Progress report on the capture and culture of presettlement fish from Solomon Islands

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Introduction

Interest in alternative ways to catch fish (particularly very young fish) for the marine aquarium trade is growing steadily (see articles by Dufour, Pet-Soede et al. in No. 10 of this bulletin). The WorldFish Center (formerly ICLARM) in Solomon Islands has been investigating the feasibility of a new artisanal fishery based on the capture and culture of presettlement coral reef fishes[3] targeted by the live fish trades. Our major motivation has been to find alternative sustainable livelihoods for impoverished coastal communities in the Pacific and Asian regions (Bell et al. 1999). In short, we are seeking fishing methods that are environmentally friendly and ecologically sustainable based on harvesting reef fish at the optimum time in their life history (see section below on Sustainability). The WorldFish Center project differs from similar projects (e.g. Dufour 2002) in that the technology must be simple and affordable since our major objective is to create a new source of sustainable wealth for coastal communities with limited cash-earning opportunities.

Which fish and when?

Before we could determine if a new fishery based on presettlement fish might be viable, we needed information on the availability of culturable species in our study area and whether there was a seasonal aspect to larval supply. This is the first time that fish settlement patterns have been studied in Solomon Islands. The work, therefore, contributes to the general state of knowledge about the resource and permits comparisons with other regions with a longer history of similar research (e.g. Australia, Caribbean and French Polynesia). Some of the fish collected during this monitoring were used to evaluate the logistics and costs of culturing presettlement fish to a size acceptable to the market.

The idea of using light traps and crest nets to collect early life history stages for aquaculture was discussed at a workshop on sustainable reef fisheries held in Kota Kinabalu, Malaysia, in 1996 (Carleton and Doherty 1999; Dufour 1999). Light traps are submerged devices that attract phototactic presettlement fish from the water column (Doherty 1987). Crest nets are stationary nets fixed on reef tops that intercept potential colonists travelling through shallow water on their way to lagoonal habitats (Dufour and Galzin 1993). We used both methods to monitor larval supply of presettlement coral reef fish[4] around Gizo, Western Province, for 24 lunar months between November 1999 and September 2001. Traps and nets were deployed around the new moon each month, when the greatest numbers of fish were leaving the plankton (Milicich and Doherty 1994).

Light traps yielded 92,693 coral reef fish from more than 200 species, belonging to 50 families. Cardinalfish, damselfish and gobies dominated the catch, collectively comprising 94 per cent of the total catch. Crest netting yielded 147,665 coral reef fish from more than 390 species in 81 families. Wrasses, gobies, cardinalfish and eel *leptocephali* were abundant, but more than 20 families made up 95 per cent of the catch. In addition, 2858 cleaner shrimp (*Stenopus hispidus*) and 262 lobster pueruli (*Panulirus versicolor*) were collected by crest nets.

Very few fish of potential value to the live reef food fish trade (LRFFT) were collected by either technique, so all of our results relate to the supply of ornamental species.[5] Fifteen per cent of the light trap catch (13,786 fish from 36 species) were considered to be of value to the ornamental trade. Almost all of these were damselfish, which unfortunately have low marketability in Solomon Islands (see section below on Economics). Only five per cent of the net catch (7796 fish from 88 species) were ornamental species but more than half of these were of higher value than damselfish. It is likely that the valuable component of the catch from both methods has been underestimated due to the deliberate exclusion of gobies and wrasses. Both taxa were abundant in our catches (especially in nets) and certainly included a number of attractive species. We did not include them as potential

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3. Presettlers are postlarval individuals that are ready to leave the water column and adopt a benthic reef-associated lifestyle.
4. The term “fish” here includes teleosts and selected decapods (shrimp and lobster).
5. Marine ornamental fish are generally small brightly coloured species, or species that may exhibit unusual behaviour. Ideally, they should have non-restrictive diets and be capable of adapting to a captive existence (Pyle 1993).

aquaculture targets, however, since most were very small (difficult to identify) and fragile (at least with the net design used in our study). Through improved capture techniques, we hope to add some of these taxa to our list of culturable species.

There was no evidence of seasonal trends in supply of any abundant species or family. Over the 24 months of monitoring, there were numerous pulses of recruitment for various taxa but no predictable patterns. The single exception was that significantly greater numbers of lobster pueruli were captured between June and September in both years (confirmed by further sampling in 2002).

Pros and cons of the two collection methods

In general, the two methods caught complementary sets of species, although crest nets collected a greater diversity of families and also more taxa of high value (Hair et al. in press). Survival was higher among fish collected by light attraction. For example, 90 per cent of butterflyfish from light traps were alive on collection, compared with 40 per cent in crest nets, and 100 per cent of pufferfish from light traps were alive, compared with 13 per cent in nets. Operational features of the harvest methods must therefore be considered before deciding on the preferred technique for any new fishery.

Light traps were found to have three advantages over crest nets. First, traps allow more flexible deployment (deep, shallow, drifting, anchored), resulting in lower site dependency. Second, they yield lower bycatch because trapping depends upon active responses (positive phototaxis and adequate swimming performance) by captured fish. Third, this size-based selectivity and constant water exchange through the submerged trap lead to good survival rates of the retained catch. Light traps were also found to have three disadvantages relative to crest nets. First, the taxonomic selectivity resulting from phototaxis produces fewer valuable fish for Solomon Islands' ornamental market (see section below on Economics). Second, the electrical components of traps require regular maintenance. Third, traps are relatively expensive due to the need for a regular supply of batteries.

Crest nets have two desirable characteristics. First, the cash and logistic costs of operating are modest. Once deployed, a single person can retrieve the catches — in ideal situations reaching the site by foot or by paddle canoe. Second, nets collect a greater diversity of high-value species. Nets also have two inherent disadvantages relative to traps. First, crest nets require very specific physical settings (aspect, exposure, tidal range) for optimal performance (Doherty and McIlwain 1996), which restricts their use to communities living near these ideal locations. Second, the indiscriminate filtration of water crossing the crest results inevitably in a larger bycatch component and greater mortality among the retained catch.

Based on these assessments, it is clear that crest nets offer the better option for a low-cost artisanal fishery, despite inherent limitations and notwithstanding the availability of cheaper light trap designs (Watson et al. 2002). The greater bycatch in nets is the most serious issue with this technique but we emphasise that our nets were designed for sampling larval supply and, as such, they were rigged with cod-ends intended to retain everything without regard to their condition after capture. We believe that purposeful redesign of the cod-ends could result in devices with much lower impact upon the retained catch.

Grow-out of fish and invertebrates

Fish that survived capture and were perceived to be of value were grown out. Initially, we used concrete raceways with flow-through seawater available at the WorldFish Center at Gizo. This strategy allowed us to observe the behaviour of captive fish, develop appropriate feeding strategies, and track their mortality with reasonable accuracy. In the first two years of our study, we maintained more than 120 species of fish from 29 families in these raceways to assess their suitability for aquaculture and subsequent sale. Fish were fed a variety of cheap feeds such as fish roe and minced bonito. Fish pellets and commercial aquarium flake food were also tested but we have not determined whether the expense of such imported feeds is justified. Live rock was offered for shelter and provided a foraging substrate for a number of species (grazing fish, invertebrates).

During our survey, we communicated regularly with the sole aquarium fish exporter based in Solomon Islands (in Honiara), who provided feedback on the marketability of our product. We became aware that many fish on trade lists from other areas (e.g. Baquero 1999) were of little or no value in Solomon Islands and we directed our efforts towards the most valuable species. In the raceways, damselfish, triggerfish, and surgeonfish were more robust than butterflyfish, angelfish, and boxfish. Invertebrates (cleaner shrimp and lobsters) were among the easiest to culture, however, and represented some of the best value among our catches (see section below on Economics).

Towards the end of 2001, we moved the rearing from shore-based facilities to sea cages in the lagoon, mainly because this is the most likely scenario for an artisanal fishery. In mid-2002, we constructed a floating cage system capable of holding up to 16 pens, each enclosing about 1 cubic metre. Fish in these pens had higher survival rates than fish in the raceway. With this structure, we also succeeded in rearing recalcitrant species that had failed to metamorphose in the raceways (e.g. boxfish and angelfish). The floating pens were unsuitable for our two invertebrate species, but these did well in fixed cages attached to the bottom in shallow water under the sea cage.

Dufour (2002) reported that weaning presettlement fish onto an artificial diet produces several benefits, including faster growth. In keeping with our objective of developing simple and cheap culture methods, we are developing modest feeding regimes that will be adequate to precondition fish to life in aquaria without being excessively difficult or costly for the prospective farmer. Our current practice in the sea cages is twice-daily feeding with the same diets that we used with fish reared in the raceways — that is, feeds made from locally available products such as fish roe and minced bonito. Based on this regime, we found that most species were marketable after just two months of culture.

Reducing mortality associated with the fishery

It is a given that mortality of bycatch and target species must be minimised in any responsible fishery (Sadovy 2002). In this case, where cultured products from a new artisanal fishery would have to compete against the wild product currently taken relatively cheaply and easily from reefs, we believe it is essential for the cultured product to have some market advantage. Some form of good practice certification (e.g. the eco-labelling scheme being established by the Marine Aquarium Council), which could result in a price premium being paid for captured-cultured product, would help to offset costs incurred during the capture and culture process.

In order to achieve this advantageous certification, two sources of mortality will need to be minimised in a fishery based on collection of presettlement fish. We have referred above to the mortality of bycatch, which we suggest can be reduced substantially by better design at the back end of the collecting nets. The second source of mortality concerns that of the target species. Wood (2001) suggests that wild-caught juvenile fish — although popular in the aquarium trade — may be more difficult to maintain than adults due to their specialised diets and low resistance to stress. However, our preliminary results support Dufour's (2002) claim that juvenile fish reared in captivity from their presettlement phase and weaned quickly onto an inert diet, handle stress better than their wild counterparts. Ultimately, we accept the recommendations of others (Wood 2001; Sadovy 2002) that it is important to release species found to be unsuitable for culture, treating them as part of the bycatch.

Is fishing presettlement fish sustainable?

Some aspects of the novel fishery that we propose here seem at first appearance to be antithetical to the best practices of traditional capture fisheries, but the differences must be appreciated between fishing for food and fishing for other values. Food fisheries aim to maximise harvested biomass for obvious reasons. In contrast, the appropriate currency for the ornamental trade, which seeks live fish for display purposes, is simply the number of attractive fish.

Recent studies have revealed two relevant insights into the demography of reef fish. The first insight is that many tropical reef fish, whether large or small, live to substantial ages (Doherty and Fowler 1994; Choat and Axe 1996). Maximum adult size is a poor predictor of longevity so the smaller sizes of species sought by the aquarium trade do not indicate that they are more robust to exploitation. To support this claim, large groupers sought by the LRFFT live for less than 15 years (Ferreira and Russ 1994), compared with 20 years for small damselfish (Doherty and Fowler 1994). The second insight is that the transition by presettlement fish between ocean and reef is a substantial bottleneck in their natural populations (Doherty et al. in press), mainly because of the impact of reef predators upon naïve colonists (Carr and Hixon 1995; Holbrook and Schmitt 2002). Bearing both factors in mind, it is clear that harvest of incoming settlers must be more sustainable than removing the same number of older settled stages from the reef after they have reached the greater sizes preferred by the aquarium trade. Moreover, methods for harvesting presettlement fish have no impact upon the natural habitat for settled fish, whereas the collection of settled fish from the reef often results in damage to the coralline habitat. Further, the removal of tiny individuals with minimal biomass must have less impact upon reef trophodynamics than the removal of the same number of settled fish that have grown to sizes currently targeted by the dive fishery for wild ornamental products.

Despite their efficiency, it is important to realise that crest nets are self-limiting devices due to their specific requirements for efficient operation (Doherty and McIlwain 1996). A desktop study has shown that suitable sites for the deployment of crest nets in Solomon Islands are widespread but not common. In fact, it is quite likely that markets for ornamental species may be served adequately from relatively few sites with the lowest transport costs. While these factors may limit the spread of economic benefits flowing from any new fishery based upon presettlement fish, the corollary is that it will be impossible to deplete natural populations of reef fish in Solomon Islands by using these methods. This contrasts with other examples of aquaculture reliant upon wild seed (milkfish, grouper, eel, etc.), where unrestrained harvests have raised concerns about their sustainability (Sadovy and Vincent 2002; Hair et al. 2002a).

Suggested village model for a presettlement capture-culture fishery

We envision that a modified apparatus, resembling a crest net, can provide valuable income for coastal fishers who have access to the right conditions. Although the methodology has been kept intentionally simple, some training will be required to ensure proper handling of the live product. Unlike other aquaculture ventures, which require continuous inputs of labour and energy, wild harvests of presettlement fish can be flexible, leading to wider acceptance. Fish farmers will have greater choice about where to invest their effort: switching energy between subsistence activities (gardening, food fishing) and cash generation as required by various obligations (e.g. school fees). This flexibility is enhanced by the lack of seasonality in larval settlement patterns (observed in Solomon Islands, and expected elsewhere in the tropical Pacific) and the short growout period required for most target species.

Village operations would use small cages (such as fine mesh nets suspended from inflated tyre tubes) in sheltered lagoon areas where fish exposed to natural plankton would not be entirely reliant upon the feed provided by the fish farmers. Under these circumstances, the principal care requirements would be supplementary feeding to enhance growth rates, occasional net changes to control biofouling, attention to stocking densities to reduce competition, and perhaps simple prophylactics (e.g. freshwater baths) to control parasites and / or disease. Fish will remain in the sea until they can be transferred to the next stage in the distribution chain. This flexibility is essential for people living in isolated areas where transport is irregular and unreliable.

After basic training, the proposed techniques should be suitable for adolescents or adults of either sex. We have plans for the production of a manual that will explain all aspects of the fishery in simple English and Solomon Islands Pidgin with "how-to" diagrams.

Economics of the proposed fishery

Our experience has shown that only a small proportion of the species that we have caught and reared so far meet the narrow expectations of the current market in Honiara (see below). Nonetheless, the monetary value of our catches from just two small nets (equivalent to three linear metres of reef crest) near Gizo could have sustained a profitable artisanal fishery. The catch of ornamental species from our two years of sampling[6] was estimated to be worth SBD 27,000[7] based on farmgate prices in Honiara. Crest nets provided more than 80 per cent of the value. Cleaner shrimp alone were worth SBD 17,500 (Hair et al. 2002b). Painted lobster and some novel finfish (e.g. pufferfish, batfish) provided the bulk of the remaining value, which indicates that initially at least, this fishery may complement rather than compete with established sources.

Set-up costs for a fishery based on crest nets should be relatively low, especially after modification of the devices to more closely resemble traditional fish corrals. Based on our average catches and best farmgate prices, we estimate that the capital cost of a typical family operation could be repaid within a few months. More accurate estimates can be provided after the modified fish collection device has been built and tested (sometime in 2003). The relatively short (two-month) turnaround of product should be attractive to potential fish farmers, although it will be difficult for them (at least initially) to compete on economic grounds with the larger-sized product taken from the adult population. We hope that this gap may be closed by market forces responding to a superior and / or more ethical product (certified by eco-labelling). There are indications that this will be the case. Although the fish we have produced are relatively small, we have been offered large-fish prices because fish caught and raised using these methods are less shy in tanks and accept food more readily.

Many species that we were able to rear were found not to be profitable in the unique context of Solomon Islands, which has expensive and limited volume for airfreight. Honiara is very distant from the major markets that consume ornamental reef fish. As a result, abundant but less valuable species are rarely exported (e.g. damselfish). Instead, the local dealer

6. Based on the assumption that all valuable fish recorded had survived, been reared, and sold.
7. Price sensitive to exchange rates with the major markets. For example, the value of our catch was about USD 3600 at current exchange rates, but would have been worth USD 4500 in 2001.

has been particularly interested in novel species that are difficult to obtain by conventional means (e.g. lobster, shrimp and puffers). But even a limited trade such as the one in Solomon Islands can provide useful additional income to communities, especially when few other options are available. Of course, we suspect that culturable species that may not be economically viable in Solomon Islands may be profitable elsewhere in the Asia-Pacific region.

Acknowledgements

This research was funded by the Australian Centre for International Agricultural Research. Special thanks to the WorldFish Nusa Tupe staff: Regon Warren, Ambo Tewaki and Clayton Haro for field work, and Idris Lane for logistical support and advice. Johann Bell provided helpful comments on the draft manuscript.

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Aquacultural suitability of post-larval coral reef fish

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Introduction

Previously, aquaculture mainly consisted of the intensive rearing of commercially valuable carnivorous species for the food market. Some high-yield operations have proved harmful for the environment (Kautski et al. 1998) or of doubtful profitability (Naylor et al. 2000). In the future, the focus is likely to shift either to new species, such as herbivores or detritus feeders, which occur lower down the food chain, or to the development of new activities, such as fish production for recreational fishing, natural stock rehabilitation and the breeding of species for laboratories or aquaria. These potential prospects in marine resources are at present under-exploited, especially in tropical latitudes. Some small-scale farming activities represent, for the moment, only a small output in terms of tonnage, but they can nevertheless prove highly profitable. This, for example, is the case with ornamental fish production, which can be a significant economic activity (Tauji 1996; Dufour 2002).

Mastery of breeding techniques is not always necessary and some aquacultural operations now use young specimens caught at sea that are then transferred to farms (Deniel 1973; Rimmer 1998). In the Mediterranean, the Italians traditionally harvest juvenile mullet, sea-bream and European seabass in an area stretching from Turkey to Morocco, rearing them in the “valli” of the Adriatic (Barnabé 1991). This is also similar for the milkfish, *Chanos chanos*, as Far Eastern fishers have been acquiring specialised knowledge for more than a century through capturing young specimens, which are then transferred to farming units (Smith 1981). In Japan, juvenile amberjack, *Seriola quinqueradiata*, caught in the open sea under floating seaweed masses, are used for subsequent rearing in cages (Kuronuma and Fukusho 1984). This method is still very widely used to supply production units. This kind of fishing is cheap and easy, but the harvests vary from year to year and one poor season could jeopardise a whole year’s output (Lequenne 1984).

Recently, aquacultural experiments have also taken place with coral reef fish caught in their natural environment at the post-larvae stage (Dufour 2002; Durville 2002); that is, at their final stage of larval development, which, for most species, corresponds to the stage when they migrate from the pelagic environment to the reef. These catches have been made possible by the development of new techniques such as the crest net (Dufour 1992; Riclet 1995) and light trap (Milicich 1992; Hendricks et al. 2001). On Reunion Island, many specimens were caught using these techniques during a study on the colonisation of the islands’ reef flats by fish post-larvae (Durville et al. 2002). Concurrently with that study, and in order to understand how well these coral reef fish might adapt to the requirements of fish farming at this particular stage

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