these filters had was that they acted as desaturation columns, allowing the release of super-saturated gases during the water’s low pressure passage through the sand filters, and consequently their replacement by smaller fibre-glass sand filters required additional desaturation systems to be installed into the hatchery facility.

Although a relatively expensive addition to the hatchery design, a seawater reservoir of approximately 100 cubic metres capacity would be a useful addition to an up-scaled hatchery. This would receive pumped seawater directly from the pumps, and would allow the provision of gravity-fed seawater to hatchery tanks during periods when no electrical power is available. In addition, the tanks would act as gas desaturation vessels. Such a reservoir would also enable the complete flushing of the hatchery seawater supply system without the need for electrical power.

4.2 Live food production facility

A good quality binocular microscope, with a x100 oil immersion lens, is vital for accurate counting and assessment of algal stocks. The low cost Chinese-made microscope used at Loh Mbongi was barely up to the job. The use of such a microscope should be accompanied by appropriate staff training for all staff members required to use it. The counting methods employed at Loh Mbongi, for both algae and rotifers, proved adequate, and were relatively easy to employ.

A larger autoclave than the existing one would have facilitated the more efficient sterilization of larger quantities of glassware and other culture materials.

Again, adequate staff training in the use of sterile techniques is essential, together with constant monitoring of staff performance thereafter.

A re-design of the 9000 litre algal rearing tanks would be appropriate. The existing tanks are of an inefficient shape for algae which rely upon exposure to sunlight for photosynthesis. Additional tanks offering a higher surface area to volume ratio would be more suitable, as would tanks of a larger volume – up to 50 or 100 tonnes, for example. The larger volume would minimize adverse changes in temperature and other water quality parameters. In addition, the volume of algae available for juvenile production and rotifer feeding was often limiting, so an increase in total algal production volume from the existing 45 tonnes to nearer 100 tonnes would ensure sufficient quantities of algae were available.

The open system of batch culture of algae employed by the Komodo Fish Culture Project is known to be prone to variable productivity and even sudden culture crashes, due to contamination, poor culture conditions, etc., often with serious consequences. The frequency of such culture crashes and poor productivity could be reduced by the installation of improved water treatment systems specifically for algal production and laboratory supply. A relatively small ultra-violet filtration system would be adequate for this purpose, since the total volume of seawater requirements for live food production is relatively small. A more complex, high productivity, sterile, closed system of algal production can be considered unworkable under existing conditions at Loh Mbongi, and is not recommended.

The total volume available for rotifer production should also be increased, from the existing 45 tonnes to 60 tonnes, as rotifer supply was also occasionally found to be limiting.

The use of well-trained, capable and trustworthy staff is essential for effective live food production.

4.3 Larval rearing and nursery facilities

Structural integrity of the larval rearing and nursery tanks proved sound over the 3 year period of hatchery production. Some minor cases of chipped paint and corrosion showing through the tank walls (presumably from leakages of seawater attacking the steel reinforcements) caused no problems.

Tank size is optimum, at least for the taller members of staff. Tanks are manageable and relatively easily cleaned and siphoned. All parts of the tanks are accessible to cleaning. The number of larval rearing tanks is also appropriate in terms of total rearing volume. Assuming fish can be transferred to grow-out cages at day 80 (which is possible), the total volume of nursery rearing space is also adequate. However, a longer nursery period would give rise to limitations, so either additional tank space would be required in future, or cage grow-out specifically for small fish introduced.

4.4 Electricity generation

The electricity supply to the hatchery facility at Loh Mbongi was found wanting. The generators employed consist of 4 x 15kVa generators used to supply power to the hatchery facility, and 2 x 10kVa generators for power supply to the residential units. The generators have proved reliable, and have operated for the full three year project duration with no significant disruption to the overall power supply. Parts are available locally, which is a considerable advantage when repairs are necessary.

The generators employed are excessively noisy, a fact compounded by the siting of the generator house at a location right in the centre of the hatchery facility. Also, regular changing between different generators, and the regular switching on and off, is time consuming and the resultant power surges and cuts damaging to electrical appliances in use at Loh Mbongi.

Furthermore, the capacity of the generators is limiting. Not all air conditioners, for example, can be operated at one time with the existing power supply.

It is recommended that further development of the hatchery facility be accompanied by the installation of a much larger generator capable of providing all electrical requirements, with an excess capacity of at least 20%. This generator would itself need to be accompanied by a second back-up generator.

The supply of diesel fuel to the generators is facilitated by a pipeline installed at the jetty, to allow the transfer of diesel fuel from the delivery boat directly to the generator fuel tanks. The electrical requirements of the pilot project approximate to 100 litres of diesel fuel per day, requiring the delivery of 1000 litres of diesel every 10 days or so.

4.5 Water treatment ponds

The water treatment ponds, being of simple construction, required very little maintenance and performed well. Occasional bouts of heavy rain resulted in minor collapse of the pond walls which was easily remedied.

Mangrove seedlings were planted along some of the pond walls in an effort to improve the integrity of the ponds, at least over the long term.

It was observed that the first pond would often appear eutrophic, i.e. would contain greenish-colored water and be covered by floating green algae. However, the remaining three ponds never appeared eutrophic but remained clear. This suggests that a single pond would have been adequate for the scale of production actually employed by the pilot hatchery. The first pond was also clearly the site of significant sedimentation of fine-grained sediments emanating from the hatchery.

It is interesting to note that the treatment ponds contained much marine life, including various fish species (mostly Mugilids, Therapontids, with some mangrove jack and milkfish in evidence) and mud crabs (*Scylla*). Early in the operation of the hatchery, most ponds were almost completely filled by the bottom-living jellyfish *Casseopeia.*

4.6 Freshwater borehole supply

The supply of freshwater from the borehole is reliable and normally adequate. Analysis of the water supply revealed that levels of sodium, chloride, sulphate and total dissolved solids are too high to allow the use of this water supply for drinking, but it may be used for most other purposes.

Supply is found to be slightly limiting only during periods of excessive usage (i.e. when more than 15 personnel were on site at night) during the end of the dry season.

4.7 Staff housing

The wooden buildings constructed as the office, mess, staff dormitory and manager’s house all remained in fairly good condition by the end of the first three years of use. After three years, serious termite-related damage was evident, and limited to, the verandahs of all buildings, at which time floor planking required replacement. Structural integrity of all buildings remains sound.

4.8 Broodstock

Most hatcheries hold broodstock in land-based tanks, which allows closer control of broodstock including isolation of their water supply, easy observation and facilitates passive egg collection by way of overflow egg collectors. However, holding and maintaining broodstock in cages, and collecting eggs from cages, does have certain advantages over tanks, and the Komodo Fish Culture Project has developed management methods accordingly.

A larger hatchery would possibly require the additional security of maintaining at least a proportion of their broodstock in land-based tanks, and such a strategy would be recommended for any upscaling of the existing hatchery at Loh Mbongi.

5. Hatchery production

5.1 History

The hatchery facility at Loh Mbongi has a production capacity of around 100,000 juveniles per annum. Full operational capability of the hatchery was reached by March 2003. The first batch of eggs transferred from the broodstock facility to the hatchery was of estuary grouper, collected during the night of 6 March 2003. These were hatched on 7th March and had been successfully stocked into temporary grow-out cages at Loh Mbongi by June 2003. Larval survival of this batch reached 3.7%, which is much higher than natural survival rates and also high compared by fish culture standards - an encouraging result for the first production by the Loh Mbongi hatchery.

Since this time, egg production by the broodstock at Loh Mbongi has been excellent, and the hatchery and nursery have been under full production now for over two years. Hatchery production, however, has not been without its challenges, and, although all five species stocked at Loh Mbongi have been successfully reared at the hatchery, survival rates have varied considerably.

To date the best survival rate achieved has been 7.6%, for a batch of mouse grouper produced in July 2003. During July 2003 a batch of 20,000 mouse grouper were reared in the nursery, representing the first production of a commercial-sized batch by the Komodo Fish Culture project. Unfortunately, subsequent survival was low and the improvement of nursery survival rates represents one of the many challenges to the Fish Culture Project at present.

Other commercially sized batches produced include a batch of 6,000 mangrove jack successfully reared through the nursery phase, and transferred to the grow-out unit at Warloka by December 2003, and a batch of 6,000 tiger grouper distributed between Warloka and the newly installed second community grow-out unit at Menjaga during May-June 2004.

5.2 Details of larval rearing hatchery production

From the first hatchery production of estuary grouper stocked during March 2003 to the conclusion of the Komodo Fish Culture project in June 2005, a total of 61 batches of larvae were stocked into larval rearing tanks (see appendix 1). The species breakdown of these batches is as follows:

Estuary grouper	20 batches	32.8% of total batches
Mouse grouper	17 batches	27.9% of total batches
Mangrove jack	14 batches	23.0% of total batches
Tiger grouper	10 batches	16.4% of total batches

The selection of species for rearing took into account a number of variables, including availability of eggs, quality of eggs, incidence of disease, etc. For example, it appeared that mangrove jack were not susceptible to VNN, and consequently this species was reared whilst VNN was causing particular problems with grouper rearing.

Of these 61 batches of larvae reared, 15 batches (or 24.6%) survived to the grow-out stage.

In terms of species reared, the most successful was mangrove jack, with 35.7% of all batches reared surviving to grow-out, followed by mouse grouper (29.4% surviving to grow-out), tiger grouper (20.0%) and finally estuary grouper (5.0%).

The cause of mortality for larvae during larval rearing is sometimes difficult to ascertain. However, there are certain trends which do indicate a likely reason for a mass mortality. For example, mass mortalities often occur during day 7 or 8. This coincides with the time during which larvae which have failed to make the transition to exogenous feeding starve and die. Therefore, poor egg quality and poor larval quality will often be the cause. A second period of mortality often occurs around the period day 18-20. This has been observed to be mainly due to VNN infection. Other causes of mortality may be due to inappropriate husbandry, bacterial infections and other human causes.

A breakdown of the likely cause of mortality of the batches of larvae produced reads as follows:

Total number of batches lost before transfer to nursery: 46

Batches lost during period day 4 to day 12:	24 (52.2%)
Batches lost during period day 15 to day 26:	20 (43.5%)
Batches lost during period day 27 to day 50:	2 (4.3%)

Breakdown according to probable primary cause of larval mortality:

Poor egg quality:	35%
VNN (both diagnosed and suspected):	30%
Poor algal production:	13%
Poor husbandry:	10%
Unknown cause:	8%
Bacterial infection:	4%

If survival rates are divided between the dry season and rainy season, the following figures are obtained:

	Batches attempted	*successful batches*	*success rate*
Dry season	31	8	25.8%
Rainy season	29	6	20.7%

Although broodstock of all species of fish reared appeared to be more prolific during the rainy season, improved algal production during the dry season would have improved the chance of success of the larval rearing stage. Consequently, differences in larval success between different seasons are probably not significant.

If survival rates are broken down into years, the following data result:

1st year of production:	batches attempted - 28
(Mar 2003 – Feb 2004)	batches reaching grow-out stage - 9
	success rate – 32.1%
2nd year of production:	batches attempted – 28
(Mar 2004 – Feb 2005)	batches reaching grow-out stage – 4
	success rate - 14.3%

It is also interesting to note that, of the first 15 batches of fish produced, the success rate was 46.7%. Following the first diagnosis of VNN during August 2003, the success rate of batches dropped to 13.0%. This suggests that the incidence of VNN has had a significant effect on larval rearing success at Loh Mbongi, and other apparent causes of mortality (such as poor egg quality) may have VNN as an underlying cause.

5.3 Nursery rearing

A total of 15 batches of fish were reared through the nursery phase during the Komodo Fish Culture project, including 6 batches of mangrove jack, 5 batches of mouse grouper, 2 batches of tiger grouper and 2 batches of estuary grouper.

Species	*nursery period*	*opening stock*	*closing stock*	*survival*
Estuary grouper	May 2003	3,745	3,000 (est.)	80%
Mouse grouper	June 2003	330	250	76%
Mouse grouper*	August 2003	20,221	1,938	10%**
Mangrove jack	September 2003	5,900	4,661	79%
Mangrove jack	March/April 2004	1,000	700	70%
Mangrove jack	April 2004	6,000	4,500	75%
Tiger grouper***	June 2004	5,700	4,629	81%
Mangrove jack	November 2004	400	130	33%
Mangrove jack	January 2005	1,100	1,011	92%

*three discreet batches, combined after mortality;

** mortalities due to VNN outbreak

*** two discreet batches mixed

With regular grading and proper care, grouper and mangrove jack can be brought through the nursery phase with a survival rate of around 80%. The very high mortality rate of the second group of batches of mouse grouper was due to an outbreak of VNN which struck during the nursery phase. For most of the species under consideration here, the nursery phase lasts from around day 35-40 to day 80-120, by which time the juvenile fish will have reached a weight of between 2 and 5g, depending on the species.

6. Broodstock

6.1 Broodstock collection

Broodstock used for the Komodo Fish Culture Project are all wild-caught specimens that have been collected from local waters since the ‘gango’ trials were carried out during 1997-1999. Indeed, some of the seabass, mangrove jack and estuary grouper caught during these trials were stocked in cages and now make up some of the existing stock of broodfish. Other seabass, mangrove jack and estuary grouper were caught by fishermen in the Terang area of north-west Flores, a large mangrove estuary. Tiger grouper and mouse grouper were purchased from local fishermen, and were all caught by non-destructive fishing methods such as hook & line.

The total biomass of broodstock held normally fluctuates between 2.9 and 3.2 tonnes, according to fish growth and mortalities.

During March-April 2004, broodstock of *Plectropomus leopardus* were collected from local hook & line fishermen. Most fish were around 500g in weight at the time of capture, and will therefore require a further one or two years of grow-out before they are likely to reach sexual maturity.

Some hatchery production from Loh Mbongi has been selected over the period December 2003 to December 2004 and kept as future F_1 broodstock. Fish have been selected for fast growth, optimum body shape and physical appearance, and disease resistance. By January 2004, batches of estuary grouper, tiger grouper, mouse grouper, mangrove jack and seabass were being held.

During September 2004, a stock of mouse grouper were obtained from a cage operator from Sape, Sumbawa, to act as future broodstock. The fish were of an average weight of 500g, and were collected as wild-caught juveniles.

***Table 1.**. Characteristics of the broodstock of the Komodo fish culture project. ‘protogynous’ means that females change into males, whereas ‘protandrous’ means that males change into females, ‘gonochoristic’ means that sexes are separate. ‘Number’ indicates the number of fish in the broodstock facility as of February 2004.*

Species (english, scientific and Indonesian name)	Reproduction mode	Max. length	Price per kg	Number
estuary grouper, *Epinephelus coioides*, kerapu lumpur	protogynous	100 cm	4-5 US$	134
tiger grouper, *Epinephelus fuscoguttatus*, kerapu macan	protogynous	120 cm	8-12 US$	35
mouse grouper, *Cromileptes altivelis*, kerapu tikus	protogynous	70 cm	25-35 US$	48
sea bass, *Lates calcarifer*, kakap putih	protandrous	200 cm	3-8 US$	52
mangrove jack, *Lutjanus argentimaculatus*, kakap merah	gonochoristic	150 cm	5 US$	212
leopard coral trout, *Plectropomus leopardus*, ikan sunu	protogynous	120 cm	20 US$	20

6.2 Feeding

All broodstock have been fed on locally-purchased pelagic fish and squid. The availability of these fish and squid varies considerably throughout the month. Most of the fish used are caught by way of the local ‘bagan’ fisheries, which employs lamps to attract fish prior to capture. Such methods are not effective during the 5 day period surrounding full moon, and so during this time pelagic fish are in short supply. The squid fed to the broodstock are caught by hand-line during the full moon period. Therefore, fish or squid is normally available each day of the month.

Typically fish are fed approximately 20 days of the month and squid fed approximately 10 days per month.

Up to 70kg of fish/squid are fed to the broodstock each day, representing approximately 2-3% of total biomass. Also, each cage of broodstock is typically fed on alternate days. This means that approximately half of the total stock of broodfish are fed each day, at a rate of 3-4% of bodyweight per feed. This complies with the results of current research on optimum feeding rates of broodstock. The broodfish are normally fed to appetite.

Species of fish and squid employed as broodstock feed include the following:

Amblygaster leiogaster	smoothbelly sardinella	(Clupeidae)
Amblygaster sirm	spotted sardinella	(Clupeidae)
Dussumieria elopsoides	slender rainbow sardine	(Clupeidae)
Tylosurus acus	agujon needlefish	(Belonidae)
Strongylura leiura	yellowfin needlefish	(Belonidae)
Hemiramphus far	black-barred halfbeak	(Hemiramphidae)
Decapterus macarellus	mackerel scad	(Carangidae)
Decapterus russelli	Indian scad	(Carangidae)
Selar crumenophthalmus	big-eye scad	(Carangidae)
Sepioteuthis lessoniana	bigfin reef squid	(Cephalopod)

Feed is normally supplemented with multi-vitamin mix and ascorbic acid for 5 days per month.

6.3 Spawning

From the end of 2002, when regular detailed records of spawning observations have been taken, 4 of the 5 species of fish maintained as broodstock, namely the *Cromileptes altivelis, Epinephelus fuscoguttatus, E. coioides* and *Lutjanus argentimaculatus* have spawned consistently throughout the year up to the present. Spawning typically occurs over a period of a few days each month, normally around new moon. There is an observable increase in spawning activity, and number of eggs produced, during the rainy season (September – March). All species continue spawning, at a reduced rate, throughout the dry season except for *E. fuscoguttatus* which often stops spawning altogether during the months of April and May. Most of this spawning activity is entirely spontaneous, and no hormonal manipulation is normally required. However, tiger grouper are often either injected or fed with reduced dosages of hormones (normally HCG and puberogen) to encourage them to spawn during the dry season months.

Cromileptes normally spawn during the fourth lunar quarter, most often between the hours of 2100 and 2300. Spawning may continue for up to 8 consecutive days, although the spawning duration for individual fish is not known.

Epinephelus coioides again spawn mostly during the fourth lunar quarter, but spawn much earlier in the evening than *Cromileptes*, usually between 1700 and 1800hrs. In addition, the total duration of the spawning is longer, with spawning being recorded over a period of 12 days.

Epinephelus fuscoguttatus showed the narrowest window for spawning of all the grouper species maintained, typically spawning for only a three-day period, almost always during the fourth lunar quarter. Spawning would normally occur between the hours of 2100 and 0000hrs.

Lutjanus argentimaculatus had the longest observed spawning period of all the species held as broodstock, with most spawning occurring during the fourth and first lunar quarters, typically between 2100 and 0000hrs.

For a detailed account of spawning behaviour at the Komodo Fish Culture Project refer to: 'Natural Spawning of Three Species of Grouper in Floating Cages at a Pilot Broodstock Facility at Komodo, Flores, Indonesia. Sudaryanto, Meyer, T. & Mous, P. (2004). SPC Live Reef Fish Info. Bull. No.12, Feb 2004.

The stock of seabass (*Lates calcarifer*) have not been observed to spawn from September 2002 to June 2005. Attempts at encouraging egg production by way of hormonal manipulation were not successful, and ended in the death of the female fish involved.

6.4 Sex ratios

Sex ratios typically vary to some extent according to the rate of sex change of broodstock. The mouse grouper and tiger grouper were caught as adults by hook & line, and thus sex ratios are close to 1:1. The estuary grouper were caught as juveniles, and so most fish are still in the female phase of sexual development.

Broodfish stock and sex ratios as of August 2003:

Species	*male:female ratio*	*tot. no.*	*mean body wt.*
Cromileptes altivelis	1:1.6	39	2.0 kg
Epinephelus coioides	1:6	153	7.5 kg
Epinephelus fuscoguttatus	1:1	78	10.0 kg
Lates calcarifer		54	5.8 kg

No data is available for the sex ratios of the stock of *Lutjanus argentimaculatus*.

Broodfish stock and sex ratios as of January 2005:

Species	*male:female ratio*	*tot. no.*	*mean body wt.*
Cromileptes altivelis	1:0.8	18	3.3 kg
*Epinephelus coioides**			
Epinephelus fuscoguttatus	1:0.5	38	10.0 kg
Lates calcarifer	1:4.7	51	7.0 kg

* the stock of estuary grouper were not sex determined in order to avoid excessive handling and resulting 'swimbladder disease'.

The above results show a reduction in sex ratio due to the gradual ageing of the brood stock, which is to be expected. For both mouse grouper and tiger grouper, males are now in the majority. The effect of this on egg quality and subsequent larval rearing performance has not been determined.

A stock of *Plectropomus leopardus* collected during March/April 2004 were all relatively small fish, and sex determination during June 2004 revealed the presence of a single male.

Sex determination of the stock of seabass was carried out during January 2005. Most stock consisted of fish originally caught during the 'gango' trials during 1998, with a small number of hatchery-reared stock added during 2004. The sex ratio of these fish during 2000 proved to be 1:6.2 males:females. By 2005, the ratio had changed to 1:4.7, due mostly to the additional of male hatchery-reared stock and the mortality of female stock of the intervening 5 year period. It is interesting to note that conventional wisdom states that seabass start their sexually mature life as males at around 2kg, and normally change to females at a size of around 8kg. However, the broodstock held at Loh Mbongi included a male of 9.2kg and a female of only 2.5kg. This may be due to the separation of the stock into cages of small and large fish, and the start of a natural sexual equilibrium becoming established within a particular stock of fish.

6.5 Broodstock health and stock losses

The commonest problem affecting all species of broodstock held is infestation by the ectoparasitic monogenean *Benedenia*. This parasite is not normally particularly harmful, but may cause damage to the body surface of the fish if present in large numbers, particularly the cornea of the eye. Infestation is clearly visible by the naked eye, and easily controllable by regular freshwater baths of around 3-5 minutes duration. The broodstock at Loh Mbongi are regularly given freshwater baths every 6 weeks or so.

Other health problems occasionally encountered include physical damage from biting and fighting during spawning. This a particular problem amongst the mangrove jack broodstock, which have particularly long and sharp canine teeth, and 2-3 mortalities per month of this species can be expected. Occasional tiger grouper mortalities are also found after fighting.

Some broodstock of all species occasionally suffer from bloated bellies, in a condition known as being 'egg bound'. This is thought to be due to a problem such as an infection of the ovaries or a malfunction of the normal spawning process, and fish typically are unable to maintain their equilibrium in the water. This is a relatively rare occurrence, and does not seem to have an infectious cause.

Estuary grouper do seem to be prone to a 'swollen belly' problem, characterized by a swelling of the abdomen and floating at the water surface. This often occurs immediately after fish have been handled, for example during routine sample weighing and bath treatments. Post-mortem examination typically reveals an extremely distended swim-bladder. The cause of this problem is unknown, and its incidence can be minimized by reducing the handling of estuary grouper to an absolute minimum.

Some broodfish of all species are occasionally found with eroded fins and a subsequent infection of the exposed tissue. If not advanced, this problem is normally responsive to a sequence of antimicrobial bath treatments.

A number of stock losses have occurred by way of escapes through holes in the nets, including 17 of the tiger grouper broodstock and a majority of the F_1 estuary grouper broodstock. Both cases were due to human error, and highlight the need for regular maintenance of net condition and extreme care and attention during live stock transfer operations.

Complete stock assessments, and sex determination, of the broodstock were made during December 2003 and January 2005, and from the figures obtained mortality and stock loss rates can be determined.

Summary of broodstock losses between December 2003 and January 2005:

Species	*stock as of Dec '03*	*stock as of Jan '05*	*total loss*	*% loss*
Cromileptes altivelis	29	18	11	37.9%
Epinephelus fuscoguttatus	58	38	20	52.6%
Epinephelus coioides	*148*	*132*	*16*	*12.1%*
Lutjanus argentimaculatus	242	205	37	15.3%
Seabass	54	51	3	5.6%

The above stock losses represent an annual stock loss rate. The mouse grouper are by far the most sensitive and delicate fish held, and the relatively high mortality probably reflects this. The high loss rate for the tiger grouper includes the accidental loss of 17 fish during a fish transfer operation. Without this loss, the natural mortality rate equals a very low 5.2%. The loss rates of the estuary grouper and mangrove jack reflect losses from disease and spawning-related damage. The stock of seabass was supplemented with hatchery-reared stock.

6.6 Selective breeding program

The stock of broodfish has been supplemented with carefully selected first generation hatchery production estuary grouper, tiger grouper, mouse grouper, mangrove jack and seabass. This is part of a long-term selective breeding program, which aims to introduce genes for fast growth, disease resistance and optimum physical appearance into the total stock of broodfish. Selective breeding is considered the key to gaining improvements in growth rate and survival rate of hatchery-reared fish, and in the control of the viral disease VNN.

All stocks of fish produced by the hatchery at Loh Mbongi will have been exposed to the VNN virus, and thus any fish surviving to grow-out and market will presumably possess some form of resistance to the disease. Additionally, any fish reaching grow-out will also possess those characters which make that fish robust enough to survive the artificial culture process. Future broodstock are also selected for fast growth and a good physical appearance.

Growth of the F_1 broodstock has been closely monitored and recorded (see Appendix 2). Since these future broodstock have been fed mostly with fresh fish and squid, this will allow some sort of growth comparison with those fish grown-out at the community-operated cage units and fed on pellets. However, it must be remembered that those fish selected as future broodstock are the faster growing fish of each batch, and can therefore be expected to exhibit faster growth rates if fed on a comparable diet.

7. Community-based grow-out

7.1 Site selection

All villages in the Komodo area received a preliminary assessment of their suitability for cage culture as early as September 2002. Parameters considered include population size and distance from Loh Mbongi. Suitability for cage culture was not considered at this stage.

Following is a list of all villages in the immediate Komodo area. A scoring system has been used as follows:

Village size: small (most suitable), 3 points; medium, 2 points; large (least suitable), 1 point.

Distance from Loh Mbongi: 0 – 20km (most suitable), 3 points; 20-50 km, 2 points; more than 50 km (least suitable), 1 point.

Village name	*Village size*	*Distance from Loh Mbongi* (nautical miles)	*Points*
Seraya Kecil	small	1 nm	6
Gorontalo, Flores	small	3 nm	6
Kukusan	small	8 nm	6
Menjaga, Flores	small	8 nm	6
Rangko, Flores	small	3.5 nm	6
Medang, Flores	small	11 nm	6
Boleng, Flores	small	7 nm	6
Papagaran	medium	14 nm	5
Kmp Rinca	medium	14 nm	5
Seraya Besar	medium	3 nm	5
Kerora	small	27 nm	5
Golohmori	medium	18 nm	5
Longos, Flores	medium	14 nm	5
Pasir Butih, Sumbawa	small	54 nm	4
Labuan Bajo, Flores	large	3 nm	4
Mesa	medium	10 nm	4
Warloka, Flores	medium	12 nm	4
Kmp Komodo	medium	27 nm	3
Bajo Tengah, Sumbawa	medium	54 nm	3
Bajo Barat, Sumbawa	medium	54 nm	3
Bugis, Sumbawa	large	54 nm	2

This was followed by site surveys of all suitable locations for cage installation.

A total of 28 sites within the Komodo area were surveyed for their suitability for the installation of traditional wooden grow-out cages. Such cages are relatively flimsy and therefore require well-sheltered sites in order to avoid damage and destruction during periods of bad weather. Consequently, parameters used for site selection included exposure to wave action (maximum wave height of 1 metre), depth (at least 12-15m), seabed type (i.e. not over sensitive ecosystems such as coral reefs), expected currents and tidal flow (currents of less than 1 knot), a proximity to the shore base (i.e. the participating village) and the presence of other coastal resource users.

The results of these surveys can be seen in Appendix 3 (Results of Site Selection for Ongrowing Cage Farms).

The most suitable sites were finally identified at Menjaga, Warloka, Boleng and Medang, all coastal villages on the island of Flores. Sites inside the Komodo National Park were not considered at this time.

7.2 Community selection

Once suitable locations had been decided upon, meetings were held with the relevant communities to assess their level of interest of involvement in the Komodo Fish Culture Project.

A significant level of interest in the Komodo Fish Culture project on the part of local stakeholders and potential grow-out investors was apparent from an early stage, and a number of village leaders, potential investors and local government personnel visited the hatchery facility at Loh Mbongi (see Appendix 5 for further details).

Meetings were held with those communities considered most suitable for collaboration with the Komodo Fish Culture project, using existing teams of The Nature Conservancy's Community Outreach division. The aims of the project were discussed, and the level of interest of each community in involvement in the project assessed.

The level of interest varied widely. Some communities expressed a strong interest for involvement from a very early stage, such as Warloka, Menjaga and Pulau Mesa. Others showed no interest, such as Boleng. It was recognized early on that the level of interest shown by a coastal community for involvement in the project was the key factor in community selection for grow-out.

7.3 Community collaboration model

A model for community collaboration in the grow-out of fish produced by the Komodo Fish Culture project was developed and refined over the 5 month period March-July 2003, and a draft collaborative agreement was finally agreed upon by July 2003 (see Appendix 6).

Interested parties in each collaborating community were asked to form a group consisting of a total of 11 members. Of these, 6 members would receive training and would thereafter operate the cage grow-out facility on a full-time basis. These 6 'trainee' members would be supervised by, and be responsible to, a group of 5 'senior' members. The senior members would normally include the head of the mariculture group, and would also be expected to include such people as the local Kepala Desa, and other key community figures whose involvement in the project would be considered necessary. The working schedule and working hours are decided by, and managed by, the senior members group, with the prior agreement of the Komodo Fish Culture project management, and typically the trainees carry out both daily work and night security tasks).

Trainees are provided with a small monthly payment (Rp.200,000, or approximately US$21), to compensate for any lost earnings caused by their full-time presence at the grow-out facility. In addition, the senior members are provided with a smaller monthly payment (Rp.150,000 or approx. US$16). The group is also provided with funds to cover the cost of meals (Rp.1,000,000 per month, or US$106). Non-cash provisions include the supply of diesel, petrol, cooking gas and fresh water. The total cost of grow-out support provisions (excluding fish feed and other fish rearing requirements) is therefore approximately US$330 per grow-out unit per month.

The rationale of the grow-out collaborative agreement is that all facilities, provisions, fish juveniles, pelleted feed and other biological materials, training and technical support, are provided to the grow-out group in return for a percentage of gross sales income, with the eventual aim that all facilities and inputs be paid for fully and taken over by the grow-out group. In this way, the Komodo Fish Culture project assumes all financial risk for the project, whilst the grow-out group gains practical training and an opportunity to invest in fish cage culture from the proceeds of fish sales.

It is recognized that such an arrangement is only possible over a longer term than that available to the Komodo Fish Culture pilot project, and so a simple pay-back percentage of 80% of gross income from fish sales is implemented, chosen to represent a reasonable profit margin for an operation of this type.

7.4 Training

All grow-out project members are invited to Loh Mbongi on the first day of the formal collaboration, to receive a full project briefing. Thereafter, the 6 trainees remain at Loh Mbongi and undertake a full-time residential training course in cage management. This training course is carried out by mariculture and other Nature Conservancy team members, and includes also training in other parts of the project, such as hatchery and live food rearing, and also more general training on the conservation work of The Nature Conservancy in the Komodo area.

The residential phase of the training programme includes the transfer and installation of the floating cage platform at the grow-out site, and all grow-out group members are encouraged to assist in the installation. The delivery of the first batches of fish coincides with the end of the residential training phase, in order that the trainees actually take part in the fish transfers and then remain at the grow-out site thereafter to operate the cage unit.

The grow-out group then receives 6 months of full-time on-site training and technical support. A Komodo Fish Culture project team member remains on-site on a permanent basis (for a minimum of 5 days per week) during this period.

After this period, when the training phase of the project is considered complete, regular weekly visits to each grow-out unit are carried out, to provide technical support and to monitor feeding regimes, growth rates, net cleaning schedules, etc.

7.5 Cage construction and design

7.5.1 Cage platform

The cage platforms installed at the community-operated grow-out units consist of a single floating platform divided into 16 individual cages of differing sizes. In addition, a floating work platform and 'guard house' are included in the installation. The design reflects the traditional use of simple, low cost cage production units widely used in Indonesia and other countries in south-east Asia. Such designs are limited to installation in sheltered locations, however, since they do not possess the strength or durability to withstand any significant wave action.

The cage platform itself is constructed of wooden planks nailed together to form the cage structure and walk-ways. To the wooden frame are tied, by rope, 200 litre plastic drums (empty chemical drums readily available the world over). The drums are filled with polyurethane foam, in order to maintain some buoyancy should a leak occur. Although at first glance relatively flimsy, the use of wood as a cage construction material does allow a good combination of strength and flexibility. Repairs are easily made if and when necessary. The cages presently in use at the grow-out installations remain in excellent condition after over 2 years of use, with no significant degradation apparent. Furthermore, the plastic drums used are extremely robust, and not one incidence of a burst or leaking drum has yet been observed.

The platforms are subdivided into a total of 16 cages, including four 3x3m cages, six 4x4m cages and six 5x5m cages. All cages are square. The use of different sized cages allows the efficient use of cage space when stocking different sized batches and different aged batches together on the same platform. Experience has shown that these cage platforms work well. Fish are easily transferred between cages, and sufficient walk-way area is available for efficient and safe working practices.

Each cage platform is accompanied by a working platform, complete with roof, and a ‘guard house’. Both facilities are constructed of a square wooden platform (using wooden planking and plastic drums as floaters) on which are constructed a metallic roof (working platform) or both walls and a roof (guard house), and conform to the traditional practice in south-east Asia of keeping staff on duty at the cage facility over a 24 hour period, primarily to provide a security presence throughout the night. The working platform and guard house are individual units, which are tied to the cage platform with rope. However, the whole facility is moored as a single unit.

Construction of the floating cage platforms was contracted to carpenters from the village of Boleng, and overall construction standards were good. Cage construction was carried out on the beach at Loh Mbongi.

The purchase and installation of plastic cages was given some consideration. Plastic cages are considerably stronger and more durable than wooden cages, and would open up the opportunity for cage culture in semi-exposed waters, considerably increasing the number of potential grow-out sites in the area. Although of potential benefit to a commercial operator, their purchase and use was not within the scope of the Komodo Fish Culture project, since this pilot project aims to involve local communities, with extremely limited resources, in the culture of reef fish by way of inshore, low cost cage installations.

7.5.2 Moorings

Moorings used for the grow-out units are simple, reflecting the use of sheltered locations for cage installation. Moorings consist of 50kg ‘grapple-style’ anchors, shackled to a 5 metre length of ground chain (20mm). This is then connected directly to the cage unit by way of 28mm polypropylene rope. No cushion floats are employed, and the mooring ropes are tied to appropriate parts of the cage platform by way of two turns fastened by a bow-line. Typical mooring length to water depth ratios employed are 3:1.

Mooring anchors are fitted, via a rope, with a small, hard plastic surface marker buoy, to act as a marker float and to allow the re-positioning of the anchors with the use of a boat, without the need for diving. Hen anchored in soft sediment, anchors were found to drag during periods of strong wind. This was due to the use of grapple-style anchors, which are designed for holding on hard irregular substrates, such as rock or coral (spade-style mooring anchors are no available locally, and their purchase was not considered cost effective). The drag on the cage platform during periods of strong winds is caused primarily by the presence of the guard house, the walls of which offer significant resistance to wind flow over the installation.

Anchor dragging will result in the gradual re-location of the cage platform, which is readily remedied by the re-positioning of the mooring anchors using the marker buoy lines attached to the anchors and a boat.

7.5.3 Nets

Nets used are cut and sewed together from rolls of knotless nylon netting imported via an Australian supplier. Net construction is carried out by mariculture staff, who provide training to the community fish culture group, who then take over the net construction. Netting is cut to suitable lengths and sewn together with nylon thread to make nets of 3x3x3m, 4x4x4m and 5x5x5m, or of any other size required. Typically, 10mm rope is included in the net design, to provide strength and a certain degree of rigidity to the completed nets, and to assist in the sewing together of net panels.

Knotless netting is not widely available in Indonesia, since most local cage operators use the low cost knotted variety which is more widely available. Consequently, the cost of purchasing and importing knotless netting is considerably higher than the purchase cost of local knotted netting. Despite this, the use of locally-made knotted netting is discouraged, since the abrasive nature of this netting may damage fish and restricts the cage management practices which may be employed on the cage production units, and the use of knotless netting is here promoted as a 'best practice' for cage management.

Nets are weighted with small rocks fitted into net bags.

Nets are cleaned when necessary, using sun drying methods and a pressure washer for the removal of dead fouling organisms.

7.6 Grow-out installation and fish stocking history

Construction of the first grow-out platform commenced during November 2002. Construction was carried out by Komodo Fish Culture project personnel at the Loh Mbongi hatchery site. Construction of the guard house and working platform was considered beyond the capabilities of the Komodo Fish Culture team, however, and was contracted to carpenters at Boleng during December 2002. Both the floating cages units and the guard house and working platforms were completed by March 2003, and were placed on temporary moorings until the first community-based grow-out unit was selected.

Construction of the second cage platform was contracted entirely to the carpenters at Boleng, and was completed, at Loh Mbongi, during May 2003. This cage platform was placed on temporary moorings at Loh Mbongi. The guard house and floating platform were built at Boleng, and were delivered to Loh Mbongi by July 2003.

The first production batch of estuary grouper was ready for transfer to sea cages by June 2003, and the first transfers of juveniles to the temporary cages at Loh Mbongi took place during 26th June, by which time the fish had already reached a weight range of between 20g and 50g.

During July 2003, a batch of 8g mouse grouper juveniles was also transferred to the temporary cages, due to space limitations in the nursery section of the hatchery. During August 2003 an additional batch of 2g mouse grouper juveniles was transferred to the temporary cages following an outbreak of VNN in the hatchery at Loh Mbongi.

By September 2003, the estuary grouper had already reached an average weight of 150g, with the following batches of mouse grouper reaching 30g and 10g respectively.

During September the final decision was made to install the first grow-out operation close to the village of Warloka, on the mainland of Flores immediately south of Labuan Bajo, close to the northern tip of Pulau Rinca. A well-attended meeting was held at Warloka during 18th September to discuss the project further, and the community leaders present confirmed their desire to proceed with the collaboration. Possible sites for cage installation were inspected, and by 3rd October the members of the community grow-out group had been selected. Site surveys, including underwater inspections, were carried out of the possible cage installation sites in the vicinity of the village of Warloka, and the site immediately facing the village was chosen.

The cage installation was towed to the grow-out site at Warloka during November 2003. The installation was towed in two parts – first the guard house and working platform, followed by the cage platform - behind the Komodo Fish Culture project workboat KM Manta, from Loh Mbongi directly to Warloka. Towing time was approximately 7 hours for each trip, representing a towing speed of just under 2 knots. When on-site, mooring anchors were dropped up-wind of the site of installation, the cage platform attached, and the remaining moorings laid thereafter.

The batches of estuary grouper and mouse grouper were transferred from the temporary cages at Loh Mbongi to the grow-out cages at Warloka from 9th to 15th December, 2003 by way of the live fish transportation tank installed in the KM Manta. In addition, a large batch of mangrove jack was transferred to Warloka directly from the nursery tanks at Loh Mbongi during 16th and 17th December. All transfers were carried out with minimal mortalities, at stocking densities of up to 50 kg per cubic metre without problems, over a distance transport time of approximately 2 hours. During unloading, all fish stocks were counted prior to stocking into the holding cages and the number of mortalities recorded. A total of 6,443 fish were transferred to Warloka during this time, making up a total biomass of over 500kg of fish stock. Further batches of mangrove jack and tiger grouper juveniles were transferred to Warloka during April and May, 2004.

By February 2004, the village of Menjaga had been decided as the site of the second community grow-out unit. The community of Menjaga had shown considerable interest in involvement in the project for some time, and the location was particularly suited to cage culture. Negotiations continued throughout the month of February, and final agreement was reached by March 2004.

Residential training at Loh Mbongi for the Menjaga grow-out group was carried out throughout May 2004. The floating cage installation was towed to, and installed at, Menjaga on 26-27th May, with a towing time of 4-6 hours. After moorings were checked and installation completed, the first batches of fish were delivered to Menjaga during June 2004, including a batch of 3,000 mangrove jack and 1,500 tiger grouper.

After the delivery of a batch of tiger grouper to Warloka in June 2004, it was decided to send all further hatchery production to Menjaga. This was due to poor performance of the Warloka grow-out group and resistance to the grow-out project from other parts of the community. Three further batches of mangrove jack were sent to Menjaga during December 2004 to February 2005. These were the final batches of juveniles to be delivered from the hatchery to the grow-out units during the pilot phase of the Komodo Fish Culture Project.

Grow-out stocking history

Date	***Grow-out location***	***Species***	***number transferred***	***mean wt.***
09/12/03	Warloka	mouse grouper	1,017	35g
10/12/03	Warloka	estuary grouper	387	175g
15/12/03	Warloka	estuary grouper	378	300g
16/12/03	Warloka	mangrove jack	2,857	50g
17/12/03	Warloka	mangrove jack	1,804	30g
17/04/03	Warloka	mangrove jack	700	5g
19/05/04	Warloka	tiger grouper	2,800	5g
07/06/04	Menjaga	mangrove jack	3,100	10g
08/06/04	Menjaga	tiger grouper	1,554	15g
09/06/04	Warloka	tiger grouper	1,175	15g
09/12/04	Menjaga	mangrove jack	130	15g
09/12/04	Menjaga	mangrove jack	260	10g
01/02/05	Menjaga	mangrove jack	1,011	8g

7.7 Fish production

7.7.1 Growth rates

A total of 10 batches of fish were transferred to Warloka and Menjaga for grow-out over the course of the Komodo Fish Culture pilot project. The first batch, of estuary grouper, reached market size, and was harvested, during June 2004. The first batch of mangrove jack had reached an average weight of 1kg by June 2005, and were awaiting sale. All remaining batches of fish, except for one small batch of mangrove jack, were approaching market size by the end of the pilot project in June 2005. In August 2005, all marketable fish were sold.

Total stock remaining as of 10 June, 2005:

Menjaga

Species	*Batch*	*mean wt.*	*no.*	*biomass*
mangrove jack	jack 3	556g	1209	672 kg
mangrove jack	jack 3	436g	1668	727 kg
tiger grouper	tiger 2	484g	803	389 kg
tiger grouper	tiger 2	384g	150	58 kg
tiger grouper	tiger 2	240g	257	62 kg
mangrove jack	jack 4/5	226g	340	77 kg
mangrove jack	jack 5	102g	430	44 kg
mangrove jack	jack 5	86g	380	33 kg
Totals			*5237*	*2062 kg*

Warloka

Species	*Batch*	*mean wt.*	*no.*	*biomass*
mangrove jack	jack 2	338g	353	119 kg
tiger grouper	tiger 2(s)	338g	820	277 kg
tiger grouper	tiger 2(l)	425g	805	342 kg
mouse grouper	mouse 1	380g	452	172 kg
mouse grouper	mouse 1	280g	230	64 kg
mangrove jack	jack 1	740g	2954	2186 kg
mangrove jack	jack 1	1100g	1440	1584 kg
Totals			*7,054*	*4,744kg*

Mean weight data of all production batches were taken on a monthly basis, always by the Komodo Fish Culture project’s grow-out officer. Weights recorded were occasionally inaccurate, due mostly to the use of poor quality balances and the difficulty in obtaining good representative samples of fish under prevailing conditions. Although individual weight records may occasionally be inaccurate, the resulting growth curves for each batch of fish show clear growth patterns (see Appendix 4 for growth curves for all production batches).

The mean weight data recorded here represents that mean weight for the entire batch, including large and small grades. It must be borne in mind, if the figures reproduced here are to be compared with other grow-out operations, that commercial operators will often ignore the performance of slow-growing grades of fish and quote growth rates for the best performing batches of fish. Grow-out data here also assumes that grow-out starts from a 5g juvenile.

Daily records were also kept of food fed per cage, and mortalities removed per cage. Unfortunately, the accuracy of these figures is wanting. Despite intensive and thorough training, some members of the grow-out groups either lacked the capacity or the motivation to keep accurate records, feed was occasionally not given to fish, and mortalities were occasionally not removed from cages or recorded. Therefore, stock losses at the time of harvest are expected and food conversions figures may occasionally be suspect. However, despite all of these problems, the data which have been obtained are all extremely valuable.

The fast and variable growth rates of the species of fish cultured during this project requires the regular grading of stocks. This is required to minimize losses through cannibalism and to improve feeding efficiency of the fish stocks. Between the size of 5g and 50g, grading is required as often as every 2-4 weeks, particularly for those species most prone to cannibalism, such as tiger grouper. However, unlimited grading is not possible, and a balance needs to be reached between sufficient grading to minimize cannibalism and maintaining the most efficient stocking densities in the number and sizes of cages available.

Although recognized as a source of stress to the fish stocks, grading does allow the regular determination of stock numbers, in order to determine the number of un-recorded mortalities or stock losses. During this pilot project, no losses of fish were recorded through holes in nets, by predation or due to theft, and therefore all stock losses must be assumed to be due to mortality.

Ambient seawater temperatures ranged between 27°C and 30°C, and are not thought to have affected growth rates to a significant extent. Other physico-chemical parameters, such as salinity and dissolved oxygen levels, were similarly constant.

Growth rates quoted below are specific growth rates (SGR), which are the percentage increase in bodyweight per day.

7.7.1.1 Estuary grouper

The very first production batch of fish, estuary grouper, reached an average weight of 500g (usually considered market size) after 11 months of grow-out (see Appendix 4). Initial specific growth rates of juveniles may reach 5.0, which drops to around 1.0 at a weight of 100g and then to approximately 0.5 by the time the fish reaches its market size of 500g. Overall specific growth rates for the full grow-out cycle were 1.45 at Komodo.

Perhaps 10% of this batch showed a deformity of the caudal fin, which was not considered significant by the fish buyer at harvest.

7.7.1.2 Tiger grouper

Three batches of tiger grouper were grown out, one at Warloka and two at Menjaga. This species showed a slightly slower growth rate overall than the estuary grouper, with a full grow-out specific growth rate of 1.23 being achieved at Komodo (see appendix 4), and a total of 12-13 months of grow-out being required to reach 500g. Growth rates were found to be similar to those of estuary grouper in the earlier stages of grow-out, but slowed significantly between 300 and 500g to a rate of approximately 0.2 (as opposed to 0.5 for estuary grouper).

The three batches of tiger grouper maintained as future broodstock reached a weight of 500g within 10 months (see Appendix 2). However, these batches of fish were selected from the production batch for fast growth, and so comparisons should be made with caution.

A significant percentage (approx. 20%) of deformities to the spine and head were apparent amongst these batches of grouper.

7.7.1.3 Mouse grouper

One batch of mouse grouper were grown-out at Warloka. Two other much smaller batches were grown out as future broodstock (see section 6.6). This batch of mouse grouper had suffered from an outbreak of VNN (viral neural necrosis) during the nursery phase, and it is not known how much this affected subsequent growth rates.

Mouse grouper were significantly slower growers than the other species of grouper grown by the Komodo Fish Culture project. After 22 months of grow-out, the entire batch had reached a mean weight of 330g, with the largest size grade reaching 380g. This represents a full grow-out growth rate of 0.6, less than half that of both estuary grouper and tiger grouper. Growth rates of around 1.2 were achieved for the period between 10g and 100g, dropping to 0.6 from 100g to 200g, and down to below 0.2 from 200-250g. Between 250g and 350g growth rates dropped to 0.1. It is thought that this very low growth rate may be due to deficiencies in the manufactured pellets specific to mouse grouper (since other species reared at both Warloka and Menjaga appeared to grow reasonably well). This is supported by the performance of the batch of mouse grouper kept as future broodstock (see appendix 2).

These growth rates can be compared to those mouse grouper grown as future broodstock at Loh Mbongi. The main difference between these batches is that the future broodstock were fed with trash fish and squid, whilst the batch grown at Warloka was fed entirely on pellets. The Loh Mbongi batch grew at a rate of 0.6 between the size of 100 and 400g, and reached the market size of 500g after 19 months of grow-out.

Approximately 20-30% of this batch suffered from various deformities to the spine and head.

7.7.1.4 Mangrove jack

Of the five batches of mangrove jack grown-out at both Warloka and Menjaga, the two to have reached a weight of 500g within the span of the pilot project have done so within 12 months of grow-out. This represents a full grow-out specific growth rate of 1.2. Growth curves obtained are essentially straight, showing no drop in growth rate during the 500g growth cycle, as is found with the groupers. In fact, the first batch of mangrove jack grown at Warloka had reached almost 1kg in weight within 20 months of grow-out. This is significant, since the market size for mangrove jack is commonly as large as 1.2kg, and so extended grow-out for this species needs to be considered. It is also significant, since it shows that species can be reared to 1kg using commercial pellets.

Even faster growth may be possible. The mangrove jack selected for fast growth, and fed on fresh fish and squid, to be grown as future broodstock, reached a weight of 1kg within 13 months of grow-out (see Appendix 2).

The main problem with the batches of mangrove jack produced at Loh Mbongi is the high rate of deformities. Up to 40% of the entire batch appear to be suffering from deformities of the spine, particularly the posterior part, giving the fish a ‘shortened’ appearance when viewed from the side. This is consistent with compressed vertebrae, and the cause is unknown at present. However, it can be considered a mild form of deformity, and may not affect the marketable value of these fish significantly.

7.7.2. Grow-out feeds and feed conversion efficiency

All batches of fish were fed almost exclusively on JAPFA Comfeed grouper pellets. This is the only significant Indonesian producer of grouper pelleted feeds at present, and the formulation used was developed with the assistance of Gondol Research Institute for Mariculture, Bali. Pellet sizes range from 1.0mm all the way up to 12mm, providing the full pellet size range necessary for normal grow-out.

Physical characteristics of this feed appeared reasonable, although the light colour would suggest a relatively low inclusion rate of fish oil (probably 8-10%), and excessive dustiness was occasionally a problem. The aroma of the pellets suggests a reasonable, but not high, inclusion rate of fish meal (perhaps 50% of total protein content?). The relatively fast sinking rates of the pellets were well suited to feeding grouper.

Palatability of these pellets was food, and fish accepted them readily. Also, pellet size was appropriate to the large mouth sizes of some species, particularly the tiger grouper, which are capable of eating a 12mm pellet from as small as 100g in weight.

All fish, with the exception of the mouse grouper, grew well using this diet (see growth curves Appendix 4). The mouse grouper growth tailed off at around 350g, and almost no growth was evident beyond this size, indication some deficiency within the pellets for fish of this size (mouse grouper grown as broodstock on fresh fish continued growing to beyond 500g).

Food conversion figures are necessarily estimates, since such data relies upon accurate stock figures and accurate sample weights. At the grow-out units of the Komodo Fish Culture Project, regular stock counts were not carried out, and so stock figures were estimated from the original stock figure less those mortalities removed and counted. The collection of accurate sample weights was hampered by the lack of a good quality balance and occasional difficulties in obtaining accurate samples of fish. No balance accurate enough to weight fish of less than 50g was available.

Despite these limitations, a good estimate of the food conversion ratios obtained during grow-out can be obtained in 2 ways. Estimates of food conversion rates per species and batch can be collected monthly and collated into reasonable estimates of total food conversion over the full grow-out cycle. The second method is simply to divide the total stock of fish produced during grow-out by the total quantity of pellets used, to arrive at a food conversion figure for the entire stock.

Stock by stock food conversion rates (FCR) obtained are as follows:

Species	*FCR*	*comments*
Estuary grouper	1.5	harvested at 700g during June 2004
Mouse grouper	5.2	grow-out over a 22 month period, with reduced growth after 300g
Tiger grouper	1.9	grow-out over a 12 month period to 500g
Mangrove jack	2.9	grow-out to harvest weight of 1kg over a period of 20 months
Mangrove jack	1.6	grow-out to a harvest weight of 500g over 12 months

Clearly, food conversion values will vary according to the size of the fish at harvest. For example, mangrove jack can be grown to a weight of 500g at a food conversion ration of 1.6. Also some species variability can be expected – mouse grouper is a much slower-growing species than mangrove jack and the other species of grouper cultured.

If the total tonnage of fish produced during grow-out (7.3 tonnes as of June 2005) is divided by the quantity of pellets fed during the entire duration of the Komodo Fish Culture project (17.18 tonnes by June 2005), a total food conversion ratio figure of 2.35 results for all fish stocks combined. If all fish were harvested at a weight of 500g, a final food conversion figure of well below 2.0 can be expected.

7.7.3. Fish health and mortalities

Fish health during the grow-out phase has been excellent, with very few incidents of disease or significant loss to other causes.

7.7.3.1 Mortality rates

Only a single batch of fish had been harvested, and therefore counted in detail, by June 2005. This batch of estuary grouper revealed a total grow-out loss of 39%. 90% of these losses occurred during the first 3 months of grow-out, and were mostly due to cannibalism.

Stock losses from all remaining batches need to be estimated from those mortalities collected and counted during normal operations. Obviously, this will involve some underestimating since a number of mortalities will go unobserved and unrecorded. The following are estimated total grow-out mortalities for all batches of fish produced to date:

Estuary grouper (Warloka):	39%
Mouse grouper (Warloka):	33%
Mangrove jack 1 (Warloka):	6%
Mangrove jack 2 (Warloka):	50%
Mangrove jack (Menjaga):	7%
Tiger grouper (Warloka):	47%
Tiger grouper (Menjaga):	22%

With the exception of batch mangrove jack 2, all remaining batches of mangrove jack showed very low mortality rates. This species is robust, and does not appear to suffer from VNN. The grouper species experienced mortality rates of between 22% and 47%. These losses were largely due to a combination of cannibalism and the occurrence on a number of occasions of an undiagnosed short-term mortality (thought to be of bacterial origin).

The difference in mortality rates between those tiger grouper stocked at Warloka and Menjaga may reflect differences in husbandry between those two sites, and a total grow-out mortality rate of around 20% should be achievable under optimum husbandry conditions and in the absence of significant disease outbreaks.

7.7.3.2. Treatments

All fish batches were given freshwater bath treatments as and when required to control ectoparasitic flukes, particularly *Benedenia sp.* Although not a serious problem in itself, excessive levels of infestation can lead to poor health and make fish more susceptible to other ailments.

Occasionally numbers of fish were found to possess lesions on the body and fins. These fish were effectively treated with bath treatments of oxytetracycline.

On a number of occasions, the stocks of tiger grouper suffered from a low level, but persistent, mortality. Although of unknown cause, this problem did seem to respond to oral treatments of oxytetracycline.

7.8 Results of collaborative model and community performance

The operation of the above two community-based grow-out units over the duration of the Komodo Fish Culture Project has revealed some challenges, some foreseen, others quite unexpected, in operating alternative livelihood projects with stakeholder communities, and a number of valuable lessons have been learnt. The general attitude of the participants in the project has varied greatly between the two units – one group is almost totally self-reliant and diligent with respect to day-to-day fish production operations, whilst the other has required constant supervision and guidance. One group can see the future earning potential of the project, and patiently awaits the first harvest, whilst the other sees more value in the limited monthly operational payments than the final income from harvest.

Most importantly, other factors, unrelated to the fish culture operations, may have a significant effect on the long term success of the project, including intra-community politics, tensions and rivalries, which can be exacerbated by the introduction of an alternative livelihood project to a community lacking a strong and decisive leadership, or a strong sense of cohesion within that community. Many of these factors are difficult to foresee, and underline the need for extensive and detailed community-based research and preparation for additional grow-out operations, and indeed other alternative livelihood projects of this type.

Further requests for information, and expressions of interest, continue to be received from communities requesting participation in this project, such as Pulau Mesa, Kukusan and Sape, and further development of the grow-out model established by the Komodo Fish Culture Project, with the installation of additional grow-out units in key interested communities, will be pursued.

8. Carrying capacity and development of best practices

During January, 2003 a workshop was held in Labuan Bajo to discuss the future governance of an aquaculture industry in the Komodo area, with particular emphasis on the determination of a maximum carrying capacity to allow safe environmental limits to future fish farm development. The workshop and subsequent studies were coordinated by Michael Phillips of NACA, and involved contributions from Dr Adi Hanafi (Gondol) and Dr Bambang Widigdo, Head of Faculty, IPB (Department of Aquatic Resource Management, Bogor University).

The objectives of the workshop were:

1. To design an environmental monitoring programme for the four pilot cage sites, including the construction of a baseline study, a decision on the relevant parameters to measure, the frequency of sampling and a minimum allowable change for those parameters, and the calculation of theoretical carrying capacity values for each site.
2. To agree on recommendations on an approach to carrying capacity/monitoring guidelines for fish culture in the Komodo area.
3. To agree on a list of best hatchery and grow-out practices, at farm level, to be implemented by the Fish Culture Project.
4. To construct a list of ‘best governance practices’, eventually to be overseen by fishfarmer associations or government.
5. To review the existing governance systems and legal framework for aquaculture development in the Komodo area, and Indonesia as a whole, and to assess the possibility of zoning plans with respect to aquaculture development.
6. To devise a list of recommendations for the strengthening of governance systems for aquaculture development, including zoning systems, in the Komodo area.
7. To review existing legislation with a direct effect on aquaculture, such as use of pharmaceuticals and other chemicals, transfer of live animals and water quality/discharge regulations.

Unfortunately, funding was subsequently unavailable to proceed with this project in its entirety. However, a number of its objectives were reached, and valuable work within the field of best practice standards completed. Results of this workshop are available from TNC CTC in Bali.

A simple environmental monitoring programme was designed, and may be used as the basis for any future implementation of actual environmental monitoring of cage-based grow-out units. This programme included the establishment of a baseline study of relevant parameters, and the subsequent monitoring of those baseline parameters in order to establish any possible effects caused by the presence of the cage facility in question. Simple parameters, such as water temperature, weather conditions and water turbidity, were measured at both grow-out units involved in the Komodo Fish Culture project.

The establishment of best hatchery and grow-out practices, at the farm level, has received a great deal of attention within the Komodo Fish Culture Project, since the establishment of an environmentally and financially sustainable fish culture industry within the Komodo area has been the main aim of this project. The mariculture manager delivered a presentation on the application of best practice standards to the Komodo Fish Culture project at the World Aquaculture Society Conference and Exhibition at Bali during May 2005, which is expected to contribute significantly to the development of industry-wide best practice standards. A report on the application of best practice standards to the Komodo Fish Culture Project is available at TNC CTC, Bali.

The review of existing governance of the aquaculture industry within Indonesia, and the development of recommendations to improve that governance, remain to be completed. The development of the effective governance procedures is considered vital to the future development of a sustainable fish culture industry in Indonesia and beyond.

9. Partnerships and training

As culturing of grouper still poses some technical challenges, the fish culture project created partnerships with institutes that have the necessary know-how. The main partners in the Komodo fish culture project are the Gondol Research Institute for Mariculture (Bali, Indonesia), the Department of Primary Industries, Queensland (Australia) and the Network of Aquaculture Centers in Asia (based in Bangkok, Thailand).

On May 23 2002, a Memorandum of Understanding was signed between The Nature Conservancy and The Research Center Institute of Aquaculture (RCIA, the mother institute of the Gondol Research Institute for Mariculture) of the Ministry of Marine Affairs and Fisheries. The objective of the cooperation is to conduct research on the development of sustainable mariculture and to generate alternative sources of income for local communities. The agreement was signed in the presence of the former Minister of Marine Affairs and Fisheries, the Honorable Dr Rokhmin Dahuri at the RCIA campus in Gondol.

As one of the first fishery research institutes in the world, Gondol succeeded in reproducing mouse grouper fingerlings from captive broodstock. Cooperation with the Queensland Dept. of Primary Industries was sought because of their extensive expertise in fish culture in general, but specifically in the culture of sea bass. This cooperation resulted in the participation of the Komodo fish culture project in the AusAID-funded Government Sector Linkage Project, which facilitated exchanges between Komodo, Gondol and the Queensland Dept. of Primary Industries.

In the framework of the aforementioned Government Sector Linkage Project, Elizabeth Cox and Julien O'Brien from the Department of Primary Industries visited the Komodo project on September 24-29 2001. They provided training on diagnosis and treatment of fish diseases to staff of the Komodo fish culture project. During the period March 18-30 2002, Mr. Gatot Wibisono (Mariculture Officer) and Primus F.S. Baru (Mariculture Assistant) attended a course at the Gondol Research Institute for Mariculture. The course focused on fish pathology, live feed production, and formulated feed production. Over the period April 12–23 2002, 2 staff of the mariculture team, Sudaryanto (Mariculture Coordinator) and Frederik G. Bataona (Mariculture Officer) were invited to receive training at the Department of Primary Industries of Queensland (Cairns, Australia). This training focused on brood-stock maintenance; induced spawning; tagging; hormone treatment, pathology, packing; and transportation of fish.

A number of technical support visits have been made by key staff members of Gondol Research Institute for Mariculture since the start of the project. A management support visit was carried out from 25-28 July 2003 by Dr Fris Johnny Ravael (senior fish pathologist) and Dedi Rohaniawan (hatchery technician), who provided valuable advice and training to mariculture staff. A technical support visit to Gondol was made during January 2004 by Mariculture Manager Trevor Meyer and Hatchery Officer Gatot Wibisono, and a further visit was made during September 2004. An additional technical support visit to the Fish Culture Project was made by Dr. Eri Sutiadi, a larval rearing expert at Gondol, in order to assist with problems experienced with poor larval survival rates.

The Komodo fish culture project became a member of the Network of Aquaculture Centres in Asia (NACA) to link up with aquaculture experts in Southeast Asia. During July 2003, both the Mariculture Manager and Mariculture Coordinator attended the 7th Technical Advisory Committee meeting of NACA, held in Bali.

The Komodo Fish Culture Project has provided regular residential training courses to the Fisheries High School at Sape. Four training courses have been completed to date, each accommodating 6 students for a period of up to 2 months. These courses were delivered from 28th July – 28th August 2003, 9th February – 9th March 2004, 1st September to 7th November 2004 and 14th February to 13th April 2005. The courses included training in hatchery production techniques, production of live feed (algae, rotifers and Artemia), and grow-out in fish cages and provided valuable training to local communities who would not normally have access to such amenities, and assisted in the dissemination of information to local stakeholders on the aims, methods and operations of the Fish Culture Project, The Nature Conservancy and environmental issues in general. On the strength of these training courses, the Fisheries High School of Sape has expressed an interest in joining the Fish Culture Project as the site of a community grow-out unit.

10. Business development

To get a first impression of the economic viability of a fish culture business based in West Flores, an expert team visited the Komodo area to collect data for the compilation of a business scenario for the fish culture enterprise in July 1999. The team consisted of Mr. Bill Rutledge (consultant), Dr. Mike Rimmer (Dept. of Primary Industries, Queensland, Australia) and Dr. Ketut Sugama (Gondol Research Station for Coastal Fisheries). The resulting business plan was reviewed by Dr. Stephen Battaglene, Senior Research Fellow of the Tasmanian Aquaculture and Fisheries Institute.

This business plan envisages that sea bass and estuary grouper will be used to get experience with hatchery techniques during the start-up phase of the project, after which the focus will be changed to mouse grouper and tiger grouper. The conclusion was that the hatchery, even at pilot scale, could return a profit provided that the full capacity was realized and that production would eventually focus on the most expensive grouper species, mouse grouper. Though based on incomplete data and ballpark assumptions, this analysis provided a sound basis to continue the project. As experience was gained while implementing the pilot project, it became clear that the project could only achieve profitability by up-scaling to a production capacity of 200 tons per year, and that operational continuity requires to maintain a multi-species approach. The design of the hatchery is modular, and the land on which the hatchery is located allows for further expansion. Further investment is needed for additional construction of hatchery facilities and grow-out units.

While local communities are starting to produce the first batches of marketable fish, the pilot project has entered it's most critical phase: transformation into a triple bottom line business that is not only profitable but that also benefits local people and that is environmentally sound. As a global non-governmental, non-profit organization, The Nature Conservancy fully realized that this transformation must be driven by the private sector, with The Conservancy only in a supporting and catalytic role.

Business development has been The Nature Conservancy's main focus for the final phase of the fish culture project. The Conservancy initiated discussions on the formation of a business development partnership with the following potential partners:

- *Indonesia International Rural & Agricultural Development Foundation (INIRADEF),* a Bali-based foundation who has close ties with PT BPI. INIRADEF operates three eco-lodges, one of them situated in Komodo, and has experience with rural development projects that were funded by bi-lateral development aid. INIRADEF brings expertise in agriculture development, and maintains high environmental standards for its operations (for example, for its eco-lodges INIRADEF works with the environmental certifying agency Green Globe).
- *PT Bruno Phala International (PT BPI),* a private Indonesian company based in Bali. PBI is involved in community-based fish culture in Baru, South Sulawesi, and PBI has developed agriculture of corn in South Sulawesi, involving some 2000 local farmers. BPI, enabled by INIRADEF and a Dutch development aid agency, also developed a feed-mill for broilers and shrimp using state-of-the-art technology. The company set up an Industrial Development Council for South Sulawesi Province, which acts as an advisor and coordinator for the agribusiness and industrial development of the province. Divisions within this company are involved in various medium-sized businesses in Bali such as manufacturer of export quality furniture, freight forwarding company and interior design. BPI's director visited the Komodo fish culture project in February 2004.
- *Asia Conservation Company (ACC).* ACC is the first investment holding company in Southeast Asia that adheres to the triple bottom line principle. ACC was incorporated on December 11, 2001 to build a bridge between private sector investment and biodiversity conservation. The goal of ACC is to construct a network of private sector investments that proactively conserve biodiversity while remaining profitable and competitive in the market place. The ACC model has been approved for a Global Environmental Facility (GEF) grant from the World Bank to be implemented by the International Finance Corporation which will give US$4.5M to conservation sites associated with ACC investments. During July 2004, senior representatives of ACC visited the Fish Culture Project as part of a fact-finding visit to the Komodo National Park, and preliminary terms of reference of their involvement in the project were drawn up. This was followed up with meetings between ACC and both PT BPI and INIRADEF over July and August 2004. During September, 2004, a member of ACC visited the Gondol Research Institute for Mariculture, in Bali, for an assessment of the current status of the grouper hatchery industry in Indonesia, and further talks were held with The Nature Conservancy in Bali.
- *PT. Prabuana Surya Mariculture.* This company has recently been involved in a community-based grow-out grouper farming operation in South-East Sulawesi, and as such is actively involved in promoting the 'triple-bottom-line' approach pursued by the Komodo Fish Culture project. The company is also actively involved in the sale of live fish products to the Hong Kong market. The director of the company, Mr. Ridwan Simansjah, visited the hatchery facility at Loh Mbongi and the grow-out units at Warloka and Menjaga during January 2005.

- *PT. Nuansa Ayu Karamba.* This company operates a grouper hatchery and grow-out operation at Pulau Seribu, and is owned by a conglomerate also involved heavily in the Indonesian tourism business. The managing director of this company, Mr. Henry Sulysto, visited the hatchery facility during January 2005. He followed this up with a further visit to the hatchery and grow-out units together with the manager of his fish culture operation in February 2005.
- *PT. Karamba.* A Bali-based company active in the aquaculture industry, including a grouper cage operation in Lombok and smaller mud-crab production projects. A sister company is involved in the tuna export business. A delegation from this company, which included the grouper farm operations manager Mr. Hery Suditha and international grouper culture consultant Mr. Shogo Kawahara, visited the hatchery at Loh Mbongi and the grow-out operations during March 2005. A further visit took place during June 2005.

After careful consideration, it was decided to offer PT. Karamba the opportunity to take over the Komodo Fish Culture project. After two additional visits to Loh Mbongi during June 2005, representatives of the company finally signed all relevant documents allowing the transfer of operations to proceed as of 1st July 2005. The transfer is formalized through a Cooperative Agreement, signed on June 18 2005 by the Ministry of Forestry, Directorate General of Forest Protection and Nature Conservation, The Nature Conservancy, and PT Karamba.

11. Staffing

By June 2005, the Komodo Fish Culture Project was staffed as follows:

Mariculture Project Manager: Mr Trevor Meyer (hired 18 August, 2002)
Broodstock & growout Coordinator: Sudaryanto
Mariculture Officers: Edi Bataona, Gatot Wibisono, Vitalis Jelanu and Primus Baru
Mariculture Assistants: Jamarong Djuje, Juaedi Koro, Wengking Latul, Deden Dong, Ahmad K.Ibrahim, Sahruddin, Ruben Noti, Siprianus Engko, Guntur, Ramaddhan.
Mariculture mechanic: Martinus Sengga
Boat crew: Martinus Ardi (boat driver), Kasmir Kamis (boat driver), Abdullah Hasannudin (boat crew)
Night guard: Mustaking Ali, Gerardus Loli, Nasrul Hasan
Cook/housekeeper: Imelda Sul, Rosalia Amut, Nurhayati
Mariculture Volunteer: Ozden Meyer

12. Contacts

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APPENDIX 1. Details of Hatchery Production

Batch no.	***Species***	***Date stocked***	***Result***	***no. transfer to cages***
1	E. coioides	5 March 2003	3.7% survival by day 55	3,600 June 2003
2	L. argentimaculatus	27 March 2003	total loss by day 4	
3	C. altivelis	30 March 2003	total loss by day 7	
4	E. fuscoguttatus	31 March 2003	total loss by day 35	
5	C. altivelis	7 April 2003	0.1% survival by day 23	268 July 2003
6	E. coioides	9 April 2003	total loss by day 14	
7	E. coioides	3 May 2003	total loss by day 7	
8	L. argentimaculatus	3 May 2003	total loss by day 7	
9	C. altivelis	5 May 2003	total loss by day 7	
10	C. altivelis	23 May 2003	1.9% survival by day 50	
11	C. altivelis	2 June 2003	2.5% survival by day 55	1,950 Aug 2003 (batches 10–13)
12	C. altivelis	3 June 2003	3.3% survival by day 58	
13	C. altivelis	4 June 2003	7.6% survival by day 57	
14	L. argentimaculatus	4 July 2003	total loss by day 18	
15	L. argentimaculatus	24 July 2003	3.0% survival by day 50	6,000 Nov 2003
16	E. fuscoguttatus	29 July 2003	total loss by day 16	
17	C. altivelis	18 Aug 2003	total loss by day 13	
18	E. fuscoguttatus	26 Aug 2003	total loss by day 13	
19	C. altivelis	16 Sep 2003	total loss by day 13	
20	E. fuscoguttatus	22 Sep 2003	very low survival	30 Dec 2003
21	C. altivelis	27 Sep 2003	total loss by day 25	
22	C. altivelis	19 Nov 2003	total loss by day 29	
23	E. coioides	24 Dec 2003	total loss by day 20	
24	E. coioides	27 Dec 2003	total loss by day 17	
25	L. argentimaculatus	12 Jan 2004	1.0% survival by day 40	700 Apr 2004
26	L. argentimaculatus	17 Feb 2004	1.5% survival by day 40 (batches 26–27)	4,500 Apr 2004
27	L. argentimaculatus	18 Feb 2004		
28	L. argentimaculatus	21 Feb 2004		
29	E. fuscoguttatus	18 Mar 2004	2% survival by day 44	6,000 May 2004
30	E. fuscoguttatus	22 Apr 2004	1% survival by day 50	50 June 2004
31	C. altivelis	22 Apr 2004	total loss by day 8	

32	L. argentimaculatus	15 May 2004	total loss by day 15		
33	L. argentimaculatus	26 May 2004	total loss by day 6		
34	C. altivelis	13 June 2004	total loss by day 17		
35	E. coioides	20 June 2004	total loss by day 10		
36	C. altivelis	12 July 2004	total loss by day 26		
37	E. coioides	19 July 2004	total loss by day 24		
38	E. coioides	9 Aug 2004	total loss by day 7		
39	E. fuscoguttatus	12 Aug 2004	total loss by day 7		
40	E. coioides	16 Aug 2004	total loss by day 8		
41	E. coioides	19 Aug 2004	total loss by day 8		
42	E. coioides	8 Sep 2004	total loss by day 15		
43	L. argentimaculatus	9 Sep 2004	0.2% survival by day 50	110	Dec 2004
44	E. coioides	5 Oct 2004	total loss by day 20		
45	C. altivelis	13 Oct 2004	total loss by day 7		
46	E. coioides	17 Oct 2004	total loss by day 10		
47	L. argentimaculatus	27 Oct 2004	0.6% survival by day 43	1,100	Dec 2004
48	E. coioides	12 Nov 2004	total loss by day 5		
49	L. argentimaculatus	17 Nov 2004	total loss by day 4		
50	E. coioides	16 Dec 2004	most loss by day 20	30	Jan 2005
51	E. coioides	4 Jan 2005	total loss by day 10		
52	E. fuscoguttatus	8 Jan 2005	total loss by day 8		
53	C. altivelis	8 Jan 2005	total loss by day 10		
54	E. coioides	16 Jan 2005	total loss by day 12		
55	E. coioides	31 Jan 2005	total loss by day 20		
56	L. argentimaculatus	20 Feb 2005	total loss by day 7		
57	E. fuscoguttatus	7 Mar 2005	total loss by day 7		
58	E. coioides	16 Mar 2005	total loss by day 19		
59	E. coioides	6 April 2005	total loss by day 10		
60	E. fuscoguttatus	9 April 2005	total loss by day 6		
61	C. altivelis	9 May 2005	total loss by day 22		

APPENDIX 2. F_1 Broodstock Growth Curves

Fig.3. Largest grade of first batch of estuary grouper, eggs stocked during March 2003 and remainder of batch harvested during June 2004 at an average weight of 700g. The irregularities in the growth curve are due to the addition and removal of stock during the recorded growth period.

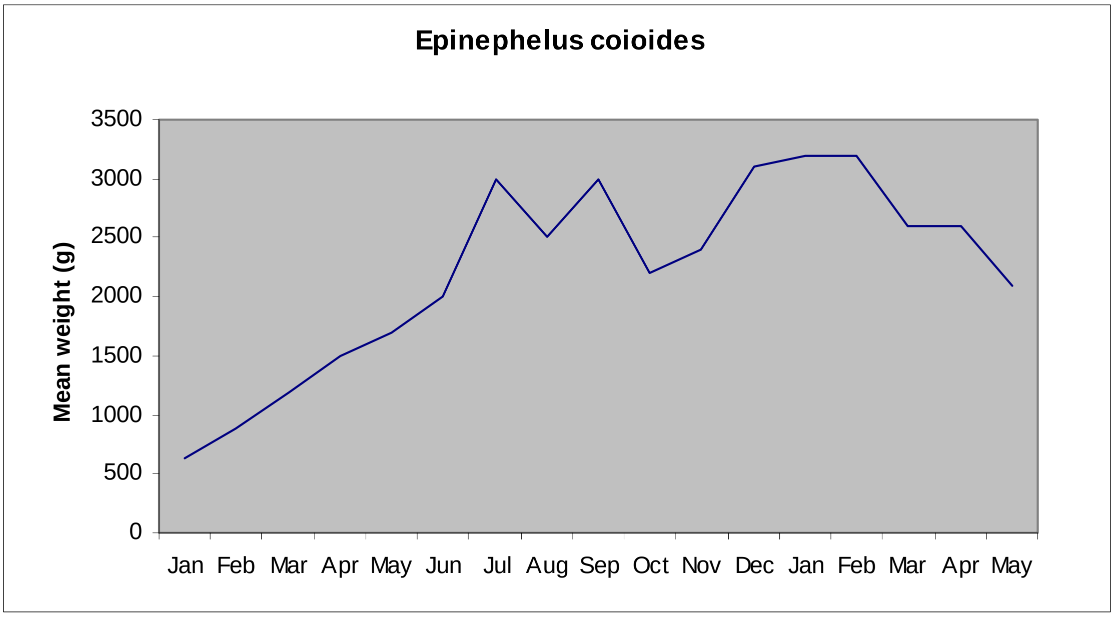


Fig.4. A small batch of mouse grouper stocked as eggs during April 2003.

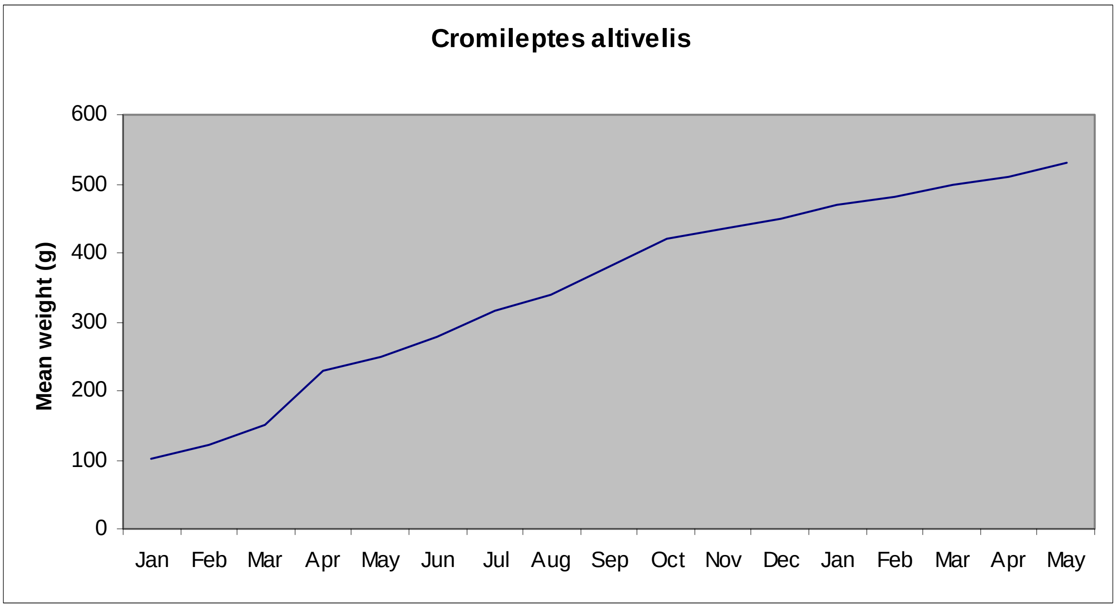


Fig.5. Selected from the largest grade of a batch stocked as eggs during July 2003.

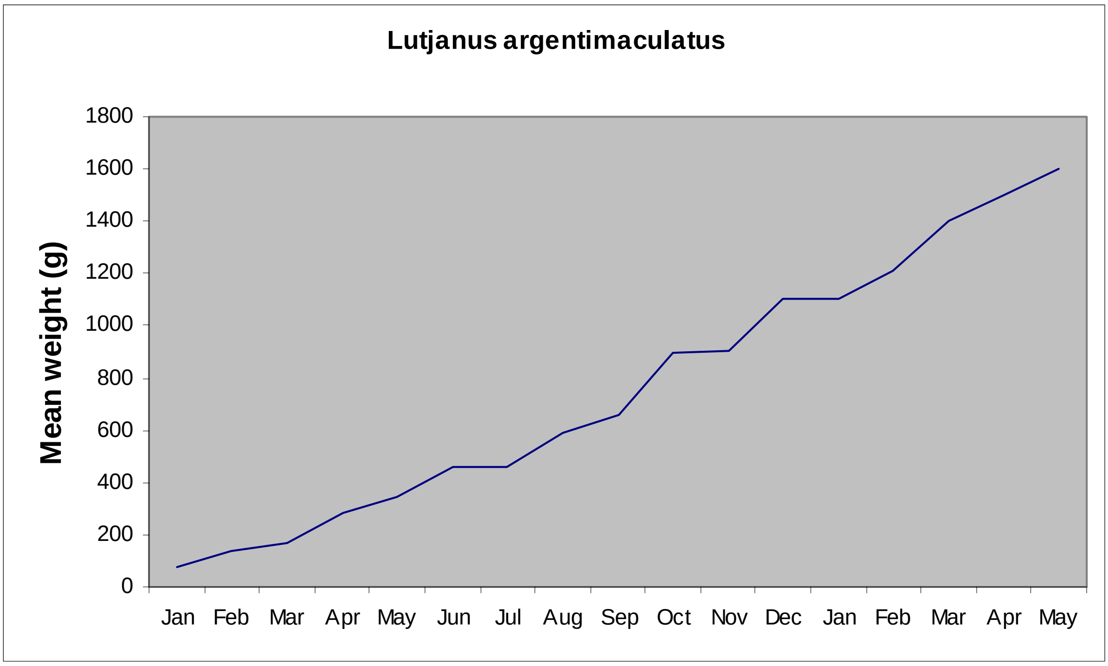


Fig.6. A small batch of tiger grouper stocked as eggs during September 2003.

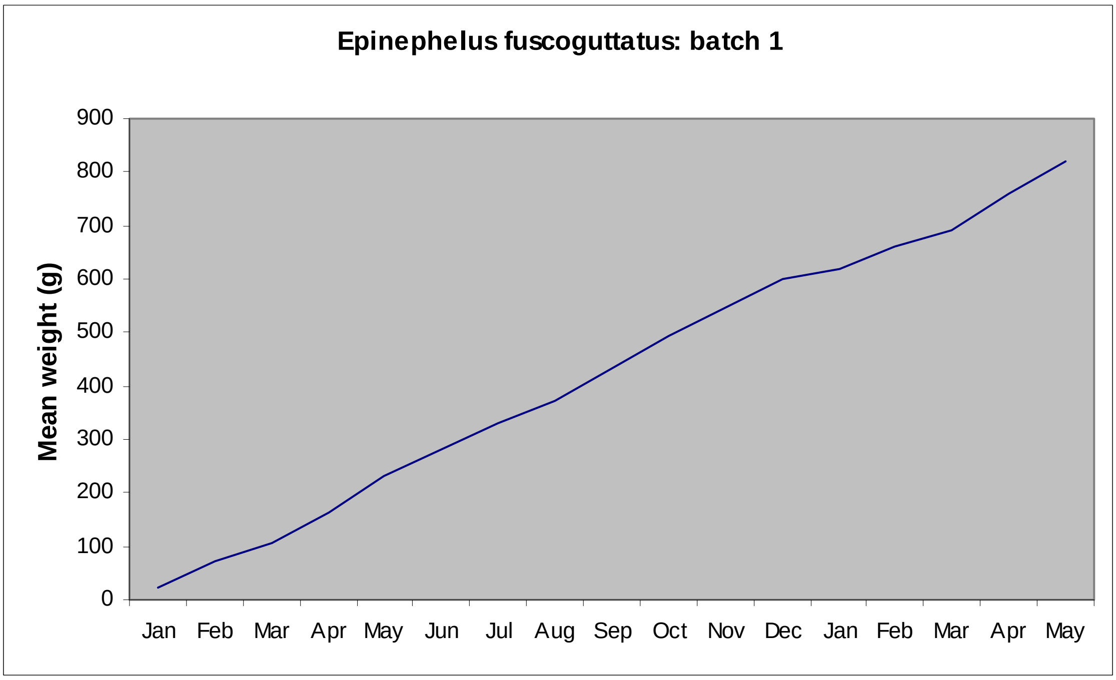


Fig.7. The fastest growing fish selected from a batch stocked as eggs during March 2004.

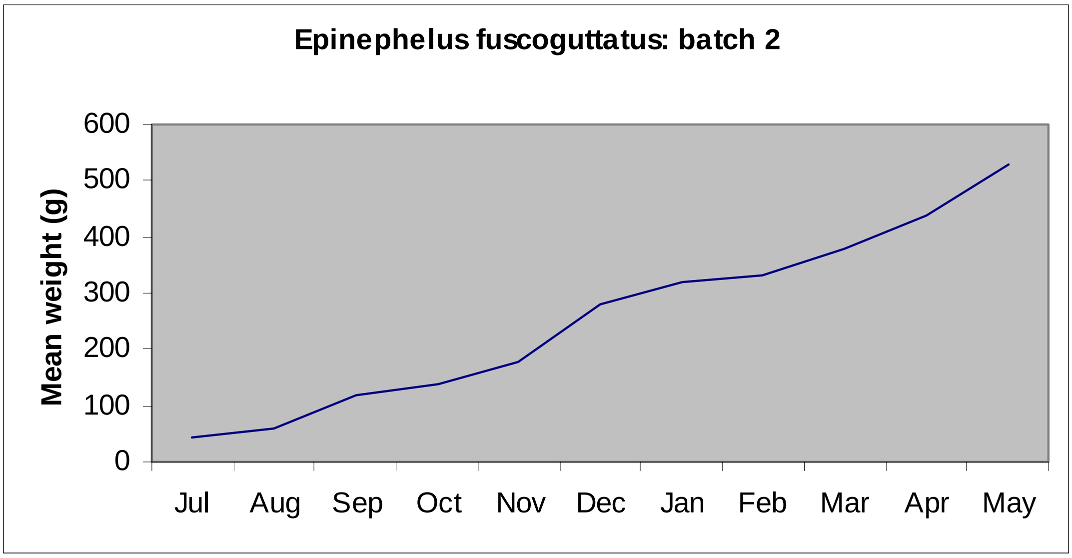
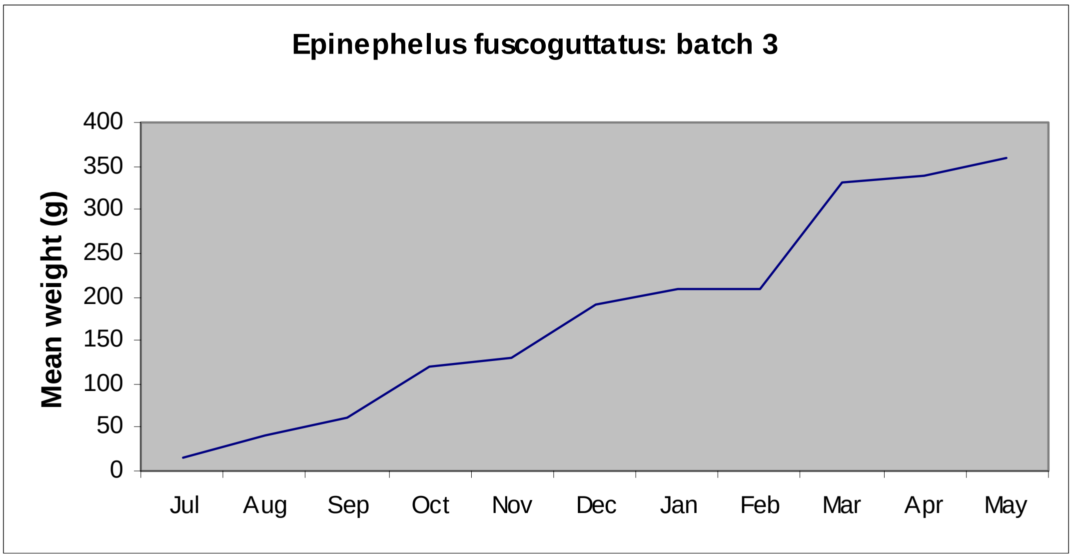


Fig.8. A small batch of fish stocked as eggs during April 2004.



APPENDIX 3. Results of Site Selection for Grow-Out Cage Farms

Carried out during 29-31 October and 4 November, 2002

1. Kukusan 29th October 2002

Description: Kukusan and Bangkau share a shallow reef patch with an indentation on its southern side, between the two islands. All prospective sites are situated at the south edge of the reef

Site 005

S 08 33 417 ; E 119 48 004

Depth: over 20m

Situated south of Kukusan island. A semi-exposed site, with direct exposure from SW, a short fetch (2-3 km) from S, SE and E, and reef shelter from NE, N, NW and W.

Site 006

S 08 33 318 ; E 119 48 043

Depth: 10m

Closer inshore than 005, close to reef edge.

Exposed to SW and S winds, reef shelter from other directions.

Semi-exposed site

Site 007

S 08 33 109 ; E 119 47 624

Depth: 8m

Tucked inside an inlet in the reef, with slight exposure from S and SE (fetch 2.5 - 3 km). Reef shelter from other directions.

Semi-exposed site

Site 008

S 08 32 959 ; E 119 47 574

Depth: 15m

Similar to site 007 above

Summary: Too much exposure to S and SW for wooden cages, and minimal land shelter (ie prone to surface wind action). **Not recommended**

2. Menjaga 29th October, 2002

Description: Menjaga is a small village on the coast of Flores. The coastline is NW facing, with some shelter from the NW by Pungu, Bangkau, Kukusan and Kelor and their associated reefs. The coast is lined by reefs with mangrove forests at shoreline.

Site 009 S 08 33 310 ; E 119 49 058

Depth: 9m

This site is exposed from the NNW, with some other exposure from NE and SW.

A semi-exposed site, not suitable for wooden cages.

Site 010 S 08 32 731 ; E 119 49 810

Depth: 10m

This site is sheltered behind Pulau Menjaga, and as such has minimal exposure from the SW and total land shelter from W, NW, N, NE, E, SE and S. The depth measured was close to shore, with an accessible beach close by. Most surrounding land protected by mangroves. Seabed was observed to be bombed-out coral.

A sheltered site, well suited for wooden cages. Highly recommended.

3. Pungu Besar 30th October 2002

Description: A circular island with a fringing reef. All possible sites are on the south reef edge.

Site 011 S 08 31 925 ; E 119 47 771

Depth: 15m

Exposed to W and SW (long fetch), and also from E.

Site 012 S 08 31 949 ; E 119 47 628

Depth: 16m

Similar to 011 above.

Site 013 S 08 31 952 ; E 119 47 348

Depth: 6m

As above, but more exposure from SW

Summary: **Too much exposure from W, SW and E for wooden cages.**

4. Pulau Misa 30th October 2002

Description: Misa is a small island with a very high population density, consisting of around 500 families, all presumably linked to the fishing trade. As such, cage development is considered a priority at this location.

Misa itself is situated in an area of islands and submerged reefs and as such has patchy shelter.

Site 014 S 08 32 109 ; E 119 44 816

Depth: 13m

Situated on the NE edge of a submerged reef 700m south of Misa. Exposed to NW, NE and SE.

Site 015 S 08 32 023 ; E 119 44 629

Depth: 15m

500m west of site 014 above, on the same reef.

Exposed to W, NW, N, NE, E and SE

Site 016 S 08 30 938 ; E 119 50 899

Depth: 10m

Located on the south-east edge of a reef 1.5km NW of Misa.

Sheltered from W, NW and S by land, and from N by a submerged reef. Exposed to SW and NE and E.

Also situated in a channel between two reefs, with possible strong tidal currents.

Site 017 S 08 31 080 ; E 119 43 893

Depth: 10m

Situated 700m to the southwest of the same reef as site 016 above.

More shelter from E, but additional exposure to S and SW.

Summary: **All of the above sites can be considered as semi-exposed to prevailing winds in this area, and as such are not suitable for wooden cages.**

5. Sabayor Besar 30th October 2002

Description: A large island 3km northwest of Misa, offering good protection from N, NW and W winds and wave action. The coastal reefs are close to another reef patch to the southeast, so forming a channel approx 300m wide, with an attendant risk of strong tidal currents.

Site 018 S 08 30 644 ; E 119 43 380

Depth: 12m

Situated on northwest side of channel. Good land-based shelter from W, NW, N, E and SE. Exposed to S and NE. Risk of tidal currents.

Site 019 S 08 30 559 ; E 119 43 645

Depth: 12m

Situated 1km northeast of site 018 on south side of same channel. 3km from Misa. Sheltered from W, NW, N, SE and S. Exposed to NE and SW.

Risk of tidal currents.

Summary: **Good sheltered sites, but the risk of strong tidal currents should be assessed prior to cage installation. Should investigate due to importance of Pulau Misa for alternative livelihood development.**

6. Labuan Bajo 30 October 2002

Description: A chain of 4 large islands running westwards from the village of Labuan Bajo, all providing shelter from NW, N and NE winds and wave action.

Site 020 S 08 29 426 ; E 119 50 899

Depth: 10m

Tucked into an inlet in the coastal reef on the south coast of Kokotoan island. Sheltered from W, NW, N, NE, E. Slight exposure from SW. Sheltered from S by submerged reef.

Quite a nice site which should be followed up with meteorological data ie fishermen's observations etc.

Small risk of damage to wooden cages from SW winds, but recommended.

Site 021 S 08 29 319 ; E 119 51 332

Depth: 10m

Situated on reef edge on south coast of Tenga island. Some exposure to S and SW.

Risk of damage to wooden cages from SW winds.

Site 022 S 08 29 565 ; E 119 51 835

Depth: 14m

Situated on reef edge of south coast of Bajo island. Some additional shelter from submerged reefs means that only significant exposure is from SW.

Risk of damage to wooden cages from SW winds.

7. Boleng 31st October 2002

Description: A village on the north-east coast of Flores island. Situated on an island guarding the mouth of a large bay (2km across).

Site 023 S 08 26 478 ; E 119 59 677

Depth: 17m

Situated behind Boleh island, in front of village of Boleng. Sheltered from all directions (1 km fetch from S).

A sheltered site close to village. Recommended.

Site 024 S 08 27 219 ; E 119 59 655

Depth: 8m

Situated at southern end of bay. Exposed to NW winds.

Too exposed for wooden cages.

Site 025 S 08 25 973 ; E 120 00 343

Depth: 12m

Situated 700m east of Boleh island, on eastern edge of bay. Partially exposed to NW, with some protection from a reef.

Risk of damage to wooden cages from NW winds.

8. Medang 31 October 2002

Description: Small bay on north coast of Flores, facing NE. Almost total protection provided by Meda island at mouth of bay.

Site 026 S 08 23 482 ; E 120 02 445

Depth: 12m

Situated on western side of bay. Totally protected in all directions.

Excellent site for several wooden cage installations. Good depth, and in close proximity to village.

Highly recommended.

Site 027 S 08 23 397 ; E 120 02 769

Depth: 17m

Situated approx 100m south of the village of Medang. Protected from all directions.

Recommended.

9. Sape, Sumbawa 4th November 2002

Description: The village of Sape consists of settlements situated within a large easterly/northeasterly facing bay, with an island (Pulau Nisasanai) providing shelter from the east and northeast. Sape is a relatively large port with a large fleet of bagan fishing boats and regular ferries to Flores.

A number of cage installations are already present around Nisasanai (holding cages for the live reef fish trade) together with seaweed culture ropes. Sape is considered important for cage development due to the prevalence of fishermen previously, and currently, reliant upon cyanide and blast fishing techniques.

Site A: S 08 34 780; E 119 02 457

Depth: 22m

Situated to the southwest of P. Nisasanai, this is a sheltered site well suited to wooden cage culture. At least 10 other wooden cage installations are present in the area, together with extensive seaweed culture rope and float systems.

The presence of holding cages may represent a disease risk to an ongrowing site at this location.

Site B: S 08 34 245 ; E 119 02 452

Depth: 14m

This site is further north than site A, in a well sheltered location with one other cage installation in the area. The reduced presence of other cages may be of advantage with respect to fish health and risk of disease transmission.

Recommended.

Site C: S 08 34 668 ; E 119 02 248

Depth: 15m

Situated south of the small populated island to the west of P. Nisasanai. Other cage installations presently in the area, and close to a busy sea lane to Sape port, but sheltered and **well suited to wooden cages**.

Site D: S 08 35 568 ; E 119 01 969

Depth: 15m

Located in a north-facing bay within the larger bay in which Sape is located. Slight exposure from the north-east. One existing cage facility.

Suitable for wooden cages.

Site E: S 08 31 542 ; E 119 01 414

Depth: 18m

Located in an easterly-facing bay to the north of Sape. Slight exposure from the north and north-east, but no other cage installations present.

Distant from the main target fishing communities of Sape, however.

Suitable for wooden cages.

10. Conclusions

The following sites are considered the most suitable for the installation of traditional wooden cages, in descending order of suitability:

1. Medang	Site 026
2. Medang	Site 027
3. Sape	Site B
4. Boleng	Site 023
5. Manjaga	Site 010
6. Sape	Site A
7. Sape	Site C
8. Sape	Site E
9. Labuan Bajo	Site 020
10. Sabayor Besar	Site 018
11. Sape	Site D

APPENDIX 4. Growth curves for all production batches of fish produced during the Komodo Fish Culture Project

Fig.9. Growth curve for batch of estuary grouper, from May 2003 to harvest during June 2004.

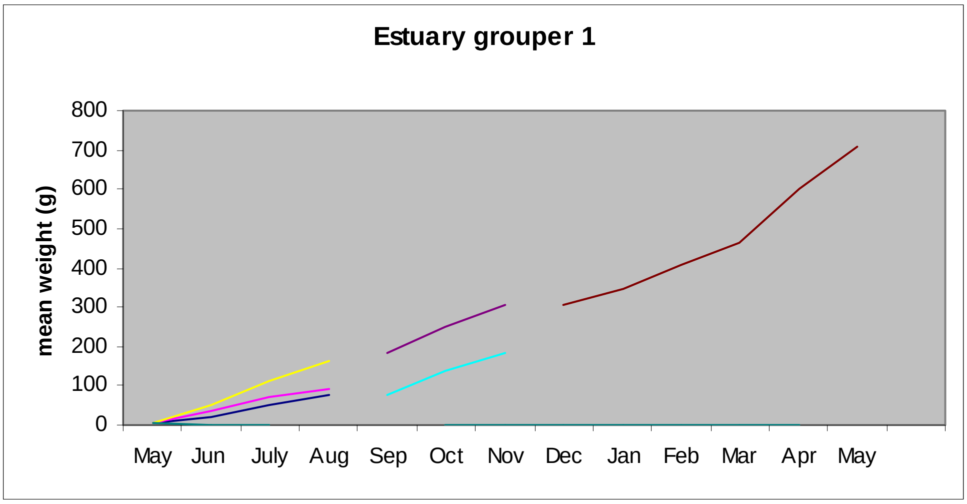


Fig.10. Growth curve for the production batch of mouse grouper, from June 2003 to June 2005.

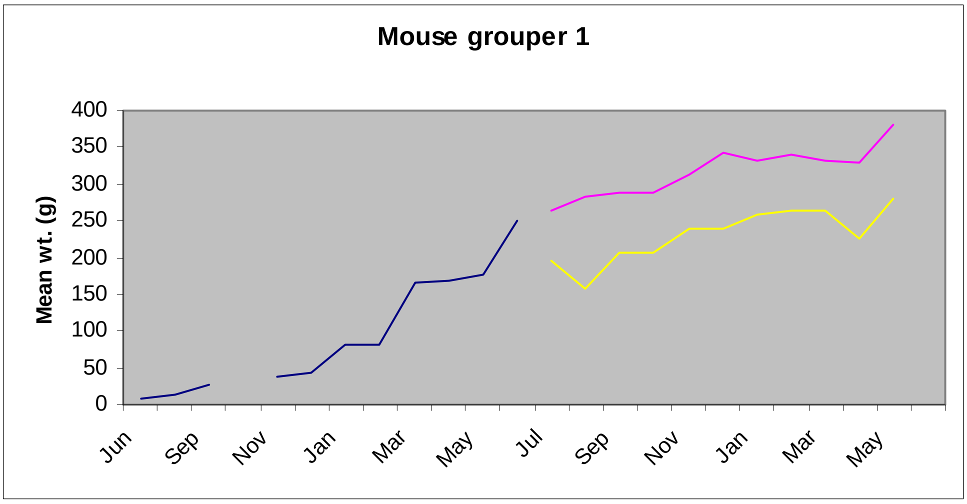


Fig.11. Growth curves for 5 production batches of mangrove jack, from November 2003 to June 2005.

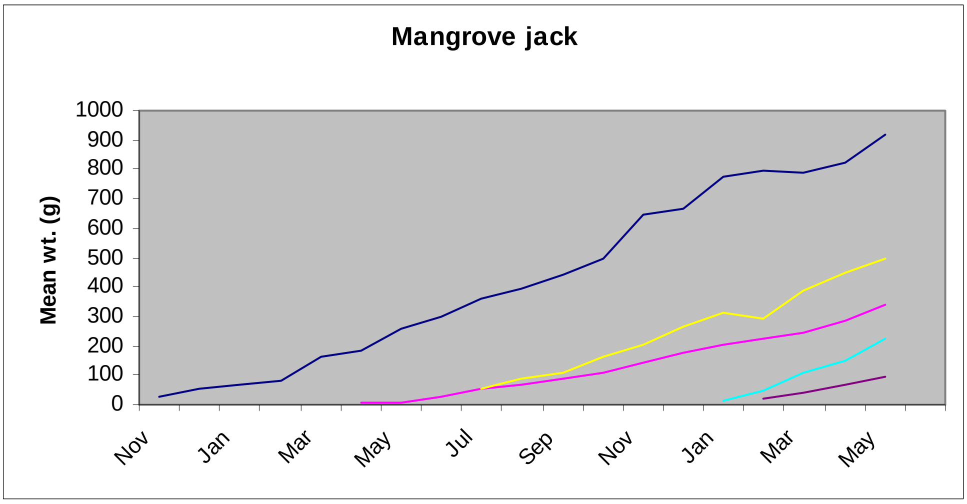
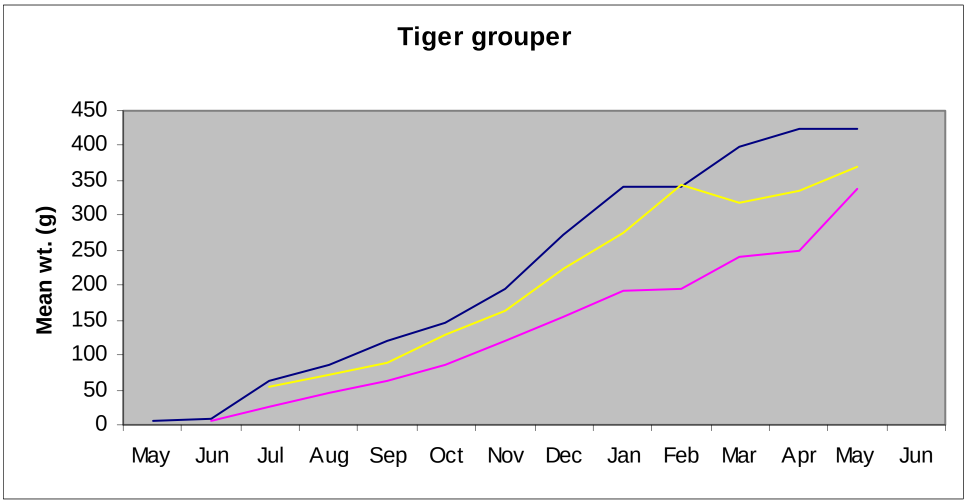


Fig.12. Growth curves for 3 production batches of tiger grouper, from May 2003 to June 2005.



APPENDIX 5. List of selected stakeholders and potential investors visiting Loh Mbongi

Date of visit	***Name***	***Village***
24 September, 2002	Haji Rashjid	Boleng, Flores
20 March, 2003	Muhammad Hatta	Kepala Desa, Warloka
20 March, 2003	Abdullah	Menjaga
20 March, 2003	Abdul Muin	Desa Batu Tiga
20 March, 2003	Jufri Abarineh	Pulau Mesa/Pulau Putih
9 April, 2003	Frans Lebu Raya	Vice-chairman NTT parliament, Ruteng
5 May, 2003	Abdullah Rahim	Seraya Kecil
	Santuo	Seraya Kecil
	Haji Samsuddin	Seraya Kecil
11 May, 2003	Haji Rasula	Pulau Papagaran
3 June, 2003	Hamka Abdullah	Pulau Mesa
	Sarosul Bahri	Pulau Mesa
29 June, 2003	Pak Arif	Ruteng
13 July, 2003	9 x community members	Pulau Papagaran
31 July, 2003	Bupati & delegation	Kebupaten Buton, south-east Sulawesi
4 August, 2003	Haji Mujib	Sape, Sumbawa
6 August, 2003	Mudin Ahmad	Kepala Dusun, Warloka
9 August, 2003	Muhammad Tayeb	Pasir Panjang, Rinca
9 August, 2003	Abdullah	Menjaga
9 August, 2003	3 x community members	Pulau Kukusan
9 August, 2003	17 x community members	Labuan Bajo
9 August, 2003	Haji Rasula	Pulau Papagaran
9 August, 2003	4 x community members	Boleng
11 August, 2003	11 x community members	Pulau Sape, Sumbawa
13 October, 2003	9 local government officers	Kebupaten Selayar, Sulawesi
17 November, 2003	Haji Akbar	Kampung Komodo
17 November, 2003	Abulahar	Pulau Papagaran
31 January, 2004	Aven Lirions	Boleng, Flores
2 February, 2004	4 x community members	Sape, Sumbawa

13 March, 2004	4 x community members	Warloka, Flores
23 April, 2004	7 x fishermen	Boleng, Flores
16 August, 2004	3 x potential investors	Ruteng, Flores
14 January, 2005	4 x cage operators	Sape, Sumbawa
19 January, 2005	Henry Sulysto	Jakarta
28 January, 2005	Ridwan Simansjah	Jakarta
27 February, 2005	Henry Sulysto	Jakarta
15 March, 2005	Herry Suditha	Lombok
27 March, 2005	2 x potential investors	Ruteng, Flores
18 April, 2005	1 x potential investor	Ruteng, Flores

APPENDIX 6. Draft Collaborative Agreement for Community Grow-Out

COOPERATIVE AGREEMENT

Today on ……….. date ……………… month year who have signed below:

1. Name :
   Address :
   Position :

Who represents The Nature Conservancy, referred to here as the FIRST PARTY, and

2. Name :
   Address :
   Position :

Who hereby represents the Community Fish Culture Group, which consist of eleven members, referred to here as the SECOND PARTY.

The FIRST PARTY and SECOND PARTY hereby agree to establish a pilot fish culture training program and cooperative for duration of … months, effective ……………., where the initial training in Loh Mbongi was started .

The pilot program shall serve as a model for future community-based mariculture programs for communities lived around Komodo National Park. The Nature Conservancy, in their effort to support the marine conservation program of Komodo National Park authority, with close coordination with District Government of Manggarai Barat, provides infrastructure and ongoing supplies, training, technical assistance and financial support. The objective of such a program is to reduce the dependency of community lived around the park to the fish resources from the park area, by promoting the formation of alternative livelihoods for the surrounding communities.

In this agreement the parties have agreed as follows:

1. Infrastructure, supplies, materials: The First Party shall provide to Second Party all the training materials, including cage infrastructure, moorings, nets, working materials, fish fingerlings and feeds and a canoe.

2. Training and supervision: First Party shall conduct a 30 days induction course to second party to be held at Loh Mbongi prior to on-site training and supervision, which started by deployment of pilot cages at ……. Trainees will receive on-site training and supervision and technical assistance, at a minimum of once a week. At this point, the six members who receive the above on-site training will be called as Active Trainees, while the other five members will be called as Supervisor.

3. Costs: All budgeted costs associated with the above materials, supplies and training are described in detail in the attached Exhibit A.

a. The Parties agree that as part of establishing this self-sustaining Fish Culture Project, therefore the SECOND PARTY must be able to assume the Costs of the Project as described in Exhibit A, from the proceed of fish sales .

b. The Parties further agree that the FIRST PARTY shall assist in advancing all Costs until this agreement is terminated.

4. Fish Sales: The SECOND PARTY agrees that it will take responsibility for fish sales, and will be obliged to obtain the best price possible.

a. The SECOND PARTY shall then use the proceeds to reimburse the FIRST PARTY for all advanced Costs incurred as described in Exhibit A , up to a maximum of eighty percent (80%) of the proceeds of fish sale.

b. The SECOND PARTY may continue to use up the infrastructure as long as eighty percent (80%) of the proceeds of each fish sale is used to cover continuing advancing costs associated with the mariculture project, such as ongoing training,technical assistance, fingerlings and feeds, etc. as outlined in Exhibit A..

c. If the SECOND PARTY wishes to continue the fish culture project after the duration of this agreement ended, the parties will negotiate a new agreement which will include reimbursement to the FIRST PARTY of capital costs described in Exhibit B.

5. The FIRST PARTY will provide regular technical assistance for the duration of this agreement.

6. The FIRST PARTY will retain the right to approve all proposed members of the mariculture members group.

7. The FIRST PARTY will retain the right to expel any member found to be in breach of this agreement, and to keep the members group leader informed of any such expulsion.

8. In the event the option stated on point 4.b. is not happened and the SECOND PARTY does not wish to continue and enter into a new agreement with the FIRST PARTY, all fish will be sold at the end of the agreement period in the manner stated in point 4.a, unless otherwise agreed between both parties. All infrastructures shall be returned to the FIRST PARTY.

9. The FIRST PARTY shall monitor and evaluate progress of the training and take any remedial action when required to do so.

10. The SECOND PARTY, in this case is the Active Trainees, shall follow the training activity until this agreement is ended and Active Trainees and Supervisors shall be responsible for the trainees' good conduct, obedience and adherence to all training rules and regulations.

11. The SECOND PARTY shall ensure proper maintenance and upkeep of the project and training facility pursuant to FIRST PARTY's guidelines and ensure the security of all supplies, materials and equipment.

12. All Active Trainees entitled for basic food supplies and also daily allowances of ………. per month per person. All supervisors entitled for a monthly allowances of ………. per person.

13. Distribution of income within the group is decided by all members.

14. In the event of conflict between parties, where possible it will be solved by deliberation and negotiation between the parties. Where conflict issues are unresolvable by way of deliberation between FIRST PARTY and SECOND PARTY, the conflict will be passed to the West Manggarai law-court office.

15. Either party may terminate this agreement, for any reason, and at any time. Written notice of such termination should be supplied to the other party one month prior to termination. The parties will work together to wrap up any outstanding matters during this one month period.

16. Upon termination of this agreement, all facilities described in Exhibit B will be returned to the FIRST PARTY and the remaining fish stock will be sold as described in point 4.a.

17. This agreement may be terminated should either party be in breach of the terms and conditions of this agreement.

18. At the end of this cooperative agreement, a new agreement may be drafted, or the agreement will terminate, and all assets will be returned to the FIRST PARTY as described in point 16.

19. On the first and the second original paper of the cooperative agreement shall be placed a stamp of Rp. 6.000 (six thousand rupiahs), so these have a same level in judgment value.

20. The FIRST PARTY shall take no responsibility for any accidents occurring during the terms of this agreement.

21. In the event of fish mortality occurring beyond the control of trainees, further stocking of fish be carried out in accordance with the existing schedules. In the event of a catastrophic loss of fish stock, this agreement will be re-evaluated.

22. At the end of this agreement period, should the SECOND PARTY not require a contract extension or new agreement, all facilities shall be returned to the FIRST PARTY in un-impaired condition.

23. Any items not included in this agreement, or any amendments thereof, shall be subject to negotiations between both parties.

24. The Letter of Cooperative Agreement shall consist of 5 (five) copies. There will be affixed a stamp of Rp. 6.000 (six thousand rupiahs) on the first original paper and second original paper for the FIRST PARTY and SECOND PARTY respectively, remaining papers will be distributed to other relevant parties.

This Letter of Cooperative Agreement is signed by the FIRST PARTY and SECOND PARTY at Labuan Bajo on the day and date which is mentioned and acknowledged by Bupati of District West Manggarai and the Head of Komodo National Park.

The letter is proved since signed.

SECOND PARTY	FIRST PARTY

Acknowledge by

Bupati District West Manggarai	Head of Komodo National Park

Witness

District	Sub-District Head	Representative
Fisheries Services	Komodo	Komodo Police

APPENDIX 7. Chronology of the Komodo Fish Culture project

1997	Feasibility assessments
1997 - 1999	‘Gango’ project to source juveniles for grow-out from the wild.
1999	Feasibility study for a hatchery-based grouper culture operation
December 2000	The Nature Conservancy receives support from the Tahija Foundation to lease 150,000 m^2 of land for hatchery construction.
2002	UKL/UPL (legally required impact assessment) for the planned hatchery
May 23 2002	Signing of a Memorandum of Understanding between The Nature Conservancy and the Research Center Institute of Aquaculture
January 2003	Planning workshop for carrying capacity studies (with NACA)
March 2003	Completion of the hatchery, full operational capacity at pilot scale
July 2003	Inauguration of the Komodo fish culture project by the Minister for Marine Affairs and Fisheries, Prof Dr. Rokhmin Dahuri
December 2003	First community-operated grow-out cage deployed (Warloka)
June 2004	Second community--operated grow-out cage deployed (Menjaga)
June 2004	Sale of first batch of fish produced at a community-operated grow-out cage.
2004 – 2005	Identification of business partners
June 30, 2005	Transfer to PT Karamba, through a Cooperative Agreement between the Directorate General of Forest Protection and Nature Conservation (Ministry of Forestry), The Nature Conservancy Indonesia Program, and PT Karamba.

APPENDIX 8. Pictures

Aerial photo of the hatchery in Loh Mbonghi, February 2004

Mouse grouper broodstock

Estuary grouper broodstock

Hatchery-reared tiger grouper juveniles

Broodstock holding facility

Broodstock-holding facility, preparing fish for feeding to the broodstock

Broodstock-holding facility, preparing fish for feeding to the broodstock

Community-operated grow-out cage

Grow-out unit in Warloka

Grow-out unit in Warloka, with project team members and trainees from the community

Jetty at the hatchery facility in Loh Mbonghi, with the project speedboat 'KMP2'

Larvae rearing facility in Loh Mbonghi

Mangrove jack larva, produced at the hatchery

Hatchery facility, main building

Hatchery facility, staff quarters

Hatchery facility, nursery

Hatchery facility, laboratory building

Hatchery facility, algae and rotifer culture units

Algae cultures in the laboratory of the hatchery

Hatchery facility, waste water treatment ponds

Hatchery facility, main building and laboratory

Hatchery facility, staff canteen

Community event at one of the grow-out units

Sale of one of the first batch of fish

Training in fish hatchery techniques for students from Sape at the hatchery in Loh Mbonghi