Appendix 6 A proposal to create an aquacultural facility Wakatobi Marine National Park, SE Sulawesi, Indonesia

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Summary

This report proposes the development of a multi-use aquaculture facility on Kaledupa Island to grow on pre-settlement fish larvae, giant clam and a red coloured shrimp species for export to the western aquarist market. The proposal would be to form a co-operative from existing licensed reef fishers who would surrender their licences in exchange for becoming shareholders in the business. The establishment and operational costs of the facility would be in the order of £100,000 (note this is an approximate figure only). If the Trustees agree the logic of the proposal then it is proposed that some of the Darwin Initiative funding is directed to developing detailed designs and costings for the facility. These detailed plans could then be forwarded to COREMAP and other potential funding sources.

Introduction

I was asked by Operation Wallacea Trust as part of the Darwin Initiative (Project Ref. No: 162/16/002 'Building capacity for sustainable fisheries management in the Wallacea region') to undertake the following:

1. To identify the species, prices paid and quantities required in the UK and European aquarist markets for tropical marine species that could be cultured in the Wakatobi and exported to the UK or Europe.
2. To identify on site potential species that could be cultured for this market and how these species could be cultured most effectively.

By way of background information, there is an urgency to establish a best practice example of coastal fishery management in eastern Indonesia since the reefs are being heavily overfished [(1)]. The reefs in eastern Indonesia are the most biologically diverse in the world, yet if the over-fishing continues the reefs may undergo a catastrophic phase shift because of the removal of most of the algal grazing species, allowing algae to colonise [(2)].

Kaledupa Island Reef Fishery Management Project (in collaboration with COREMAP - a World Bank/GEF sustainable fisheries initiative) started this year with free registration of fishers, their boats and equipment. Implementing registration and community enforcement to ensure only registered fishers are utilising the reefs around Kaledupa, will reduce the overall fishing pressure on the reefs by excluding fishers from other islands. However, this alone is unlikely to be sufficient to reduce fishing pressure to levels where the fish stocks can recover. In order to achieve this, a percentage (to be determined from the results of the fisheries monitoring) of licence holders will be offered small businesses in exchange for surrendering their licences. Thus those that are removed from the fishery will do so voluntarily and only in exchange for businesses that create more income than they would have earned from fishing. One such possible business might be to raise ornamental marine fish found on the local reefs and export them to Europe and elsewhere, where they have high added-value.

Accordingly, a visit to Hoga and Kaledupa took place in July/August 2007. Opwall kindly provided supporting facilities such as accommodation and, most importantly, the services of an interpreter, Wawan Kidner. To them and to him my grateful thanks.

The marine ornamental trade in perspective

The existing marine ornamental fish market is part of a substantial world ornamental fish industry worth in 2004 an estimated USD 15 billion annually. However, fish are estimated to be just 15% of turnover, the rest being hardware like aquaria, food, etc. When the figures are stripped out and having made due allowance for transportation costs, wages, profit margins, etc, the FAO estimate for world ornamental fish exports is USD 251 million in 2004 (3).

Notes:

1. USD = US Dollar

2. Industry definition of ornamental fish and live rock:

Ornamental fish is often used as a generic term to describe aquatic animals kept in the aquarium hobby, including fishes, invertebrates such as corals, crustaceans (e.g., crabs, hermit crabs, shrimps), molluscs (e.g., snails, clams, scallops), and also live rock. Live rock is a general term for any type of rock encrusted with, and containing within its orifices, a wide variety of marine organisms including algae and colourful sessile invertebrates. Live rock serves as the principal biological and chemical filter in many marine-type tanks, and the encrusted organisms usually provide much of the background coloration in the tank (4).

Since 1985 the value of the international trade in ornamental exports has increased at a growth rate of about 14%/annum (5). The majority (> 90%) of freshwater ornamental fish are captive bred whereas only about 25 of 8,000 marine ornamental species can be easily raised (6).

The retail value for a kilogram of coral reef fish destined for the aquarium trade may be worth $500 to $1,800 USD (£250,00 - £900,000/MT)(MT = Metric ton) while a marine fish used for human consumption can be priced between $6 and $16.50 USD per kilogram (7). This suggests live ornamental marine fish are worth about 80-fold to 110-fold more than their food counterparts in the USA.

About 350,000 individual fish are imported into the UK annually, with a wet weight of just over 3 MT. An average value is given of £400,000/MT at import (8). This can be at least tripled to give an end-customer price. In this same period tropical Groupers and Wrasse were available from retail fishmongers for human consumption at approximately £10,000/MT (8). This suggests live ornamental marine fish are worth about 120-fold more than their food counterparts in the UK. (Cf the USA figure above).

To place the environmental effects of reef collection of fish for this trade into perspective, around 10 million ornamental marine fish are imported annually throughout the world. The weight of these fish may total 86 MT, using the above conversion figures. This figure should be contrasted with the total of 100 million MT of sea fish caught for consumption, and the 17 million MT of by-catch (waste) that is thrown back into the sea each year by the world's fishing fleets (data adapted from [8]).

Note:

These macro-economic statistics are known to be unreliable because of difficulties of collection and inconsistencies of interpretation, so they come with a strong health-warning.

Because of these perceived (as well as real) environmental and also welfare concerns [9], well-financed NGO's such as the Marine Aquarium Council (MAC) have been created to promote responsible collection and delivery practices within this trade.

The purpose of managing a fishery is to maintain the resource so that it is renewable and therefore sustainable. Responsible aquaculture practices rely on sustainable production systems, to minimise impacts on the natural environment, and support resource conservation. In other words, the harvest of fish from the wild or their domestic culture, if performed with sound foundations in ecological and economic principles, can be sustainable and self-reliant commercial industries.

In traditional subsistence fisheries, fishermen use primitive and inefficient gear, such cyanide, to capture most marine ornamental fish. However, supply of such fish is not inexhaustible, and signs of over-fishing are becoming apparent in localized areas. With the high demand and pricing of many beautiful species, ornamental fish are being harvested at greater volumes and higher rates, threatening the viability or sustainability of the fishery [10].

The entire genus *Hippocampus* was listed on CITES Appendix II at CoP 12 2002, though only in part due to concern about losses relating to the marine ornamental trade. In 2007, for the first time, an attempt was made by the US government to create a CITES designation for another marine ornamental fish species – the Banggai cardinalfish, *Pterapogon kauderni,* endemic in Banggai Islands of Indonesia and latterly in the Lembeh Strait, N Sulawesi. The population was at risk solely due to capture for the marine ornamental trade. The proposal to protect this species under the CITES Appendix II was rejected in June at the CITES CoP 14 meeting [11]. However, in September 2007, the Banggai cardinalfish was assessed by The International Union for the Conservation of Nature and Natural Resources (IUCN) as 'Endangered' under Criterion B and placed on their Red List, based on the very small area of occupancy, the severe fragmentation and the ongoing continuing decline due to exploitation for the international aquarium trade [12].

Note:

All Tridacna species (Giant Clam) are already listed in CITES Appendix II.

Although some marine ornamental fish and invertebrates are aquacultured by the industry e.g. Tropical Marine Centre (Chorleywood) in the UK and ORA ('Oceans, Reefs

& Aquariums' on campus at Harbor Branch Oceanographic Institution, Florida) in the USA, and intermittently by hobbyists, the greatest majority of marine ornamentals (> 90%) are from wild-caught fisheries. They generally command higher prices, sometimes substantially so, than freshwater ornamental fish.

In the UK a major importer/wholesaler has quoted the following indicative prices for fish and invertebrates:

Damsel Fish (Pomacentridae) from $0.50 for common species to $20.00 – $50.00 for desirable rarities

Tang (Surgeon Fish) $7.00 - $50.00

Blood or Fire Shrimp (Lysmata debelius) $5.00 - $6.00

Giant Clam (Tridacna species) $20+ for well-coloured specimens.

Note:

1. Prices in the trade are almost always quoted in USD.

2. All prices are on FOB basis. FOB is 'Free On Board'. It is the price offered on condition that the seller meets all costs until the goods are loaded on the aircraft at the airport of export. The buyer meets all further costs.

3. Sizes of all of the above - 5 cm approx. Larger sizes can actually be cheaper because aquarists usually dislike them - marine aquaria are expensive and necessarily small.

Aquaculture of potentially valuable species

Wakatobi Marine National Park is centrally placed in 'Wallacea', the biogeographical zone of Indonesian islands encapsulated within the lines drawn by Alfred Wallace and Richard Lydekker. It is considered to be one of the worlds top biodiversity hot spots and contains many endemic species [(13)].

Because many of the islands are separated from one another by deep water, there is tremendous species diversity between islands as well. As a consequence, there is a huge variety of rare and unusual fish and invertebrates present. For example, there are over 438 species of fish present on Hoga reefs [(14)]. Such an enormous variety is double-edged, representing both a great opportunity for new aquacultural possibilities but also inherent difficulties in identifying those species both suitable for the ornamental fish trade whilst at the same time amenable to culture techniques.

Another, and more serious, of the obstacles to such aquaculture revealed during my visit is the sheer remoteness of the site in relation to international airport hubs such as Jakarta or Denpasar. Any increase in travel time over about 36 hours will begin to impact on survival. Times approaching 60 hours are unlikely to pass MAC standards.

Note:

The MAC international Standards sets the allowable limits of marine aquarium organism mortality at the species level at 1 percent dead on arrival (DOA) and 1 percent dead after arrival (DAA) per species and per shipment for each link in the chain of custody. The typical links in the chain of custody occur between

1) the collection area and the collector/fisher;
2) the collector/fisher and the exporter;
3) the exporter and the importer; and
4) the importer and the retailer.

The proposed new airport at Wanci, when fully operational, will considerably improve delivery times and represents a very positive step in this evaluation process. The minimum journey time from Kaledupa to Makassar or Kendari (excluding waiting for connections, administrative delays, etc) would be an acceptable 3 hours.

Until such future time the options are more limited. If the existing airport at Baubau were to be reliable, which it is not, then a Kaledupa to Makassar time of 15 hours minimum might be possible. Ferries do connect directly from Kaledupa to Kendari (but not in bad weather - perhaps 3 months per year), a sea-time of 14 hours [(15)].

Otherwise the existing long but relatively reliable 28 hour total seaferry route has to be the basis for calculation. This will land either in Kendari or by (unreliable) PELNI in Makassar. From Kendari to Makassar then takes <1 hour flying time. Makassar to Denpasar takes 1.5 and to Jakarta 2.25 hours.

Once at an international hub the flight time to the UK is usually 20-22 hours.

It can be seen that the most reliable option is also the longest, taking >50 hours minimum journey time into the UK. When a reasonable time allowance is added for waiting times at connection points and for administrative procedures to take place then the ‘difficult’ 60 hour journey time becomes a reality.

One way to overcome this will be to enter into agreements with ornamental fish exporters based at or near the two Indonesian international hubs. The export process would then be broken up into two stages (a) Kaledupa to Jakarta/Denpasar (b) Jakarta/Denpasar to Heathrow or Manchester. This would necessarily cost more because of additional handling/repackaging and will give rise to higher infection/disease risk but it adequately resolves transport time issues. Reliable companies do exist at these sites [(16)].

Prior discussion with a major UK importer strongly indicated that to concentrate on a single species for culture would be a mistake [(17)]. Not only might a species-specific disease become a problem but, like most retail operations, the ornamental marine trade is subject to the vagaries of fashion, with consequent ups and downs of demand for a species. By growing a small variety of species, both fish and invertebrate, a more stable basis for trade will be created.

As well as fish, a shrimp and a clam will be proposed – see below. Accordingly, consideration has been given to creating a multi-purpose aquacultural facility, capable of growing a variety of species at any one time and of adapting to the introduction of new species over time. As previously mentioned, the usual need for growing on to large sizes would be counter-productive. This gives the immediate benefit of substantially reducing the size and cost of the facility.

Usefully, there are a number of common strands to the raising of most young tropical marine animals - keeping broodstock, breeding, larval/fry/juvenile rearing and the provision of microscopic live food, both plant (microalgae) and animal (brine shrimp/copepods/rotifers). So it is entirely feasible to grow a variety of species from different phyla at any one time in a relatively simple system. As will be seen, even the keeping of broodstock and breeding can be largely eliminated.

Before proceeding to detail proposed species it is necessary to consider widening the scope of the project. Its fundamental purpose is not merely to provide alternative employment and income for local fishermen but to successfully address the underlying causes of over-fishing. If a mechanism for solely income generation is put in place, then there is a real risk that, for socio-economic and cultural reasons, it will probably be unsuccessful [(18)]. For example, occupational multiplicity is an important strategy for survival in rural coastal communities, as is job satisfaction [(19)(20)]. Unfortunately, the road to failure is paved with good intentions - with apologies to Samuel Johnson.

It is therefore strongly suggested that, as equal and parallel outcomes of creating an aquacultural facility, there are added the further aims of (a) creating a reef restocking element and (b) providing juvenile stock to local fishermen for growing on for food. The last may be either for their personal consumption or for sale in local fish-markets. If these objectives can be achieved, even in part, then reef repair and fishing pressure on the reef may well reduce.

An example of local initiative was observed by the author when Bajau from Sampela brought large Trevally to Hoga for sale to the camp cooks. They chose a particularly windy day when tuna-fishermen would be kept ashore and consequently secured a good price! It is understood that these were caught as fingerlings and raised in cages at the village. This small example hints at the ability, by these ‘fishermen par-excellence’, to be self-motivated about non-fishing alternatives like fish-rearing. Something, perhaps, to capitalise on…

As a financial model for the basis of the aquaculture facility, it is proposed to use a recent design for a bivalve hatchery [(21)]. It is not only well-designed and up-to-date, but appears very cost-effective, when priced (2004) at about $100,000 (approx £50,000) – not including land, labour, concrete bases and shipping costs. These costs apply to a Bermudan location, so it might be significantly cheaper in an Indonesian context. The design does include a somewhat costly heating system for inducing spawning. As will be shown, this may not be needed, thus creating useful savings.

Note:
On the other hand, a full ‘belt and braces’ hatchery can cost $1,000,000 and with running costs of $200,000/annum [(22)]. To place this in perspective, this hatchery, in Mexico, is designed to fulfill the complex requirements of a tropical marine fish R&D centre. It is a large facility - the annual production capacity, to supply to industrial partners, is to be about 160,000–200,000 one-gram juveniles, produced in three or four

rearing cycles. All pipes, pumps, generators are duplicated or triplicated, with full backwashing and/or sterilization of all pipes and equipment.

However, what should not be scrimped on is the choice of materials, whether for tanks or piping. Inappropriate materials will only cause production problems and inefficiencies and will always ultimately need to be replaced – retrofitting is inevitably more expensive than selecting the correct material in the first place.

As a singularly salutary example, a fish hatchery on Komodo Island used mild steel tanks as sand filters - a major flaw in the original design specifications of the hatchery. The cost advantage of their purchase was far outweighed by serious water quality problems encountered from corrosion, with filter medium and iron deposits entering the entire hatchery system, including the larval rearing tanks [(23)].

Another example is the use of PVC pipes - in one case, in airlines from blowers. The high temperature of the air from the blowers reduces the strength of the pipes and leaches out toxic components, causing important problems [(24)]. In another case, despite recommending them (!) for a location in Bermuda, the author mentions that in tropical areas they can be prone to cracking over time, especially when exposed to sunlight and associated higher temperatures [(21)].

The basic principles of modern marine hatchery design all include a highly filtered and efficiently pumped seawater supply, combined with ultra-violet lamps to ensure sterility [(21) (24) (25) (26) (27)]. The precise choice of design will be greatly influenced by site-specific issues once a site has been chosen. For example, the pipe inlet from the sea may be open and water pumped onto land-based sand-filter beds at the head of the hatchery [(21)] or the beach sand itself may be utilised to act as filter prior to pumping [(24)].

A further common feature is the high priority given to live food production [(28) (29) (30)]. In order to do so successfully great emphasis is placed on avoidance of contamination of culture lines. Whilst growing algae indoors in axenic conditions is often recommended, outdoor culture, especially in tropical conditions, is significantly cheaper, even though it is difficult to grow a monoculture for extended periods due to contamination. Simple and cost-effective methods of concentrating algae produced during good growth times may serve to alleviate this problem [(31)]. They can be stored in cool conditions as a paste and re-suspended for use when normal algal production is in a declining phase.

The production cost of microalgae using conventional phototrophic means, is high, ranging from 20–50% of hatcheries' operating costs [(32)]. Nutritionally adequate alternatives have been sought that may be more cost-effective than relying on on-site algal production. The routine use of commercially purchased dry algae for growing older bivalve spat, prior to transfer to grow-out sites, has been found satisfactory [(21)].

Note:
Dry microalgae may be purchased from Reed Mariculture (http://www.reed-mariculture.com/microalgae/).

A final common strand that links the multi-purpose concept of the project should be the strong avoidance, if possible, of keeping broodstock and the consequential spawning and early rearing phases. These are always difficult procedures, requiring skill and experience and prone to failure. It would be even more so if new and unknown (to aquaculture) species from the area were selected. The solution is to use light-traps or crest-traps to catch post-larval stages without harming the reef environment [33] [34] [35] [36] [37].

The ecological principle behind this is that reef fish share a similar life history with nearly all other bottom-associated marine fish and invertebrates; a bipartite life history with a planktonic larval stage that ends with a metamorphic transition to benthic habitats. Thus, a majority of marine fish and invertebrates are likely to encounter a variety of larger, more experienced predators during and immediately after settlement. On average, predators consume approximately 56% of newly-settled fish within 2 days of settlement [38]. It may even be that, because of selective pressure, it is the rarer species that are over-predated [39].

"Based on my work and the work of others, collecting larvae before they settle and raising them out for sale to the aquarium trade is a much better and more sustainable strategy than collecting fish from the reef (for the ornamental marine trade). This is for several reasons: 1. The fish that settle and survive the first few weeks represent only a small fraction of the pelagic larvae available. Thus, removing them from the reef would have an impact on the benthic population. 2. Individuals collected as larvae and reared in tanks should adapt more quickly to an artificial diet than individuals collected from the reef" [40].

Note:
Light traps [41] and crest traps [42] are easily made. It is a fortunate coincidence that one of the light-trap authors, Dr Stephen Simpson, is the Tropical Fish Ecologist at University of Edinburgh. He and his student Emma Kennedy are keen to look at reef bioacoustics on Hoga…
Otherwise, they can be purchased from:
(a) P2A Développement sarl - http://www.p2adev.com/Home.html)
(b) Bellamare LLC - http://www.bellamare-us.com/HTML/ProductDetails.asp?productID=142

The collection of pre-settlement fish would require the consent of the Wakatobi Marine National Park Authority. The considerable quantity of published work showing the minimal effect on coral reef ecology plus the potential reef restocking benefits will be persuasive.

A purely scientific benefit would be to use DNA barcoding to accurately match the larva to the adult, at present an inexact science, especially for rarer species.

Although the outcome of trapping post-larval fish will be to supply an extremely wide variety of fish for growing on in the proposed facility, this will have benefits. By the time the fish have achieved their target 5cm size they will be identifiable and can be sorted into three groups:

(a) Those suitable for selling for growing on by local fishermen for food. Typically Caesionidae (Fusiliers) Serranidae (Groupers) Lethrinidae (Emperors) Labridae (Wrasses) and Carangidae (Trevallies) might be expected and valued. The geographically close Komodo Fish Culture project concentrated on breeding three species of Groupers (Estuary, Mouse & Tiger), Sea Bass and Mangrove Jack, albeit for the live reef-fish market [23]. Their intention was to produce 100,000 fingerlings that would be grown on to 25 MT at satellite fish farms deployed at nearby villages. It is useful to note that their best hatchery survival rate was 7.6%. Significantly and in vivid contrast, captured post-larval coral reef fish showed survival rates after 196 days varying from 63% for *Chromis viridis* - Blue-green damselfish to 92% for *Stegastes nigricans* - Dusky farmerfish [43].

(b) Those suitable for selling to the ornamental marine trade. A major UK importer would expect and be pleased to see from Indonesia the following:

Pomacanthus navarchus - Bluegirdled angelfish; *Pomacanthus xanthometopon* - Yellowface angelfish; *Chrysiptera cyanea* - Sapphire devil; *Chrysiptera hemicyanea* - Azure demoiselle; *Lo vulpinus* (or *Siganus vulpinus*) - Foxface rabbitfish; Labridae [various] - Wrasse[17].

Worldwide, the top five most commonly traded species, for the years 1997-2002, were: *Chromis viridis* - Blue-green damselfish; *Amphiprion ocellaris* - Clown anemonefish; *Dascyllus aruanus* - Whitetail dascyllus; *Chrysiptera cyanea* - Sapphire devil; *Dascyllus trimaculatus* - Threespot dascyllus[44].

It is important to note that all of the above species, or their very close relatives, are already present on Wakatobi [14].

(c) Those suitable for restocking the local reefs. Advice would need to be sought (and given) and agreement reached with the Wakatobi Marine National Park Authority on a species by species basis. It has already been noted that algal grazing species are a particularly important component of the reef ecology [2].

Giant clams (Tridacna sp) are one of the most conspicuous of the numerous invertebrates found on the Indo-Pacific coral reefs. In the region, giant clams have long been a traditional food source and the use of the shell has been important in some locations. They were once very common inhabitants of Indonesian coral reef ecosystems throughout the archipelago. Despite their long standing history, they are presently overexploited in most countries. Their decline and increased exploitation has occurred despite the fact that they are a fully protected species by national law (Forestry Ministerial Decree No. 12/Ktps/11 1987) and international law – all Tridacna species are listed in CITES Appendix II. The policing of the national law is difficult and, when combined with continual coastal population expansion, results in considerable pressure on the giant clam population.

Success of a population depends on the density and their reproductive capability. Giant clams are hermaphrodites, however, they primarily use external fertilisation. The spawning of a single individual causes a cascading response by its neighbours, thus, increasing the possibility of cross-fertilisation. Hence, in order for fertilisation to take place, populations must have a high number of individuals due to the “allele effect”, if the distance between males and females is too great, fertilisation will not take place, which has great implications for the fishery. As a consequence of constant removal, the distance between individuals increases, raising the likelihood of local extinction. Therefore, the main life history traits may explain the fragility of giant clam stocks [46].

Tridacna culture is well-established [46] [47]. There are several critical features from the point of view of this proposal.

There may be no requirement to remove broodstock from the reef and into the hatchery - spawning can be in situ. Suitable clams on the reef are identified and injected with serotonin hormone. Within 5 minutes sperm will be ejected from the excurrent siphon. These are collected in a plastic bag. After 30 minutes eggs will be released, which are collected in a separate bag. Fertilisation, using separate parents to avoid self-fertilisation, is completed on the boat and the eggs are brought to the hatchery to be raised through trochophore, veliger, pediveliger and metamorphosis at Day 30 to juvenile 'spat' stage.

Clams do not inherit zooxanthellae from their parents. From Day 3 at the hatchery the larvae need to be fed blended pieces of mantle taken from selected well-coloured adults. The final colour of a clam is unpredictable, being a mixture of genetic influence and the choice of zooxanthella clade [45]. After about one year the clams are 5cm shell size and the best-coloured ones saleable to the marine ornamental trade. Photos of Tridacna sp (T. maxima and T. crocea) found on Hoga reef were shown to a UK importer who rated their colour as excellent.

Rejects can be seeded on the reef for restocking purposes or offered to fishermen for growing on. Meat production in an 'ocean nursery' can take up to six years for adductor muscle optimal size [48]. Ownership of the nursery and prevention of poaching are important issues that must be settled by prior agreement of the local community.

It will be critical to discuss and agree with Indonesian authorities beforehand the issue of export licences for clams. This is an absolute prerequisite for their successful importation into the EU under CITES regulations. In the Philippines legal obstacles have been placed in the path of farmers of cultivated clams when the government regulatory agency prohibited the export of cultured clams, regarding this as a threat to the conservation of wild individuals [49].

Even then, the obtaining of an import licence into the UK is not guaranteed because of the interpretation, or misinterpretation, by the receiving authority of CITES Conf. 12.10 (Rev. CoP13) 'Guidelines for a procedure to register and monitor operations that breed Appendix-I animal species for commercial purposes' when sometimes 'captive-bred' animals are still considered to be 'wild', even after 2nd generation captive culture. And Tridacna is in Appendix II !

It should be pointed out that once the clams have passed into the EU through any EU member state's 'point of entry' they are then free to be re-exported within the EU without hindrance. Some EU countries have more amenable officials than others…

In 1993 the cost of raising a one-year old (5cm) clam in Micronesia was quoted as $0.82 [48]. Converting this to current prices using the 'U.S. Department of Commerce Gross Domestic Product: Implicit Price Deflator' gives a cost of $1.12. It was quoted earlier that current wholesale price in the UK is $20 - but this is strongly affected by colour quality.

The operating costs of the clam hatchery and nursery are dominated by wages, from 45% – 74% of the total, in 1993 [48].

There is a population of rare anchialine shrimp *Parhippolyte uveae* present in Sombano lagoon, Kaledupa. Its proper identity was confirmed by Sammy de Grave, Oxford University Museum of Natural History. It is not normally available for sale in the UK due to its unusual habitat and possibly because it is often revered by local people [(50)]. It is exceptionally well-coloured (an orange-red) and is active during the day.

From the published account and my limited observations it appears to be omnivorous and possibly have ‘cleaner-shrimp’ behaviour. It breeds readily, is extremely hardy and survives well under laboratory aquarium conditions [(50)]. It might therefore be a very good candidate for sale to the marine ornamental trade. Before this can be certain, it will need to be evaluated to ensure that it is ‘aquarium-friendly’ and does not eat or attack either others of its own species or the aquarium community in general. A few dozen will need to be imported, or a suitable enthusiast or dealer in Indonesia approached, with a view to fully observing and assessing its tank behaviour.

As with clams, shrimp culture is well established. Much necessarily relates to the agricultural production of food shrimp species in huge ponds throughout SE Asia. There is nevertheless considerable interest in marine ornamental production especially of Lysmata and Stenopus species [(51) (52) (53) (54) (55)]. It should be noted that Parhippolyte is closely related to Lysmata, both being members of the family Hippolytidae.

As previously noted with fish rearing, it may be possible to avoid the first, difficult, raising of nauplius and mysis stages by catching post-larvae from the lagoon using crest traps [(33)].

The rearing of shrimp does require a small modification of the ‘universal’ hatchery mentioned previously. Larval aggregation in the bottom of the tanks would cause ‘tangling’, damage larval appendages or even the death of the larvae. Rearing systems based on ‘planktokreisel’ have proved to be very appropriate for the culture of the frail spiny lobster larvae. The main characteristic of these systems is the maintenance of larvae and food in suspension only through water upwelling motion. Water aeration may induce damage to the larvae and sometimes does not provide an adequate water circulation, which will cause late stage larvae to sink in the rearing tanks. The planktokreisel-based system allows larvae to develop with minimal mechanical stress, while providing adequate water renewal and circulation [(53)].

An economic model of the post-larval capture/culture operation has been developed, but not published [(33)] The model used a discounted cash flow analysis to determine the annual cost structure and the likely profitability of the operation. The model assumed a project life of 20 years and used a real discount rate of 8% to calculate the net present value (NPV). The budget also incorporated the initial capital and establishment costs. The variables input into the model included the number of traps, catch rates of, in this case, banded cleaner-shrimp (plus small numbers of lobster and teleosts), landed value of each of the valuable species and costs of capital items (nets and traps), maintenance and labour. Risk analysis was carried out to determine the robustness of the financial result to variations in yield (catch) and market value.

Using the model and selling 2.5cm shrimps at a farmgate price of $1.00 indicated the fishery was profitable over a wide range of inputs and debt could be recovered in the first year. However hatchery costs were not included, since growing-on would be done by the fishermen themselves.

Overall, a method of raising larval fish and invertebrates at minimal technical skill and cost is being suggested. A capital cost of at least £50,000 can be envisaged but does not allow for on-site homes for staff, access road, provision of services, laboratory equipment, security fences, etc (21). A reasonable estimate might be nearer £100,000.

Running costs are likely to be dominated by staffing costs (48). To give 24 hour coverage and allow for shift work it may be envisaged that at least five persons would be involved. Using a figure of £100/month salary then the annual wages bill would be £6,000 basic, without administrative oncosts. The remaining running costs would largely be made up of cost of food production or purchase, chemicals, repairs, fuel, depreciation and repayment of loan. A reasonable estimate for overall running costs, including labour and cost of finance, might be £30,000/annum.

Is such a cost sustainable? Leaving aside the issue of 'environmental' subsidy for the other benefits to the reef and to local fishermen outlined earlier, it would be ideal if the value of traded ornamental fish at least met this break-even cost and preferably substantially exceeded it. The very worst FOB price that might be expected would be $1.00 per 'item' (fish or invertebrate). So to cover the running costs 60,000 'items' would need to be sold at the farm gate. For a 'standard' fish or invertebrate world demand might be 100,000/annum (17). For example world trade in Tridacna was 126,000 in 2001. World imports for Chromis viridis, the most popular fish of all, were 322,000, dropping to 103,000 for Dascyllus trimaculatus (44).

Is there room for a new producer? Any fish or invertebrates produced by this hatchery will have to compete in the world market, which is dominated by wild-caught specimens. Whilst aquarists' sentiment may be for cultivated individuals, for both environmental ('saving the world') and practical (farm-raised specimens are normally tougher and more adaptable) reasons, price always dictates purchase. It is argued that even wild-caught species provide an income to poor coastal communities and encourage sustainable management of coral reefs (44). So it will be more realistic to sell at prevailing commercial prices rather than to expect premiums for 'Fair-Trade' or other reasons.

Reliability, continuity of supply, sensible pricing, absence of disease are all important factors that will make for a durable relationship with major importers.

Ideally such a facility should follow the 'triple bottom line concept': builds its business in a way that is financially profitable, environmentally sound and socially responsible (22).

<u>Summary of Recommendations</u>

(a) That the creation of a small hatchery to raise fish and invertebrates is considered.
(b) That its location needs be determined and capital and running costs be properly evaluated.
(c) That cost/benefit analysis should be undertaken that includes a proper value being given to the reef environment by restocking of surplus or unwanted (by the marine ornamental trade) species.
(d) That training and support of local fishermen be undertaken so that they may grow-on food fish and invertebrates provided by the hatchery.

References

(1) May D & Coles T 2004 ‘Proposed strategy for the recovery of the Kaledupan coastal fisheries’ Operation Wallacea

(2) Mumby PJ et al 2007 ‘Thresholds and the resilience of Caribbean coral reefs’ Nature 450, 98-101

(3) Ploeg A 2007 ‘The volume of the ornamental fish trade’ in ‘International Transport of Live Fish in the Ornamental Aquatic Industry’ Ornamental Fish International Publication No 2

(4) Livengood EJ & Chapman FA 2005 ‘The Ornamental Fish Trade: An Introduction with Perspectives for Responsible Aquarium Fish Ownership’ University of Florida Cooperative Extension Service

(5) Bartley D 2000 ‘Responsible Ornamental Fisheries’ in FAO Aquaculture Newsletter No 24

(6) Main K Harbor Branch Oceanographic Institution - World Conference on Ornamental Fish (Aquarama 1999)

(7) Cato JC & Brown CL (Ed) 2003. Marine Ornamental Species: Collection, Culture, and Conservation. Ed: Ames IA Iowa State Press. ISBN 0-8138-2987

(8) The Ornamental Aquatic Trade Association (OATA) Wessex House Westbury Wiltshire

(9) Håstein T et al 2005 Science-based assessment of welfare: aquatic nimals Rev. sci. tech. Off. int. Epiz. 24 (2), 529-547

(10) Lunn KE & Moreau MA 2004 Unmonitored trade in marine ornamental fishes: the case of Indonesia's Banggai cardinalfish (*Pterapogon kauderni*). *Coral Reefs* 23:344-351.

(11) Species Survival Network Results of the CITES CoP14 Species Proposals http://www.ssn.org/Meetings/cop/cop14/cop14_results_EN.htm

(12) Allen GR & Donaldson TJ 2007. IUCN Red List of Threatened Species http://www.iucnredlist.org/search/details.php/63572/summ

(13) Conservation International http://www.biodiversityhotspots.org/xp/Hotspots/wallacea/Pages/default.aspx

(14) Daniel Exton pers. comm. The Coral Reef Research Unit - University of Essex

(15) John Fletcher pers. comm. Operations Manager (Indonesia) - Operation Wallacea

(16) Christiane Schmidt pers. comm. Certification Systems Director - Marine Aquarium Council

(17) Derek Thompson pers. comm. Livestock Manager - Tropical Marine Centre

(18) Crawford B 2002 'Seaweed farming: an alternative livelihood for small-scale fishers?' Working Paper - University of Rhode Island http://www.crc.uri.edu/download/Alt_Livelihood.pdf

(19) Collier et al 1977 'Income, employment and food systems in Javanese coastal villages' Papers in International Studies No 44 – Ohio University

(20) Pomeroy RS 1992 'Aquaculture development: an alternative for small-scale fisherfolk in developing countries: problems and perspectives' International Centre for Marine Resource Development - University of Rhode Island.

(21) Sarkis S 2007 'Installation and operation of a modular bivalve hatchery' FAO Fisheries Technical Paper 492

(22) Dr L Alvarez-Lajonchère pers. comm

(23) Meyer T & Mous PJ 2005 'Final report on the Komodo Fish Culture Project' The Nature Conservancy, Coral Triangle Center in collaboration with the Komodo National Park Authority

(24) Alvarez-Lajonchère L et al 2007 'Design of a pilot-scale tropical marine finfish hatchery for a research center at Mazatlán, Mexico' Aquacultural Engineering Volume 36 Issue 2 pp 81-96

(25) Cansdale G 1981 'Seawater Abstractions' in Hawkins AD (Ed) Aquarium Systems Academic Press pp48-61

(26) Huguenin JE & Colt J 2002 'Design and Operating Guide for Aquaculture Seawater Systems' Second Edition. Elsevier Science Publishers, Amsterdam, 329 p.

(27) Colt J et al 2006 'Evaluation of Seawater Pumping Systems for Use in Marine Aquaculture' Proceedings of the Sixth International Conference on Recirculating Aquaculture' Virginia Polytechnic Institute and State University, Roanoke, Virginia pp 122-127.

(28) Lavens P & Sorgeloos P (eds.) 1996. 'Manual on the production and use of live food for aquaculture' FAO Fisheries Technical Paper No 361. 295p

(29) Treece GD 2000 '*Artemia* Production for Marine Larval Fish Culture' SRAC Publication No. 702

(30) Brown M & Robert R 2002 'Preparation and assessment of microalgal concentrates as feeds for larval and juvenile Pacific oyster (*Crassostrea gigas*)' Aquaculture 207, pp 289-309.

(31) Knuckey RM 2006 ‘Production of microalgal concentrates by flocculation and their assessment as aquaculture feeds’ Aquacultural Engineering 35(3): pp 300-313

(32) Coutteau P & Sorgeloos P 1992 ‘The use of algal substitutes and the requirement for live algae in the hatchery and nursery rearing of bivalve molluscs: an international survey’ J. Shellfish Res 11: 467–476.

(33) Hair C et al 2004 ‘Catching and rearing postlarval cleaner shrimp for the aquarium trade: results from a WorldFish Center project in Solomon Islands’ NAGA, WorldFish Center Quarterly 27 (1 & 2)

(34) Durville P 2003 ‘Aquacultural suitability of post-larval coral reef fish’ SPC Live Reef Fish Information Bulletin 11

(35) Anderson TW et al 2000 ‘Current velocity and catch efficiency in sampling settlement-stage larvae of coral-reef fishes’ Fish. Bull. 100:404–413

(36) Dufour V 2002 ‘Collecting Post-larvae of Coral Reef Fishes and Invertebrates: a Multiple Purpose and Sustainable Exploitation Principle’ EPHE International Coral Reef Fish Workshop Univ. California - Moorea, French Polynesia

(37) Hair C et al 2004 ‘Conclusion of Research on Capture and Culture of Pre-settlement Fish for the Marine Aquarium Trade in Solomon Islands’ Asia-Pacific Marine Finfish Aquaculture Network Magazine IX (2) pp 41-43

(38) Almany GR & Webster MS ‘The predation gauntlet: early post-settlement mortality in reef fishes’ Coral Reefs (2006) 25: 19–22

(39) Almany GR & Webster MS 2004 ‘Odd Species Out as Predators Reduce Diversity of Coral-reef Fishes’ Ecology 85(11) pp. 2933–2937

(40) Dr GR Almany pers. comm.

(41) Watson M et al 2002 ‘Low Cost Light Traps for Coral Reef Fishery Research and Sustainable Ornamental Fisheries’ NAGA The ICLARM Quarterly 25: 2

(42) McIlwain JL 2005 ‘Monitoring the arrival of puerulus stage, spiny lobster (*Panulirus cygnus*) to juvenile habitat at Ningaloo Reef, Australia’ Bulletin of Marine Science 77 (2) pp. 297-304

(43) Patrick Durville et al 2003 ‘Aquacultural suitability of post-larval coral reef fish’ SPC Live Reef Fish - Information Bulletin 11

(44) Wabnitz C et al 2003 ‘From ocean to aquarium’ UNEP-WCMC, Cambridge, UK.

(45) Green S 2003 ‘A comparison of the abundance, size composition, age class structure and habitat selection of giant clams in the no fishing zone with adjacent exploited areas in the Wakatobi Marine National Park, South East Sulawesi, Indonesia’ - University of York Thesis

(46) Mingoa-Licuanan SS & Gomez ED 2007 'Giant clam hatchery, ocean nursery and stock enhancement' Aquaculture Extension Manual No 37 – SEAFDEC 109p

(47) Helm MM et al 2004 'Hatchery Culture of Bivalves - A Practical Manual' FAO Fisheries Technical Paper 471

(48) Leung P 1993 'Production Economics of Giant Clam (*Tridacna* species) Culture Systems in the U.S. - Affiliated Pacific Islands' Department of Agricultural and Resource Economics University of Hawaii Center for Tropical and Subtropical Aquaculture Publication 114

(49) Gomez ED & Mingoa-Licuanan SS 2006 'Achievements and lessons learned in restocking giant clams in the Philippines' Fisheries Research 80 pp46–52

(50) Wear RG & Holthuis LB 1977 'A New Record for the Anchialine Shrimp Ligur uveae in the Philippines with Notes on its Morphology, Behaviour and Ecology'. Zoologische Mededelingen 51 (8)

(51) Calado R et al 2007 'A recirculated maturation system for marine ornamental decapods' Aquaculture 263(1-4) pp 68-74

(52) Calado R et al 2005 'Growth, survival, lipid and fatty acid profile of juvenile monaco shrimp *Lysmata seticaudata* fed on different diets' Aquaculture Research 36 (5) pp 493–504.

(53) Calado R et al 2003 'A rearing system for the culture of ornamental decapod crustacean larvae' Aquaculture Vol. 218, No. 1-4 pp 329-339

(54) Palmtag MR & Holt GJ 2007 'Experimental Studies to Evaluate Larval Survival of the Fire Shrimp, *Lysmata debelius*, to the Juvenile Stage' Journal of the World Aquaculture Society Volume 38 (1) pp 102-113

(55) Figueiredo J & Narciso L 2006 'Productivity improvement of *Lysmata seticaudata* larval rearing protocol through modelling' Aquaculture 261 (4) pp 1249-1258