Catching and rearing postlarval cleaner shrimp for the aquarium trade: results from a WorldFish Center project in Solomon Islands

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Abstract

Between 1999 and 2003, the WorldFish Center in Solomon Islands conducted research into the feasibility of a new fishery based on the capture and culture of postlarval coral reef fish for the live fish trade. The work was carried out in two phases: a research phase from late 1999 to the end of 2002; and a "fine-tuning" phase in 2003. Most of the species were of value to the marine aquarium trade, with very few live reef food fish recorded. The most valuable ornamentals were the banded cleaner shrimp, *Stenopus* species. Cleaner shrimp were harvested using crest nets, the method being modified with the addition of a solid, water-retaining cod-end designed to increase survival at capture. Grow-out techniques were improved by rearing the shrimp separately in jars to prevent aggression. The jars were painted black to protect the shrimp from sunlight. An economic model using experimental catch data and farm gate prices indicates that the fishery based on shrimp, supplemented with small numbers of lobster and fish is economically viable. The next step will be setting up a demonstration farm in a village in the Western Province of Solomon Islands.

Introduction

Coral reef fish species form the basis of two markets that utilize live individuals. The live reef fish food trade targets mostly serranids with some lutjanids and a labrid species. The major markets are in Hong Kong and mainland China. The marine aquarium industry trades in hundreds of species from dozens of families, for markets in the UK, Japan and the US. Both trades have been associated with over-harvesting and the use of destructive techniques to harvest fish (Sadovy and Vincent 2002; Sadovy et al. 2003). On the other hand, there is also an urgent need for alternative sustainable livelihoods in the Asia Pacific region. Between February 1999 and December 2003, the WorldFish Center investigated the feasibility of a new artisanal fishery based on the capture and rearing of pre-settlement coral reef fish for both these markets. Sustainable methods were used to capture postlarval fish as they settled from the plankton and simple aquaculture techniques were used to grow these fish to marketable size. The rationale for harvesting fish at this stage of their lifecycle is that postlarvae are very abundant before settlement, but the process of settlement is accompanied by very high mortality (Carr and Hixon 1995; Doherty et al. in press). This is primarily due to high predation rates when naïve postlarvae return to reefs following their planktonic dispersal phase (Hixon 1991). Harvesting pre-settlers should not affect natural replenishment to the reefs because they are removed immediately prior to this high mortality. The project was funded by the Australian Centre for International Agricultural Research (ACIAR) and based at the WorldFish Center station in the Western Province of Solomon Islands. The Australian Institute of Marine Science (AIMS) played an important collaborative and advisory role. Officers from the Solomon Islands Department of Fisheries and Marine Resources (DFMR) also participated in the study.

The study was divided into two phases. The first comprised research into the feasibility of the concept and ran from 1999 to 2002. During this period, two methods of fish harvest were investigated: light traps and crest nets. Both of these were originally developed for scientific sampling of competent late stage fish and invertebrate larvae (Doherty 1987; Dufour and Galzin 1993). Routine monthly sampling using both techniques was carried out for two years. Light traps caught almost 93 000 individuals belonging to 52 families. Crest nets caught over 150 000 individuals from 83 families. Of these, only a small part of the catch was of value to the aquarium trade (15 per cent for light traps and 5 per cent for crest nets) and a negligible number of live reef food fish species were recorded. Marine ornamental species included juvenile painted lobster (*Panulirus versicolor*) and angelfish (*Pomacanthus* and *Centropyge* species). However, by far the most valuable and abundant ornamentals were the banded cleaner shrimp from the genus *Stenopus*. These were taken almost exclusively from crest nets. *Stenopus* and *Lysmata* shrimp are amongst the ten most

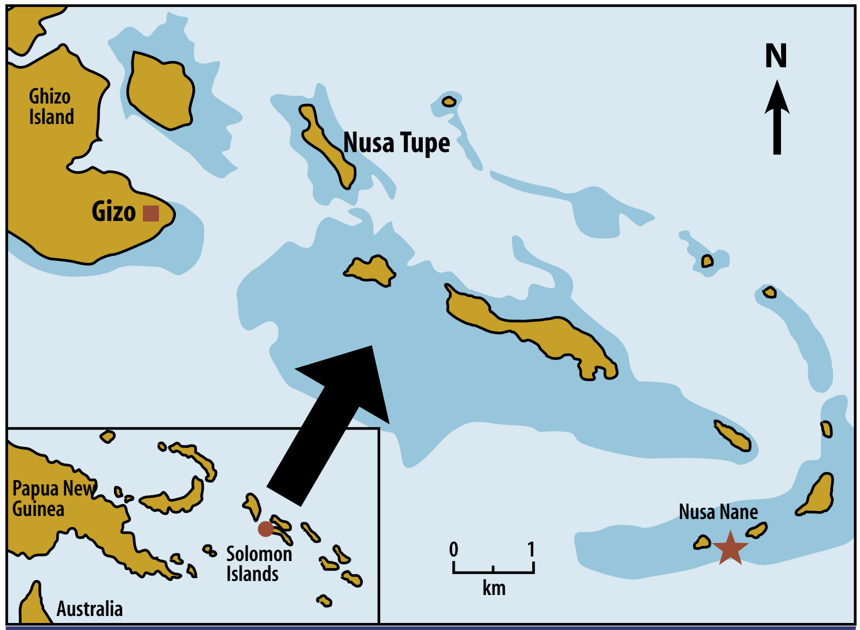

Fig. 1. Location of the WorldFish Center (Nusa Tupe) and the reef crest (Nusa Nane).

Fig. 2. Reef crest at Nusa Nane.

traded invertebrates worldwide (Wabnitz et al. 2003). They are attractive, relatively easy to maintain in a tank and perform a beneficial cleaning and scavenging role (Wabnitz et al. 2003). Although the life cycle of several cleaner shrimp species has been closed, there are a number of constraints to commercial production of *Stenopus* species (Calado et al. 2003). Hence, most are still collected from the wild, despite some concern that over-fishing could have detrimental effects on natural reef ecosystems (Wabnitz et al. 2003).

At the conclusion of the first phase, we recognized that there was potential to develop an economically viable fishery based on postlarval reef species, primarily crustaceans. The second phase was through 2003 and was devoted to "fine-tuning" the capture and culture methods, specifically for high value species. Given that crest nets caught more and higher value species and were cheaper, easier to operate and more reliable than light traps, a modified form of this technique was developed for the new fishery. In this article, we describe efforts to catch, rear and market banded cleaner shrimp reared from postlarvae in Solomon Islands.

Materials and Methods

Study site

The WorldFish Center in Solomon Islands is located at Nusa Tupe near Gizo in the Western Province (Fig. 1). The crest net sampling site was approximately 6 km from the field station on a two-kilometre long reef crest that was exposed at low tide.

Capture of shrimp

Crest nets are small mesh nets fixed on a shallow outer reef crest, immediately behind the surf zone (Hair et al. 2002a, Fig. 2). They sample fish coming through the surf zone from the open sea into the lagoon (Dufour and Galzin 1993). Nets were deployed in the week leading up to and following the new moon each month, when the highest number of fish are leaving the plankton (Milicich and Doherty 1994; Dufour et al. 1996). The catch was retrieved early each morning.

From November 1999 to September 2001, two crest nets were set during every new moon period. In 2002 and 2003, only some months were sampled. Two types of net were used during the first research phase: (i) 1.5 mm plankton mesh nets, mouth size 1x1.5 m and 3 m long with a detachable soft cod-end (Doherty and McIlwain 1996), provided by AIMS (Fig. 3a) were used until February 2001 (Hair et al. 2002a); and (ii) 3 mm knotless mesh nets, mouth size 1 x 1.5 m and 3.5 m long, also with a soft cod end, were used until the end of sampling in September 2001 (Fig. 3b). Shrimp catches from the old and new nets were compared during the months of February and April 2001, and no significant difference was found in the number of shrimp collected (Hair et al. 2002b).

In the fine-tuning phase of the work in 2003, a third catching device was developed. The crest nets were modified by replacing the soft cod end with a rigid, water retaining cod-end in order to reduce mortality and improve the condition of harvested postlarval shrimp (Fig. 3c). During both phases of the project, some cleaner shrimp were retained for aquaculture. However, most grow-out trials were carried out in 2003.

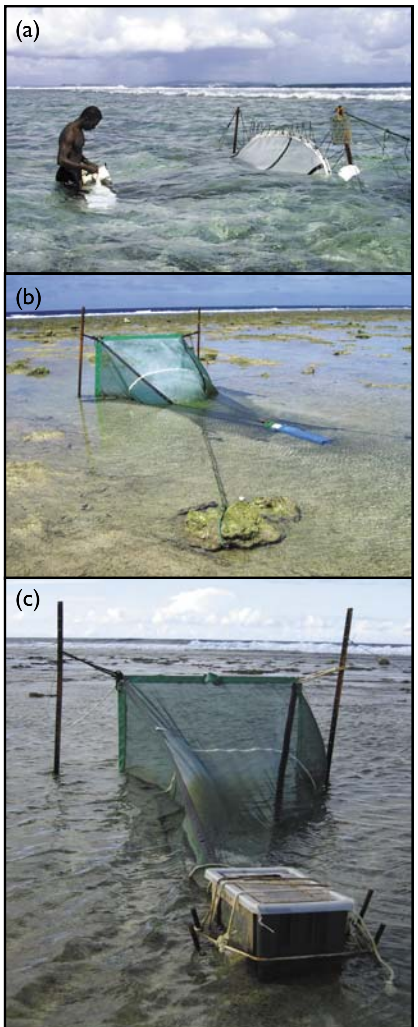

Fig. 3. Sampling gear used in the study: (a) original AIMS crest net with soft cod-end; (b) green knotless mesh crest net with soft cod-end; and (c) green crest net with solid cod-end.

Grow-out of shrimp

Cage culture

Due to variable nightly catches and the uncertainty of catching enough shrimp for experimental treatments, cleaner shrimp were classed as a single cohort for rearing if they were caught within three successive nights. During 2003, different types of cages were filled with live rock and placed on trestles to keep them off the sea floor (Fig. 4). Banded cleaner shrimp were grown *en masse* in cages for periods of 21 days in plastic prawn trays (56 x 31 x 10 cm) lined with 1.5 mm net mesh to prevent escape and predation, stick frames covered with mesh, and plastic wastepaper baskets with mesh lids (56 cm high x 31 cm diameter). Shrimp were fed twice daily on a diet of minced fish, crustacean and mollusc flesh.

As mortality was generally high in *en masse* cage culture, a series of experiments were designed to investigate why. Shrimp were grown in prawn trays in deep versus shallow water and in trays with separate compartments and with pipe shelters. In another experiment, shrimp were reared using different feeding regimes: (i) feeding at two-hourly intervals; (ii) feeding twice daily; and (iii) not fed at all. Survival of shrimp in these various treatments was compared after three weeks of culture.

Jar culture

Our observations of cleaner shrimp indicated that their aggressive nature contributed to the high mortality recorded during *en masse* grow-out. To investigate this, shrimp were grown individually in 200 ml clear plastic jars (Fig. 5). All jars had holes drilled in them to facilitate water flow but minimize food loss. The jars were positively buoyant. Food was placed in the jars, with uneaten food removed and new food added twice a day initially. Twice-daily feeding was found to be very labor intensive, so the feeding regime was reduced to once daily with little change in survival.

Although intraspecific fighting was eliminated, a new problem emerged as shrimp reared in jars developed algal growth on their exoskeleton (Fig. 6). After moulting the shrimp would regain normal coloration but quickly start to look "green" again. In addition, an individual fouled with algae often lost appendages or died during moulting. This problem appeared to be directly related to the amount of algal fouling.

Two experiments investigated the role of light as a determinant of algal growth on the shrimp exoskeleton. First, shrimp were reared in jars in the sea at the surface (in shaded and unshaded cages) and near the sea floor (in shaded and unshaded cages). Second, shrimp were reared in jars that were painted black. During these trials, shrimp were checked

Fig. 4. Examples of baskets used to rear shrimp *en masse*.

Fig. 5. Jars used for rearing shrimp individually.

for the amount of algal fouling on their exoskeleton and mortality recorded daily.

Marketing of shrimp

The cultured shrimp were shipped by air to an exporter in Honiara, then exported to the US for sale in retail aquarium stores. During the initial research phase, specimens were sent to the exporter for feedback on their value and condition. In 2003, fish were sold to the marine aquarium company to verify the quoted prices for these species.

Economic model of the fishery

An economic model of the postlarval fish capture/culture operation was developed by B. Johnston (Queensland Department of Primary Industries and Fisheries). 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 per cent 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 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 labor. A risk analysis was carried out to determine the robustness of the financial result to variations in yield (catch) and market value.

Fig. 6. Banded cleaner shrimp with algal fouling on its exoskeleton.

Results

Identification

Most cleaner shrimp were from the genus *Stenopus*, family Stenopidae. Most small *Stenopus* postlarvae looked similar at capture (Fig. 7a), although larger individuals were distinctive (Fig. 7b). All individuals could be positively identified by the third day after capture at the latest. During the research phase, only *Stenopus hispidus,* banded cleaner shrimp (Fig. 8a) were recorded. During 2003, *S. zanzibaricus* (gold-banded coral shrimp Fig. 8b) and *S. tenuirostris* (blue-banded coral shrimp Fig. 8c) were also captured. The identification of extra species was attributed to improvements in capture techniques in this second phase of the project. The rare and highly sought-after banded cleaner shrimp, *S. pyrsonatus,* was not recorded during this study, although a small number of *Lysmata amboinensis* (Indo-Pacific white-striped cleaner shrimp, family Hippolytidae) were captured and reared. Identification is important since different species have different growth characteristics and commercial value.

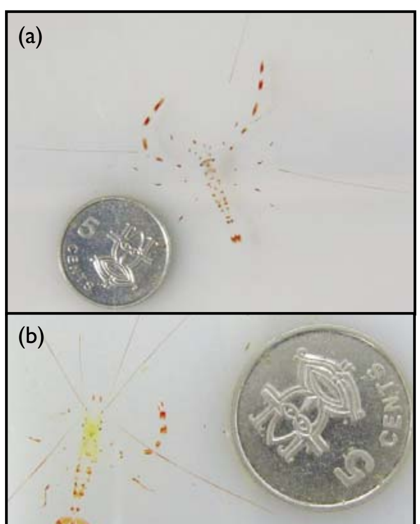

Fig. 7. Postlarval *Stenopus* species: (a) unidentified postlarvae; and (b) *Stenopus zanzibaricus*.

Catch data

Temporal variation in crest net catches (1999-2003)

Mean monthly crest net catches of cleaner shrimp per night for all new moon periods fished between November 1999 and November 2003 are shown in Fig. 9. Catches varied greatly, ranging from almost zero in November 1999 and March 2001 to almost 20 shrimp per net night in September 2003.

Comparison of gear types– (2003)

Crest nets with solid cod-ends caught similar or greater numbers of cleaner shrimp compared to crest nets with soft cod-ends (Fig. 9). The best survival was recorded in the solid cod-ends in all months (Table 1).

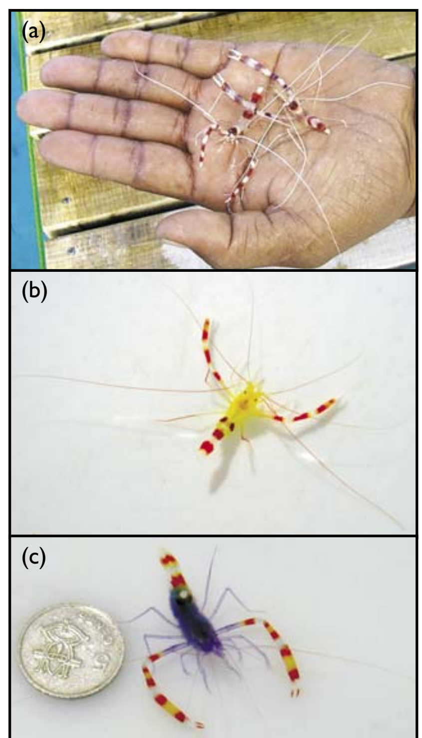

Fig. 8. Adult (export size) *Stenopus* species: (a) *Stenopus hispidus*; (b) *S. zanzibaricus*; and (c) *S. tenuirostris*.

Table 1. Average shrimp survival (%) in solid con-ends versus soft cod-ends during sampling in 2003.

Treatment	Jul.	Aug.	Sep.	Oct.	Nov.
Solid cod-end	90%	95%	100%	95%	100%
Soft cod-end	60%	60%	60%	75%	80%

Grow-out trials

Benthic cages

Mortality of shrimp grown *en masse* in cages on the sea floor was calculated weekly. Very high mortality (between 40 and 80 per cent) was experienced in the early, unreplicated trials. Furthermore, manipulating depth, type of shelter and frequency of feeding did not improve survival rates: mortality remained between 60 and 88 per cent. Generally, the greatest number of shrimp died or were lost in the first week after capture. Mortality continued throughout grow-out, albeit at a lower rate than the first week. Mortality remained at similar levels, regardless of shrimp densities in the cage.

Jars

Results of effects of shading on shrimp in jars are shown in Table 2. Mortality of shrimp in unshaded jars was at least twice that of the shaded jars at either depth. Although slightly higher survival occurred in surface treatments, this factor was less important than shading. Surface treatments had higher algal levels than sea floor treatments in both cases and unshaded shrimp grew more algae than shaded shrimp at each depth.

Table 2. Overall mortality (%) during shrimp jar shading experiments in 2003.

Treatment	% mortality	Av. algal level
Sea floor shaded Surface shaded	30-40% 20-30%	0.4-0.5 0.7-0.8
Sea floor unshaded Surface unshaded	60-100% 60-70&	0.4-0.8 1.1-1.2
Black jars Clear jars	0-20% 30-40%	0-0.1 0.3-0.6

(n=10 jars in each treatment. Algal level was estimated as 0= nil algae; 1=small amount on legs only; 2=small amount on legs and body; 3=dark algae on full body).

Once jars were painted black to further reduce light, mortality of shrimp fell further and was lower than that experienced in clear jars (Table 2). Levels of algae on the shrimp exoskeletons was also reduced in black jars.

S. hispidus grew well in jars and were ready for export after about four weeks at around 25 mm body length. Unfortunately, the other species did not grow well in jars and did not reach export size, even after two months of grow-out.

Value of the catch

Based on prices quoted by the exporter, the estimated value of the crest nets catch from October 1999 to September 2001 was \$2 777[1]. Cleaner shrimp accounted for 65 per cent of the potential total value for that period despite making up only 13.5 per cent of ornamentals by number. The farm gate price for cleaner shrimp was \$1.00 each.

During 2003, 10 shipments of fish, worth a total of \$245 were sold. The highest value came from banded cleaner shrimp with \$144 for 146 shrimp. Eighty lobsters netted \$79, and 97 fish (mostly angelfish, puffers and butterflyfish) were worth \$21. These were taken from about 75 night's fishing using three nets each night.

Economic model

The economic model was run using a range of values in order to confirm its robustness to variations in production (either due to variable catches or fluctuations in survival during culture) and market price. The parameter values were based on actual catches of shrimp, while lobsters and teleosts were included as a supplementary component of the fishery. Capital costs included two traps at \$175 each and \$140 for rearing facilities. A small labor cost was included (\$280 per annum) and \$700 paid to the owner/operator per annum (although it is likely that in the early stages of operation, the fish-farmer will depend on unpaid family labor, only occasionally withdrawing funds). Experience with village giant clam farming in Solomon Islands indicated that paid labor might be employed once the operation is established and profitable (C. Oengpepa, pers. comm). The model indicated that the fishery was profitable over a wide

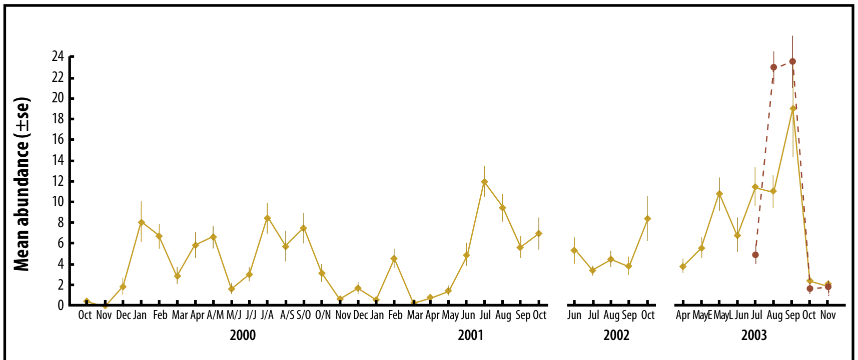

Fig. 9. Mean nightly abundance per net (±se) per month of banded cleaner shrimp and lobster for all sampling periods from 1999 to 2003. Solid line denotes catches in soft cod-ends and broken line denotes catches in the solid cod-ends.

[1] All values are in US\$.

range of inputs and debt could be recovered in the first year.

Discussion

The marine aquarium trade generates $200 to $330 million worldwide each year (Wabnitz et al. 2003). As most valuable fish are sourced from tropical seas in developing countries, it provides an important source of income to coastal communities in the Asia Pacific region. Unfortunately, specimens are often collected using cyanide or destructive fishing techniques and there are fears that over-fishing is occurring for some species in some areas (Sadovy and Vincent 2002). When this project commenced, it was envisaged that harvesting pre-settlers might take pressure off existing coral reef populations by providing an alternative to the collection of large juveniles and adults for the trade. Our final results, however, suggest this is unlikely. The small range and relatively low abundance of target species harvested using crest nets (and light traps) means that the new fishery is more likely to complement the existing dive fishery, not replace it. Nevertheless, it could positively impact the socio-economic situation by providing a sustainable livelihood in the region.

The final year of the project was devoted to "fine-tuning" the catching and rearing methodology to a stage where it could be introduced to coastal communities. The effectiveness of the solid, "fish friendly" cod-end was well demonstrated by the improvement of survival in the catch. Average survival of shrimp was 10 per cent between 1999 and 2001 (Hair et al. 2002b). In 2003, with fish friendly cod-ends, survival rose to 97 per cent. Survival of other target species and by-catch also improved markedly with solid, water-retaining cod-ends. Shrimp could be maintained in good condition between collection at the reef crest and delivery to their grow-out habitat by handling them gently and separating them at retrieval from the cod-end. *S. hispidus* is naturally aggressive and in the ornamental fish trade adults are maintained in tanks as mated pairs or isolated in jars (L. Squire, pers. comm.). The observed drop in mortality when the shrimp were isolated in jars suggested that aggression occurs from around the time of settlement. One drawback of the jar rearing method is the increased likelihood of shrimp growing algae on their exoskeleton since banded cleaner shrimp are nocturnal and cryptic in the wild yet exposed to strong sunlight when grown out in jars. The algal growth was controlled with black jars and shade over the grow-out cages. Growing shrimp in jars is more labor intensive but is a simple procedure and can be handled by most age groups. This is an advantage for a family run operation in a village.

Cleaner shrimp were the most abundant and valuable species we collected throughout the study. The value of the ornamental catch from light traps and crest nets from October 1999 to September 2001 was $598 and $2 777, respectively. Low-value damselfish, predominantly caught in light traps, made up nearly 80 per cent of ornamentals by number but only 21 per cent of the value. Cleaner shrimp made up only 13.5 per cent by number but accounted for 65 per cent of the total value. Economic modeling of the fishery using actual catch abundances and their real value indicates that banded cleaner shrimp could support a fishery. There is potential to increase profitability if grow-out of the blue-banded and gold-banded cleaner shrimp can be improved and if other species (e.g., *Lysmata*) can be targeted. Juvenile painted crayfish and a small range of ornamental teleosts (finfish) would provide extra income. Additionally, recognition of the techniques as a sustainable, responsible fishery may lead to certification by the Marine Aquarium Council with subsequent market advantages (Holthus 1999).

The next step involves the establishment of a village demonstration farm in the Western Province of Solomon Islands. If the operation is a success, the techniques will be transferred to other countries in the region. Funding for this activity is again being provided by ACIAR as part of a larger project that supports sustainable aquaculture in the Pacific region. The lead agency is the Department of Primary Industries and Fisheries in Queensland (DPI), working in close collaboration with the WorldFish Center in the Pacific and Secretariat of the Pacific Community (SPC).

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