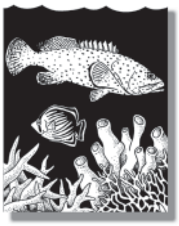

Current status of marine post-larval collection: Existing tools, initial results, market opportunities and prospects

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Introduction

All marine fisheries — no matter the scale at which they occur — involve removing a portion of the targeted stocks, which are often limited and finite. This is a serious problem because stocks of certain species are becoming increasingly depleted and in some cases even exhausted. This overexploitation of resources is evident not only for food species but also for reef species that are popular for the aquarium fish market.

In general, most fishing techniques take adults, often breeders, thereby diminishing not only current stocks but also futures stocks. Open-ocean fishing techniques, whose destructiveness varies depending on the technique used (e.g. gillnets) and the amount of fish caught, do, however, spare habitat. This is not the case for coral reef fisheries, which, depending on the technique, can have a direct effect on habitat conditions (e.g. cyanide, explosives). Russ and Alcala (2004) found that 75% of the coral reefs in the Philippines have been damaged. In other words, not only is there overfishing but the fishes' habitats have been destroyed, leaving nature with no way to recover from such disturbances.

Recent studies have shown that most marine reef fish species have a pelagic larval stage in their life cycles that concludes with oceanic post-larvae returning to their "original" reef habitat. Yet, during settlement, more than 95% of post-larvae disappear due to natural causes. Collecting a small percentage of these post-larvae before they are lost to this high level of natural predation offers a new exploitable marine resource while helping ensure the sustainability of coral reef ecosystems.

Post-larval collection is certainly not the only solution to overexploitation of demersal species[2], but it is, nevertheless, a path worth exploring, not only for developing an innovative and sustainable type of aquaculture but also for repopulation efforts, which are just beginning (Delbeek 2006).

Overview of the life cycle and non-impact of post-larval collection

Most coastal fish (coral reef fish and also demersal fish in temperate zones) have oceanic larval phases at the beginning of their life cycles (Sale 1980; Leis 1991; Leis and Carson-Ewart 2000). This phase allows them to colonize new habitats, thereby facilitating the species' broad distribution and, consequently, their persistence (Choat and Robertson 1975; Lobel 1978; Victor 1986a).

Depending on the species, larvae spend from 20 days (Pomacentridae) to more than 100 days (Aulostomidae) in the open ocean (Brothers et al. 1983; Victor 1986b; Wellington and Victor 1989; Victor and Wellington 2000). Fairly passive during most of this phase, they finally become active — entering their competence phase (Doherty and Williams 1988; Cowen et al. 2000; Fauvelot et al. 2003) — in order to look for their new habitat. This settlement phase takes place at night, if possible when there is no moonlight. Still, most of those post-larvae (more than 95%) disappear during the week that follows settlement, mainly due to predation (Planes and Lecaillon 2001; Planes et al. 2002; Doherty et al. 2004).

Post-larval collection techniques make it possible to recover these animals before this phase of high natural mortality. Given the very large number of post-larvae arriving from the ocean, collecting a small percentage of them has almost no impact and one that is limited in time (Bell et al. 1999). These techniques provide access to a previously unexploited marine resource, without impacting stocks or damaging the environment (Lecaillon 2004).

Today, thanks to a range of existing collection tools and the know-how developed by certain private and public agencies, these post-larval fish can be kept alive, weaned and grown out to become a new marine resource, while respecting the spirit of sustainable development and biodiversity conservation.

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1. Founders of the company Ecocean, holders of a patent on the CARE technique, and founders of the association Moana Initiative for development of post-larvae collection. 1 rue St Sauveur; 34 980 St Clément de Rivière; France. Email: ecocean_label@yahoo.com

2. Demersal species are bottom-dwelling species (as opposed to "oceanic / pelagic" species such as tuna).

Post-larval fishing techniques

Currently four main systems of post-larval fishing are used.

Crest nets on barrier reefs

This technique consists of setting a net on the barrier reef (with the open end towards the ocean) in order to catch the post-larvae surfing over the reef crest to enter the lagoon (Fig. 1).

This technique was developed by both a French laboratory (École Pratique des Hautes Études – EPHE – of Perpignan) (Dufour 1991) and an Australian one (Australian Institute of Marine Science – AIMS) in collaboration with the WorldFish Center (Hair and Doherty 2003). The technique was used by a private firm based in Moorea, French Polynesia, which is no longer in business.

A number of people are needed to set up the poles that support the nets on the reef crest. The equipment wears out quickly because it is constantly hit by waves. These nets can only be used near amphidromic points (where tidal ranges are very small) and, by definition, only in those areas where there are crests / ridges. Thus, this considerably reduces the number of countries where the technique can be used (these nets cannot be used in temperate settings). Finally, *Sargasso* and *Turbinaria*-type seaweed can get caught in the net's collector and can abrade the post-larvae and damage them.

Hoa nets between small islands and on reef ridges

Certain islands, particularly coral atolls, have very shallow (2 m) channels on their reef ridges surrounded by dry land, called *motu* in Polynesian. The channels, or *hoa* (meaning "marine rivers"), allow the ocean to fill the lagoon. This technique consists of setting a net across these *hoa* to catch the post-larvae concentrated in the water masses passing between the *motu* and entering the lagoon (Fig. 2).

The technique was mainly developed by the EPHE of Perpignan and the SPE (Fisheries Service) of French Polynesia. It is currently used by a private company based in Rangiroa, French Polynesia.

If a site has a *hoa*, setting up the net is simpler than for a crest net. There is less wave force on the gear so it is easier to set the net up and take it down. This device traps everything going through the *hoa* and so is very effective. It is sometimes the victim of its own high level of effectiveness because when the post-larvae of a given species are particularly abundant, millions of post-larvae can be caught. But because there are too many of them in the collector, most die from a lack of oxygen. This is not profitable for either the fisher or the environment.

This technique arose from efforts to optimize the use of crest nets and so has appeared more recently. Of course, a *hoa* must be present in order to use this method. Unfortunately, these geomorphologic structures are even rarer than reef ridges, so use of this technique is also limited geographically.

Figure 1.
Crest nets in Moorea, French Polynesia.

Figure 2.
Hoa net. Rangiroa, French Polynesia

Light-trap

Many different models of light-traps exist because this method has been used by scientists for many years. First developed by the Australians (Doherty 1987), then optimized by the French, the light-trap consists of a casing surrounding an autonomous underwater lamp. Post-larval fish, attracted by the light, are trapped when they go through the slots into the trap (see arrows on Figs. 3 and 4).

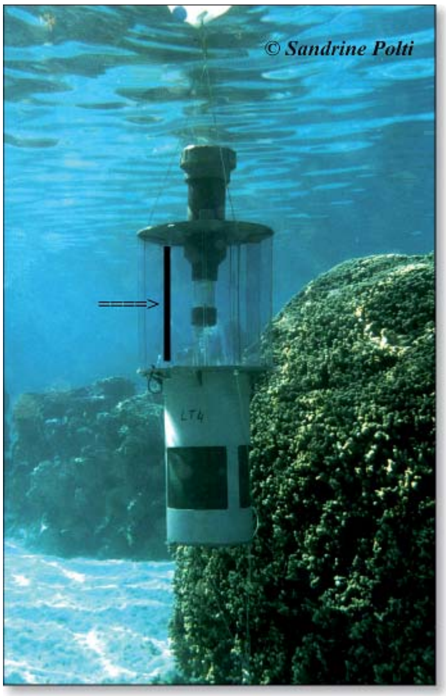

Figure 3. Light-trap, French model.

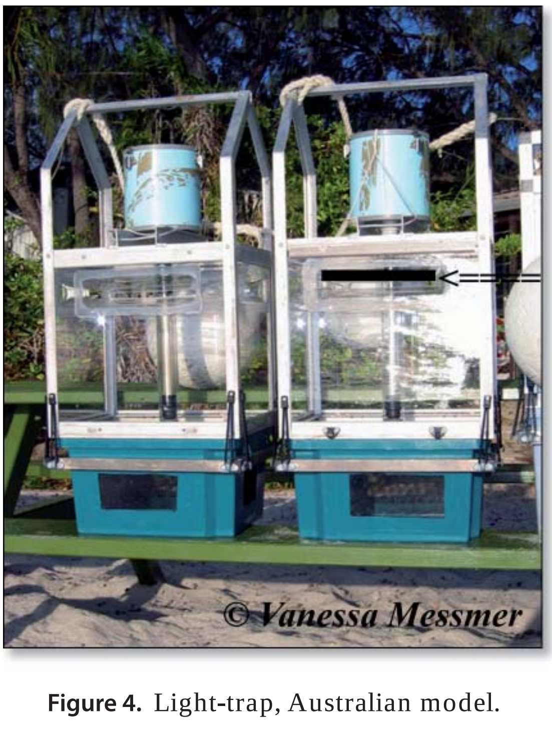

Figure 4. Light-trap, Australian model.

This technique is widely used for scientific studies because it can be set up rapidly (Watson et al. 2002). Because it does not depend on reef ridges or *hoa*, it can be used anywhere. But light-traps have their limits because the post-larvae have to find the slots (which are vertical in the French model, and horizontal in the Australian one; Figs. 3 and 4) in order to be trapped, and this reduces the trap's effectiveness. In addition, certain small pelagic fish (e.g. sardines) are also attracted to the light, and because of their horizontal swimming style, they become trapped, and then panic and die.

CARE (Collect by Artificial Reef Eco-friendly)

This new technique was recently developed by a French company (patented by Ecocean in 2002). It uses a lighted artificial reef that takes advantage of the behaviour of new recruits to trap them: their attraction to light (phototropism), their desire to come into contact with a solid object (thigmotropism) and their desire to find shelter from predators (Fig. 5). These sensory elements are important for post-larval fish, which have very acute senses during recruitment (Sweatman 1988; Lecchini 2003).

This technique has the advantages of light-trap fishing, while being more efficient and free of the problem of also attracting pelagic species. It attracts the post-larvae of reef or demersal species that are in the settlement phase. The post-larvae choose to take shelter in the artificial reef, while unwanted small pelagic fish just swim over the reef.

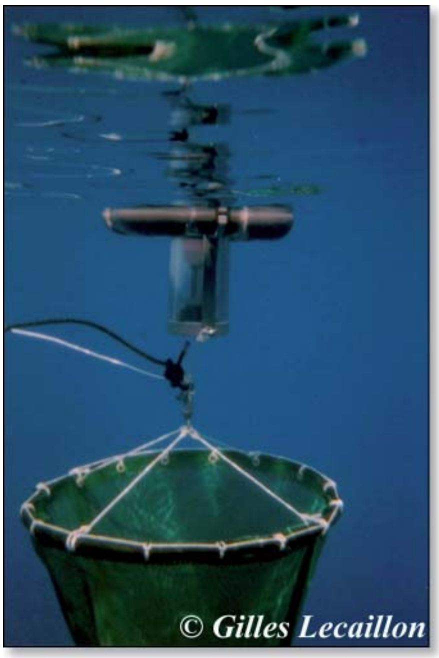

Figure 5. CARE, underwater view.

Other techniques

There are also other, less frequently used, post-larval collection techniques, not described in detail here, such as Bongo nets, SMURFs (Ammann 2004) and plankton nets pulled behind a vessel. These techniques are used by researchers to collect eggs, larvae and post-larvae, but few of them survive.

Table 1 provides a comparative summary of the four most commonly used techniques.

Notes on fishing results

Since the authors began collecting larvae, almost all the fish families (except for very rare, extremely deepwater families and large pelagic fish) have been collected at least once.

In Mayotte, *in situ* comparative trials were carried out with two types of light gear, light-traps and CAREs. The devices were set up 200 m apart so as not to interfere with each other. This experiment was carried out over a 12-night period around the new moon in June 2002. The results of this study found that the CARE trap was 78% more effective than the light-trap, with an average of 35.8 post-larvae caught per night per device, as compared with 20 post-larvae for the light-trap.

This difference can be explained by the fact that with the light-traps, post-larvae are attracted by the light but must find their way through the slots in order to be trapped and "saved" from predators; with CAREs, they take shelter in the collection net themselves after being attracted by the light. So, the CARE trap's scope of action seems to be wider. In addition, we saw post-larvae coming back out of the slots in the light-trap due to micro-currents inside the device created by the swell.

In late 2004 (from 19–24 November), the authors were able to compare the effectiveness of CAREs and *hoa* nets: 8184 post-larvae were collected in one week using three CAREs (65 species collected), compared with 537 with one *hoa* net (only 35 species collected). Some of the species from the CAREs had never been collected in nets before. *Hoa* nets did, however, prove to be more effective over the long run in terms of both catches and the diversity of species collected. Unfortunately, these data are confidential and we could not go any further with our comparisons.

The species composition of the catches made with CAREs at several sites were (ignoring catches of Apogonidae, cardinalfish):

- 10–15% ornamental fish (excluding Pomacentridae, damselfish),
- 50–60% damselfish (low-value ornamental fish),
- 20–30% food fish (in descending order in terms of abundance: Siganidae, Lutjanidae, Lethrinidae, Carangidae, Serranidae), and
- 10–20% invertebrates (shrimp, squid) and non-targeted fish (e.g. Synodontidae)

We did not take into account the large numbers of Apogonidae collected with light collection techniques. However, these species can be used for scientific studies or even, in some areas such as in the Philippines, be promoted as food fish.

Given the large variability in the abundance and diversity of species collected and in the collection sites and periods (e.g. new moon, full moon, dry season, wet season), statistically comparing collection data between projects and devices is difficult. Also, collection data are often misinterpreted. Reports of certain projects include the small pelagic species in their catch results even though they are not post-larvae. Others include the catches from extremely rare events (e.g. on the order of a million fish in one night) in their reported mean daily catches.

Market opportunities and ongoing trials

The technique used to collect this new marine resource and rear it is called post-larval capture and culture, or PCC.

The Reef Check Foundation, directed for the past 10 years by Dr Gregor Hodgson, is using larval collection techniques to find marine resource management solutions in the Philippine Islands through two of its projects.

Through know-how mainly developed by the French, post-larval fish, collected with whatever method, can now be farmed so as to produce large quantities of marketable product. The entire procedure, from collection to grow-out, is explained in a brochure produced by the Moana Initiative that can be downloaded at www.moanainitiative.org. This guide, which was funded by UNESCO through its Man and the Biosphere Programme, describes potential market opportunities for this new resource (Lourié and Lecaillon 2005).

According to numerous specialists, post-larval collection is a socioeconomic solution that can contribute concretely and rapidly to the creation of new jobs in several areas listed below.

Alternative aquarium fish farming

Here, opportunities exist mainly in developing countries such as the Philippines and Indonesia (whose current exports account for 80% of the world market). Aquarium fish farming generates foreign exchange income through exports to markets such as the USA and Europe.

The steps for post-larval collection, grow-out and shipping are very well known and several trials have been successfully carried out in the Comoros, Hawaii, French Polynesia and the Philippines. On average, about three months of grow-out are needed to get fish of a "small" marketable size (less than two months for Pomacentridae but more than four months for Labridae and Chaetodontidae).

This new procedure makes it possible to produce immunized and disease-resistant specimens, thereby bringing a certain level of quality to a declining market for wild product, for which the mortality rates range up to 90% between the points of collection and final purchase (Schmidt and Kunzmann 2005).

Currently, one private enterprise exists in French Polynesia and others will be created soon in Asia. A project also began in Hawaii in late 2006 with funding from the US National Oceanic and Atmospheric Administration.

Supplementary multi-species aquaculture

Here again, opportunities exist mainly in developing countries. This activity can provide ciguatera-free protein for local consumers, as well as product that could be destined for the Asian live fish market.

It should be noted that most food fish families have "large" (>2 cm) post-larvae, which makes it possible to produce meal portion-sized specimens after about six to eight months of in-cage grow-out. Currently, trials are underway in the Philippines, in collaboration with Reef Check and the Municipality of Tubigon (island of Bohol), as part of the Marine Aquarium Market Transformation Initiative (MAMTI). Initial results for in-cage grow-out of Siganidae and Lethrinidae indicate growth coefficients that were 1.8 times greater than those in land-based tanks.

Another project underway (September 2006–September 2007) in the Philippines, with funding from the US-based National Fish and Wildlife Foundation, is attempting to transfer knowledge about larval harvesting techniques to local communities. This project has the unanimous support of various fishers, farmers and decision-makers. The farm belongs to a local non-governmental organisation (NGO), Feed the Children, and the operational project is part of a Coastal Resource Management Plan set up by the Municipality of Tubigon. This project also has the goal of repopulating a local marine reserve with some 10,000 juvenile fish.

Some developed countries may also be interested in collecting post-larvae, particularly in order to study the growth rates of certain target species before attempting to improve particular reproduction phases (e.g. increasing gamete production rates, limiting stress, etc.) Finally, biotechnical companies could be interested in the bio-molecules contained in oceanic post-larvae, which have low parasite levels.

Managed repopulation with native species

There is increasing interest in repopulating native stocks. Several repopulation programmes — including a programme underway in Fiji (CRISP, Coral Reef Initiative South Pacific; www.crisponline.net), one being tested in marine protected areas (MPA) in the Philippines, and another that has been completed in French Polynesia — demonstrate the enthusiasm for this procedure. It offers the possibility of repopulating degraded or overexploited zones with native fish that have not been genetically modified.

Some MPAs, such as in the Philippines (Russ and Alcala 2004), have taken a long time to recover their initial marine populations. Repopulation is designed to accelerate the natural process of growth in populations after a halt in exploitation and to select, as best as possible, those species to be reintroduced so as to fill the various ecosystem niches, such as detritivorous species and herbivores. The results at this time are encouraging but very few studies have been completed. The projects underway in Fiji and the Philippines will lead to more concrete results.

It should be noted that species that are not appropriate for repopulation (e.g. predators such as trevallies and groupers) can, nevertheless, be of interest to local fish farmers, so PCC can still be useful for those species.

A pilot project similar to those undertaken in tropical settings was completed in the Mediterranean in September 2006 (Moana Initiative 2006). This project, funded by the Hérault (France) General Council, was designed to test, in a temperate setting, the technical feasibility of reintroducing grown-out larvae on artificial reefs. Given its success, a wider project is anticipated for 2008.

Many questions have been raised and will continue to be raised about marine repopulation. These are just the first, very promising, steps for this activity.

Bio-monitoring

A recent survey showed that estimates of species biodiversity through genetic identification of marine animal larvae are more precise than those from visual census surveys of adult specimens in the wild, particularly for species with dispersive oceanic larval phases (Barber and Boyce 2006). In this study, 50–150% additional manta shrimp species were found through analysis of the larvae's genetic "bar codes".

Since areas of high diversity are major conservation targets, collecting post-larvae and examining them genetically should make it possible to identify new species.

In addition, multi-year recruitment studies using collected post-larvae of demersal species could contribute knowledge about the population dynamics of such species and make it possible to predict variations in stocks. Such predictions could be made well before those based on traditional methods of assessment that rely on counting landed fish. Today, fishery management decisions are largely based on the annual catch statistics maintained since 1950 by the Food and Agriculture Organization of the United Nations. When catches from year to year are stable, it is supposed that an equilibrium between stock renewal and the effects of fishing has been reached. But according to Loury (2005) of l'Institut de Recherche et Développement (IRD) in Noumea, New Caledonia, this assessment method has come under strong criticism because, in a great number of cases, the collapse of a stock has been preceded by a period of stable production.

Finally, fishing for post-larvae around a "model" MPA should make it possible to compare the effectiveness of MPAs versus non-protected areas or one MPA versus another.

Comparative table to assist in selecting collecting gear

It is difficult to obtain precise comparative statistics on the effectiveness of the various post-larval collection devices. For example, as mentioned, most collection data for crest and *hoa* nets are confidential. Nevertheless, all the techniques work. Each has its own advantages and disadvantages, which are summarized in Table 1. It should be noted that there are different versions and add-ons for each type of device, which could affect the relative advantages of each device and alter the scores given in the table.

These comparisons have been made on the basis of the authors' work in the field and their personal data as well as published and unpublished data. The authors have worked at least once with every one of the techniques described in this table and have more than eight years of experience in larvae collection. The authors have assessed each of the four devices on a scale of 1 (excellent) to 4 (poor) for each of the following attributes and uses:

- Flow studies of larvae entering the lagoon, which yield scientifically valuable data.
- Ease of installation; that is, the time and number of people needed to set up the device, etc.
- Diversity of species and families caught.
- Collection of unwanted species (plant and / or animal).
- Source of stress and / or physical damage to larvae, mainly because of agitation in the environment and / or the presence of predators or algae in the collection containers.
- Abundance of larvae collected (excluding any non-reef species such as sardines and other small pelagic species that are occasionally collected in large numbers but are not post-larvae).
- Cost of fishing gear.
- Universality of the device; that is, the different types of places (ocean, lagoons, tidal pools, outer reef slopes, mangroves, etc.) where it can be set up.
- Ergonomics of the device, which is important for fishers who use it on a daily basis (e.g. accessibility, fatigue caused by fishing, whether the collection time depends on sea conditions, need for diving, transport, etc.).

Table 1. Summary evaluation of post-larval collection device attributes.

	Flow studies	Ease of installation	Diversity	Unwanted species	Source of stress	Abundance	Cost	Universality	Ergonomics
Crest net	1	4	3	4	4	3	2	3	4
Hoa net	2	2	1	3	3	1	1	4	2
Light trap	4	2	3	3	1	3	3	1	3
CARE	4	1	2	2	1	2	2	1	1

1 = excellent; 2 = good; 3 = acceptable; 4 = poor

This table, the scores in which are solely attributable to the authors, makes it possible to choose which post-larval collection device to use, depending on the situation in the field and the desired results.

The CARE technique was developed by the authors after they had used the other techniques. The main reasons for this were to develop a tool that could be used anywhere in the world, in both tropical and temperate settings whatever the tide levels, and in areas where nets cannot be used (outer slopes); and to make it possible to collect and grow out post-larvae under the best possible conditions; that is, to minimize stress on them so as to obtain a high-quality live product.

Conclusions and prospects

Use of post-larval collection and grow-out techniques is growing. Nevertheless, apart from aquaculture, some of its applications, such as repopulation, still require years of research and more data collected over longer periods of time in order to better understand the complex recruitment processes on a worldwide scale. As is often the case with innovative techniques, the main limiting factor is the lack of trials carried out with this tool. For this reason, the authors believe that it would be useful for NGOs and research laboratories to integrate this new technology into their research and monitoring programmes. This is already the case for the EPHE laboratory in Perpignan, France (under the direction of Mr Galzin), the American NGO Reef Check Foundation, and IRD (COREUS group).

It is important to note that certain techniques that have been mastered for reproducing marine aquaculture species or for massively repopulating a single species, as in Japan, required decades of research and huge investment.

Efforts will also have to continue so as to inform all those involved with the sea — local authorities, fishers, fishing cooperatives, public aquariums — of the existence of this tool. This will require greater international collaboration. The research laboratories and private agencies involved in this concept have to unite in order to better understand the recruitment periods of families of interest so as to optimize the use of PCC.

Finally, it is vital to continue work on optimising the design of collection gear so as make it useable by all, including those in developing countries. In particular, integrating sound or pheromones so as to increase effectiveness (i.e. catch per unit of effort) are paths to be explored.

A UNESCO-funded publication, which presents the various "eco-jobs" that are possible from the collection of marine post-larvae (Lourié and Lecaillon 2005), has been sent to all the "Man and Biosphere" reserves in the inter-tropical belt. Preparation of a new publication funded by the Total Corporate Foundation for biodiversity and the sea is underway and is planned for release in the summer of 2007.

The use of post-larval collection techniques can be an alternative to certain types of over-exploitative activities in marine settings, particularly in developing countries, where, for the most part, such activities are managed as though resources were unlimited.

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