

Summary of regional survey of fry/fingerling supply for grouper mariculture in Southeast Asia

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Introduction

The demand for, and value of, live reef fish for food, particularly the groupers (Family Serranidae), have grown markedly in the last two decades in parts of Southeast (SE) Asia. For 1997, the volume of live fish traded in the region was estimated at about 53,000 metric tonnes (t), comprised of approximately 30,000 t of grouper (based on figures calculated for Hong Kong and assuming that Hong Kong (and China) represents about 60% of regional trade) (Johannes and Riepen 1995; Lau and Parry-Jones 1999). Approximately two-thirds of this demand is met by capture fisheries of market-sized fish, the rest is from 'cultured' fish. Most of these cultured fish are grown out from smaller wild-caught fry/fingerlings or juveniles, although Chinese Taipei also produces hatchery-reared fry.

There are three issues that must be addressed if the trade in this family of reef fishes is to remain viable in the future. The first is the vulnerability of the groupers, like other large and slow-growing reef fishes, to overfishing, as well as indications that in many areas overexploitation of groupers has already occurred (e.g. Cesar et al. 2000; Sadovy and Vincent in press). The second is the use of destructive fishing practices, especially cyanide, and the threats these pose to habitats on which reef-associated species depend for shelter and food and other reef inhabitants (e.g. Johannes and Riepen 1995; Barber and Pratt 1997). The third concern is over human health; as wild sources of market-sized fish have become depleted within SE Asia, buyers have looked ever further into the Indian and Pacific Oceans for new supplies and, unwittingly at first, brought back to major consumption centres fishes that bear naturally-occurring ciguatoxins (Sadovy 2001). There is, therefore, an urgent need to develop alternative sources of grouper to take pressure off wild stocks, to reduce the use of cyanide-caught fish and to provide safe, ciguatera-free, fish.

As a partial solution to these problems, as well as a means of generating foreign exchange and enhanc-

ing livelihood options in coastal communities, there is a keen interest in expanding and improving the mariculture of grouper and other high-value, marine species. Presently, however, in SE Asia, grouper mariculture is not well-organised, is largely based on the grow-out of wild-caught grouper seed (i.e. fry, fingerlings and juveniles) which are often insufficient and unreliable in quality and quantity to meet demand, and is confronted by a series of problems (disease, mortality, poor feed conversion, etc.) that significantly hinder its expansion (Leong 1998; Napitupulu 1999; Quinitio 1999; Chao and Chou 1999; Ruangpanit 1999; Yashiro et al. 1999; Yongzhong 1999; Johannes and Ogburn 1999). The most pressing of these problems is the fishery of wild-caught seed that may be unsustainable at current levels (Ahmad and Sunyoto 1990; Chou and Lee 1997; Sadovy and Pet 1998; Quinitio 1999).

There is clearly a need, therefore, to examine current mariculture practices more closely in terms of capture, trade and utilisation patterns of grouper seed destined for mariculture grow-out, to determine how better to focus mariculture development in the region and to assess the respective roles of hatchery and wild-capture in supplying seed of the appropriate quality. A comprehensive survey and review of available data/literature on seed-capture from throughout the region was carried out over 18 months from summer 1999. The aims of this study were to survey the species and sizes of juveniles taken, species preferences, capture practices, transport routes, major sources of mortality, and other details of the practice of wild grouper seed harvest and trade in relation to mariculture. This information should allow a better understanding of the constraints, problems, needs and bottlenecks in the wild fry and fingerling supply component of this rapidly developing industry.

Methods

The survey included the principal economies in Southeast Asia where significant grouper capture,

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culture or trade is practised commercially for fry/fingerlings/juveniles. The survey included visits, interviews through questionnaires, literature review and personal communications, including telephone interviews and letters. The economies surveyed were: Thailand, Vietnam, Philippines, Indonesia, Malaysia, People's Republic of China (PRC), Hong Kong Special Administrative Region (HKSAR) and Chinese Taipei. The broad scope of the country surveys precluded a comprehensive analysis of any one country. However, the focus on all levels of seed fishery, trade and culture across eight economies and over a relatively short time period allow a unique insight into key issues and the identification of major problems of, and possible solutions for grouper seed supply.

Results

About 180 interviews were conducted, and indicated that approximately 15 grouper species are cultured in SE Asia. Dominant species tend to vary somewhat regionally. However, overwhelmingly, the most consistently abundant species (synonyms commonly used in the aquaculture literature are included) captured wild for culture and also reared in hatcheries are *Epinephelus coioides* (= *suillus*) and *E. malabaricus* (= *salmoides*). Other important species are *E. bleekeri*, *E. akaara*, *E. awoara* and *E. areolatus*. Also cultured in small amounts are *E. amblycephalus*, *E. fuscoguttatus*, *E. lanceolatus* (although hatchery production of this species has recently increased, see Chan, this issue), *E. sexfasciatus*, *E. trimaculatus* (= *fario*), *E. quoyanus* (= *megachir*), *E. bruneus* (= *moara*), *Cromileptes altivelis*, *Plectropomus leopardus* and *P. maculatus*. Note that *E. tauvina* is often referred to in the literature but it is very probably a misidentification of *E. coioides* (or *E. malabaricus*) as it has not been confirmed from most economies in the region, with the exception of Chinese Taipei (Heemstra and Randall 1993). Moreover, reports of *Epinephelus akaara* caught in central and southern Vietnam may be misidentifications of *E. fasciatomaculosus*. Although many results are semi-quantitative or anecdotal in nature, the following section was based on a clear consensus and on strong patterns that arose from the information collected.

Discussion and recommendations arising from survey results

Availability, capture and trade of grouper seed destined for mariculture grow-out in SE Asia

Grouper seed are caught in coastal areas, particularly around seagrass, mangrove and shallow brackish-water areas near river mouths and estuaries, as well as in tidal pools and around reefs

throughout the region. They are collected using a wide range of fishing gears by small-scale fishers. Often the catch has a strong seasonal component, at least for the smallest size classes of fry, while fingerlings and juveniles are often taken year-round. Although a wide range of species is cultured region-wide, most are of the genus *Epinephelus* and by far the greatest volumes cultured, from both wild and hatchery sources, are *E. coioides* and *E. malabaricus*. Seed are traded both domestically and internationally, often through a complex network of buyers, middlemen and exporters.

The sizes of grouper seed caught and traded vary between 1 and 25 cm, i.e., from the moment of settlement out of the plankton to well over one year of age. Most capture, however, focuses on fish up to about 15 cm (about one year of age; sexual maturation occurs above 25 cm TL in *E. coioides*). The smallest size classes of fish, 1–2 cm fry are caught by the millions over short periods each year, while smaller quantities of larger size classes are typically taken over more extended periods. There is often a tidal or lunar component to catches, especially for the smallest size classes.

Gears used to take various sizes and species of seed were of about 8 different categories: large fixed nets (e.g., fyke nets); traps and shelters; hook and line; scoop/push nets; artificial reefs; fish attractors; tidal pools and chemicals. Some gears, especially of the 'fish shelter' type, have been specially developed to take fish seed and show potential for taking seed sustainably. Other gears take high levels of bycatch, produce poor quality seed (or cause high mortalities) and some may be damaging to the habitat. As examples of destructive gears, those dragged across the substrate, like the scoop net, can cause habitat damage. For this reason scoop nets are controlled or banned in several places. Cyanide, although not widely reported for seed capture, is also destructive of habitat. Lights are sometimes used to enhance the catches taken in fish shelters but seed mortality with lights is higher than when no light is used. High mortality is also associated with fyke nets (these are banned in some places). A second concern with fyke nets is that single units can take a significant amount of seed from a given area leading to possible social inequalities (see Johannes and Ogburn 1999, for discussion). Also worthy of attention are gears that take high levels of bycatch, much of which may be wasted. A 12-month study in Indonesia demonstrated that a very high percentage of total catch taken in artificial reefs (*gangos*) are non-target species and the method of harvesting the *gango* leads to mortality in much of the bycatch (Mous et al. 1999). Although such high bycatch may not apply where the *gango* is widely used (Philippines),

or may vary with season, it is clear that a better understanding of gear operation in general could lead to less wastage and mortality. For many other gears, and during certain periods, bycatch can be high. While some of this bycatch may be used for fish feed, its possible impact on local resources cannot be ignored. As an example, wasteful bycatch of small rabbitfish (*Siganus* spp.) juveniles, most of which perishes, was often high, yet this species is a favoured food fish at larger sizes. There is clearly a need to examine the function of selected fishing gears in terms of waste and damage.

The volumes of seed caught each year and cultured/traded regionally, as indicated by interviews, trade figures and by crude calculations, exceed hundreds of millions of individuals. The greatest volume is of the smallest size classes (1–3 cm), the catch of which during peak seasons can reach several tens of thousands by one unit of gear in one night by one fisher (e.g. fyke net). Even larger sizes of fish are being taken in massive numbers region-wide each year. It is sobering to realise that the amount of seed not untypically produced in the region's hatcheries (outside of Chinese Taipei at least) in one year (i.e. 20–80,000 fry), can be the same as the catch of a single peak night by one fisher using one gear!

If we calculate the numbers of seed that go to producing a particular volume of market-size fish, the numbers are astonishing and strongly suggest crude and wasteful culture practices. To produce the regional estimate of 23,000 t of table-size live fish from culture annually (roughly 10,000 t of which is included in the regional LRFT volume provided above), about 60 million seed are necessary. Yet, crude estimates indicate that hundreds, maybe thousands, of millions of fingerlings, are traded annually in the region implying enormous mortality and wastage of biomass. The magnitude of such wastage, which does not include mortalities following capture and transport to demand centres, calls for examination of its causes and a significant reduction for better use of wild resources. Given the global depletion in marine fisheries, it is no longer acceptable to consider such high levels of mortality as inevitable or unavoidable.

Mortality levels were often exacerbated when demand from exporters/buyers was high. This was because large volumes of seed were caught in a short time, less care was taken in capture, more destructive gears were used and there was generally less interest in delivering animals in good quality. High mortality levels were also noted when the price of market-sized fish was low, producing a situation of reduced interest in local cul-

ture and more interest in rapidly collecting and shipping out large volumes of seed.

The trade in grouper seed throughout SE Asia is complex and extensive. Major trade routes for grouper seed involve Hong Kong, China and Chinese Taipei as major destinations. Major source countries are Philippines, and Thailand, and to a lesser extent Indonesia, Malaysia and Chinese Taipei (about two-thirds of production from Chinese Taipei is based on the grow-out of hatchery reared fry; note also that Chinese Taipei exports both hatchery produced seed and imports and re-exports wild-caught seed).

Some trade is probably illegal because of a concern in some countries about keeping adequate numbers for local use, or of importation of disease with the seed (e.g. between Malaysia and Hong Kong, Chinese Taipei and Thailand, from Johor (Malaysia) through Singapore to Chinese Taipei, between Myanmar and Thailand, and from Chinese Taipei to the PRC). Some trade from Vietnam to the PRC may also be illegal, but this could not be substantiated.

Other, possibly more minor, trade routes identified were from Indonesia and the Philippines to Brunei, and from PRC to Hong Kong. Sri Lanka has supplied seed to Hong Kong. Seed also enters the PRC from Thailand and Chinese Taipei through Hong Kong. In this survey, note that the roles of Singapore, Sri Lanka, Japan and Korea have not been included although they play a minor part in various aspects of the live reef fish trade. The absence of detailed trade data makes it difficult to fully evaluate trade routes.

Potential for wild-caught juveniles to supply mariculture grow-out in SE Asia and implications of wild seed capture for natural stocks of both target and non-target species

Despite the enormous numbers of seed caught compared with numbers of fish grown out, there is a widely acknowledged shortage of grouper seed and strong indications that in many areas wild seed supplies are declining, especially those that have been long and heavily harvested. Reasons for the declines cannot be evaluated without careful, controlled studies, but may include, one or a combination of the following: overfishing of grouper adults, adult and seed, habitat destruction, destructive fishing techniques, pollution, and high export (i.e., market) demand. Several examples indicate that real declines in seed supply have occurred with the virtual disappearance of seed of popular species like *E. akaara* from the northern sector of the South China Sea (also see Johannes

and Riepen 1995). Hong Kong, Chinese Taipei and China, the major demand centres for live fish, no longer have viable grouper seed fisheries.

It is noteworthy that the fishery and trade for grouper seed have received such limited attention despite the interest taken in some areas in seed fisheries for other commercially important fishes such as milkfish (*Chanos chanos*) and rabbitfish (*Siganus* spp.). Apart from a few restrictions on exports (e.g., Vietnam, China and Malaysia), controls on grouper seed harvest and trade are limited despite declines noted in several places. Clearly there is an urgent need for more attention to be given to this fishery. It is suggested that well-designed, long-term studies be established in a few key areas to examine the fishery over time, inclusive of socio-economic components, market factors, habitat and adult fisheries of seed-producing species of interest, i.e. a more holistic approach that acknowledges the links between adults and juveniles. In the meantime, it is also clear that a precautionary approach to grouper seed harvest is needed if significant seed are to persist well into the future. "For too long fisheries and aquaculture have been treated as sectors in isolation, a practice that has ignored important linkages and externalities" (Williams 1996). The effect of aquaculture, including wild seed capture, on world capture fisheries in general is only recently receiving serious attention (Naylor et al. 2000).

It is important to understand the basics of the reproductive biology of the groupers to better understand the kinds of questions we need to be asking regarding the sustainability of the capture of grouper seed. Groupers are pelagic spawners — the eggs are released into the plankton, where they hatch and develop into larvae before 'settlement' in shallow coastal areas. Millions of eggs are produced by individual females when they spawn and there is clearly a high natural mortality of eggs and/or larvae and, possibly, of small post-settlement fish since, on average, each female will produce two individuals that survive to breed in the next generation. What is not clearly understood is when the bulk of this natural mortality occurs. If it remains high after settlement, then some removal of fry or fingerlings for culture may have little impact on adult stocks since the probability of any one seed surviving is very low. If, on the other hand, natural mortality drops quickly after settlement and before their capture, then seed removal could have a significant effect on future adult numbers. In the latter case, such a high volume capture fishery may not be sustainable (Sadovy and Pet 1998). The critical question is how quickly do early mortality rates decline to adult levels?

From what we understand about post-settlement mortality, removal of fingerlings and juveniles could have a significant impact on adult stock. Our country reviews indicate that there is a substantial fishery, and demand, for fingerlings and juveniles in the 5–10 cm range, many of which may have entered the adult fishery had they not been captured. Juvenile and adult fisheries of target fisheries thus seem inextricably linked.

To safeguard regional supplies we should not wait until we can gauge sustainable harvest levels for seed fisheries before we regulate and manage them, especially those for seed in the larger size classes. There is also a need to protect the adult stock, and especially the spawning aggregations, where the seed are produced (Johannes 1997). Given the likelihood of high natural mortality in the smallest settling fish, several workers have already proposed fisheries for very early post-settlement, or even pre-settlement, seed (e.g. Dufour 1999) as a way exploitation that does not affect long-term persistence of the resource. These initiatives are to be lauded, but I caution that we still do not know enough about these very early life history phases to know how much harvest of which size classes is advisable. There is a need, therefore to exercise the precautionary principle in developing such approaches on a wide-scale basis.

Given the apparent insufficient supply of seed for regional demand, unsustainable seed capture practices and apparent widespread declines in seed resources, I recommend strongly that export of wild-caught seed throughout the region be banned. This measure, in various forms, is already in place in several economies. It is the best single measure to address many of the most pressing problems in the grouper culture industry in the region. It will help to preserve seed for source countries to culture locally (for example, in Thailand and the Philippines local seed supply is probably sufficient for local demand but high exports of grouper seed periodically produce local seed shortages). It should also significantly reduce the risk of disease transfer around the region, place responsibility and accountability for local resources in the hands of local governments and stakeholders, and enhance the economic value of local resources to the source country through the value-adding process of grow-out to market-size. Moreover, it is very likely that if seed resources are cultured in source countries, there will be greater incentive to develop capture methods that make better use of the resource by producing appropriate sizes of better quality seed in a non-destructive or wasteful way. Seed transport is stressful; less mortality will occur during transport to local culture facilities than during the longer transport times

usually involved in export to other countries. Local seed will also be better adapted to local conditions. Finally, reduced trade should restrict the introduction of genotypes around the region into areas where they do not occur naturally

Scope and potential of wild-caught versus hatchery produced fry in grouper culture and coastal livelihoods

The wild-capture of grouper seed is expected to persist into the foreseeable future. Suitable areas for grow-out (i.e., where there is good water quality) to market-size and the production of seed by hatcheries have consequences for coastal communities and grouper demand and supply regionally. For example, successful hatchery production in Chinese Taipei depressed demand and prices in countries that supply wild seed, while deteriorating water quality has recently led to reduced demand for seed for grow-out in a major demand centre, Hong Kong. With the exception of Chinese Taipei, there are no strong indications that hatchery production is close to meeting demand for seed and for markedly increasing the diversity of cultured species in the short-term. It is, therefore, important to examine both the implications of wild-capture of seed and the consequence(s) of hatchery production in relation to regional grouper seed supply and their possible social and economic implications. It is also important to determine whether wild sources of grouper seed could be used less wastefully.

Aquaculture is defined by the Food and Agriculture Organization (FAO) of the United Nations as: "...the farming of aquatic organisms, including fish farming, implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated..." The key here is the word 'enhance'. In examining grouper culture it needs to be considered whether current grouper mariculture activities and practices indeed enhance marine resources and address regional objectives for mariculture development.

The contribution to production of market-size grouper through culture (compared to wild-caught market-size fish) is significant in SE Asia. Cultured fish have the potential to take pressure off wild stocks, be a source of safe-to-eat (ciguatera-free) fish, and provide livelihood options in coastal communities (Cesar et al. 2000). However, to effectively fulfil this role, the culture sector needs to ensure that it recognises and rewards good practice, as well as to carry out quality control on production and culture conditions. Moreover, when culture is

based on the grow-out of wild-caught fry or fingerlings, such capture must be maintained at sustainable levels. Towards such ends, a certification system (along the lines of the Marine Stewardship Council) could be introduced to encourage sustainable harvest, and internationally accepted guidelines, such as HACCP (Hazard Analysis Critical Control Point) and the FAO International Code of Conduct for Responsible Fisheries, adopted respectively to ensure fish are safe for human consumption and are taken sustainably.

Turning to the role of hatchery production in relation to the earnings of coastal communities, we need to ask several questions. How will hatchery production of grouper seed address issues such as price control, control of the means of seed production, better use of existing (biological) resources, access to good quality fry, species diversity for the live fish market, a sustainable culture sector and community earnings from seed capture and culture? Will hatchery produced seed be widely available to small-scale culture operations and to what extent might the private sector be able to control prices of hatchery produced fry? Moreover, what controls might there be on hatchery production to avoid over-production and low prices due to gluts? In Taiwan recently, for example, business interests have been keen to see grouper fry overproduction (in some seasons) purchased for 'restocking' (usually done as large public events), the benefit of which, for fishery enhancement, is questionable at best, and certainly unproven for groupers (see "Editor's mutterings", this volume).

In terms of control of prices and means of production, hatcheries have the potential to take the former away from traders/middlemen and the latter away from the fishers and their communities. A recent case in point is the successful hatchery production in Chinese Taipei that has had a marked effect on demand for grouper seed. Exporters and importers were generally not enthusiastic about hatcheries because of concerns that the increased production would diminish the value per fish. The exception to this position was from a businessman who took a long-term interest in the stability of seed production, rather than considering only immediate business goals and constraints. On the other hand, if fry capture is largely replaced by hatchery production, fishers may well find that grouper seed capture no longer provides much-needed income.

Hatchery production also has other advantages and disadvantages. Advantages are the potential for high volume production of standard and good quality seed, a diversification of the species available for culture (especially high value species for which seed

are not readily available) and reduction of pressure on wild stocks. However, given the low volumes currently produced (Chinese Taipei is an exception for a few species) and difficulty in procuring broodstock in many cases, the potential for large-scale production of a diverse range of high quality reef fishes is unlikely to materialise in the near future. Moreover, the most successful culture model for grouper, that of Chinese Taipei is unlikely to be one that is readily transferable, at least not in its complete form, to coastal communities. Its success is in organisation and specialising, not in reducing mortalities. It, therefore, seems likely that large-scale hatchery production will be limited to government institutes and private companies.

There are many tens of thousands of fishers in SE Asia who practice grouper seed capture for part or much of the year. There is, therefore, a compelling reason to ensure that coastal communities benefit from small-scale seed fisheries, and promote low intensity grouper culture operations, while ensuring that resources (both the seed and habitats on which they depend) are properly managed. Government assistance at the community level is also going to be necessary to improve the possibility for fishers to move into culture operations, assist them in breaking away from relationships of indebtedness that characterise some communities, and provide cheap, good quality hatchery-produced seed to make up shortfalls from healthy, but limited, wild seed sources.

Recommendations in respect of future developments of mariculture in the region arising from the survey results

1. Prohibit all export of wild-caught grouper seed. Grouper should be cultured to market-size within source countries.
2. Develop and implement careful and controlled studies on selected grouper seed fisheries whereby information is integrated on catches, socioeconomics, market forces, associated adult fisheries and habitat.
3. Reduce or eliminate the use of destructive (i.e. of habitat) or particularly wasteful (i.e. producing high mortality in, or damage to, target and/or non-target species) fishing gears or methods for grouper seed. Conduct studies on preferred gears to ensure that their operation does not incur unnecessary waste or damage.
4. Ensure better use of existing resources and reduce wastage of wild grouper seed biomass (and bycatch) arising from unnecessary mortality from harvest, transport and culture.
5. Examine, scientifically, the possibility of focusing the seed capture fishery on life history stages with the highest levels of natural mortality. Also, improve the means of nursing this phase to one suitable for widespread, small-scale culture. One possible approach might be to establish 'nursing' stations in areas where there is a seed capture fishery and culture operations.
6. Develop management approaches to protect key seed settlement and nursery habitats, such as mangrove areas and seagrasses in river mouths and estuaries, and protect the production of those seed by safeguarding the spawning adults (i.e. in spawning areas or spawning aggregations).
7. Provide government assistance in terms of incentives or low-interest loans to enable small-scale fishers to enter the culture sector to produce low intensity, high quality, cultured grouper, in suitable grow-out areas. Provide assistance in breaking relationships involving indebtedness.
8. Develop certification systems for quality products and address food safety issues; ultimately, high quality, certified, fish should command higher prices. Actions: (a) distinguish between hatchery-produced and wild-caught seed; (b) identify seed of good quality through biochemical testing; (c) identify good mariculture practices; (d) identify cyanide-free seed and ciguatera-free market-size fish; (e) encourage food safety guidelines, such as HACCP. Classify 'live fish' as a food item in Hong Kong.
9. Examine the role of hatcheries in supplying grouper seed for culture and how these might best complement the objectives of grouper culture development in the region.
10. Promote the application of the precautionary principle in the exploitation of grouper resources and adopt the FAO International Code of Conduct for Responsible Fisheries.

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Opportunities and constraints of grouper aquaculture in Asia

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Abstract

This study examines the future potential and possible pitfalls of grouper aquaculture in Asia. This culture could contribute to the protection and sustainable use of coral reefs and associated ecosystems by supporting a transformation of current destructive fishing practices — cyanide fishing, harvesting of spawning aggregations, and so on — to an economically viable and environmentally friendly live reef food fish business. Grouper aquaculture is one of the few options to achieve this transformation. And it could create jobs and income for rural and coastal populations and, thus, indirectly feed poor coastal communities. It would also bring in foreign exchange. Yet, aquaculture has so far mainly benefited owners of sufficient capital. And as groupers are piscivores, successful grouper aquaculture may push up the demand for trash fish, so that fish prices for the poor might go up. Also, if grouper aquaculture leads to lower prices for groupers, demand might increase. At the same time, it is argued that piscivore aquaculture should not be stimulated in the first place because of current levels of overfish-

ing, unless applied research can alter the food conversion factors to levels similar to those of herbivorous fish. Additionally, grouper aquaculture would rely heavily, at least for the time being, on catching wild breeders and, to some extent, also on catching wild fingerlings. Such a practice is only sustainable if very well managed.

Given these pros and cons of grouper culture, a cautious approach is needed, consisting of four tracks.

First, research is needed. Currently, the food conversion factor for grouper culture is such that large amounts of trash fish are needed, and stimulation of the sector would only increase this demand. Also, mortality of cultured fingerlings is still high and for most species, breeding is not even economically viable. Besides, there are disease problems that will only grow once the sector is further developed. A close relationship between the industry and the aquaculture research community — nationally, regionally and globally — is needed in order to solve biological problems.

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