

FINAL REPORT

Regional survey for fry/fingerling supply and current practices for grouper mariculture: evaluating current status and long-term prospects for grouper mariculture in South East Asia

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Final report to the Collaborative APEC Grouper Research and Development Network
(FWG 01/99 revised)

December, 2000

Additional information and comments on this report would be welcomed by the author.

Suggested citation for the report:

Sadovy, Y. (2000). Regional survey for fry/fingerling supply and current practices for grouper mariculture: evaluating current status and long-term prospects for grouper mariculture in South East Asia. Final report to the Collaboration APEC grouper research and development network (FWG 01/99). December, 2000.

A. 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 Southeast (SE) Asia. Most of this demand is met by capture fisheries of market-sized fish. However, there are three issues related to grouper fisheries that need to be addressed if the trade in this family of reef fishes is to remain viable in the future. The first is the growing concern over the vulnerability of the groupers, like other large and slow-growing reef fishes, to overfishing and indications that in

many areas overexploitation of groupers has indeed occurred (e.g. Sadovy, 1997; Cesar et al., 2000; Sadovy and Vincent, in press). The second is the use of destructive fishing practices, especially the use of cyanide, and the threats these pose to habitats on which reef-associated species depend for shelter and food (e.g. Johannes and Reipen, 1995; Barber and Pratt, 1997). The third concern is one of 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 ciguateras (Sadovy, in press). For example, in Hong Kong in 1998, hundreds of people came down with ciguatera after a large live fish carrier vessel returned to Hong Kong from the western Pacific with a contaminated shipment. Since live fish are not considered to be 'food' in Hong Kong (under the law only fish that are dead are considered to be food), consumers are not well-protected from ciguatera in this major consumption centre for live reef fish. There is, therefore, an urgent need to develop alternative sources of grouper to take pressure off wild stocks, to reduce the use of cyanide-sourced fish and to provide safe, ciguatera-free, fish.

As one potential solution to these problems, as well as a means of generating foreign exchange and enhancing livelihood options, 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-organized, 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 confounded by a series of problems that hinder its expansion (Leong, 1998; Napitupulu, 1999; Qunitio, 1999; Chao and Chou, 1999; Ruangpanit, 1999; Yashiro *et al.*, 1999; Yongzhong, 1999). The supply of wild-caught seed for grouper mariculture can also involve wasteful bycatch and destructive fishing practices (Sadovy and Pet, 1998; Johannes and Ogburn, 1999; Mous *et al.*, 1999). Moreover, there appear to be a number of additional problems, such as those of disease transfer resulting from international trade in seed, and wasted biomass from high mortality rates in capture and culture that represent further obstacles to the sustainable and healthy development of grouper culture. Positive steps to address many of these issues are being made by the Network of Aquaculture Centres in the Asia Pacific (NACA) and its partners (<http://www.enaca.org/>).

The most pressing problem, however, appears to be the shortage or, and reliance on, wild-caught seed. Not only may wild-capture be unsustainable at current levels (Ahmad and Sunyoto, 1990; Chou and Lee, 1997; Sadovy and Pet, 1998; Qunitio, 1999) but it could also compound the overfishing of grouper adults by removing fish that might otherwise survive to reproduce and supplement adult stocks. On the other hand, despite many years of research and many attempts at large-scale hatchery production of grouper seed, there is only one economy, Chinese Taipei, that is currently able to produce grouper seed at commercially viable levels, albeit for only two species, the 'green' groupers, *Epinephelus coioides* and *E. malabaricus* (note, however, the recent success with the Giant grouper, *E. lanceolatus*, also in Chinese Taipei). The hatcheries that produce these species are private hatcheries and there is no obvious small-scale means of transferring the complete hatchery model (i.e. from spawning to grow-out) of Chinese Taipei to most communities that currently culture grouper. This latter point is important in examining the role of hatchery, versus wild, production of seed in the development of culture in many of the coastal regions of SE Asia.

There is clearly a need to examine current mariculture practices more closely in terms of capture, trade and utilization 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 and reliability for grouper culture. Given the relatively recent development of grouper culture compared to the culture of species such as milkfish or shrimp, there is an opportunity to develop good mariculture practices before poor practices cause problems and shortages akin to those experienced in other sectors (e.g., with shrimp).

In December 1997, Hong Kong hosted an APEC workshop, under the Marine Resources Conservation Working Group, on destructive fishing practices in the region. One of the specific recommendations from that workshop was to carry out trade surveys to monitor volumes and methods of fingerling harvest to better understand the resource base and to assess capture techniques. The present survey directly addresses this recommendation.

While several preliminary surveys on the mariculture industry in Southeast Asia have been carried out, none were region-wide. In Chinese Taipei, TRAFFIC International produced a report of the industry largely through review of import/export records (Wu, 1999). In southern PRC a consultancy (unpublished) was carried out at several mariculture establishments for The Nature Conservancy, a private conservation group. In the Philippines, Thailand, Indonesia and Vietnam, there have been studies which examine gears, habitats, species, etc. in varying degrees of detail.

Information to address the questions and concerns outlined above in a standardized and region-wide context, however, and taken within a limited (18 month) time frame, is either unavailable or incomplete, and has never been compiled to gain a broader perspective. This is because much of the necessary information is not readily available (indeed, it may not exist) and there persists some confusion over species names and other terminology, making it difficult to compare across studies. A comprehensive survey and review of available data/literature on seed-capture from throughout the region was, therefore, proposed. 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. The four specific objectives were:

- 1. To examine availability, capture and trading practices of grouper seed (fry/fingerlings/juveniles) destined for mariculture grow-out in SE Asia;*
- 2. To assess the potential of wild-caught juveniles to supply mariculture grow-out in SE Asia and the implications of wild seed capture on natural stocks of both target and non-target species;*
- 3. To assess the scope and potential for grow-out regionally while evaluating the importance to local fishing communities of juvenile capture, mariculture grow-out practices and the role of hatchery-produced seed;*
- 4. To develop recommendations in relation to the seed fishery, in respect of future developments of mariculture in the region, arising from the survey results.*

B. METHODOLOGY

A survey was designed to address the specific objectives and conducted to include the principal economies in Southeast Asia where significant grouper capture, culture or trade is practiced commercially for fry/fingerlings/juveniles (see Appendix Ia for Terminology but note that the term 'seed' will be used to refer as a general reference to all three stages). The division between fry and fingerlings was not always clear but I have tried to be as specific as possible.

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. Visits were made to all economies and lasted from 1-2 weeks during which interviews were conducted at government offices, with private mariculturists, with traders, middlemen, exporters and importers, in fishing communities, at academic institutions and hatcheries, and with conservation groups and other

interested NGOs, to establish the nature and scope of national mariculture practices and international trade and to gain insight into attitudes and perspectives. Fishing gear and grow-out facilities were documented and photographed whenever possible and much effort was made to witness fishing operations or to see species of fish being taken, rather than rely on descriptions, to ensure correct species identifications. Assistance in locating information and making contacts was sought from interested organizations, including the NACA, HKSAR Agriculture, Fisheries and Conservation Department, Bureau of Fisheries and Aquatic Resources (BFAR), Yadfon, National Institute of Coastal Aquaculture (NICA), APEC forums and from academic, industry and trade contacts throughout the region. Information and data were also obtained from government records/statistics and unpublished reports. Standardized letters were written to governments of each economy requesting information on the current status and development plans for mariculture as well as regulations relevant to mariculture and grouper seed capture and trade. However, only one government, that of the HKSAR, replied to this letter; therefore all accounts of regulations are from interviews and should be validated with respective government departments, if necessary.

In order to standardize the interview process, detailed questionnaires were designed for: grouper fry fishermen; grouper fry middlemen, grouper fry exporter/importers, grouper mariculturists, grouper fry hatcheries, (see Appendix 1b for one example). However, although a key core of questions was included whenever possible, it was not always appropriate to rigorously follow the format of the questionnaire. Loose adherence ensured standardization but it was also essential to be flexible to allow the pursuit of unanticipated directions and to adapt to local or changing circumstances. Emphasis was given to smaller numbers of in-depth interviews, rather than many shorter ones, because of translation and travel time constraints.

The literature survey aimed to determine the knowledge base for grouper seed capture activities. It was not intended to be a comprehensive survey of grouper culture activities (for which there is a broad and excellent literature already) but in some cases, issues such as the grow-out phase or hatcheries are covered when directly relevant to the subject of seed supply and to give a context to activities in the economy under discussion. Moreover, there was significant literature in the Thai and in Indonesian languages of relevance and while, assistance was sought in reviewing a number of these papers, language constraints precluded a comprehensive review of all foreign language publications.

Results are presented by economy in the following sections: a brief literature review, capture fishery (for seed, which includes gears, locations, production estimates, species and sizes of grouper seed), grow-out, grouper hatcheries, trade, socioeconomic issues, history of the seed fishery and relevant regulations. The broad scope of the country surveys precludes a comprehensive analysis of any one economy. However, the focus on all levels of seed fishery, trade and culture across eight economies and over a short time period allows a unique insight into key issues and identification of major problems and possible solutions. Completed country summaries were independently reviewed by individuals familiar with respective economies.

General areas visited during the surveys are indicated in Figs. 1a and 1b as numbered red dots. Areas for which additional data on fry/fingerling collection areas were provided during country visits and which were later verified by telephone discussion or other communications, are also given and indicated by green squares but these sites were not visited.

Lengths of fish are given as total length (typically from the tip of the nose to the far end of the extended caudal fin. For conversion between lengths and weights the equation of Letourneur et al. (1998) for *E. coioides* is useful:

$$\text{Weight (g)} = 0.0105 \times \text{Length (cm)}^{3.084}$$

This equation was developed from fish of 6.5-111 cm TL (Fig 2a) in New Caledonia. A growth equation for *E. akaara* (Li et al., 1988) from PRC is:

$$\text{Weight (g)} = 3.04 \times 10^{-5} \text{ Length (mm)}^{2.971}$$

An approximate growth curve for the first year of life for *Epinephelus* species commonly used in mariculture is given for reference (Fig. 2b).

C. RESULTS

A total of 181 interviews of different levels of detail were completed. About 15 grouper species are cultured, ranging from very low to very high volumes, in SE Asia. Fish are taken between 1 and 25 cm (all are therefore sexually immature since the most commonly cultured species attain first sexual maturity above 25 cm). 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 is *E. coioides* (= *E. suillus*), with *E. malabaricus* (= *salmoides*) the next most abundant. Other important species are *E. bleekeri*, *E. akaara*, *E. awoara* and *E. areolatus*. Also cultured in small amounts are *E. amblycephalus*, *E. fuscoguttus*, *E. lanceolatus* (although hatchery production of this species has recently increased: it is interesting to note that the three most successively cultured species are all to some degree estuarine-associated during their life cycle), *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).

a. INDONESIA

Literature

Grouper fry, fingerling and juvenile fisheries in Indonesia are carried out along the coasts of Sumatra, Java, and Sulawesi. Capture activities can differ markedly between areas, with the focus on fry/fingerling capture especially evident in Sumatra and Java. In western Sumatra, a survey of fishing grounds for seed showed locations of grounds, and species composition, from interviews with 30 fishers. Nine species of *Epinephelus* were noted, the most common being *E. coioides*, in estuarine, seagrass and reef areas in and around Sibolga bay and surrounding islands (Matondang et al. 1997). *E. coioides* was also the most common species taken in Banten Bay, NW Java (S. Nuraini, unpubl. data). In Riau Province, while there is no developed fry/fingerling fishery, it has been suggested that the Malacca Strait coastal areas should be protected to allow the development of a fry fishery and grow-out facilities because of the presence of fry in the area (Systems Science Consultants, 1994). In some areas, while there is no fry/fingerling fishery, larger (sub-market-size) fish (often juveniles) may be taken for mariculture. These fish are typically over 500g at capture and are maintained in floating net cages until fattened for sale. Examples were reported from S. Sulawesi where coral trout (*P. maculatus* and *leopardus*), barramundi cod (*C. altivelis*), Napoleon wrasse (*C. undulatus*), rockcod grouper (*E. fuscoguttatus*) and greasy groupers (*E. coioides* and *E. malabaricus*) are often taken (Ahmad, in litt. 24/11/00).

There has been research carried out on wild fry supply and fisheries in various parts of Indonesia; given the difficulties of organizing extensive translations, we only reviewed part of this literature. Considerable work has been carried out in western Java, primarily at Teluk Banten (Banten Bay), a shallow embayment of 20 x 10 km, NW of Serang, with additional work in Jakarta Bay. The fishing gears used in NW Java are beach seines

(*bondet*: mesh size 5 - 10 mm) which take some groupers but are also used to target other small estuarine fishes, rabbitfishes and mysids. Scoop (push) nets (*sudu/sodo/jarring dorong*: mesh size 2 - 5 mm) are used for the seasonal capture of grouper fry and rabbitfish, and bamboo traps (*bubu*: 80 cm long by 30-40 cm high and 2.5 cm mesh) are common (Ismail and Nuraini, 1983; Sunyoto, 1996; Nuraini, 1997). The stow net (*ambay*) is used in many rivers, mainly to take shrimp and the small fishes often used to feed cultured fish, but occasionally these also take small groupers. While the *ambay* is not an important gear for groupers, fish traps which do take grouper are often set at the bases of *ambays*. In some areas in Indonesia, fishers use cyanide to collect fish destined for grow-out (Murdjani, 1999).

Research in NW Java has focused on catch rates, early life stage, mortality, habitat and patterns of recruitment. Small groupers recruit to seagrass beds in Banten Bay especially from February to April, as determined by weekly surveys in the early 1980s using a beach seine (Sugama and Eda, 1986). In this study, the main species was *E. coioides* (reported as *E. tauvina*), with single hauls sometimes taking over 100 individuals measuring 4 cm in January to >12 cm in May. In the 1980s during the peak season, catch per fisher was 100 fish per day over 60 days of effort, while in the low season 110 days of effort yielded 10 fish per day, using the scoopnet (Nikijuluw et al., 1989). Loss of seagrass beds in Banten Bay between February 1989 and January 1993 resulted in the loss of 50 ha of seagrasses (Kiswara, 1995). The fisheries are artisanal and operate close to shore with different gear types; boats may or may not have engines.

In the late 1990s (1998-2000), monthly research surveys in seagrass beds were again conducted in Banten Bay which provided data on fishing gears, settlement patterns, habitat and catch per unit of effort (CPUE), and a comparison with earlier studies (S. Nuraini, unpubl. data). The predominant species was *E. coioides* which was collected at lengths ranging from 1.6 cm (transparent) to 300g (max 650g). Other species were also taken, including *P. maculatus* and *E. sexfasciatus*, *E. caeruleopunctatus*, *E. bleekeri*, *E. malabaricus*, *E. fuscoguttatus*, *E. ongus*, *P. leopardus*, *Cephalopholis boenak* and *C. formosa*. The smallest fish were noted between November and April and measured 1.6-2.0 cm with higher numbers of juveniles in more dense and mixed habitats i.e. seagrass and macroalgae. In this study, fishers came from several communities and from different ethnic groups and three types of fishers were noted: 30-40 parttime scoopnet (scoopnets have been used since at least 1988) fishers; 15 hook and line, and 25 trap fishers. Seed were only found in seagrass beds and scoopnetting took a large proportion of available recently settled (recruited), seed. CPUE by scoopfishers could be 160 g/trip during the peak season and include fish up to 10 g in weight. Fish traps and hook and line took fish ranging from 100 to 1000 g. The trap CPUE was 300-700 g/trip and hook CPUE was 600-800 g/trip.

Several concerns were expressed in the literature. In Banten Bay, the loss of seagrass beds, an increase in fishing activity (especially by scoopnetters) and considerable reclamation and development are believed to have contributed to declining catches (Kiswara, 1995; S. Nuraini, unpubl. data). Seagrass beds, especially mixed habitats, are clearly important as recruitment areas for juvenile grouper fry which then move out into the bay and towards reef areas as they grow. There is no management of seed resources (Nikijuluw et al., 1989) and comparisons of studies from the 1980s and 1990s suggest a decline in fry of at least fivefold. Production figures for market-sized groupers could not be located.

Research Findings

Interviews were conducted with 10 fisher/culturists, 4 middlemen/culturists and 8 government officials/biologists. See sites 1 and 2 in Fig. 1a.

1. CAPTURE FISHERIES

Results from visits and interviews within Indonesia, as well as direct communications with biologists and government officials based in Indonesia, indicated that the principle grouper fry/fingerling collection areas were located in Sumatra and Java (Fig. 1a). Larger fish (>200g) were also taken for grow-out in other areas where there was no confirmed fry/fingerling capture activities (see below under 'Grow-out'). Within Sumatra, the areas indicated were Aceh (for very small fry), NE Sumatra (Langkat area: especially P. Kampai, P. Sembilan and Jaring Halus) for a range of fingerling and juvenile sizes, and also western Sumatra (Sibolga Bay, including Nias and Batu Is.), and southern Sumatra at Lampung. In Java, Banten Bay, near Serang western Java, is important and in eastern Java, Situbundo and environs were identified as collection sites. Many people began to capture or to culture fish following visits by outside, often foreign (from Chinese Taipei, Singapore and Hong Kong), agents looking for a supply of grouper.

The most important grouper species collected as fry/fingerlings in both Sumatra and Java, in terms of numbers, is *E. coioides* (referred to as *lumpur* or *bulat lumpur* in Sumatra and *krapu lumpur* in NW Java). Other species taken included *E. malabaricus* (*bulat/hitam/chinpan*) and *E. bleekeri* (*gepeng, sapan merah*); in some areas, *E. coioides* and *E. bleekeri* were not distinguished by fishers and were jointly referred to as *chingmapan/sapan* or *sapan*, although most individuals seen were *E. coioides*. Occasionally, small individuals of *Plectropomus* sp. and *E. fuscoguttatus* were also caught. In N. Sumatra, sizes were typically marketed in three ranges: 5-10, >10-15, 17.5-20 cm. The smallest animals (2.5 cm) in N. Sumatra were taken at Aceh while larger animals (>5 cm) were taken on both the northeast and northwest coasts in embayments, river mouths and around nearshore islands. Seasonality in capture was noted, especially for smaller fish, in the range of 50-100 g, and catches also depended somewhat on lunar or tidal phases.

Gear: fishing was carried out by fishers who often had a few floating net cages for grow-out and may spend part of the year earning money outside of the fishery sector, such as in farming; the fishers transferred the fish from the capture site to their own cages or to middleman, usually on the day of capture. Middlemen also tended to have grow-out cages, typically more in number than the fishers and were involved in collecting (from fishers) and trading (including export) fry/fingerlings and market-sized fishes. Middlemen purchased from between 10 and 120 fishers and sometimes from other middlemen (Table 1).

1. *Fish trap:* in Sumatra, these are made of a bamboo frame covered in small-meshed green netting: two sizes of trap were noted, the larger in Jaring Halus, the smaller in P. Sembilan (Plate IAa and IAb). According to reports, fish traps were formerly made of wide diameter bamboo (none of these traps were seen) but the design was changed to net/bamboo a few years ago because it was no longer possible to find broad enough pieces of bamboo. Traps were set near the base of *ambays* (Plate IAc) and around the coast, especially near river mouths, to take fish of 50-1,000g. In NW Java, traps of woven bamboo needed 2-3 days to make (Plate IAd). Fishers each had about 10 such traps and deployed them from small boats (Plate 1Ae). Catches were generally low and little bycatch, or associated mortality, was reported. In Banten Bay, fish were removed from the traps and maintained in shallow plastic containers (Plate IBi) for transport to net cages or middlemen with occasional changes of water during the day.

2. *Hook and line:* used to take fish in the range 100-2,000 g but more typically took fish of 100-500 g. Hook sizes used were quite large (Plate IAf). At high tide in P. Sembilan fishers harvested their *ambay* and catch grouper with hook and line. On one morning, I watched fishers bringing in juveniles; in one boat about 7-10 fish ranging from 12-15 cm in length were kept for at least 40 minutes in plastic bowls on the beach while the fishermen unloaded their gear: often the tide had receded markedly, leaving the fish exposed before the bowl was moved back to the water's edge seen (Plate IBk, IBl). Fishers indicated that this did not contribute to post-capture mortalities. Fish were also maintained in plastic containers on board the fishing boat with occasional changes of water (Plate IBj).

3. *Scoopnet/pushnet*: A fine mesh net held in a triangular frame is pushed over the substrate in shallow water by one operator (Plate IAg, IAh). Highest catches are taken when large numbers of small animals are recruited which tends to be seasonal. In northern Sumatra, the smallest fish and highest fish numbers were taken by scoopnet at Aceh in January and February, while a wide size range and high fish numbers were taken between November and April in Banten Bay. Bycatch taken with this gear is often rabbitfish although a wide range of species may be present, as indicated by scientific surveys (Plate Ibm right). Larger grouper are caught in low numbers (Plate Ibm left) and animals kept alive by placement in a floating fish transporter until conveyance to middlemen (Plate IBn).

Production: there are no overall production figures but the data on catches by gear provide some indications of catch rates locally. In the peak seasons, scoopnet daily catches could reach, per fisher, 1,000-2,000 fry of 2.5 cm. In some areas there may be 1,000 scoopnet fishers. Trap fishers would take as many as 2-10 larger fish (50-200 g) per day and small areas might have 10-20 trap fishers.

2. GROW-OUT

Grow-out in Indonesia is carried out in many areas and there are several problems and concerns. Fish are held in net cages for varying lengths of time, but typically 4-12 months, with the market-size fish then sent to major domestic centres or exported. Grow-out is typically carried out in either floating or set-net type cages, principally the latter (Plate IBo, IBp). There is some limited pond grow-out, particularly for the smallest size classes, but a general shortage of land for ponds was identified; the need for land-based ponds for the raising of the smallest size class (few cm) of fish, which cannot be maintained in floating cages, was particularly acute. In the Riau Archipelago, various species, including *Plectropomus leopardus*, are grown from 100-300 g to export size of 500-900 g over 4-8 months (M. Erdmann, pers. comm.). They are typically fed locally obtained "trash" fish. In N. Sumatra, there are many grow-out cages in both the Sibolga and NE Sumatra (Langkat district and Jaring Halus) areas.

Within the last decade, culture activities have expanded rapidly. For example, in 1996 there were about 600 cage farms in the Langkat district (Napitupulu, 1999), now there are about 1,200. Expansion of cage culture in the Sibolga area was similarly rapid, with farms increasing from 14 to 398 between 1989 and 1994; this was followed by a decline due to problems with disease and mortalities. The eastern coast of Sumatra is believed to have much potential for grow-out activities and there is considerable interest in developing the area for this purpose (System Science Consultants Inc., 1994). In S. Sulawesi, there are 9 coral reef fish traders involving about 450 fishers and 450 cages (5x5x5 m) in which larger individuals are raised to market size (Ahmad, in litt. 24/11/00). In eastern Kalimantan there is collection of fish of about 200 g by fish trap and handline (*pancing*) for grow-out in net cages at Kapupaten Berau near Samarinda and at Bontang. The production here is about 1,000 t of fish a year and the species are *Cromileptes altivelis*, *Epinephelus tauvina*, and *Plectropomus leopardus* (H. Amarullah, pers. comm. 19/12/00)

Fishers and middlemen both maintain various numbers (2 to 75 per person) of net cages and have reported problems with mortality, water quality, disease and access to sufficient feed. Cages were constructed some metres offshore from houses (Plate IBp) in coastal waters, or below the docks and dwelling areas. An example of the latter was in Jaring Halus (Plate IBo) where the water appeared polluted and animals were being raised below diesel storage and other work areas. High temperature and low dissolved oxygen (DO) were also cited as problems at certain times of the year. Culture was not intensive and densities had apparently been reduced in response to some of the problems reported to solve the problem of high mortalities (e.g. in P. Semilan 300 fish of 50-100 g were kept in cages of 3x4[3]x5 m deep). In Jaring Halus, there were 500 households and 3,200

people, with 500 cages (1-5 cages each of 5x5x7 m); before 1993, there were only 100 cages (set nets).

Mortality rates during grow-out varied with fish size (60% or more for fish 5 cm or less; 30% for fish <10 cm; 20% for fish < 15 cm, and, overall, 30-40% mortality was common) and conditions. The handling and transport practices used for juveniles were not considered to be a problem, but in the few cases I witnessed, fish were often stressed and improvements at these stages might reasonably be expected to reduce some of the mortality. There also appears to be considerable scope for work by the government in training in better practices to reduce mortality levels at all stages from fishing, through transportation and cage management.

The most significant problems identified to improve cage culture activities include seed supply of the right range of sizes, "trash" fish supply, high mortality levels, especially in the smallest size classes (2.5-5 cm TL) of fry, poor water conditions (high temperature and low DO at some places and during some periods) and treatment of disease (Napitupulu, 1999; Murdjani, 1999). The wastage of grouper resources and income through these problems appears to be considerable and, if mariculture is to play an important role in balancing demand and supply in marine production and in benefiting coastal communities, these problems need to be addressed (e.g. Ahmad and Sunyoto, 1990). At present, grouper grow-out ventures are developing in many areas of Indonesia and there is clearly concern that the seed supply will be insufficient for the total 750,000 floating cage units anticipated in the near future (Ahmad, pers. comm.).

3. GROUPEL HATCHERIES

Much research in Indonesia is being carried out on hatchery production in anticipation of increasing demand and depleting marine resources generally (Ahmad, pers. comm.). For grouper fry production, research has been carried out since 1985. The main problems for hatchery development are the lack of male spawners for all species of interest, possibly due to overexploitation. Moreover, sex ratios may be difficult to control in the laboratory due to hermaphroditism. It is anticipated that it will be some years yet before fry will be hatchery-produced on a commercial basis. Several conversations held in my presence indicated an urgent need for an increase in fry supply. I could locate no estimates of annual fry production for Indonesia from hatcheries.

Hatcheries in Indonesia are located in several locations. In northern Bali, the Gondol Research Station for Coastal Fisheries has had success with the full-cycle culture of mouse (or panther or barramundi cod) grouper, *C. altivelis*, which was first spawned naturally in 1996, and *E. fuscoguttatus* (Sugama, et al., 1999; Sugama, Hat Yai meeting 1999). The mouse grouper is also valued in the marine ornamental trade and is exported to the USA, Singapore and Hong Kong for this purpose. The need, not only to increase seed production but also to successfully convert fishers into backyard culturists through the development of simple and inexpensive techniques, was recognized. Trials on a range of species have also been carried out at the Regional Brackishwater Aquaculture Development Centre in Situbondo, eastern Java (Murdjani, 1999). Work is ongoing at the Research Institute for Coastal fisheries in Sulawesi (Ahmad, pers. comm.), including experiments on breeding and culturing of the Humphead wrasse, and formulation of an artificial feed for this species. Other work is being carried out at the Mariculture Development Centre at Lampung and elsewhere around Indonesia. The Nature Conservancy is developing a hatchery to provide grouper seed to small-scale culturists in the area of the Komodo National Park in western Flores.

4. TRADE

Indonesia's trade in groupers is considered to be economically important, especially its exports to Chinese Taipei, Hong Kong and Singapore (also some trade to Brunei and Japan) (Pudadera et al., 1999). It is an export trade, by both air and sea, which includes all size classes of fish. There are no official records on the trade in sub-market-sized fishes (i.e. fry, fingerlings, some juveniles) such that activities can only be indicated by

individual accounts from interviewees and some import data in receiving countries. The following accounts are from middlemen in Medan and NW Java. From Medan, fingerlings and market-size fishes are sent monthly to Hong Kong and Hainan Is. (China), with preferred juvenile sizes of 12 cm. Formerly, there were also sales to Singapore but these have declined for lack of good quality grow-out areas. Malaysia prefers to import table-sized fishes (approx. 400g). While both *E. bleekeri* and *E. coioides* seed are exported, there is a preference to maintain *E. coioides* in Indonesia for grow-out. Boats bound for Hong Kong take both market-size and juveniles with 10-15% mortality and about 8 days travel to HK. A single middleman in Medan exports 300,000 fry a year especially from April to June (30 boxes of 200 small pieces each; 1 piece is 1 fish) while demand for market-sized fish is high prior to Chinese New Year. In NW Java, Bantem Bay, a holding facility of floating net cages stores fish prior to export and/or shipment to Jakarta. Of the 100 of so cages, typically full 5 years ago, only half are typically filled recently. The species held are *Plectropomus leopardus*, small (17.5 cm) Humphead wrasse and *E. bleekeri* from Medan and 3-4 tons are regularly shipped out every 2 weeks.

Import trade figures from the Hong Kong Census and Statistics Department recorded US\$200,000 worth of marine fry (HK Harmonized System commodity code 0301-9912-marine fish fry) from Indonesia – all of it by air and representing about 2% of Hong Kong marine fry imports for that year (Lau and Parry Jones, 1999). This would include all species of marine fry which are mostly groupers. No sea imports were noted, possibly because imports by sea are poorly monitored (Sadovy, 1998).

5. SOCIOECONOMIC ISSUES

The grow-out of small groupers is a value-adding process of considerable economic benefit to communities and can increase income without further stressing exploited resources (e.g., System Science Consultants Inc., 1994). The financial benefits from the groupers can be illustrated by specific examples in Indonesia. In the Moslem community of Jaring Halus, NE Sumatra, visits to Mecca only became possible in the 1990s from the profits of the grouper businesses, while individual fishers often earn a significant percentage of their annual income from grouper resources. Given such economic benefits, while some fishers do have a few cages, why don't more fishers involve themselves in grow-out? Several reasons were cited, but in particular the lack of funds for initial establishment of a cage facility. Many considered that they lacked the skill to embrace culturing activity in the daily care and feeding activities required (Ahmad and Sunyoto, 1990). Relationships of indebtedness are also significant impediments in some communities. Cases were communicated of middlemen supplying gear, supplies, interest-free loans, etc. in return for obligatory purchasing at below-market prices to middlemen. Such relationships were sometimes isolated cases; at other times whole communities were involved, as in the Riau Is. and Tauke system of indebtedness (Erdmann, pers. comm.).

To promote or facilitate grow-out operations among impoverished fishers there is a need for government assistance in the form of financing, extension work and training, as well as market information and assistance in breaking out of relationships of indebtedness with the resultant concentration of trade in the hands of the few (Napitupulu, 1999; Nikijuluw et al., 1989). Such assistance is essential for resolving some of the socioeconomic inequalities in fishing communities and for bringing greater financial benefits to those who exploit the resources in their nearby coastal waters.

6. HISTORY

The impression was strong that seed supply was insufficient for demand, highly variable and had been considerably better in the past, for all size classes and all gears. Information on the history of the fishery was not available for Kalimantan. In N. Sumatra, declines appeared to be most marked for the tiniest fish. Traps were widely and consistently perceived to be taking several-fold less in numbers of animals and returning with

more zero catches than in the past. Hooks were no longer catching the larger size classes. Reasons proposed for the declines observed varied, but, in general, declines were noted more in numbers of fish than in fish size. In the Langkat area, in particular, the perception was that declines had been particularly marked within the last three years. In the Sibolga Bay area, where fish of 50 g and over are taken, seed was much more readily available 15 years ago than now and there had also been declines in market-size fish in recent years. It was suggested that seed is less than before because of habitat damage and the use of chemicals (termed 'Potass') for collection. In Jaring Halus, overall, a general decline and shortage of seed was perceived, with fish now scarcer than in the early 1990s. In Teluk Banten, 100-200 g fish (preferred sizes for grow-out) were noted to be substantially fewer (30%) than before the 1990s, scoopnet catches were down 75% and trap catches were down by 2-5 times since 1995. In this location, the concerns were that many new people had started to capture grouper and that divers had come in to local waters with poisons and spears and hookah. It was also noted that the waters seemed more warm recently and that coastal development had affected nearshore waters, killing seagrasses and causing loss of coral areas which had sheltered the fish.

7. REGULATIONS:

The only regulations relevant to the capture, culture and export of fish species of interest to the live reef fish trade are those controlling the capture, culture and export of the Humphead wrasse, *Cheilinus undulatus*. Ministerial Decree of Agriculture No. 375/KPTS/1K.250/5/95 (16th May, 1995) prohibits capture of Humpheads except for research and cultivation. Directorate General of Fisheries No: 330/DJ.8259/95 (6th Sept. 1995) allows traditional fishermen to catch Humphead wrasse in selected fishing grounds with boats < 5 gross ton, using hook and line, fish trap and gill net and only for animals weighing between 1-3 kg. Any company purchasing/exporting such fish must have a permit. Ministerial Decree of Trade No. 94/KP/V/95 (24th May, 1996) bans all exports of Humphead wrasses except for those animals caught as specified by law (above).

b. MALAYSIA

Literature

There was little available literature describing grouper fry capture in Malaysia. Seed of *E. coioides* and/or *E. malabaricus* (reported as *E. tauvina*) were collected between September and January in Malaysia; there was no information on fish size or capture location(s) (Bensam, 1993). Fry collectors take *E. coioides* (reported as *E. suillus*) and *E. malabaricus* fry at Setiu lagoons in Terengganu on the eastern coast of west Malaysia between May and July; this area is covered by mangrove and other vegetation (*nippas*) (Doi *et al.*, 1991). Fishing gears reported in the literature for grouper seed collection include *temarang* (a home-made artificial habitat), siene net, hook and line, *coreng atap* (fish trap of about 50 cm length made of bundles of twigs with leaves), bamboo traps and dip net (Doi *et al.*, 1991; Bensam, 1993). Grouper seeds were exported from Malaysia to Brunei for mariculture (Pudadera *et al.*, 1999). In general, most live reef fish operations are in Sabah with capture and grow-out in Sarawak and Peninsular Malaysia limited due to small areas of reef or to local depletions of stocks. Although local consumer demand for live reef fishes is growing, especially among the Chinese communities, Malaysia is primarily a producer and there is activity in both grow-out and in the export of market-sized fishes (Bentley, 1999). The annual production of market-sized grouper for 1994 was estimated at 600 mt for peninsular Malaysia (Ali and Ali, 1999) and for all coral reef fish for the same year in Sabah at about 800 mt (groupers are some unknown percentage of this total and the total may also include fish that were captured at market size) (Busing *et al.*, 1999).

Research Findings

Twenty-one people were interviewed: 7 fishery officers, 7 fishers, 6 culturists and 1 private hatchery owner, at sites 3-10 in Fig. 1a.

1. CAPTURE FISHERIES

Since Government Fisheries Departments are somewhat independent from each other in East and West Malaysia, the results for the two areas are reported separately for clarity in most of the following sections.

EAST MALAYSIA

East Malaysia consists of 2 main states, Sabah and Sarawak in north Borneo. Grouper seed collection, hatchery and grow-out are only known from Sabah (Nicolas Pilcher, *pers. comm.* 01.02.2000).

Based on the findings from the trip to Sabah, all grouper seed collected were used to supply local grow-out activities; seed export is illegal. Grouper fry/fingerling collection occurred mainly at Tuaran and Sandakan. In Sandakan, fishermen used to catch small grouper fry prior to 1994. However, following problems with high mortality rates during grow-out of these smaller fish they switched to targeting larger seed. All grouper fry/fingerling collectors are part-time and work as trawler fishers the rest of the time. In the Sungai Sibuga area of Sandakan, there is limited fry collection which originates as bycatch from hook and line and trap fishing. The target size of grouper seeds was 7.5-15 cm (about 100 – 200 g).

Collection areas were typically in the mouths of small tributaries in waters ranging in depth from 0.6-1.5 m and around mangrove areas. In Tuaran (located north of the capital of Sabah, Kota Kinabalu), grouper seeds have been collected at Lakes Suleiman and Mengkabong, both located at river mouths and surrounded by mangroves (e.g. Plate II Ag) since 1970. In Sandakan (located on the eastern coast of Sabah), grouper fry/fingerlings capture activities were mainly found in the Se Kong area.

The peak grouper fry collection season in both Lake Suleiman and Lake Menakabong extends from September to January when grouper fry of about 7.5 – 10 cm are common. In the Se Kong area, the peak season for grouper seed capture extends from April to October.

The major species harvested in Tuaran are *E. coioides*, *E. malabaricus* and *E. bleekeri*. Both *E. coioides* and *E. malabaricus* are collectively called green grouper by the fry collectors and the culturists in Sabah and are preferred for culture since *E. bleekeri* grows too slowly. Indeed, fry collectors in Tuaran usually return the fry of *E. bleekeri* to the water. Fry of other grouper species, such as *Cephalopholis boenak* and *E. quoyanus*, were also occasionally collected. The dominant capture species in Sandakan was green grouper fry/fingerling.

Gear: fishers use several methods to collect groupers and grouper seeds. Since most fishers used several methods, it was difficult to estimate the production of seed per fisher. The following methods are used in eastern Malaysia (Sabah) (Table 2):

1. *Bubu:* fish traps are made of bamboo or nylon mesh (Plate IIAa, IIAb, IIAc, IIAd) and deployed along rocky shores (Plate IIAe). In Tuaran, *bubus* are set with bait during the morning and harvested during the afternoon. Collected grouper fry are put into an open-water circulating tank in a sampan and transported directly to net cages. In Sandakan, an average of about 30 – 40 grouper seeds was harvested by 7 *bubus* during the peak season and the mortality is reportedly about 5%. The *bubu* was appraised by many fishers and culturists in both Tuaran and Sandakan to be the best method for obtaining good quality grouper fry.
2. *Kilong:* long nets with a mesh size of about 2.5-3.75 cm (the mesh is the same as that of trawl nets which size is controlled by Sabah Government regulation), the mouth of which is fixed on both sides by bamboo fences. The nets are set in river mouths during high tides and harvested during low tides. Grouper fry are taken but are not the target

species of this method. Fishers from Tuaran operate just one *kilong* at a time and harvest it once daily. This is not a preferred gear for grouper fry/fingerling capture.

3. *Gurungan*: a newly introduced, and inexpensive, method for grouper fry and fingerling collection which is becoming popular in Tuaran. It consists of a hollow, round and thick bamboo, PVC or wooden tube of about 0.3-1 m long and catches grouper seeds of about 10 cm (Plate IIAh, IIBi). No obvious mortality of grouper fry is associated with this method. *Gurungan* in Tuaran are set on the bottom of the river for 2 - 3 days prior to harvest. Each fisher in Lake Menkabong handles about 100 *gurungan* simultaneously and about 30 – 40 grouper fry, on average, are harvested during the peak season from the 100 units. In the non-peak periods, about 10 grouper fry were caught in each 2-3 day harvest.

4. *Ranggas/Belat*: an artificial aggregating device/fish shelter made up of a mixture of twigs and leafy branches joined together and set up along the coast (Plate IIBj and IIAf). When harvested, the fisher gathers up the device and uses a scoop net to collect the fish trapped within. The number of animals, and their sizes, taken at each harvest vary markedly, ranging from small fry to large juveniles. This method was reported to take good quality grouper fry although there is some mortality when they are trapped together with poisonous fish (presumably pufferfish).

5. *Hook and line*: fishers in Sandakan mentioned that hook and line was only used in calm waters and indicated concern that this method can damage the fish by hurting the gill and mouth of the animal which may also be stressed and damaged from fighting on the line. Similar concerns were mentioned by local culturists who find that the quality of grouper fry caught by this method is often poor.

6. *Gill nets*: this method was once used in Tuaran for catching grouper fry of 12.5 – 15 cm in the past but the mortality rate was very high and the method is no longer used today.

7. *Cyanide fishing*: sodium cyanide solution is used to stun the fish to make them easier to catch; it is used in Sabah to catch large grouper but was not reported for grouper seeds.

Production: annual production of grouper fry is difficult to estimate since no detailed figures are kept and estimates varied widely. A Sabah Fisheries Department officer estimated that about 100,000 grouper fry of about 7.5-10 cm were collected from Lake Suleiman which accounts for about 90% of all fry taken in the Tuaran area. However, local fishers estimated that the total harvest of grouper fry was much higher and closer to 500,000 annually.

West Malaysia

In west Malaysia, grouper fry and fingerling capture activities take place along the east coast of the Malaysian Peninsula. The major fishing grounds are Besut and Setiu (between Kuala Besut to south of Kuala Terengganu). These 2 areas are the source of about 90% of all grouper fry/fingerlings produced in west Malaysia and the major capture areas are in the vicinity of river mouths. Additional, but limited, grouper fry capture activities are also known from a few other locations, such as Mersing (in Kuantan Province) on the east coast. An officer of the Marine Finfish Production and Research Centre in Terengganu reported that there were also some fry capture activities in Johor, close to Singapore, but could not supply details of species, season or gears.

The grouper fry/fingerling capture season lasts approximately from November to April with a peak in December and January. Captures are particularly good shortly before, and for about a week after, the new moon phase. Although the fishing of grouper fry is not permitted during November and December, fishers reportedly do not follow this regulation.

The two major grouper species in Terengganu taken as fry/fingerling are *E. coioides* and *E. malabaricus*, with *E. coioides* the more common species. Moreover, *E. coioides* dominates the harvest during March (about 70% of total harvest) while *E. malabaricus* dominates the harvest during January – February (over 90% of total harvest). Fishers also caught *E. bleekeri*, particularly during the dry season in March and April.

Only one capture method, the *temarang*, is used by fishers in Terrangganu:

8. *Temarang*: an artificial aggregating device/fish shelter which consists of about 25 small bunches of dried leaves and branches of the plant Temarang (Plate IIBk, IIBl) strung out in bundles along a 33 m long line. The line is kept floating close to the surface of the water by marker buoys (maybe a plastic bottle or a plastic ball) attached at its ends (Plate IIBn lower). Usually, 2 fishermen can handle 500 m of *temarang*, and about 500 fry can be caught per 33 m of *temarang* and collected by scoop net (Plate IIBn upper, IIBo). The usual capture size ranges from 2 – 2.5 cm. The mortality by this method is only about 3% which occurs when fishermen shake the *temarang* to remove the fish, damaging and stressing the animals on occasion. One broker in Besut said that the bycatch of *temarang* is about 10%, most of which is rabbitfish. This method was evidently introduced from Thailand. Fishers in Terengganu have tried to use another plant, Ribu-Ribu (Plate IIBm), instead of the Temarang plant, but this was found to be far less effective at aggregating grouper fry/fingerlings.

Production: from the major fishing grounds of the east coast of west Malaysia in 1999 was estimated at about 5 million grouper fry of about 2 – 2.5 cm, both from interviews with fishers and by a major grouper fry broker in Terengganu. This broker reported that there were about 20 brokers in Terengganu and that he alone got about 600,000 grouper fry from fishermen in Terengganu.

2. GROW-OUT

East Malaysia

Grouper culture in Sabah was noted from 9 areas with high activity particularly at Tuaran and Sandakan which accommodate 60 % of the total mariculture cages in Sabah (1,202 cages in 1998). Cage culture in Kota Kinabalu is not considered 'real' culture (see below) while those cages in Tawau are used for prawn rather than fish culture. Cage grouper culture in Tuaran started in 1970. Most cages are of the floating net cage type (Plate IIBp).

A senior officer of the Fisheries Department in Sabah noted that there were 2 types of grouper culture in Sabah, 'System' culture and 'Real' culture. System culture involves the feeding of large captive juveniles or small adults which are taken from the wild and maintained and fed in cages until the fish reach saleable table size. This type of culture is common in cages based at Kota Kinabula (Pulau Gaya) and involves a variety of species: Leopard coral trout (*Plectropomus leopardus*; Malay: *Sunoh*); Humphead or Maori wrasse (*Cheilinus undulatus*; Malay: *Maming*), rarely, Barramundi cod (*Cromileptes altivelis*), snapper (*Lutjanus gibbus*), *Psammoperca* sp. and Sea bass (*Lates calcarifer*). Most of these fishes are caught around Pulau Mengalum and Pulau Banggi. A culturist in Kota Kinabalu reported that the large fish are either purchased and sold immediately, or purchased at about 200 g fish and kept in 'system' culture until they attain an exportable 400 g – this takes about 1 year and the average mortality during this period is about 30%.

'Real' culture involves the raising of small grouper fry/fingerlings purchased from fishers and taken from the wild. The main grouper species used in real culture in Sabah are *E. coioides* and *E. malabaricus*. In Tuaran, fishers reported that they used to keep newly collected grouper fry/fingerlings in separate cages for 1 – 2 days

from those which had been culture for a while. This treatment reduced the mortality compared to adding the new fish directly to cages containing fish already under culture. In Sandakan, 'real' culture was the dominant culture system. Again, the 2 main culture species were *E. coioides* and *E. malabaricus* (together composing at least 60% of total culture). They usually grew the grouper seeds from 10-15 cm to table size. The survival rate of grouper in culture conditions between 12.5-15 cm and 1 kg is about 60%. Most mortality occurred during the first 2 weeks after introducing the fry into the cages.

3. GROUPEL HATCHERIES

East Malaysia

Grouper hatcheries are not well established in Sabah. One private company "Aqua-Vision" started working on grouper hatchery research in Sabah in 1997. Another company was started by a culturist in Sandakan in 1997 but did not focus on groupers at that time.

Aqua-Vision started their hatchery research on barramundi cod but stopped after about 1 year because they found the growth rate to be too slow for grow-out. Now, the company is working on the hatchery of Tiger grouper (*Epinephelus fuscoguttatus*) as the growth rate of this species is fast and it has good potential for culture and a higher market value than in the past. They also plan to work on Giant grouper and Leopard coral trout. The company has no problem in finding broodstock, including the larger males. However, to date there has been no success with any species in their hatchery activities. The major problem is the high mortality of post-hatch larvae almost all of which were lost within 2 months. The company wants to work on the Humphead wrasse but finds the sexes difficult to distinguish.

The Sandakan hatchery works with sea bass (*Lates calcarifer*) and Mangrove snapper (*Lutjanus argentimaculatus*) and hopes to shortly start work on the Green grouper (*E. coioides*). However, they have also had considerable problems with post-hatch mortalities. Since no grouper fry/fingerlings can be imported into Sabah, the potential and importance of hatcheries in the area are seen to be significant.

West Malaysia

The Marine Finfish Production and Research Centre, at Terangganu, was established in 1983 as the Prawn/Fish Production Centre and was the first of its type established in West Malaysia. This research centre is managed by the Fisheries Department of Malaysia. The purpose of the research centre is to produce fish fry for culturists, private hatcheries, and nursing and also for restocking if production is in excess of demand for culture. Stocking/restocking of seabass (*Lates calcarifer*) and small numbers of grouper was done in 1986 but no monitoring was carried out afterwards so the success, or otherwise, of this approach is not known. Originally, the fish species researched was the seabass (*Lates calcarifer*), but JICA later initiated grouper hatchery research on *E. coioides* resulting in natural spawning and larval rearing of this species in 1989 – 90; HCG-induced spawning was also achieved. The maximum production of Green grouper fry at that time was 20,000 pieces per year. The survival rates ranged from 0 – 20% and production was very unstable. Because of unstable production rates and also a flooding incident which killed most of their broodstock, JICA stopped their hatchery research on grouper at that time. The Centre uses land-based tanks, of at least 3 m depth, for grouper broodstock spawning and is now working on a Tiger grouper broodstock. There have been considerable difficulties in feeding post-hatch larvae and research efforts will be concentrated on the first 5 days post-hatching.

A private hatchery was established in Penang 7 years ago with grouper production only starting 4 years ago using hatchery techniques learned from Chinese Taipei. The owner anticipated that demand from hatchery sources would increase in the future and claimed that his company is the only grouper hatchery in Malaysia

which currently breeds and raises grouper fry successfully. The private hatchery in Penang works on *E. fuscoguttatus* and *E. coioides* and is based on concrete tanks. Spawning of both *E. coioides* and *E. fuscoguttatus* extends from January to September each year and about 30 – 40 broodstock of 8-15 kg each are maintained. Each female produces about 500,000 fertilized eggs and about 70% of the fertilized eggs hatch successfully. The facility produces about 100,000 Green grouper and 40,000 Tiger grouper fry each month for 9 months for both species. However, fertilized eggs have to be imported from Chinese Taipei since production cannot meet demand. The owner used to grow the hatched grouper fry to about 6 cm for selling but uses the majority of his own production for grow-out. The owner said that hatchery fry has a 70 – 80% survival rate during grow-out while wild capture fry has only about 20% survival and that 20-30% of his annual production of fry is exported through Singapore to Chinese Taipei. The Penang hatchery is also preparing to culture Giant grouper (*E. lanceolatus*) and Coral trout (*Plectropomus leopardus*).

4. TRADE

No records of grouper fry export were available from the government export statistics. Import figures in Hong Kong's Department of Census and Statistics for 1997, using the commodity code for marine fry (includes non-grouper species), indicate that only 2% of Hong Kong's imports of marine fish fry came from Malaysia with a value of US\$228,000 and that all imports entered Hong Kong by air (Lau and Parry-Jones, 1999).

East Malaysia

There is no export of grouper fry/fingerlings from Sabah. Only table size, or bigger, grouper are exported from Sabah. According to an officer of the Sabah Fisheries Department, about 70 – 80% of table, and larger, size groupers exported from Sabah come from wild capture sources, while the remaining 20 – 30% were supplied from culture which was also based on wild caught fry and fingerlings.

West Malaysia

There is no grouper fry export but fish caught within Malaysia may be transported domestically to culture facilities. Fry are transported in aerated plastic bags (about 500 fry per bag) full of seawater. Ice is placed put both inside and outside the bags and these are transported in a PVC box. The water temperature is kept at about 24 – 25 °C. Mortality levels during transport were reportedly low. For one grouper fry broker, about 60% of grouper fry were sold to Johor while 20% were sold to Perak and the remaining 20 % were sold to both Selangor and Kedah. The broker also said that grouper fry are smuggled from Johor through Singapore to Chinese Taipei.

5. SOCIOECONOMIC ISSUES

In East Malaysia, since there is no export of fry, all the part-time grouper fry/fingerling fishers either sell their harvest directly to local culturists or keep them for their own culture.

6. HISTORY

There is a general perception that the supply of grouper fry/fingerlings has declined markedly over the past decade. Almost all grouper seed fishers in Tuaran (Sabah) noted a decline in harvest over the past 10 years. Fishers in Lake Mengkabong reported a decrease of about 20% over the same period. One of the reasons given for the decline was the increasing numbers of fishers looking for small groupers, a situation that evidently led to overexploitation. Some fishers in Lake Mengkabong also suggested that the increased numbers of tourist cruises in the lake may have caused declines in the harvest but did not explain why that might be.

7. REGULATIONS

All of Malaysia is subject the same federal legislation which prohibits the use of cyanide for fishing.

East Malaysia

There are no special regulations for grouper fry capture in Sabah although regulations may act indirectly. For example, some gears, such as *bubu* and *kilong*, that are made of trawl net, are subject to trawl mesh size control. Fertilized eggs and grouper seeds cannot be imported to Sabah for culture to avoid spreading of fish diseases.

West Malaysia

To protect and sustain grouper fry resources, grouper fry fishing is not allowed during November and December. It is only permitted during the peak season from January to April. There is currently no export permitted of grouper fry/fingerlings smaller than 15 cm (another report indicated the minimum size is 12 cm). Such export was permitted in the past and fish went to Chinese Taipei. However, it was determined that this was not economically sound practice since Chinese Taipei raised the fry to a larger size and then sold them back to Malaysia at much higher prices. However, fry can be exported if they are hatchery produced.

c. THAILAND

Literature

Thailand is a major supplier of grouper seed within SE Asia and locally caught seed, although much of it is exported, is also used for local culture activities. Only a few species form the bulk of the capture and culture of groupers in Thailand and there is little written on the grouper seed fishery. Increased cage culture of grouper followed declines in shrimp-farming from 1990 when disease and environmental problems forced many closures. Most culture is carried out in floating net cages (90%) and is mainly done in coastal areas of southern and eastern Thailand with about 5,655 cages dedicated to grouper culture; most (>80%) are located in SW Thailand Phuket, Phang-nga, Satun and Trang (Yashiro, 1999; Yashiro et al., 1999). Total annual grouper production is 40-60 t (400-600 g) (Yashiro, 1999). A major constraint to grouper culture is insufficient seed supply from hatcheries and inconsistent supply from the wild (the main source of seed). Annual production from hatcheries between 1991 and 1996 of *E. malabaricus* juveniles (50-55 days) varied from 15,000 (1991) to 265,200 (1995), dropping to 58,475 (1995) (Yashiro, 1999). The smallest sizes of grouper (1-2.5 cm) are nursed before they can enter culture cages at 7.5-12.5 cm, a process carried out in concrete tanks, nylon net cages or earthen ponds. The most important two species cultured are *Epinephelus coioides* and *E. malabaricus* with five species of minor importance: *E. lanceolatus*; *E. areolatus*; *E. fuscoguttatus*; *Plectropomus maculatus* and *Cromileptes altivelis*. *E. tauvina* is also reported but its presence has not been confirmed from Thailand (Heemstra and Randall, 1993; Yashiro, 1999).

At least three different gear types are deployed to catch fry, fingerlings and juveniles. Fish traps, known as *pum*, are used to catch grouper fry (Yashiro et al., 1999). *Pum* are made of bundles of dried twigs with leaves of plants called *yan-li-pow*. During grouper fry fishing, a *pum* is enclosed in a nylon net to form a fish shelter. *Pum* are usually set in the canals along mangroves and brackish coastal waters and checked at 2 - 3 hour intervals. Fish are collected by lifting the nylon net and shaking them out into a scoop net (Yashiro et al., 1999). Gill nets of mesh size 0.5 - 1 cm are also used for catching grouper fry by blocking waterways where fry are known to pass through. Grouper fingerlings are also caught by *pum* in Thailand. To take larger juveniles, Thai fishers use small fish traps, called *sai* or *lob*, gill nets in mangrove and reef areas (Yashiro et al., 1999).

During the survey visit to Thailand, 9 culturist/fishers, 3 culturist/middlemen, 3 exporters, 8 biologist/government employees and 2 NGOs (Yadfon, NACA) were interviewed or visited at sites 11-16 in Fig. 1a.

1. CAPTURE FISHERIES

The most important species in terms of volume for both export and culture are *E. coioides* (*Pla Gao Tae, Gau [dok] dang*), *E. malabaricus* (*Pla Goa Tae, Gau dok dum*) and *E. bleekeri* (*Pla Gao Gae, Gau dok marg*). These species are found in most locations where fishing and culture occur but in varying quantities relative to each other and according to local conditions. In general, most trade is in *E. coioides* and *E. bleekeri*. *E. malabaricus* is traded in smaller numbers and, along with *E. bleekeri*, is evidently more readily found in SW Thailand. Small numbers of other grouper species are taken in SE Thailand, such as Giant grouper, *E. lanceolatus* (*Gau tang*) and *E. quoyanus*, *Plectropomus maculatus* and *P. laevis*. The main capture/culture species are taken in small or high volumes depending on season and at a wide range of sizes, from 1-25 cm. Note that *E. coioides* is often reported as *E. tauvina*; we saw no *E. tauvina* at any location.

Fish caught in brackish waters and around mangroves are *E. coioides* and *E. malabaricus* while *E. bleekeri* may be found in cleaner, deeper, water. Small size classes of the more common species are also taken in shallow waters (1.5-2m) on sandy substrates where salinity is reduced along the coast in some areas (e.g. Pattani) (Plate IIIf). The peak capture season varies somewhat by species and location. In the area west of Trang, the peak for the larger, preferred size, seeds, is in the rainy summer season in August to November. In the Songkhla area, SE Thailand, the main season for the smallest seed is during the winter, especially in February when spring and neap tides yield highest catches. Fish trap catches may be better at the full moon period, for a week or so before and after. *E. lanceolatus* is taken in small numbers in estuaries over a 6-month period in SW Thailand.

Most capture and culture takes place in southern Thailand. Three of the main areas for seed capture are Pattani (Yaring, Sai-buri, Pa-na-rae, Mai-gaen), Satun and west of Trang. In SE Thailand, Songkhla, Narathiwat and the coast of NE peninsular Malaysia (just over the border from Thailand) are also important sources of seed. In SW Thailand seed are also taken from Krabi and over the border in NW Malaysia. Some fry capture also occurs at Chanthaburi (NE Thailand) and this is sold to Chonburi and Rayong (also NE Thailand) culture facilities. However, southern Thailand supplies the great majority of grouper seed from wild capture. Some Thai fishers also get seed from Kampuchea and southern Vietnam, as well as from Myanmar and northern Malaysia.

Gear: in some areas mainly one type of fishing gear is used, in other areas, several types, according to season, demand, size and species sought, may be used. Gill nets with a fine mesh size were also mentioned but no details of this gear were given. No mention of sodium cyanide to catch grouper seed was made. Catches are highly variable according to season (Table 3).

1. *Fyke net or set net (pong-pang)* (Plate III d)--used in Pattani and the most common method there. This gear can be used at times of high winds and takes fry of 1 cm. Bycatch during peak times is about 10% and mortality can be high, at 20-30%. A single unit needs about 4-5 people to handle it and the gear must be checked regularly. During the peak season, 10,000-30,000 fish can be taken per night per net. In Pattani, this gear may be supplied to the fisher by a middleman on the agreement that the fisher sells to the same middleman.

2. *Fish trap (lob, sei, rotan, rop)* (Plate III a, III b, III c): traps are used to collect groupers in the size range of

seed from 7.5 to 25 cm, and even larger, in SW Thailand where larger fish are occasionally taken in larger traps. Traps are typically set in mangrove areas or around reefs and some smaller mesh traps take smaller fish. The traps vary somewhat in shape and size as well as in the mesh size used, depending on the size of seed sought. The trap frame is made of wood, metal or bamboo. In Satun, each fisher has about 30 cages and the gear gets the best harvest at neap tides. Traps also take a bycatch of other species. SW of Trang, there are 20 boats working with traps that take fish of 20-25 cm: bycatch is 10%. Fishers here use black netting on their traps to catch *E. bleekeri* and green netting for *E. coioides* and each fisher has 70-80 traps set; in some areas a fisher might have as many as 1,000 traps. The traps are harvested frequently and used to get 3-7 fish per trap in the past during the peak season, now, however, only 1-3 per trap in the size range of 5-25 cm are taken. During the non-peak season catches drop by 10-20 fold.

3. *Hook and line*: this gear takes larger fish, from about 7.5 cm and up and seems to be more in use in SW Thailand than in SE Thailand. It is a good method for catching *E. bleekeri* in reef areas. Around Trang, 30 boats work with hook and line fishers, each boat has 2-3 fishers each and a very small hook size is used. These fishers, together, can catch as many as 20,000 10 cm fish at the peak times per day. The bycatch with this gear is generally low (about 10%) and mortality is variable, ranging from a few percent, to high a few days after the animal has been caught, presumably because of damage from capture. For this reason, in Krabi, the middlemen do not like to buy hook-caught fish.

4. *Push/scissor net/sacbag (Owun-roun)* (Plate III d): this is a net on a triangular frame that collects small seed by being pushed over the substrate. It damages seed because the animals move against each other after capture as well as amongst the litter that is also scooped up. Middlemen do not like animals caught with this gear but it is used particularly when the price of the small seed is low and when there is a demand for high volume because large numbers of small seed can be collected quickly. Mortality can be as high as 80% and even higher if mortality in the few days post-harvest is counted. In the peak season and when demand is very high, the push net may be used day and night to fill orders.

5. *Fish shelter (pum)* (Plate III e): consists of leafless twigs which are generally bundled together in a large mesh net bag. In the peak season (about February to May in SE Thailand and November-February in SW Thailand) this gear is set in canals of shallow brackish water and mangrove areas at dawn or at high tide and harvested once or twice in 24 hours; the placing of this gear is said to be important and it takes the smallest fish (1-3 cm). Best catches are around the full and the new moons. The shelters are shaken and the fish collected with a scoop net. This gear is widely used and collects seed of very good quality. Reports of mortality with this gear varied from low to high. Bycatch is also low during the peak season. One cm fish are taken in the largest numbers at the beginning of the peak season and one fishing village of 100 fishers. Each fisher has 100 shelters, can get 2 million 1 cm fry, and take 1,000-5,000 fish per shelter over a 3-4 day period. In some areas fishers may each have 200-300 shelter units and catch up to 100 seed of 1 cm per harvest; in other areas, fishers have 30-50 traps each and catch 500-600 fry of 2 cm each at low and high tides. Many part-time 'fishers' also use this gear, such as students working after school (e.g. in Satun). In the months following the peak period the shelters are harvested less frequently and the size of the fry becomes larger, at 2-3 cm.

Production: About 90% of Thailand's seed production (from wild capture) is from the south. Wild-caught seed is used both for export and for grow-out in culture areas within Thailand. Numbers of seed captured each year have not been systematically surveyed anywhere in Thailand. It is clear that numbers captured

are highly variable over time and place and there was a strong indication that local seed supply was sufficient for local culture but not when there was also a heavy demand for export. There is not much catch of adult grouper in Thailand and exports of table-sized fish are largely those coming from culture zones. There is little fry production in NE Thailand (Chonburi to Trad) despite culture activities here because, it was suggested, of the damaging effect on fry supply of toxic effluents from shrimp farms.

Examples from interviews provide an indication of annual exports and capture levels. In Songkhla, one exporter at the time of our visit to his packaging facility had 200,000 fish in 98 floating cages and 2,000-3,000 per cage. Some of these were being grown to a larger size of fingerling for export. Other fish were being maintained in covered areas and concrete tanks and were awaiting export. In 1998, in Pattani, an important collection area in SE Thailand, harvest was about 50,000-60,000 fry per month per fisher and there are about 100 fishers. This produced a total of 5,000,000 per month for four months, about 20 million fry for the year. From nearby Yaring and Narathiwat, in 1998 and 1999, a major exporter sent out 100,000-200,000 fry, with about 15% to HK and 75% to Chinese Taipei with only about 10% sold locally. Before 1998, the same exporter sold 500,000-600,000 fry per day during the peak harvest periods which lasted for about 7 days over several months each year. For a year, the total export was estimated at 12 million fry although another exporter indicated that annual exports could exceed 30 million 2 cm fry. On the SE coast of Thailand, in the Trang area, during the peak season, 5,000 fry of 5-7.5 cm were purchased daily in recent years by one middleman buying from several villages. Locally, 10 villages may produce 30,000 fry per day and one good fisher, in 1998, got 4,000 seed (mainly *E. coioides*) of 5-25 cm size fish using fish traps. Around Trang, one of three middlemen purchased 100,000 *E. bleekeri* fry in this area in 1998 and averaged 1,000 *E. coioides* and *E. malabaricus* per month in 1997, about 12,000 per year in 1998.

Exporters based in Bangkok gave approximate export volumes for different sizes of grouper seed. One indicated that the seed supplied to Chinese Taipei (generally the smaller size classes are preferred compared to Hong Kong) was about 60 million (2.5-5 cm) seed per month but has decreased since former times, possibly because (he suggested) of the lower quality of the fry in recent years. This comment about a reduction in seed quality in recent years arose several times in relation to reduced exports. For larger seed (juveniles), the total export from Thailand in 1999 was 400,000-500,000 for 20-25 cm fish. Demand has evidently declined in the last couple of years, both from Hong Kong and from Chinese Taipei, the two major export markets. Species preferred by these two markets vary, with preference in Hong Kong shifting from *E. coioides* to *E. bleekeri* in recent years. Thailand exported 10 million *E. bleekeri* to Hong Kong annually; year unspecified.

2. GROW-OUT

Grouper grow-out culture is an important activity in Thailand but an insufficient supply of suitable size and quality of seed is a continuing problem. Grouper are one of the preferred grow-out fish species because of their high market price. Almost all culture is cage culture (Plate IIIg, IIIh). There is very little culture using ponds although in some areas old shrimp ponds have been converted to pond culture for grouper. About 10% of all marine fish cultured in Thailand is grouper and it was suggested that the future of the grouper culture industry depends on the success of hatchery production of seed. However, it was also opined that, without export of seed, there could be enough for culture within the country even despite the annual and unpredictable variability in supply. For example, in the SE, between 10-50% of the annual capture go for local culture, the rest (and much of the smallest size classes) is exported. Overall in Thailand, most of the grouper seed caught is exported. Grouper culture is extensively practiced up the SW coast with some activity along the NE coast and little on the SE coast. In general, trash fish is used as fish feed and artificial feed is new in Thailand and rather too expensive for the farmers, so is not widely used.

The preferred size for grow-out in Thailand is 10-15 cm since mortality at this stage is reasonably low. Smaller fish are available and these may be grown (from 2.5-10 cm) before being placed in net cages for grow-out. This 'nursing' phase is carried out in earthen ponds in SW Thailand but is not common practice. Most culture involved the raising of fish from about 10 cm to 1 kg which takes 9-19 months.

There are a number of problems associated with culture activities although under favourable conditions mortality is maintained at low levels. Diseases have plagued some areas, especially viral diseases, in the last 5 years. In SE Thailand, culture is more limited because of problems with salinity which limit the growing season. In Krabi, the major disease problems are parasites and gas bladder disease, especially during the warmer summer months. In general, grow-out mortality may be 20-30% for 7.5 cm to table-size fish and culture is still economically viable at levels up to 30% mortality. Sometimes, mortality levels are higher, at 40-50%, especially when the temperature increases or there are problems with salinity or pollution. In some areas there are also problems with poachers.

3. GROUPEL HATCHERIES

There are several grouper hatcheries in Thailand although production at none of them is yet at commercially viable levels; there are no private sector grouper hatcheries. It is government policy to promote cage culture of grouper and sea bass in Thailand. In southern Thailand, there is a very active National Institute of Coastal Aquaculture (NICA) facility in Songkhla. This facility works on *E. coioides* and *E. malabaricus* and has had some recent success with *E. lanceolatus*. NICA is a government facility established in 1981 using Japanese money (JICA) and has about 120 staff. The objectives of NICA include the promotion and development of coastal aquaculture and research on the reproductive biology and physiology of grouper and other species, including Tiger prawn, seabass and seaweed. There are three research stations as well as hatcheries in Krabi and Satun. NICA is the oldest and largest hatchery for grouper in Thailand. There is also a marine biological centre in Phuket working on grouper hatchery and grouper work started at NICA in 1991. Several other smaller stations were also mentioned from eastern Bangkok. In terms of hatchery production, grouper is the second most important species at the facility; seabass is the first.

Several problems are faced by the hatcheries and research efforts are working towards tackling these. For example it has been difficult to get sufficient broodstock and, as a result, biologists are trying natural and hormone-induced sex change (MT and LHRHa). The former is preferred because the production of milt is better; female broodstock can be used from 3-4 years old and males from an older age. Broodstock of *E. coioides* come both from the wild and also from hatchery grown fry. At the Songkhla facility about 300 broodstock of this species are maintained and some fish are tagged with microchips to follow sex changes. The main culture species are *E. coioides* and *E. malabaricus* but there are also plans in some facilities to work on *E. lanceolatus*, *Plectropomus maculatus* and *Cromileptes altivelis*. Research is being carried out on the development of feed.

Annual fry production at the Songkhla facility was estimated at about 100,000-170,000 7.5 cm fingerlings. This represents but 1% of the total fry production in Thailand (suggesting that, of this size, between 10 and 20 million seed are captured each year). This hatchery production needs to be substantially increased to better serve grouper culture in Thailand and the possibility of importing hatchery produced grouper fry from Chinese Taipei has been discussed. One of the more pressing problems recently is the *Vibrio-iridovirus*, with breeders infecting the young fish. The virus is proving difficult to eliminate and cause mortality of fry at several sizes.

There was also mention of the plan to produce enough grouper seed to eventually allow restocking to be carried out in certain areas. This was considered to be one possible approach to restoring grouper populations, albeit

an expensive one. It was stressed that seed would have to be released into unfished areas.

4. TRADE

Trade in grouper seed of sizes ranging from 2-25 cm occurs both domestically and internationally with exports the major activity, although customs records of seed exports for grouper were not available. Most of the seed captured in Thailand is exported, and mostly from Bangkok, although some goes directly out of Phuket, to both Chinese Taipei and Hong Kong (and China). From southern Thailand in general, seed may be exported through Bangkok after travelling to the capital by air or by road. There appears to be no commodity code for grouper seed and even table-size live grouper were not found in export records after the mid 1990s. Several middlemen and exporters indicated that even if exports are declared (it was not clear under what category they would be declared) any quantities would likely be underestimates to avoid tax payments. Most exporters are based in Bangkok and there are relatively few large companies (less than 20) with most export carried out by 5-6 companies, down from 10 a decade ago. Some of the same companies also export fry from the Philippines and most are involved in trading a range of seafood commodities apart from grouper seed.

The annual export trade in grouper seed involves tens of millions of fish and has a seasonal component but has declined markedly to the two major export economies in the last few years. To both Hong Kong and Chinese Taipei, most trade is after the Chinese New Year, and especially during April to August, to match the growing seasons (and warmer waters) of the recipient economies. Trade to Hong Kong has declined over the last 3 years because of severe problems in Hong Kong with culture due to reduced water quality (see Hong Kong section). In the case of Chinese Taipei, reduced demand was thought to be due to the greatly increased success in hatchery production of fry in recent years (see Chinese Taipei section). One exporter shipped 10 million fry to each of Hong Kong and Chinese Taipei prior to the downturn in demand from both areas.

Demand by species has changed over time and differs somewhat between Chinese Taipei and Hong Kong as does the quality of the fry from different source areas within Thailand. In Hong Kong (and China) requests for *E. coioides* have declined in favour of *E. bleekeri*, probably, it was suggested, because the latter species survives better in poor water conditions (however in the Trang area it was indicated that *E. coioides* does better in polluted water!). Moreover, Hong Kong prefers fish in the size range of 7.5-20 cm (especially 10-15 cm) because of their ease of culture combined with price, while Chinese Taipei prefers *E. coioides* of a small size (2-3 cm) because the price is low and the cost of transport is relatively small compared to larger fish. Chinese Taipei has the ability to 'nurse' the smaller seed successfully. In selecting animals for export, middlemen sort out fry in good condition and generally consider that fry from SW Thailand is the best. However, there is a perception that, overall, the fry from Thailand is not as good in quality as that from the Philippines and mortality rates are higher in culture in Hong Kong and Chinese Taipei.

Apart from trade with Hong Kong and Chinese Taipei, there is also trade with neighbouring economies, sometimes carried out illegally. Fry is sold to Malaysia and purchased from Myanmar and Sabah. Seed also come into Thailand from Kampuchea and southern Vietnam and is sold to Singapore. There is a limited trade from Sabah, through Thailand, to Hong Kong. An unknown proportion of the seed goes to China, much of it via Hong Kong. It is not clear if seed goes directly from Thailand to China. One interviewee said that there are direct flights from Thailand to Guangzhou in southern China of both table-size and seed grouper.

Fish have to be transported from the point of capture to the middleman/culturist and often from the middleman to the exporter. For short distances, fry are placed in a styrofoam box or a bucket, with or without aeration (often provided by middlemen), or with holes in the bottom for water exchange, and moved for about 10 minutes to two hours to the next destination. Post-harvest mortality is low. For longer periods in transit, fish are packed in

23-25°C seawater, with aeration, about 50 fish of 7.5 cm in a bag or 100 fish of 1 cm per litre of water or 200-300 fish of 3-7.5 cm in a bucket. Sometimes ice is used to keep the water cool; this is for a 7-hour journey. Some exporters use anaesthetic, either quinaldine or MS222, but consider the latter to be rather expensive. The use of anaesthetic was considered important to reduce the likelihood of spines piercing the plastic transport bag. For export, fish are packed in styrofoam boxes of various sizes and each shipment has about 20,000 fish and 300 boxes.

5. SOCIOECONOMIC ISSUES

The number of grouper seed fishers in Thailand has not been assessed but clearly in certain key collection areas in the south this harvest is a key activity, especially in certain seasons. For many fishers and middlemen in the south, the income from grouper seed collection and trade is a significant part of their annual income.

Demand and prices are determined largely by exporters and recipient economies, especially Hong Kong and Chinese Taipei, and have a significant impact on fishing activity. High mortalities in cage culture areas in Hong Kong have led to reduced demand and some non-payment by a Hong Kong importer, according to exporter comments. Moreover, when the prices of fry are low, or demand particularly high, the fishers tend to use the more destructive gears to supply more fish more quickly (see section on gears above) when the quality is evidently not of major consideration. When the unit price is higher or there is a clear demand for lower numbers of quality fish, more care is taken in fishing operations. Moreover, when prices go down for table-size fish, fisher/culturists will just catch seed and no longer culture. With such marked demand and price fluctuations it is difficult for middlemen to plan and so most middlemen are involved in several different types of trade. In any one area, there are relatively few middlemen who are supplied by large numbers of local fishers and who may buy from other middlemen; these traders both export and sell seed locally. Some middlemen are also culturists themselves. The number of middlemen will vary according to market condition. For example, in Trang, there were 10 middlemen when prices were high and now there are 3. One of these middlemen sells *E. bleekeri* for export and of the *E. coioides* and *E. malabaricus* he receives, he sells 80% for export and trades 20% locally. In Krabi, there are 6-7 middlemen and 30-50 fishers.

Relationships of indebtedness between middlemen and fishers were identified and place significant control of price in the hands of the former, creating financial hardship for the latter. In Trang, for example, I learned of cases where fishers had become heavily indebted to middlemen and needed many years to pay off their debts; indeed, several fishers interviewed felt that they would never be able to pay off their debts. In other areas, middlemen supply gear or otherwise give assistance and fishers must sell their catch to that middleman.

6. HISTORY

The capture of grouper seed in Thailand began in the late 1980s in response to requests for seed from foreign traders. The response to the high prices by both fishers and culturists resulted in much increase in activity in grouper capture and culture during the 1990s. In southern Thailand, buyers from Hong Kong and Chinese Taipei came looking for grouper fry in 1991 from Pattani. Trade was easy at first as exporters provided money up front and seed supply was high. Fishing effort increased during the 1990s. In Pattani, 7 years ago, there was much interest in the culture of 10-12.5 cm fish and an increased demand for fishers to provide this size of fry. At this time there were about 20 fishers, while now there are about 100 who take grouper seed, despite the decline in seed prices. At Trang a fisher of 10 years (and culturist of 5 years) said that he had started in grouper seed capture and culture after middlemen came to ask for fry. He had borrowed money from an agriculture bank and had rapidly become indebted. He was finally given assistance by the Yadfon cooperative in Trang.

During interviews with fishers, middlemen and biologists, it became clear that in most places there was the perception that grouper seed supplies had declined markedly during the last decade. While this is probably partly a response to recent changes (i.e. recent downturn in demand, discussed above) in the export market (with about 30% fewer exporters compared to 5 years ago), it was also thought that real declines in resources had occurred. Catches had declined despite an increase in the number of fishers and, in Satun, fishers catch fewer seed (at least 50% less) than 10 years ago and it was suggested that there was too much fishing effort. One culturist claimed he bought and exported 300-500 fry of *E. lanceolatus*, from Krabi, measuring 15-17.5 cm, 6-7 years ago but now cannot get any of these fry and considers them to be rare. In Krabi, middlemen spoke of decreasing supplies in the last decade, beginning about 7-8 years ago, possibly because of too many fishers, while the fishers suggested that the problem was due to an unspecified change in the environment. In Trang (Kao Kheam), 100,000 grouper fry were caught in 1999, a decline from 1-2 million fry from years before. The declines were thought to have come from an air bubble gear used on inshore reefs which scare fish away. One fisher from the area said that the number of fishers had trebled over the last 10 years and that a decade ago he had caught all sizes of grouper seed but that now only the smaller size classes were available. This fisher used to catch 35,000-40,000 fry 10 years ago and last year he only got 4,000 animals. Using traps, he used to get 3-7 fish of 5-25 cm in the peak season from 70-80 traps 10 years ago and now he got only 1-3 animals per trap. One middleman noted declines in supply from 10 to 4 years ago of about 5-10% per year. He suggested that a possible cause was the shrimp culture which used tea seed cake and sodium cyanide (this poison was only mentioned by one person during the Thailand visit) to clear ponds and these could kill grouper seed in coastal waters. One middleman used to export 40-50 million grouper seed to Hong Kong (and China) and Chinese Taipei, but more recently (3 years ago) exports were only 20% of this, and are currently even lower. In one of the few exceptions to the comments on declines, grouper fry production is now 20% higher than five years ago in Yaring.

Work on grouper hatchery began in 1991 because of the high market value of grouper and because NICA was approached by fishers asking for high quality and consistent size of grouper seed. Fishers/culturists were concerned about the unreliable supply of seed and had also noticed problems with high mortalities in the smallest seed size classes (2-3 cm) and wanted to have steady access to larger seed (10-12.5 cm). Since *E. bleekeri* fetches lower prices, NICA only worked on *E. coioides* and *E. malabaricus*. The director of NICA felt that, although it was clear that grouper fry numbers fluctuate annually, there had been an overall trend of declines over the last decade possibly because effort was too high and from destructive fishing gears. He also noted that the sizes had not changed. At Satun, the chief provincial officer felt that gear control and production control are needed as production is probably 1.5 times the sustainable level.

7. REGULATIONS

There are regulations that prohibit or limit the use of the push net (sacbag) and the fyke net. Push nets and trawlers should not be used within 3 km of shore and trawler mesh size must be ≥ 2.5 cm. We were not able to obtain a copy of the regulations.

d. PHILIPPINES

Literature

Grouper seed are taken extensively throughout the Philippines, one of the biggest suppliers of wild-caught grouper fry, fingerlings and juveniles in SE Asia. Major sources of fry have been listed in various publications, the more recent of which mention Cagayan, Ilocos sur, Pangasinan, Quezon, Camarines Sur, Masbate, Samar, Panay Gulf, Zamboanga del Sur and SW Mindanao (Castanos, 1999). Another key paper which discusses

areas of seed capture is that of Ogburn and Johannes, 1999 (summarized in Johannes and Ogburn, 1999) who list about 60 locations within Luzon, the Visayas and Mindanao. Major capture areas were identified by Baliao et al. (1998) to be Pangasinan, Cavite, Mindoro, Quezon, Ormoc, Masbate, Bulacan, Cagayan, Dadiangas, Negros Occidental and Capiz. Export and domestic trade figures for 1995-1997 list the key sources of traded fry as Cotabato (Mindanao), Bacolod (Negros Occidental), San Jose (Occidental Mindoro), Davao (SE Mindanao) Ozamiz (Mindanao) and Legaspi (Albay) (IMA, 1994-1997). A map of capture areas is given in Castanos (1999). In these capture areas, fry and fingerlings are taken from near big rivers, in coastal waters near mangroves and from reefs and there is often a distinct seasonal component to availability. Fish are typically taken from about 2-15 cm TL. The main species is *E. coioides* with significant quantities of *E. malabaricus*. Also taken in from certain locations are *E. bleekeri* and limited numbers of *E. fuscoguttatus*, *Plectropomus leopardus* and *Cromileptes altivelis*.

Fishers use a wide range of gears which vary by location, season and by fish size range targeted. At least 14 have been described in a recent comprehensive survey (Ogburn and Johannes, 1999). One of the better described gears is the *gango* (or fish nest) which includes branches, mangrove wood and stones to build a loosely-knit structure which acts as fish shelters to aggregate grouper fry and juveniles (Leong, 1998, Ogburn and Johannes, 1999). *Gangos* have been used in the Philippines for over 50 years and are typically deployed in tidal areas near mangroves (Ogburn *pers comm.* 03/02/99). In some areas there may be 1,000 or more in use. When harvesting these *gangos*, fishermen enclose them with a net to collect the fish fry. Although this gear is considered to be one of the most ecologically sustainable of all of the gears used, there is some concern over high bycatch (i.e., non target species) rates and the use of mangrove wood for construction, although bycatch may be reduced by careful handling (Mous et al., 1999; Ogburn, *pers comm.* 03.02.99). Research on *gango* catches, carried out in Komodo (Indonesia) by The Nature Conservancy, indicated that only 1.4% of total *gango* catches were target species, the rest of the catch was non-target bycatch: Green grouper (*E. coioides*) were found within the fry/fingerling size range, and above, while other non-target, but commercially important, species (e.g. *Lutjanus argentimaculatus* and *Lates calcarifer*) were larger than the fingerling size (Mous et al., 1999); moreover large volumes of mangrove wood were estimated to be necessary to establish a viable *gango* capture fishery during the Komodo study and there were large number of small non-commercial species also. While the *gango* is not used in Indonesia and its catch properties might be quite different in the Philippines (i.e., more or less bycatch or different handling of bycatch to reduce mortality, etc.), nonetheless, it is clear that target catch and bycatch rates need to be examined for fishing gears to determine their suitability for sustainable seed harvest.

Other methods for collecting wild grouper seed in the Philippines include hook and line (*kawil*), bamboo shelter (*sugong*), scoop or dip net (*sikyap*), 'miracle holes', fish shelter (static-*habong* or suspended-*pailaw*), lift nets (*paapong*), mangrove net (*sira-sira*), fyke net (*sangab*), scissors net (*sudsod*), traps (*bubo*), drag net (*sabay*) and fish corral (*bungsod*) (Ogburn and Johannes, 1999) [note that the names of these gears can vary markedly by region]. Miracle holes are popular in some areas and were introduced in 1986 by the Central Visayas Regional Project. Some gears are considered to be damaging to the habitat (e.g., scissor net, cyanide), and to take a disproportionate number of fish thereby contributing to social inequalities (e.g., fyke net) (Quinito and Toledo, 1991; Wilson, 1997; Ogburn and Johannes, 1999). Other gears result in poor quality fry, a major problem for culture activities (Juario et al., 1993).

There are few data on the production, or volume, of grouper seed taken in the Philippines and no countrywide estimates; the grouper seed fishery is little understood even compared to other local fry fisheries (e.g. rabbitfish, milkfish, shrimp). While not monitored as a capture fishery, there are sporadic unpublished reports or datasets on the grouper fry fishery which provide important data (e.g., Wesley Rosario, surveys in Luzon, early 1990s, *pers. comm.*). Indications of capture volume are provided by sporadic survey data at certain collection sites and

domestic and international trade data allow a crude evaluation of trade volumes. However, trade data from airport declarations are typically underdeclared and do not, in any case, factor in mortality levels between capture and shipments. Trade data, therefore, allow little better than minimum estimates of capture.

Trade data strongly suggest that about 90% of all grouper fry caught in the Philippines is exported by air (out of Manila) with the remaining 10% traded domestically, and that many tens of tons of fry are exported annually. Chinese Taipei and Hong Kong are the major recipients of grouper fry although there have been reductions in exports to both locations in recent years (Bentley, 1999). In the case of Chinese Taipei, this has been attributed to the success in hatchery production, and for Hong Kong, water quality problems have plagued the mariculture industry which has shown much lower production recently. A wide size range of fish is exported. For example, fingerlings from 7.5-15 cm are purchased by exporters in Manila from Cavite, Bicol and elsewhere, and are more desired by Hong Kong than smaller fish, whereas Chinese Taipei prefers the smaller fry (2.5-5 cm). Air shipments appear to predominate and are, in any case, more economical nowadays since smaller volumes can be shipped. For example, in the 1990s, one exporter shipped 2-3 boatloads of 3 t each to Hong Kong of fingerlings from Pangasinan Province but by 1996 could only make one such shipment because of reduced supply (Bentley 1999), and possibly reduced demand. Trade data on 'grouper fries' have been collected by the International Marinelifelife Alliance and provide a useful indication of trade volumes (IMA, 1994-1997). Through Manila international airport trade data showed that the weight (kg) of grouper fry (fry plus packaging and water) was 297,400, 121,800, 310,700 kg per year for 1995, 1996 and 1997, respectively.

For domestic trade in 1995 and 1996, 24,656 and 9,440 kg of fry/fingerlings were shipped, respectively, in boxes with each box weighing between 12 and 16 kg. Since a wide range of fry sizes is shipped and boxes contain different numbers of fry depending on fry size (ranging from 200-500 or more of the smallest fry to 20 or so of 15 cm fry depending on box size) an estimate of fry volume (weight) can only be made by assuming that the ratio of water to fry biomass is 3:1 (as is the typical ratio for larger grouper). If so, this suggests that annual exports of seed for 1995-1997 ranged from 30.5 t to 78 t. If the average fish size is 6.5 cm (weight about 3.37g - see Fig. 2a) the numbers of fish range from 9-23 million for the tonnage estimated. Not only is the average fish size likely to be on the smaller end of the size range, this estimate takes no account of underreporting of exports or of mortality between capture and export, which are often high. As an order of magnitude estimate of captures, therefore, taking into account the above factors and the capture volumes given during our interviews (below), it is highly probable that hundreds of millions of grouper seed are exported annually from the Philippines. Most exports occur in Feb-August to match the growing seasons in Hong Kong and Chinese Taipei. There are about 7 major (90% of trade) exporters and up to 12 companies, with 6-7 major ones.

Mariculture in the Philippines began in about 1980 with great increase between 1991-1995 and is widely practised in the Philippines using pen and cages in bays and adjoining tributaries. It contributes significantly to livelihoods in coastal communities; in 1997, grouper production from culture was 496 mt with an average price per kilo close to that of shrimp (Somga et al. 2000), while for 1998, grouper production from fish cages was estimated to be 33 mt (Agbayani, 2000). However, the general shortage, and unreliable supply, of seed, the economic risks of culture (weather conditions and poor water quality are major concerns) and general lack of technical knowledge by farmers preclude more widespread investment in grouper culture (Rosario, 1999; Somga et al., 2000). The Philippine government oversees mariculture and capture activities under BFAR and is carrying out applied research on fingerling production, development of broodstock, improved engineering designs for sea cages, and alternative feed for grouper. There is a very good published literature on this work that is beyond the scope of this report to review. There is a need for increased capital investment to develop grouper culture in the Philippines and a real need to transfer technologies for improved culture to fishers (Palma et al., 1989).

Interviews were conducted with 11 officer/biologist/NGO, 7 culturist/middlemen, 24 fishers and 4 exporter/wholesalers – see Fig. 1b for details of locations.

1. CAPTURE FISHERIES

Results from visits and interviews within the Philippines, as well as direct communications with local biologists and government officials, indicated that important fry/fingerling capture areas were located at numerous sites around the Philippines, that fry capture had begun in about 1980 and that demand for fry exceeds supply. Although visits were conducted to many fry supply areas, it was not possible to visit all locations. Of particular note is that sites in Mindanao, identified to be important fry supply areas, were not visited due to safety considerations. In addition to the sites visited and discussed below, interviews also identified major sources of fry to be Palawan, Mindanao and Tacloban (Leyte).

Fry and fingerling capture mostly take place in extensive mangroves and nearby tidal flats, and river mouths or areas of reduced salinity and comprises mainly two species, the 'green' groupers, *E. coioides* and *E. malabaricus*. Other species taken in smaller numbers are Red grouper, (*E. bleekeri*), Tiger grouper, *E. fuscoguttatus* and Giant grouper *E. lanceolatus* and a handful of other grouper species. Local names varied widely and often the 'green' groupers were lumped together (e.g., *Calabanga*, *Pugapo*) while *E. bleekeri* was sometimes referred to as *Tipig* or *Suno*, and *E. fuscoguttatus* as *Aswang*. There are also general names for fry/fingerlings (i.e. 'seed') (e.g., *Semillya* in Inabanga). Names were highly variable locally and only a few examples are given here.

Gears: at least 10 types of fishing gear were noted, some of which were quite specialized in particular areas or for particular size ranges of fish. Often fishers used a number of different techniques. The gill net was also reported as being used in the past but is little used nowadays because of the problem of high mortality (Table 4).

1. *Fish trap (bubo)* (Plate IVAa-d): fish traps are used to catch a range of reef fishes of a range of sizes and generally take larger sizes of groupers than other gears. Traps do not account for a large capture volume of fry/fingerlings in most places. While trap catches do vary seasonally, they do not have distinct peak seasons like many gears used for smaller fish. In Legaspi, the best season is July-September and each fisher has 10-20 traps and will take 1-6 fish during the peak time. The bycatch for these traps comprise other species of grouper in small numbers. In Calabanga, the main season is March-June for ≥ 12.5 cm fish; traps may be deployed during low tide or in shallow water and left for two days and each haul gets 2-3 fish. Bycatch is about 50% and is mainly *Siganus*. Mortality is generally low but is sometimes higher where there is strong wave action (if placed in shallow water) and when the grouper are caught together with toxic species like pufferfish. Mesh size varies; that of 3 cm will take 5-12.5 cm size fish after a 2-day soak.

2. *Fyke nets (biakos, tangger, tangab)* (Plate IVAe, IVAf): this gear consists of a large net bag supported by stakes and set facing upcurrent. Fish moving downstream are funnelled into the bag by two converging rows of staked netting. The catch can be high and the gear is popular although quite expensive. It is operated at night and takes fry of 2.5-5 cm or smaller. Bycatch is high, often $>50\%$ of total catch in the off-peak season, and often including rabbitfish. Bycatch is relatively lower in the peak grouper seed season.

Mortality rate is low, at about 5%, and fish are generally taken in good condition although some fishers reported that, in peak season, mortality can be high because the fish get damaged as they rub against each other. The nets are operated by 1-2 men and can take 400-1,000 grouper fry per night during the peak season. Among all the nets in Banao Cove, more than 1 million fish are caught by more than 100 *biakos* over the peak one-month period. *E. coioides* and *E. malabaricus* are the most common grouper species taken. The peak season in the area is between December and April for the smallest fish. At Buguey, they set the net at the mouth of a river in 4-5 fathoms at high tide during the new moon in March which is the peak period. In the past, it was possible to get a maximum of about 13,000 fish per net per night. More typically, nowadays, a single fisher will get 2,000-3,000 fish per night for 7-10 peak nights with two nets. At other times, catch rates are more typically 100 fry per night. Each fisher has from 1-3 nets. The net is expensive.

3. *Scissor net (sudsud/sudsod/sakag)* (Plate IVAg, IVAh): a triangular bamboo frame of various dimensions which may or may not have 'shoes' to assist it in moving over the substrate. Fine meshed netting is attached to the frame and the bamboo poles, which are hand-held, are crossed over each other. The frame is pushed in front of the fisher and small nets may even be used by children to harvest fish. The gear is operated in shallow waters at lower tidal phases and may be pushed continuously for up to 6 hours. This gear takes fry and small fingerlings of <2.5 cm to 7.5 cm and about 60% of the catch is bycatch. Mortality is not high but a small percentage of fry gets physically damaged using this method. Catches can be 50-200 fry a day per unit and the gear is used by hundreds of fishers and children in fry collection areas, collectively taking well over 1 million fry per month. In Legaspi, the peak season is February to August. This is the oldest gear used in Legaspi for catching grouper fry but the quality and the quantity taken are not as good as with some other gears. In Bohol, fishers catch about 300 fingerlings and juveniles (2.5–15 cm) per month, and get 3,000 per day during the peak season from the whole bay (all fishers combined) with 200 fry per person per day.

4. *Miracle hole (amadong)* (Plate IVBi): wide (2-3 m diameter), shallow holes are excavated on tidal flats. Sometimes the wall of the hole is built up with rocks. Within these holes, branches and rocks may be placed and fish seeking shelter become trapped in the holes as the tide recedes when the holes can be harvested by hand. Sometimes the holes are harvested with cyanide (reported from Bohol) because it is quicker to do this than to remove the rocks. Miracle holes are common in the Bohol area.

5. *Leaf shelter/attractor (ilay, bum bum, mono-line)*: bound bundles of leaves/branches/coconut leaves suspended from the water surface by poles or from boats and used at night in shallow waters (1.5-3 m); may or may not be used together with a light source (a more recent introduction). Strings of this gear on boats number 10-20 leaf units for small boats and 50 per large boat. They attract small grouper fry, of 2.5 cm or less, which shelter among the floating leaves and are attracted in greater numbers if there is light. The shelters are harvested at low tide by shaking, and the fish are caught up in a scoop net. This is a popular, but expensive (when used with light), gear. A line of these shelters, strung together, is typically operated by 1-2 men and can catch one million fry per month. Each night about 200 *ilay* are operated in one area in Legaspi and about 100-800 fry per gear per night are taken in the peak season. The major bycatch is rabbitfish which make up a high proportion of the total catch and other grouper are taken, although these are released since they are not good for culture. Mortality of caught fish is about 5% and generally the fish are in good condition; the exception to this is when light is used producing poorer quality of fish (as noted by both fishers and buyers although the reason for this is not known). The light is said to

attract far larger numbers of fish per unit time, about 70% more than without light. In some areas, this gear is very popular and is the major one used, and, during the peak season, it is possible to catch more than 20,000 fry per night (e.g. Capiz) during the quarter moon. In Occidental Mindoro, the main catching period (June-October) with this gear is 1 week per peak month for 8 hours; if light is used, 1 fisher with 10 *bum bum* can get 100-300 fry per harvest, and 2,000 fry per month. Following the peak season, the number of fry harvested is 20-50 but the fry are bigger. In Pangasinan, fish of about 1cm are harvested, with or without light, and each fisher has two units and can catch 1,000 seed per harvest at peak time. All fishers in the area combined take about 10,000 at peak seed times. The bycatch is high and largely consists of rabbitfish and shrimp.

6. *Fish corral (bonsods/bakalad/pasabin)*: a corral type of fishing gear originally used for milkfish, shrimp and other fishes. Groupers are only occasionally caught with this gear (mesh size 2 cm) which consists of one or two static stake circles towards which fish are guided by long rows of stakes. Not a major gear for groupers but the animals taken are in good condition and mortality is low. In Pangasinan, peak season is March when it is possible to take 100 kg of fry. This gear takes fingerlings of 5-10 cm, especially during February and August at Legaspi, with an average of about 7 fingerlings per person per day.

7. *Artificial reef (pukox, gango)*--this method consists of rock mounds and may include branches, and harvested at various intervals, ranging from days to months. These structures act as artificial reefs to shelter fish in the shallows. The main capture is fry and fingerlings. To harvest this gear, the rock mound is encircled by a net and the rocks are removed as the net encloses the trapped fish. Target species are then carefully removed. Daily catch rates can be about 5-10 fish per day and about 200 fish per person per month. One fisher may have 8-10 artificial reefs and peak harvest times at full moons can yield 100 seed, of fingerling size. Mortality is reportedly very low and bycatch is highly variable but can be high. Some of this can be used but some dies because the delay in sorting non-target species can produce mortalities; improved handling at this stage, as practiced in some areas, reduces such mortalities. A variety of species is taken and the gear is very common. A major fry importer in Hong Kong indicated that this gear produces very good quality fry.

8. *Cyanide*: this poison is sometimes used to catch fingerlings of 5-12.5 cm especially by the younger fishers because it is quick. *C. altivelis* is considered by many to be difficult to catch without cyanide. Its use was often mentioned and Bohol appears to have a particularly bad reputation in this regard. It has been used in Bohol for at least 30 years, originally for the marine aquarium trade. Cyanide is evidently available from a syndicate in Bohol and is believed (according to the packing materials) to come from Germany. Cyanide was previously used in Cavite for grouper fry (late 1980s) but poor quality fry led to cessation in this area.

9. *Hook and line*: used for catching larger fingerlings and market-sized fishes but not a preferred gear for fingerlings because of relatively low capture rates. In Bohol, the main capture season is March to June and about 7-10 fingerlings are caught per day per fisher. Bycatch is mainly *Scatophagus* spp. The only mortality is from swallowing the hook.

10. *Tidal pools*: hand collection is carried out daily from shallow tidal pools on tidal flats at low tide, especially at the new moon in two months of the year. In Legaspi, mainly green grouper are taken at 1-2.5 cm with some *E. bleekeri* in just two months of the year. One fisher can take 50-100 fry per harvest at the peak time and in one bay, 50,000 fish per month can be taken.

Production: there are no overall production figures for grouper fry and fingerlings for the Philippines but it is clear that there are tens of thousands of fry fishermen, both full and part-time, and that fishing activity for grouper fry is usually highly seasonal. Estimates obtained during the course of the survey on the production of individual fishermen, or fishing communities, provide snapshots against which to evaluate approximate trends and volumes in total production.

As specific examples of capture production and of some of the problems of seed supply, the following should serve. In Bagacay Bay (Legaspi), from 1990-1993, more than 5 million fry were taken in one year and harvest in this area has since been declining, possibly due to blast fishing and overfishing of adults; in the last 10 years an overall decline of about 50% was indicated in fry capture. At Batasan Is. (Bohol) the catch is most commonly of 7.5-10 cm fingerlings and since there are insufficient animals of this size for local culture activities, fingerlings have to be brought in from elsewhere. In nearby Tubigon, I witnessed scoopnetters operating around the mangroves, a fishing method that is widely considered to be damaging to the habitat and in many areas is illegal. Bohol was also widely known for the use of cyanide to take grouper fingerlings and aquarium fishes. In Banoa Cove (Legaspi) about 1,000 fingerlings and 2 million fry were taken annually in 1997 and 1998, with only 30,000 fry taken in 1999 partly because demand for fry had become much lower. In San Miguel bay, 100,000 fingerlings were caught in 1999 and most collection areas evidently supply more than 1 million fry per year. In Calape (Bohol) buyers (who purchase directly from fishers) deal in tens to thousands of fry each year. In Inabanga (Bohol), 200 grouper fry fishers work from December to March and catch 100,000 fry and about 30,000 fingerlings per year. In Pangasinan, in one collection area, annual production is about 150,000 fry. In Buguey (Cagayan) each fisher may get 30,000 fry a year but there is much fluctuation annually, with lower catches when there is rain or typhoon. In this area there were about 300 fishers but now there are 100 fishers with 100-200 fyke nets and catches are much lower, per fisher, than before. Many local fishers blame the introduction of 'bullybully' boats which fish the adults of their target species. In La Union at peak capture times, fishers take 10,000 fry from an area with about 1,000 collectors working hard for a few days in September and October. In Calauag Bay, Quezon, unpublished BFAR figures from occasional surveys showed that in 1996, 325,000 fry (tinies) were taken during the peak season of January to March. Business subsequently ceased when prices became markedly depressed. In San Jose (Occidental Mindoro) in 1998 a fisher estimated that about 2 million fry were taken by the 300-400 fishers in the Bay, each fisher selling 100-5,000 fry per harvest. As the fishers increased over time, the catch per fisher declined. Another estimate of the total catch from a middleman was 10-20 million annually.

The middlemen and exporters deal with thousands to millions of grouper seed annually. It is interesting to note that the middlemen, who purchase from thousands of fishers nationally, are generally unaware of annual fluctuations in numbers. The most likely explanation for this is that middlemen seek to fill the orders they receive and they typically purchase from many areas and many middlemen. They are, therefore, somewhat buffered from local short-term fluctuations and, to some extent, to longer term changes in availability. It should be noted that the numbers which are traded domestically, or exported, inevitably substantially underestimate the numbers caught since considerable mortality may occur between capture and the various levels of trade, especially for fry. As examples of trade figures, estimates given by traders ranged from 100,000 fingerlings to Hong Kong by a major exporter in 1998, to a trader based in Capiz handling > 0.5 million fry in 1998 and who noted that the supply in the past 5-10 years has been stable although he is purchasing from far more fishers than in the past.

The most detailed survey I located during the course of interviews on the grouper (and other) fry fishery in the Philippines was one from municipalities in Luzon, an unpublished study carried out in the early 1990s which provides a good baseline of information for the area (Wesley Rosario, pers. comm.). The survey provides data from fisherman interviews on species, harvest season, market outlets, prices, capture size, materials and methods of capture, transport and culture practices, and concludes that the grouper fry fishery was

understudied, that there was social inequality in access to fry in some areas, that transport and handling practices often resulted in mass mortalities, that large numbers of fry were being taken in certain areas, and that there was a lack of awareness and management of the resources.

2. GROW-OUT

Mariculture of grouper in the Philippines is based on the grow-out of wild-caught fingerlings and fry. However, there are persistent problems in procuring sufficient fingerlings of the locally preferred size (5-10 cm) for culture and a shortage of fish feed (typically the feed comes from 'trash' fish, small shrimp and sometimes tilapia). Because of the fry shortage there is a significant domestic trade in grouper seed. For example, in some areas of western Bohol many would like to expand culture activities but, due to insufficient local fingerlings, culturists have to buy seed from collection centres at Clarin, Inabanga and Tubigon. Indeed, there was a widespread feeling that the lack of fry supply was largely due to the large quantities that are exported.

Grow-out is carried out in different ways according to local conditions. In areas where there are extensive tidal flats, excavations are made to ensure that shallow pools always contain water, even at low tide and net cages are suspended over the holes by wooden frames (e.g., Bohol). Floating net cages suspended from rafts are seen in many coastal areas. In Pangasinan, fixed net cages are used to raise locally purchased fingerlings of 12.5 cm to market size (about 400g) for about 6 months. In some areas, ponds formerly used for shrimp culture have been converted to grouper culture. In general, fingerlings are sought by most culturists but in some areas, where conditions are suitable or facilities available, fry of 1-2 cm are raised for a few months and regularly graded before transfer to culture areas or export. Unfortunately, there is often considerable mortality at this stage which drops as the fish reach 5-7.5 cm and which is one of the main reasons why this is the preferred size for cage grow-out. Another reason is that this size of fish is cheaper than the larger fingerlings. To grow Green grouper of 2.5 cm to 5-7.5 cm takes about 2-3 months with a mortality of 10-40% and to grow Red grouper to the same size takes about 2-2.5 months, with a mortality of 20-80%.

There are persistent problems in mariculture grow-out. The most pressing appear to be those of disease, water quality (including red tides in some areas e.g., Dagupan), weather conditions (rains and typhoons) and poor quality fry (from capture methods such as cyanide or from damaging fishing gear; for example fish caught with lighted fish shelters have higher mortality than those caught without light, while those taken with fyke nets may sometimes be damaged). Disease problems are getting worse in some areas where mortality, apparently due to disease, is higher now than it was a decade ago. Nonetheless, farms can operate with low levels of mortality and there appears to be plenty of scope to improve culture practices through training and experience, and to reduce mortalities of wild seed by correct use of fishing gears, and proper handling and packing (N. Ogburn, pers. comm.).

3. GROUPEL HATCHERIES

Hatchery production in the Philippines is carried out largely by SEAFDEC facilities which research has focused on hatchery production, nutrition and on the problems of overcoming early mortality in the post-hatch larval phase. There are only a few private hatchery facilities but details were unavailable. As an example of one SEAFDEC facility, in Capiz, grouper hatchery research started in 1990 with *E. coioides*, for which it is easy to obtain broodstock. Other research at SEAFDEC facilities has involved breeding and studies on sex inversion and there is an excellent published literature on this research. Progress has been good although production is not yet at commercial levels and may take another 5-10 years to reach this stage, according to interviews (Marte, 1999). There is still dependence on trash fish, quite high mortality levels at various stages of development and problems with egg quality and hatching success. In some cases, male broodstock is hard to

find and sex change, induced by hormones and by social manipulations, is necessary.

Spawning can be achieved both naturally and with hormones. There is also interest in raising *Plectropomus leopardus* and *Cromileptes altivelis*.

4. TRADE

Grouper fry and fingerlings are traded both internationally (through Manila airport) and domestically, although there is no independent commodity code for grouper fry. There is no import of grouper fry to the Philippines. Interviews indicated that some limited seed export occurred from Cebu airport, although Fisheries Department staff said that there was no record of this. International trade is largely to Hong Kong and Chinese Taipei although there is also export to Brunei. Much of the trade into Hong Kong now goes on to China and much is seasonal, to match the growing seasons of Hong Kong and Chinese Taipei which have colder winter temperatures than the Philippines. Domestic trade is to culture areas for grow-out or to Manila airport for export.

The shortage of fry in some areas and the great interest in developing grouper culture mean that the domestic trade is important: approximately 10% of seed caught in the Philippines is used domestically, while the remainder is exported. Associated with this domestic trade is significant mortality from transport. Local transport to middleman or culturists is carried out by keeping fish in plastic containers or basins with holes for circulation after capture, with changes of water. Mortality is quite low under such circumstances. If for trade, the fish may be maintained for short periods by the middleman, prior to packing and shipping, either domestically or internationally. In some cases, they may be transferred temporarily (for a few days) to an 'aquarium box' (Plate IVBo, IVBp) to await buyers who come to collect fish and who pack the fry for export. Mortality can reach 10-20% at this stage, i.e., prior to selling to buyers for export or domestic trade. In general, there is low mortality if transport is < 1 hour but if more than 1 hour, and there is no aeration or frequent water changes, mortality increases and oxygen may have to be added. Buyers pack fry in double plastic bags with pre-cooled water using ice (temp. varies from 18-22°C) and salinity at 15-18 ppt. Tiny fry (2.5 cm) are packed 400-500 to a box, and 7.5-10 cm fry are packed 20-40 per box. Fry are then transported to Manila, often by truck, and the mortality incurred in such a journey of 7-8 hours could be 10-30%, or less, for fry and almost none for fingerlings. In one specific example, 300-400 fry in iced bags were sent to Manila by jeep which took 14-24 hours and the driver was asked to 'drive like crazy' to keep mortality low (mainly from overheating it was suggested).

There are fewer than 20 exporters of grouper seed from the Philippines and the majority of trade is carried out by 7 of these companies, with trade beginning in about 1982, and export volumes per company as many as millions seed annually. Most companies are Chinese, Taiwanese or Filipino-Chinese owned. Trade with Chinese Taipei has dropped 60% in recent years, probably a reflection of greater hatchery production in Chinese Taipei. Most seed exported is in the size range of 2.5-10 cm with greater numbers in the 2-5.5 cm size range; Hong Kong prefers larger fingerlings while Chinese Taipei and China generally prefer the smaller fry. The trade with China, in particular, is expected to grow. There is a strong monopoly by exporters who have a major control on the prices. Previously, the exporting countries carried out 90% of their trade with middlemen but now 30-50% is done with middlemen and the rest is with fishers or fisher cooperatives. Some exporters interviewed indicated that they preferred to deal with middlemen because they were able to organize 'nursing' of fry to a size at which mortality is lower (i.e., 7.5-10 cm). They indicated that export mortalities are generally in the order of a few percent, maybe up to 10%. As an indication of export volumes, one company exported over 100,000 fingerlings in 1998, another company 5-7 million fry a year. There has been a decline during the 1990s in the number of wholesalers selling to exporters because of intense competition and falling prices. For example, in San Jose, Occidental Mindoro, the number of wholesalers declined from 20 in 1987-1989, to 10 in

1992-1994, to 3 in the late 1990s. These wholesalers used to hire private planes for regular, even daily, shipments to exporters in Manila of 100,000-150,000 fry per trip. They used to receive advance payment to enable them to do this but the latter practice was stopped during the 1990s, making it difficult for some companies to survive.

5. SOCIOECONOMIC ISSUES

The capture of grouper fry/fingerlings and the culture and trade in grouper seed of all sizes began in the Philippines in the early 1980s and involves tens of thousands of fishers. The high price of fry and fingerlings became known in various areas initially from foreign visitors, especially from Chinese Taipei, and, increasingly, from local traders (since mid 1980s) who travelled round looking for supplies. In 1987, there was also fry capture in Bohol to sell to BFAR for its grouper culture facility at Calape. At first, most of the sales went to exporters and the demand from outside of the Philippines is still the major determinant of the fishing activity that supplies this trade. Many of the fishers who turned to catching grouper seed had formerly been involved in other fisheries, such as for marine ornamental fishes, oyster or shrimp farming. Some of the buyers had previously been involved in seaweed and shrimp buying. A large number of fishers supply a limited number of culturists and traders, a typical example in a small area would be 30 fishers supplying 3 traders. These traders (middlemen or brokers) carry out domestic trade, sell to other middlemen or sell to exporters and often maintain a few culture cages themselves. It is the brokers, and especially the exporters, who tend to determine the prices and fishers tend not to be able to bargain the prices. Prices vary markedly according to seed availability, season (the growing season for Chinese Taipei and Hong Kong, see above and country sections), the general state of the economy and probably other factors.

Fishers may be involved full-time or part-time in fishing grouper seed and, when not so occupied, get food fish by trawling, fish corral, purse seine, gill net, diving, etc., while some collect fish for the marine aquarium trade. The number of fishers who fish for fry probably number in the tens of thousands and for many of these, a high proportion of their annual income is from grouper fry; of those we interviewed, this proportion varied from 20-90%. BFAR estimated that of the 100,000 fry fishers in the Philippines, about 1-2% are grouper fry fishers but our results indicate that this percentage is likely to be much higher. For example, at just one site in Legaspi, there have been as many as 500 fishers, including children, while in San Miguel Bay, there are over 300 fishers during peak time. In Inabanga, there are 200 grouper fry fishers in the peak season, in Bagacay there are 1,000 fishers at peak season, while in Banao Cove about 100 fishers were noted at peak season. In Occidental Mindoro, where there are cooperatives of fishers, some areas have 75% of the population variously active as grouper fry fishers. Clearly, the grouper fry fishery is a significant economic activity in the lives of many fishers in the Philippines.

6. HISTORY

Grouper seed capture began in about 1980, initially with exports to Hong Kong, later in the 1980s with exports to Chinese Taipei, and, although capture activities were largely a response to demand, there have also been declines in harvest which appear to be related to declines in the resource itself. Capture activities intensified with the high value of the fry and increasing demand from Chinese Taipei and Hong Kong traders. Demand was especially high between 1991 and 1995 and it then declined until the present. Examples from different areas best illustrate the problems of supply and trends over time. In Legaspi, there was a general perception of declines in fry harvest, despite annual fluctuations in supply which are common, and a 60% overall decline in 20 years. Reasons put forward for overfishing was the take of too much broodstock, the jellyfish capture industry for which an unspecified chemical was used and the use of fish attracting devices that take too many fry. In Bohol and Cebu, the supply of fry varies with demand, with higher availability when demand is lower. Overall, it

was felt that there had been general declines over the last decade due to loss of habitat from destructive fishing and too many fishermen taking fry. In Roxas fishers have not caught much fry in the last 8 years, compared to previous years, but have seen recent improvements; this was one of the first grouper fry capture areas in the Philippines. In Inabanga, the total seed supply has declined by about 50% in the last 10 year. It was suggested that this decline had been due to an increase in number of fishers and to pollution from domestic waste. Here, fishers used to catch many more market-sized fish but the numbers have declined and so there is a growing interest in catching fish while they are still small and growing them on to market size.

Many examples of declines were provided in northern Luzon. In Pangasinan, annual production in one bay has dropped since 1993, probably because of the take of broodstock, while in Buguey the same cause was suggested by fyke net fishers for declines in their catches. One of these fishers reported catches of 10,000 fry per net per night over the short 5-6 day season in 1986, while more recently, he has only been catching a total of 20,000 fry of 1 cm annually. One net can now take 42,000 fry a year but, before, it was possible to take 500,000 year. A buyer, also from Buguey, said that his supply from fishers has declined 10-fold within the 1990s; he now finds it hard to make up his minimum shipment quantities of 10,000 fry whereas before he used to ship 300 boxes of them annually. However, since the number of fishers have declined over the last 7 years or so (from 250 to about 30) because of the decline in harvest, it is difficult to know what major factors might be involved in the decline of seed supply. In Alaminos (Pangasinan, Luzon), there were more grouper seed a decade ago than today, the reason for the declines were proposed to be pollution and dynamite fishing. Clearly, there have been declines in many of these locations, although the reasons cannot be determined.

It is clear that, although there is considerable fluctuation in annual harvests, in most places fry/fingerling supply has declined compared to past levels and, in any case, is insufficient for demand. The reasons for declines in different areas are not known, but many suggestions were proffered, including increases in the numbers of fishers, blast and other types of destructive or illegal fishing, pollution, overfishing of adults by other fishery sectors and habitat damage; in particular the loss of mangrove areas was noted. However, it is also of note that market factors are important and that production can vary markedly from year to year depending (at least partly) on the demand for fry; this factor must be considered when looking at variation in production over time.

7. REGULATIONS

There are regulations which relate to fishing gears and exports of fry while special restrictions are in place in certain locations. It is illegal to use cyanide, or any other poisonous substance, for fishing. Live fish dealers are liable for possessing fish caught with cyanide or for trading in illegally caught fish. In some areas, the scissors net is illegal since it is destructive of benthic habitat, but it is widely used nonetheless. Fyke nets have been banned, or the numbers limited, in some areas, because of social inequalities, since fyke nets can take disproportionate numbers of young. The Fisheries Code of 1998 – Republic Act 8550 – prohibits the export of fry of milkfish and prawn but its application to grouper fry is not clear.

Transportation and export of fish and fisheries products requires permits from the Quarantine section, including a health certificate from the Fish Health section of BFAR. A provincial export ban on live fish was in place in Palawan between 1993 and 1998(? current status could not be confirmed). In some areas (e.g., Buguey) it is necessary to obtain an exit permit from the mayor for fry transactions. The Philippines Fisheries code of 1998 (RA 8550), Article II, Section 51 regulates gear/structures and operation zones for fish capture and culture.

e. VIETNAM

Literature

There is limited published literature available on the grouper fry/fingerling fisheries in Vietnam in respect of species, locations of capture and the fishery. In terms of species composition, 6 species were noted from Thuan An (central Vietnam) to be *Epinephelus akaara*, *E. malabaricus*, *E. bruneus* (=moara), *E. trimaculatus*, *E. areolatus* and *E. lanceolatus* (Brzeski, 1997); these species were mainly collected in lagoons and estuaries, along the path of a 'fish fry migration', using a bottom net. Trai and Hambrey (1998) reported that the main grouper species taken as seed are *E. akaara* (most abundant), *E. bleekeri*, *E. coioides*, *E. malabaricus* and *E. tauvina* (probably *E. coioides* since *E. tauvina* is not confirmed from Vietnam). Tuan (1997) and Son (1999) reported the grouper species caught and cultured in Vietnam and Tuan provided local names to 6 species from Khanh Hoa province (central Vietnam). The species included in the two reports are *Cephalopholis miniatus* (*Ca mu do*), *Epinephelus akaara* (*Ca mu cham do*, *Ca mu tieu do*), *E. bleekeri* (*Ca mu soi*, *Ca mu tieu den*), *E. malabaricus* (*Ca mu me*), *E. merra* (*Ca mu cham to ong*), *E. sexfasciatus* (*Ca mu sau soc*) and also *E. areolatus*, *E. bruneus*, *E. awoara*, *E. fuscoguttatus*, *E. fasciatus* and *Cromileptes altivelis*. Tuan's study noted that approximately 70% of grouper seed harvested in estuaries are *E. coioides*, while 30% are *E. malabaricus*. In lagoon habitats, 55% of seed taken are *E. malabaricus*, 35% are *E. sexfasciatus* and the remaining 10% are *E. bleekeri*.

Regarding annual production, gears used and international trade in grouper fry/fingerlings/juveniles, there are no available export records but both seed and market-sized fish are exported from Vietnam directly to Hong Kong, China and Chinese Taipei (Trai and Hambrey, 1998; Son, 1999). Annual production from culture of snapper, grouper and seabream was estimated in the mid 1990s at about 130 t, with grouper some unstated proportion of the total (Son, 1999). Province-level estimates provide some idea of production. In Hai Phong and Quang Ninh provinces (northern Vietnam) the number of grouper fry captured annually in the 1990s averaged 150,000 animals (Son, 1999). The peak season for fry capture is March to July, although in recent years, the seed supply in this region declined, especially at Cat Ba Island. In central Vietnam (Quang Binh down to Khanh Hoa), the most common species are *E. akaara* and *E. coioides* (reported as *E. tauvina*). In the Nha Trang area (central Vietnam), more than 100,000 animals are caught annually with fishers catching 10-15 kg per day of grouper seed with an average weight of 70 g each (i.e. 143-214 animals of about 17 cm) mainly from March to August (Son, 1999). Tuan (1997) reports that in Hoa province, about 200,000 grouper seed were estimated from wild capture annually. This production was broken down by district within the province in terms of percentage production as follows: Ninh Hoa about 38%, Van Ninh about 24%, Cam Ranh about 20%, and Nha Trang about 18%. Capture methods for fry include hook and line, traps, push-nets and trawls (Son, 1999). Different gears may be used in different seasons and take different sizes of seed; seine net; scoop net; push net; pipe; palisade; artificial reefs, fish traps and hook and line. The three main habitats for capture were lagoon, estuary and coral reef and two species of seagrass were found to be associated with grouper seed collection areas (Tuan and Hambrey, unpubl. ms). In the area of Khanh Hoa, about 10 different gear types may be used to take grouper seed with the small seine net most efficient in collecting small fish. In this area, the estimated production is about 200,000 fish per year and most seed is used locally (Tuan and Hambrey, unpubl. ms.). In NE Vietnam, (around Cat Ba Island) fry fishers set about 100 traps and harvest them several times a day. In the peak season from February to March, their average catch is about 20 (of 200g which are 24 cm fish) per day (McCullough and Hai, unpubl. ms.).

Considerable expansion of commercial marine cage culture has occurred during the 1990s with an increasing emphasis on high value fish (Son, 1999). Mariculture is based on the capture and grow-out of wild-caught seed and groupers are particularly highly valued amongst the various marine species that are cultured (e.g. seabass, snapper, etc.) because of their market value and the large potential demand. Marine fish culture development was also able to take advantage of the availability of shrimp ponds that had fallen into disuse because of disease (Tuan and Hambrey, unpubl. ms.). The highest valued species are *E. akaara* and *E. bleekeri* and while all groupers found in Vietnam waters were typically exported (Son, 1999), there is a growing domestic market in

the restaurants of larger cities; grouper are used for Vietnamese style sashimi and for steamed dishes (N. Svennevig, pers. comm.).

Fry supply varies greatly from year to year which is a major problem in maintaining a mariculture industry. Some experimental work on artificial seed production of grouper, and other species, has begun, although survival remains low and production is unlikely to reach commercial levels for at least 5 years. Research has been carried out under the Ministry of Fisheries since 1993 on several marine species, including grouper, seabass and cobia (*Rachycentron canadum*). Trash fish is used for feed.

There are concerns that the farming of marine species is largely dependent on the grow-out of wild-caught seed (Son, 1999). The seed fisheries are not adequately monitored or regulated, which could lead to overfishing of stocks with serious consequences for the sustainable development of the industry, the fishery of adult-sized fish as well as the environment (due to damaging fishing techniques, such as cyanide). The insufficient fry availability in some areas and during some seasons is considered the major constraint to further grouper culture development and there is an urgent need for appropriate technology (suited to the Vietnam context) for fry production as well as a need to improve grouper feed supply and type (Son, 1999; Hambrey et al., unpubl. ms). (See also Socioeconomics for other constraints). Significant improvement in hatchery production is also considered to be important for future possible 'restocking' initiatives. Dependence on 'trash' fish and poor feed conversion ratios are also of concern and questionable sustainability (Hambrey et al., unpubl. ms.);

Research Findings

Key collection areas, methods, species and seasons were determined from interviews with 10 fishers, 5 culturists, 6 government officials and 1 biologist. Areas visited are indicated by sites 32-35 in Fig. 1a.

1. CAPTURE FISHERIES

In northern Vietnam, the grouper fry/fingerling peak capture seasons in Quang Ninh province are between February and April, and July and September. In the earlier of these two periods, the harvest was relatively higher than in the later period. Seed is also collected at other times of the year but at lower quantities. Grouper fry and fingerlings for grow-out at Ha Long Bay are supplied mainly by capture activities at Ha Long Bay, Cat Ba Island, Cam Pha to the north and Mong Cai near the boundary between Vietnam and China. *E. bleekeri* seed sent to research facilities in Nghe An province were also supplied from Quang Ninh province through brokers at Quynh Luu in Nghe An province (additional details were not available since this broker company was owned by military, and it was not possible to interview anyone). Dr. Luu of the Research Institute For Aquaculture No.1 (RIA-1) indicated that the main grouper fry/fingerling capture sites in Nghe An province were at Quynh Lap and Quynh Phuong. In Nha Trang (s. Vietnam), grouper fry are captured mainly at Quy Nhon (Binh Dinh province) and used for local culture.

A variety of grouper is taken for culture, according to both fishers and culturists in Quang Ninh province. *E. areolatus* are caught mainly at Mong Cai while *E. bleekeri* and *E. coioides* are caught mainly in Ha Long Bay. Other species, including *E. awoara*, *E. areolatus* and *E. akaara*, are also caught occasionally at Ha Long Bay. At Me Island of Thanh Hoa province (central Vietnam), *E. bleekeri* is the major harvest. *E. lanceolatus*, *E. areolatus* and *E. awoara* are also collected but in much smaller numbers. In Nha Trang, the 3 main groupers are *E. bleekeri* (known as brown grouper in Vietnam), *E. coioides* and *E. malabaricus* (the last 2 species are referred to as black grouper in Vietnam). Of minor importance in this southern province are *E. akaara* and *E. sexfasciatus*.

Eight different methods of collecting grouper seed were recorded. After harvest, seed are transported in containers or live wells (Plate Vc) to the fishers' net cages or to /culturists. During transport, mortality ranged from 0-10% (Table 5).

1. *Fish trap* (Plate Va): small bamboo traps (cylindrical and about 25 cm long with very small mesh) are used in Quang Ning and Nghe An provinces. Fishers use a long line to link up a series of bamboo traps which are sunk along rocky coastal areas by putting rocks inside the traps. This method is particularly preferred in Khanh Hoa province but mortality can sometimes be high, up to 50% from damage to the skin of the fish. Traps can take fish of 2-10 cm in the mouths of rivers or lagoons.
2. *Hook and line* (Plate Vb): common in Quang Ninh, Thanh Hoa and Nghe An provinces. This is one of the methods favoured by mariculturists in Quang Ninh since they find that the quality of the fish is good and mortality low. However, in Khanh Hoa province, this method was not so popular since it causes 5-10% mortality, which can reach 30 or 40% in some areas according to fishers. Hook and line are used throughout much of the year to take a wide size range of animals and particularly the larger sizes. The hook is small to avoid hurting the mouth of the fish and fish are usually taken at about 10 cm but range from 3-18 cm. Using this gear (one hook per line), in Ha Long Bay, fishers took between 2-10 fry per day and 3,000-30,000 per year depending on effort. At Thanh Hoa, fry size is 4-18 cm and the number caught per years is 10,000-60,000 fish. In Nha Trang fishers can take 7-10 seed per day of ≥ 8 cm.
3. *Fyke net or Palisade*: this method was originally used in Quang Ninh and Khanh Hoa provinces for catching shrimp at river mouths/estuaries. It is a set net, or bag net type of gear. Grouper fry/fingerlings were formerly only a bycatch of this method and the volume of harvest is very low. Mariculturists complained that this method is the worst of all the capture methods since the fish are often wounded and in poor condition. They prefer not to buy fish caught using this method.
4. *Chemical*: this method (suggested as probably sodium cyanide) was only reported by fishers from Nha Trang. Using this method, very high mortalities were noted (about 90 – 95%) in some areas, low in others. Fishers interviewed said that the people from Chinese Taipei introduced this fishing method to their area. A chemical was also reported to take larger fish in NE Vietnam. Chemical(s) is used for a diversity of species all year round.
5. *Scoopnet with light*: this method is used in Khanh Hoa province and is generally operated early in the morning (about 6:00 am) at the mouths of rivers or in lagoons. Lights are used to attract the grouper fry. The gear consists of a small meshed net attached to a frame.
6. *Push net*: this is operated by 2 fishers who push the large, fine-meshed, net that has a total length of 4 m around river mouths. It is a cheap capture method but the quality of seed is generally very poor.
7. *Pipe*: this gear comprises bamboo pieces of about 25 cm long and 10 cm diameter. The pipes are set on the seabed. This is an inexpensive method.
8. *Artificial reefs*: artificial reefs, or fish shelters, are constructed by piling up stones in estuarine and other shallow areas or by assembling units of mangrove branches. The reefs are encircled periodically by a long net to harvest the fry which come to shelter within these structures.
9. *Seine net*: a long net, up to 8-10 m long which is pulled over the substrate to take small fish. Can catch 50-150 fish per harvest of > 3 cm each.

Production: there is no official record of annual production of grouper fry/fingerling (mainly *E. bleekeri* and *E. coioides*) but estimates at the provincial level provide some idea of capture. In Quang Ninh Province, hook and

line fishers take 3,000-30,000 grouper fry/fingerlings per person per year. The sole mariculturist in Quang Ninh province purchased about 20,000 *E. bleekeri* and 10,000 *E. coioides* from local fishers in one year. Fishers either sell their harvest directly to mariculturists or grow the seed themselves from about 8 cm to about 20 cm, before sale. Bycatch taken during seed capture is sold, or given to mariculturists. In Ha Long Bay, one fisher indicated that grouper fry harvest is stable but others indicated that the increase in fry fishers in the past 5 years had led to difficulties in obtaining fry. At Thanh Hoa, fishers can take 10,000-60,000 fish per year by hook and line.

2. GROWOUT

Most mariculture facilities are small-scale operations. In Quang Ninh province, for example, there was one large-scale mariculture company called LEE Clam Co. (LCC), a joint venture between the Hong Kong private sector and the provincial government. Other culture facilities in the area consist of 1 – 2 floating net cages of fishers who have harvested their own seed (Plate Vd), while in Ha Long Bay (Haiphong province), there are more than 300 small cage farms.

The company operations of LCC provide insight into culture activities in the region. The owner said that all the grouper fingerlings he used for grow-out were bought from local fishers and that the major species in Quang Ninh province is *E. bleekeri*. He considered that this species has the best survival rate in grow-out compared with other species available locally. Fry and fingerlings of *E. coioides* were also common in Quang Ninh but in 1998 the annual seed supply of this species dropped to only 10% of former levels; the reason for this drop was not known. Other species occasionally cultured are *E. malabaricus*, *E. areolatus*, *E. akaara*, and *E. awoara*. A few (3 – 4) *E. lanceolatus* seeds of 17-20 cm were also available from fishers each year. The preference of this culturist was for fish of 15-25 cm since their mortality rate is lower than that of smaller fish. The overall average mortality rates for *E. bleekeri* and *E. coioides* during the grow-out process are 80% and 40%, respectively (from a total of 30,000 seed in a year). To reduce mortality during grow-out, culturists in Quang Ninh sort the fry from fishers into different sizes, to avoid cannibalism, and sterilize them in buckets with tetracycline before putting them into cages. The ideal grouper culture water temperature is 22 – 23°C and the salinity is 28 – 38ppt. The vulnerable grow-out periods of grouper seed, when mortality is highest, are the periods of March and April and July and August when there are marked water temperature changes.

Culture (grow-out) activities are not well-developed in Vietnam but are intensifying and the Ministry of Fisheries figures for marine fish aquaculture production for 1999 is 5,000 t (mostly groupers). At Nghi Son (Thanh Hoa province), one of local 2 mariculture areas is located within a restricted military area. In Nghe An province, there are no culture activities which operate at commercial levels but the Institute of Aquaculture No.1 (RIA-1) started a marine fish farming project. Two 6 m diameter plastic tube floating cages (Norwegian cages, each 4 m deep) were set at Hon Ngu Island (also a military restricted area), Cua Lo Beach. About 2000 *E. bleekeri* fry were put in one of the 2 cages and there are plans to add another 2,000 – 3,000 *E. bleekeri* fry. The plan is to raise the *E. bleekeri*, and other species, as broodstock for hatchery research in the future. In Khanh Hoa province, most net pen farmers have recently started spiny lobster farming because of better economic returns, while pond farmers still farm grouper (N. Svennevig, pers. comm.).

3. GROUPEL HATCHERIES

Several attempts at grouper hatcheries have been made although there is no commercial level of egg or fry production at the present time. The director of the Department of Fisheries at Thanh Hoa said that a private company had tried to start a grouper hatchery but had failed to hatch any eggs. The company closed in Thanh Hoa and moved to another area. The director indicated that some of the most pressing problems of hatchery

production in Vietnam were the lack of start-up funding and obtaining males for mating. Currently they are building a hatchery research station for marine finfish (co-funded by NORAD) in Nghe An province. In Nha Trang, the University has begun grouper hatchery research but has not been able to produce eggs or milt from broodstock. They will continue to develop these activities. At Cat Ba Island there is a research facility (now part of RIA-1) where grouper broodstock are maintained and there is production of cobia.

4. TRADE

Fish smaller than 12.5 cm are not permitted to be exported, according to interviews, but there is apparently illegal trade of smaller fish into China and legal trade of larger fish to Hong Kong and China. At Nha Trang, traders apparently came in from Chinese Taipei and Hong Kong to collect grouper of various sizes. Mariculturists indicated that fishers sell the grouper fry and fingerlings caught in northern Vietnam illegally at Mong Cai and ship them to mariculturists in China. One mariculturist at Ha Long Bay in northern Vietnam was planning to export grouper seed of 15-32 cm to Sai Tai in China where the demand for grouper seeds is high. Most export does not occur through official channels, however. Most Chinese buyers purchase directly from the farmer/fishers and transport the fry in their own live-well boats without leaving official records, according to a member of RIA-1.

Transport of seed from the fishing grounds to the culture areas is by build-in open (Plate Vc) circulation live wells in the bottom of the fishing vessels. Mortality levels are low at this stage.

5. SOCIOECONOMIC ISSUES

The capture and culture of grouper seed is relatively recent in Vietnam compared to many other areas in SE Asia but both are becoming increasingly important. The sizes of grouper caught for culture are generally larger than elsewhere and the range of species grown-out is quite broad. However, there are but a few preferred species for culture. There is a lack of organization in many of the grow-out facilities with mixed species and sizes in some cages. In Quang Ninh Province, most grouper fry fishers were previously paddy field farmers who fished the grouper fry and fingerlings only during peak seasons; the income from grouper fry/fingerling fisheries ranged from 10 to 50% of their total annual income. One fisher said that his income from grouper fry/fingerling harvest can reach as much as VND 425 million (or US\$ 3,080) annually, while in Quang Ninh a fry fisher catching 5-10 fry a day can equal the income from all other fish he might harvest. Economic constraints for many potential culturists, and to a significant role in poverty alleviation of grouper culture, in Vietnam are lack of access to low interest capital and an apparent lack of access to suitable culture sites for some of the poorer villages. There have, however, been improvements in availability of loans for the poor in the last year (N. Svennevig, pers. comm.).

6. HISTORY

Grouper fry and fingerling capture and grouper culture began to intensify about 10 years ago and show every indication of continued expansion. The fishery appears to be generally in good shape with focus on larger fish compared with other locations in the region. In northern Vietnam, the vice director of a seafood company in Quang Ninh Province said that the total production of grouper in the past 10 years had remained stable but that there is much interest by fishers of the region because they can earn more from the grouper fry/fingerling fishery than from other activities. In Thanh Hoa province, grouper fry/fingerling capture activities started in 1992 and both culturists and fishers indicated that grouper fry/fingerling harvests had remained stable over the last 5 – 10 years. In Nha Trang, fishers from Con Gwa fishing village said that no-one had targetted grouper fry/fingerling before 1997 when traders came from Chinese Taipei and asked them to catch grouper seed.

In only one area was there an indication of declines in catches. Fry/fingerling of *E. coioides* had been common in Quang Ninh but in 1998 the annual seed supply of this species dropped to only 10% of former levels; the reason for this drop was not known.

7. REGULATIONS

In Vietnam, government regulations prohibit export of groupers less than 500 g (Ministry of Fisheries). There is no limit on export volumes. For export, a health certificate from a provincial office, Fisheries Resources and Environment Conservation Sub-Department (under Ministry of Fisheries) is needed and requirements of the importing country satisfied.

f. PEOPLE'S REPUBLIC OF CHINA (PRC)

Literature

Grouper culture began in the PRC in the early 1980s. Grouper are highly valued and appreciated, especially in the south, and there have been many efforts to improve production over the years. In the 1980s, research was carried out on the two principal species cultured at that time, the Red grouper, *Epinephelus akaara* and the Yellow grouper, *E. awoara*. However, despite the initial success and considerable biological research in hatchery production of these species, the volume of seed produced by hatcheries has never been high and the majority of culture has always been based on the grow-out of wild-caught seed (Tseng, 1983; Yongzhong, 1999). In an unpublished survey in 1998, hatcheries were producing seed of *E. awoara*, *E. akaara* and *E. coioides* in Zhejiang, Fujian and Guangdong provinces in low numbers (annually 2,000-80,000 seed of various sizes are produced) (NACA, 1998).

Because of the intense interest in grouper culture and the increasing demand for live grouper for food, there appear to be renewed efforts in developing hatcheries for grouper seed. Moreover, the PRC has, as a major goal, the expansion of their culture sector (Cen, 1997). There are several institutes developing hatchery production in southern China, some of them joint ventures with Hong Kong or Japan (Anon, undated). A hatchery in Zhejiang province reported production of *E. awoara* at 80,000 seeds per year (Anon, undated) and at a Daya Bay facility, NE of Hong Kong, there is active research on *E. awoara* with natural spawning in 1998 (Yongzhong, 1999). However, as before, hatchery production still accounts for but a tiny percentage of total seed supply.

The source of wild seed is in southern China (mainly Fujian and Xiamen) and the main species were *E. akaara*, *E. awoara* and then, later, there was interest in *E. malabaricus*, *E. coioides* and *E. areolatus* as Red grouper seed underwent severe declines (Tseng, 1983; NACA, 1998; Anon, undated). Red grouper was the first grouper cultured extensively and is probably still the most favoured. Seed were obtained by line and pole fishing and sold to Hong Kong culturists by the hundreds of thousands at 12-20 cm (75-150 g) in the early 1980s with unknown volumes traded locally. In the 1980s, grouper seed were exported to Hong Kong but, nowadays, much fry is imported (although little Red grouper), often through Hong Kong, from elsewhere in SE Asia and especially from Chinese Taipei (which cannot export directly to China). Seed is also obtained from Fujian and Xiamen with some local sources in Guangdong. Seed is considered to be fish < 400 g and is caught by trap and hook and line and stocked temporarily in tanks or floating net cage until shipping; they are usually caught at 12-20 cm, (150-250 g) with the smallest size at 10 cm and 100g (Wang, 1999). About 60% of fry used in culture in Guangdong province is wild caught in China (Yongzhong, 1999).

Most grouper culture activity is small-scale and takes place in southern China, with Guangdong the major production and consumption area (Yongzhong 1999). In this area, there is a 20-year history of grouper culture and potentially a very large consumer market. The population in this rapidly developing region numbers 70-80 million people and live fish, especially the groupers, are particularly highly esteemed in the area. Culture activity also occurs in Fujian and Zhejiang provinces and Hainan Is. and 10 species of groupers are cultured, mostly *E. awoara*, with some *E. trimaculatus*. In 1997, there were 20,000 cages devoted to grouper culture in Guangdong province, where most grouper in China is cultured. Total grouper culture production in China, possibly the world's largest producer of cultured grouper, was about 8,300 t in 1997 (from government figures in NACA, 1998).

The annual demand of several million, market-sized, fish a year is expected to increase but there is considerable concern that the shortage of grouper seed from the wild, and very limited hatchery supply, will severely restrict the expansion of grouper culture (Wang, 1999). Moreover, wild seed supply fluctuates from year to year, a situation that makes businesses unwilling to take big risks of expansion especially since there are frequently shortages of fry. Moreover, the serious depletions of *E. akaara*, remain a problem for culture activities of this preferred species (NACA, 1998; Wang, 1999).

Most culture facilities are small-scale family enterprises and there remain many problems to expanding grouper culture. The major feed type used is 'trash' fish, with a poor food conversion ratio, but its availability fluctuates and there is not always sufficient good quality supply. The survival rate of grouper is only at 40-50% during grow-out because of problems with bacterial diseases (especially vibriosis) that have intensified in recent years. However, it is the shortage of grouper seed and their declining supply from the wild, both in terms of quality and quantity, which is considered the biggest impediment to development. The reasons suggested for the latter problems are degenerating conditions of the environment (water quality) and overfishing (NACA, 1998; Wang, 1999). A red tide in 1998 caused high mortality of grouper being (over 100 tons) in 1998.

Research Results

Interviews were carried out with 3 biologists, 3 government officials, 5 fishers, 4 culturists, and 2 traders during 4 trips into mainland China. Two fish markets and 5 restaurants were also visited. Visited areas are indicated by sites 36-40 in Fig. 1a.

1. CAPTURE FISHERIES

The source of fry used in culture areas in China is mainly Guangxi province (SE China-between the Vietnam border and Hong Kong) and Hainan Is., with imports from Vietnam, the Philippines and Thailand. *E. akaara* is distributed from Zhoushan Is. (Zhejiang province), south of Shanghai) along the coast to Hainan Is. In the 1980s, there was reported to be a good supply of red grouper juveniles but electricity was extensively used to take fry in shallow water and, although electricity was later banned, the numbers of fry became markedly reduced (Patrick Chan, pers. comm.). Interviews suggested that there is a rich supply of fry at the Zhoushan Archipelago (Zhejiang province) (this was mentioned several times) but evidently there is no capture as the local conditions are not good for culture. This detail needs verification since all other indications are that fry supplies all along the Chinese coast are now very low). Indeed, the overall impression was one of a severe shortage of grouper fry in coastal PRC waters. Other species taken as fry are *E. bleekeri* and *E. coioides* and an important species caught in China is *E. awoara*.

Six different capture methods were identified but few details were available and there did not seem to be much fry-collecting activity in general. Electricity was used in the past to take fry but has since been banned.

1. *Hook and line*: used for grouper larger than about 10 cm and the survival of the fish is good.
2. *Fish trap*: used opportunistically for a wide size range of fishes, but particularly for 12-15 cm (the design used is formerly one of crab pots) (Plate VIa). Traps are deployed as several hundred units linked by a line in 5-6 m water. Rock and bait are placed inside each trap which are left overnight and this set of traps can get 1,000 grouper seed per haul with low bycatch.
3. *Nets*: both beach seines and 'fixed position nets' (direct translation from Chinese) are occasionally used. The latter is set up in a fixed position near a beach to catch small fry moving into it with the water flow (acts like a bag net but has no 'bag'). The beach seine is not often used.
4. *Net ball*: these are twisted balls of net that are hung as units along a rope which is then laid in circles on the substrate. They act as fish shelters. Each rope holds about 100 units. The rope is deployed at about midnight from a small boat and two strong lights are used (Plate VIc). The rope and net balls are retrieved at dawn and fry are either trapped in the balls or move up towards the boat as the balls are pulled in. Catches are variable in time and space but it is possible at peak times to catch 10,000-20,000 seed per night of 1-2 cm fish. Mortality is low, and not more than 20%, and bycatch does not exceed 20%.
5. *Fish shelters*: several types of fish shelter are used. Waste bottles are placed in rocky intertidal areas to collect grouper fry or tree branches assembled for the same purpose. Both methods have low yields and are not commonly used. Artificial reefs of rocks are sometimes used but do not last a long time and are time-consuming to maintain. Bycatch in both methods can be high and some of this may be used as fish feed.
6. *Poison*: in the area of Hainan Island it was reported that poison was used in the past but that the mortality levels were so high that it is no longer used. The fishers said they did not know the type of poison involved.

Production: there were no estimates available of the production of grouper fry in China and it was considered by most interviewees that only Penghu Is. (Chinese Taipei) has an abundance of wild grouper seed nowadays.

2. GROW-OUT

Grow-out occurs in a number of key areas along the southern coast of China. In Guangdong Province, 30% of the 130,000 cages are used for grouper culture while in Fujian province (to the northeast of Guangdong) only about 10% of the 170,000-190,000 cages are used for grouper (the rest are for Yellow croaker, *Pseudosciaena crocea*, and Red Drum, *Sciaenops ocellatus*). The major grouper species cultured in this area is *E. awoara* with small numbers of *E. akaara* and *E. malabaricus* (probably this is *E. coioides*); in this province, the winter water temperature is quite low (can get down to 10°C) and grouper do not eat during this period, while *E. malabaricus* does not survive well in water below 15°C and so tends not to be cultured north of Pinghai (about level with northern Chinese Taipei). *E. awoara* is cultured further north in earthen ponds but may be moved from earthen ponds in Zhejiang Province, south to Fujian Province, to overwinter in less cold conditions.

In Xiamen (Fujian province) most culture is Red drum and Yellow croaker with some Red pargo (a sparid). Ten years ago, almost all cages cultured Red grouper in the region but now only low numbers are supplied by hatcheries and almost all Red grouper are from hatcheries. *E. awoara* replaced the Red grouper in volume while *E. coioides* (with some *E. malabaricus* mentioned) was introduced from Chinese Taipei in 1998. Survival rate of green grouper is 30% from seed to market and for *E. akaara* and *E. awoara* survival is 50-60%, although growth of the latter species is much lower. In general, culturists preferred *E. bleekeri* to *E. coioides* because the latter species shows higher winter mortality. Fry from Guangxi and Vietnam have a higher survivorship (>30%) than those imported from Thailand and the Philippines.

At Hainan Island there are about 2,500 culture cages for grouper but a variety of species is also cultured in the area and there are over 20,000 culture cages in all. There have been serious problems, however, with water pollution, especially in 1996-1997. The peak culture period in the 1990s was in 1994-1996 and there are two large companies involved in grouper culture and in other live reef fish, such as pompano (*Trachinotus blochii*). The market-size fish used to be shipped to Hong Kong by live reef fish carrier vessel (vivier), but at least one business seems to have collapsed in 1997/8. Another business at Railway Harbour cultures *E. lanceolatus* and *E. fusco guttatus*.

Several problems limit the potential for grouper culture in southern China, aside from poor fry supply. These include poor water quality from pollution (Plate VI d), disease, high mortalities of imported seed and low winter water temperatures in more northerly locations. Diseases are *Vibrio* and white-spot which have been difficult to cure.

Annual grouper production from culture in China is about 5 million fish (*E. malabaricus*, but mainly *E. coioides* and *E. bleekeri*) with about 4 million from Guangdong province where production is over 6,000 t. Over 90% of grouper being sold in 5 restaurants briefly visited in Xiamen were *E. awoara*. Trash fish is used for feed (Plate VI a). Other species being cultured along the southern Chinese coast are Amberjack (*Seriola dumerili*), cobia and pompano.

3. HATCHERY

Hatcheries were active in the 1980s, but lapsed, and there has been a renewed interest in establishing hatcheries in recent years. There is, and was in the past, a negligible production of grouper seed from hatcheries in China and none of them have been successful on a big scale, according to reports. In Hainan one hatchery had no success but imported fertilized eggs and seed from Chinese Taipei for nursing, selling the larger seed to culturists. In Daya Bay, at a new facility set up between the Chinese government and Japan (JICA), fertilized eggs are purchased from Chinese Taipei and recently 16,000 seed of *E. akaara* of 7-8 cm were produced. They are also working on *E. bleekeri* and have spawned it naturally; hormone-induced spawning tends to produce deformed young. The facility is currently maintaining 200 broodstock of *E. coioides* and *E. akaara*. There is a minor supply from hatcheries to culturists; typically *E. akaara* seed are given freely to culturists for experimental purposes and the culturists are supposed to return the profit to the hatchery after sale. Apparently much of the profit is never returned, however.

At the Aquaculture Department of Fujian Province, artificial propagation has been researched since the early 1990s with training received in Japan, but even now grouper fry are not produced at commercial scales because there is insufficient broodstock and not enough tanks for mass production. Fertilized eggs and fingerlings (10-12 cm) of *E. coioides* (*E. malabaricus* was also reported) are purchased from Chinese Taipei on occasion but the Fujian aquaculture facility also maintains a broodstock of 40-50 fish which live about 3 years but tend to suffer from disease. Most broodstock comes from the wild (i.e. not from hatchery-produced fish). These broodstock produced 3,000 fingerlings in 1997 and 30,000 in 1999. One of the problems with this *E. akaara* broodstock is sex change that reduces the numbers of females which then have to be replaced by females from the wild.

4. TRADE

Grouper seed, of a limited number of species, is imported, and much of that trade appears to be across the border with Hong Kong at Yantian, with some over the Vietnamese border. Fish also enter China directly from Chinese Taipei but this trade is illegal. Recently, *E. bleekeri* and a few *E. areolatus* are the main species

imported into China, coming from the Philippines, Malaysia and Chinese Taipei, often via Hong Kong. *E. coioides*, which is less popular in China, is also imported (at 1-2 cm) from Thailand and the Philippines. From Chinese Taipei this species comes in at >7cm with small quantities of *E. lanceolatus* (at 8 cm). *E. fuscoguttatus* is also imported. There appears to be very little export of grouper fry.

Transportation of fry is both long and short distance. From the fishing grounds, harvested fry are placed in a bucket with aerated seawater, or in a live well (Plate VIb), and taken directly to culturists whenever possible: mortality in such cases is low. When fish are packed for longer distances, they are placed in plastic bags and the temperature of the water is lowered with the final temperature dependent on the duration of the journey. Ice may be needed for longer journeys. Bags with fish fry are put in a foam box for shipping, often when air temperature is lower (at night). For long journeys, the seed may be allowed to rest en route. Anaesthetics are not used for small grouper or other fry, because the cold water slows their movements, but this technique is not suitable for travel of over 20 hours. Smaller fry are more vulnerable and have high transit mortalities which vary from 0-100%, depending and on packing conditions and the original quality of the fry.

5. SOCIOECONOMICS

Several former fishermen became culturists, or mix culture activities with fishing following declines in fishing harvests.

6. HISTORY

In the early 1980s, there was an abundant supply of Red grouper seed in Fujian waters. Indeed, at this time all culture was of this species. Seed was heavily exploited by a range of gears, including electricity in the early 1980s. Seed numbers declined from 1987 onwards and from 1994, seed of this species became very rare in Fujian Province. There was much export of grouper seed in the 1980s, especially to Hong Kong but there is very little now and key species, like *E. akaara*, have virtually disappeared from collecting grounds. The reasons suggested for the declines in seed were destructive fishing, overfishing and environmental pollution. From 1985/6, *E. awoara* was increasingly used and it has become the major species. However, in the last couple of years, traders report seen more Green grouper and suggest that this might be due to enforced closures of the South China Sea fishery [Note: these closures have been in force for several months in each of 1999 and 2000 and have been strictly enforced].

Four major points were clear. The first was that there had been a rapid decline in the 1980s of the fry of *E. akaara* from a once highly abundant state to virtual absence. Small numbers of fry of this species are now obtained from hatcheries for grow-out. The second was that the supply of other grouper seed in southern China was also generally low and insufficient for culture demand, and that China had apparently shifted from a net exporter to a net importer of fry. The third was that increasingly poor water conditions restrict the availability of suitable culture conditions for grouper. The fourth was that there had been considerable attempts at grouper culture in the 1980s (and there is a good literature which arose from that), and although successful, these activities never produced many fry. There has been renewed hatchery activity more recently with several private and collaborative facilities being developed.

7. REGULATIONS

Several interviewees said that China limits the number of grouper fry fishers and the capture quantities of grouper seed, that a license is needed for transporting marine fry and that export of fry is now prohibited. It was not possible to locate a copy of these regulations to verify the current law on the capture and culture of grouper

fry. There is a management regulation of Guangdong Province for shallow sea intertidal zone aquatic products cultivation which applies to those engaged in marine cultivation.

g. CHINESE TAIPEI (TAIWAN)

Literature

Grouper culture began in the Penghu (Pescadores) Islands in 1972, later becoming established along coastal areas of southern Chinese Taipei in the 1980 (Chu, 1999). At this time, culture consisted of the grow-out of wild-caught fry from the Penghu Islands, which were raised in ponds. Seed supply was not considered to be sufficient from wild-capture (1.5-3 million seed). As seed numbers diminished in the wild, seed was increasingly imported, in particular that of *E. coioides* and *E. malabaricus*, from Sri Lanka and then from various economies in SE Asia.

Research was started to produce seed artificially and success came in the mid 1980s. Since then, Chinese Taipei has developed a diverse, extensive and technologically advanced mariculture industry. There are now about 300 farms in southern Chinese Taipei, down from 500 5 years ago (Johannes and Reipen, 1995; Chu, 1999). Local hatcheries provide the bulk of production but some fry are still imported. The government distinguishes grouper fry in trade figures and imports from 1990 to 1997 of grouper fingerlings were, 7 t, 96 t, 19 t, 9 t and 8 t, 8 t, 2 t, 3 t, and 9t, respectively, mainly from Thailand, with some from the Philippines and Singapore (the source of the Singapore seed is not known but is probably Sri Lanka) (Johannes and Reipen, 1995; Wu, 1999).

Strong government support allowed the grouper hatchery and culture industry to develop and flourish. Barriers to grouper fry exports and imports were removed to promote the industry (Wu, 1999). The central government assisted in the formation of a co-operative, The Fish Breeding Association of Republic of China (FBA), in 1996 to promote the industry and develop trade ties with other countries and other trade associations. There are also government hatcheries which aim to use hatchery-reared seed to 'reseed' overexploited coastal fisheries

Chinese Taipei is the only economy in the world that has a thriving grouper hatchery industry. The main species hatchery-reared are the green groupers, *E. coioides* and *E. malabaricus* (mainly *E. coioides*), and there has been much recent success with *E. lanceolatus* (P. Chan, pers. comm.). Wild-caught seed is still used from a variety of other grouper species either caught in Chinese Taipei, or imported (Chu, 1999). Efforts for several years with *Plectropomus* species have still not yielded success. The broodstock for the hatchery operations include both locally caught and imported fishes. Other cultured species of lesser importance include *E. amblycephalus*, *E. akaara*, *E. trimaculatus* and several *Cephalopholis* species; thirteen species in all are cultured (Chu, 1999; Wu, 1999).

The production of market-sized grouper in Chinese Taipei from inland and marine culture increased from about 1,000 t in the early 1990s to >1,500 t in 1995 (Chu, 1999) to about 7,000 by 1999 (Cesar et al., 2000). To supply this culture, both hatchery produced and imported seed are used. Imports of grouper fry declined during the 1990s but are still significant and represent about 30% of seed cultured to market-size, according to Wu (1999), although some estimates are as low as 10%; in any case, there persists significant import of fry. The reason for the continued import of seed, despite local production, is related to the growing and reproduction seasons in Chinese Taipei. Since only small quantities of seed are produced in the winter months of November to January, imports are necessary to provide farmers with seed for culture. Fry also tends to be cheaper in September and October (P. Chan, pers. comm.). Moreover, when the prices of imported seed (1-3 cm) are lower than locally produced seed, it remains economically viable to continue with imports (Wu, 1999). Grouper

fry production by month for 1996 and 1997 shows that the highest production of fry is in September and October and is substantially higher than in all other months (Yearbook of the Chinese Taipei Fisheries Bureau).

To produce seed from hatcheries, broodstock are induced to spawn artificially or allowed to spawn naturally and about 20 million grouper fry are produced annually. The current culture system involves a series of specialized farms and is a unique model for grouper. Hatcheries produce fertilized eggs (artificial fertilisation or natural spawning). These then go to a fry farm where the eggs are raised to 3 cm (30-40 days). Next there is a fingerling farm and fish reach more than 15 cm at which stage they are transferred to outdoor ponds. At the fish farm, the next stage, fish are grown to market-size (600-700 g) (Chu, 1999), and up to 1.5 kg for the Hong Kong market (P. Chan, pers. comm.). Fish are also being sold for recreational use within Taiwan to stock 'fishing ponds' (0.6-3 kg). Annual fry (1-3 cm) production is highly variable, ranging from 15,000,000 in 1990 to a low of 3,000,000 in 1994 to 47,000,000 in 1996 (Wu, 1999).

Problems persist in the grouper culture industry. In particular, the low availability of males for some species. Formerly, breeders could be caught at the Penghu Islands and around the coastal waters of Chinese Taipei. The procurement and import of breeders of key hatchery species is an important part of the industry and import of breeders is common (Wu, 1999). Other production problems are those of disease, feed and egg and sperm quality and there is ongoing research by government, and experimentation in the industry, to address these (Chu, 1999).

No information was available on grouper fry collection devices used in Chinese Taipei except for the mention of poisons, such as Sodium Cyanide (NaCN), in some, unspecified, areas (Chen, 1990).

Research Findings

During the visit, 3 government officers, 5 culturists, 2 exporters, 1 biologist, and 1 trade association member were interviewed. Visits are indicated by sites 41-43 in Fig. 1a.

1. CAPTURE FISHERY

Gear: a range of species may be caught but the main culture ones, that are also caught in Chinese Taipei, are *E. malabaricus*, mainly from Penghu, and *E. coioides*, mainly from the main island. No species were seen from fishers' catches but there is evidently still wild capture of table-size fish at the Penghu Is. Breeders of important culture species were caught easily in 1985-6 but *E. malabaricus* broodstock in the wild is now less common. Five gears were recorded from interviews.

1. *Hook and line* (Plate VIIb, VIIc): this gear takes fingerlings or juveniles. Line fishing is carried out from small boats and the fish are maintained in a live well.
2. *Trap* (Plate VIIa): used for fingerlings and a live well may be used to transport fish back to port.
3. *Seine net*: in the 1960s, fishers used this net to catch grouper fry from a small boat. The gear also took some bycatch. In peak season the groupers were caught in large numbers (2 cm) in SW Chinese Taipei along the coast. At that time there were no more than about 100 fishers.
4. *Cyanide*: used in Penghu Islands before 1984 (the first place to use this chemical in Chinese Taipei) to get juvenile grouper. Fishers said that when applied to reef areas it killed all off but the groupers (the implication being that they were hardier). It was first used in this area in about 1976 and was readily available at the time. In the summertime fish of 3 cm were caught from May-August and cyanide was used because it was easier than traps. Also used in SW Chinese Taipei in deeper water on compressed air as the fish became scarcer inshore. The suggestion was that declines in the 1970s were due to

overfishing and pollution.

5. *Setnet*: this gear was used 20-30 years ago to catch settlement stage (2 cm) fry. The large nets were set along the shallow shores of southern Chinese Taipei. Sometimes a propeller was placed in the mouth to create a current of water. The seed collected were used for the first grow-out trials by fishers/culturists and the net had previously been used to catch other things before, such as eel larvae. Much bycatch was taken. Grow-out activity began in southern Chinese Taipei after fishers caught various sizes of fish by hook and line and tried to grow-out the smaller ones. When the fishers realized that the small fish in their setnets were the same as the desired groupers, they began to focus on these fish. This was a wasteful fishery since there was much bycatch in the setnets which was discarded. The main season for fry capture was April-August and catch was best with the tidal cycle. The sizes taken were 1.5-2.5 cm. On peak nights, a fisher could catch 1,000 larval grouper.

Production: the targeting of juvenile groupers reduced markedly once eggs were successfully produced and culturing activity increased. In the early 1980s, in Penghu Is., there were several hundred fishers and, at the peak season, the daily catch per fisher was several thousand seed at high tide (using cyanide). Wild grouper seed has not been available off southern Chinese Taipei for a long time in any numbers.

2. GROW-OUT

In Penghu Islands, grow-out is carried out in floating net cages and this location has about 70% of all cages (sea pens) in Chinese Taipei because of the sheltered water conditions and good quality of water. Nineteen companies are involved in grow-out in Penghu (on average each company has 70-80 net cages). In southern Chinese Taipei, culture is carried out in ponds (Plate VIII) over extensive areas of the coast. It was interesting to note that some eggs produced in the Penghu Is. are sent to southern Chinese Taipei for nursing and back to Penghu for growout.

In the Penghu Is., the feed is trash fish and there is no problem in getting supplies of trash fish from trawler bycatch. The water conditions appear to be good at the Penghu Islands for culture and there do not appear to be problems with disease; the approach appears to be one of being preventive, of avoiding such problems.

Species observed in the various farms visited, and at various stages of culture, were: *E. malabaricus* (main species at Penghu), *E. lanceolatus* and a few *E. caeruleopunctatus*. According to accounts, *E. akaara* was very common in the past and was a favoured fish for its sweet meat and relative insensitivity to colder water temperatures (can withstand down to 12°C.). However, it grows rather too slowly for culturists who particularly favour fast-growing fish. It is partly for this reason that the recent success with the Giant grouper is significant; this species is very fast-growing and it is believed that it may become cheaper than Green grouper in the future.

In southern Chinese Taipei there are problems of poor water quality, disease (especially after 1990 when large amounts of fry were imported) and there are other problems such as lack of a reliable electricity supply (this area has pond culture). The government is trying to encourage culturists in southern Chinese Taipei to use sea pens but there are problems in the areas with typhoons. Major culture areas are around Chiung-kang and Ping-tung (especially Kao-hsiung and Fang-liao).

3. GROUPEL HATCHERIES

A major problem perceived in Chinese Taipei was one of price control and the question of how to balance supply and prices was one that often arose. The problem is that over-production will lead to low prices. This is one of the reasons that seed are still imported into the country despite high local production: they are imported if

they are cheaper or to fill short-term shortfalls in monthly production.

Success in hatcheries partly depends on the availability of broodstock and the breeding cycle. Broodstock are mostly taken from the wild. In Penghu, there is no problem in getting broodstock (large fish of 10-30 kg) of both males and females locally. Natural spawning is from February to September, while induced spawning can allow more flexibility in the timing of egg production. There is little broodstock available in the waters of southern Chinese Taipei.

Egg production can be induced artificially or allowed to happen naturally – both practices take place. Spawning is artificially induced in the Penghu Is. because natural spawnings produce fewer eggs. However, broodstock induced to spawn artificially survived less well than when spawning was allowed to occur naturally, animals sometimes surviving but one spawning event. There was little indication that any broodstock had come from hatchery reared stock. The advantage of induced spawning is that eggs can be produced to order, i.e., to fill demand.

In the Penghu Islands there is high production of fry and many releases of 'excess' fry for 'restocking'. The most recent release was of 1 million seed. Restocking is also carried out on the main island. In May 2000, this occurred in 4 places with about 2 million seed (of 5 cm) released as a public event into coastal waters. There is no follow-up work to these events and it seems that restocking is perceived by traders as an excellent way to try to convince the government to buy excess hatchery production. Whether or not restocking improves the fishery is not known.

In southern Chinese Taipei there is either overproduction, or the potential for it, and there has recently been considerable success with a 'new' species. In 2000, 2 million pieces of Giant grouper fry were sold to Hainan, Hong Kong, Malaysia and Vietnam. One company has specialized on this species and holds about 500 broodstock. It took about 5 years from spawning to commercial production. The same company has also produced about 300,000 *E. fuscoguttatus*. Both species are good as they have fast growth and high survivorship. There is much interest in culturing new species. Annual grouper fry production for 1995-1997 (up to 7.5 cm) was estimated at 20 mill. – 30 mill. per year (Su, H. M, pers. comm.).

4. TRADE

Traders import juvenile grouper from several source countries and imports vary widely from year to year. A peak in imports was in 1998 when 6,000,000 fry were imported in some months (this was apparently because the price was particularly good, i.e. low). The problem with the fry trade is that numbers can never be guaranteed from the wild. The traders felt that, in general, wild-caught fry survive the culture process better than hatchery produced fry and so believe that there will always be a demand for wild-fry. Into Chinese Taipei they ship fish of 1-3 cm (because of their low price) while Hong Kong prefers importing 7-8 cm fish (because of their lower mortality). The quality of the fry from the Philippines was thought to be worse than elsewhere by one trader, possibly because of cyanide use, it was suggested, but other culturists preferred not to use Thai seed because of disease and poor quality, in favour of Philippine seed, i.e., the perceptions of fry quality with source was variable. One importer felt that Chinese Taipei does not need to import fry because local production is sufficient, the reason for imports being purely economic. Seed is imported from Thailand (*E. coioides*, 2-2.5 cm), Indonesia, Sri Lanka, (*E. coioides* and *E. malabaricus*), Philippines and Malaysia.

One of the serious problems of importing fry has been the transfer of disease with the fry. There have been disease problems with Thai seed but those from Sri Lanka were perceived to be better in quality. In 1999, about 30% of the seed in culture in Chinese Taipei came from imported fry, according to importers and a

fisher/culturist (it is also consistent with trade figures in the late 1990s). However, one representative from a large trade association said that only 10% were imported, and then only during winter months.

Fewer than 100 companies export grouper from Chinese Taipei and many apparently prefer not to export grouper seed, in order to maintain control and technology within Chinese Taipei. Most local fry production is for local use. Exports increasingly involve fertilized eggs and some of these go to China where there is considerable interest. Giant grouper seed go to Malaysia, Thailand, China and Vietnam for growout and some to Hong Kong. Buyers in Hong Kong are not so keen on the eggs and prefer to purchase fish of 5-7.5 cm.

5. SOCIOECONOMICS

The culturists tend to specialize in different steps of the complete hatching to grow-out cycle. Specializations are distinct; the production of fertilized eggs, or the nursing of the smallest size classes, etc. They appear to be well-organized and clearly have some degree control over pricing and production through their various organizations (I could not gauge how much control, however, and there are about 4 main associations). There are clearly problems of demand and supply that affect prices and have not been resolved. The culturists had a history of independence (from the government) and initiative in working towards the successes of hatchery production. There was a strong feeling that culturists 'had to stay ahead of the game' to continue being competitive and that the grouper hatchery market is a tough one to survive in.

The hatchery/culture business is clearly a difficult one. Several former culturists have changed business a couple of times because of changing prices. Culturists are always experimenting with different species for culture and hatchery because of competition on the market and there was some secretiveness about activities because of the highly competitive environment. The general perception is that the industry does not get, nor seek, much in the way of government assistance.

6. HISTORY

Culturing of grouper started in Chinese Taipei in about 1984 and the price was so good at that time that many farmers worked towards hatchery production of seed and were able to produce eggs in small numbers and seed by 1984. This was before the success of research institutes. There was also incentive to do this as an alternative source of fry to cyanide capture. (For more on the early history of grouper culture, see under Gears, *setnet*, *cyanide*, above.)

7. REGULATIONS

In the Penghu islands, fishers are not permitted to catch any grouper seed of < 6 cm to protect the fingerlings that have been released during 'restocking' exercises. The use of cyanide for fishing is illegal.

h. HONG KONG SPECIAL ADMINISTRATIVE REGION (HKSAR)

Literature

Grouper culture began in Hong Kong in the late 1960s because of strong demand for live marine fish, the increase in the standard of living and the increase in fuel prices. In the late 1970s, mariculture activities grew, the marine Fish Culture Ordinance was introduced in 1980 and culturists had to operate under license in gazetted culture zones. These culture activities originally relied heavily on the import of grouper seed from PRC and some local capture. Now, all culture depends on the import of fry from areas elsewhere in SE Asia. In

recent years, the Hong Kong mariculture industry has been plagued with many problems and grouper culture activities have become severely reduced. Production is now little more than 1,000 mt a year, whereas previously it had been about 3,000 mt a year during the 1990s (Li, 1999). Mariculture production contributes but a few percent of total fish production of Hong Kong in terms of weight, but about 15% of production value (Wilson, 1997). The recent problems largely stem from poor water conditions and a recent severe red tide destroyed almost all of the annual production. Despite such poor conditions, Hong Kong has total of 26 Government gazetted mariculture zones and grouper is the most important marine fish species cultured, in terms of value

Originally, the favoured, and major, culture species (and indeed still a preferred and high value species for its taste and colour) was the Red grouper (note that *E. bleekeri* may sometimes be referred to as the Red grouper), *E. akaara*, accounting for 90% of fish culture. However, by the early 1980s, there was a shortage of wild seed of this species in Hong Kong and its hatchery in southern China was already in the early stages of development (Tseng, 1983). Economic reforms in PRC in the 1980s affected funding to many such facilities which ceased operations.

Red grouper seed was originally obtained from line and pole fishing in several areas of southern PRC, including Hainan Is. Fingerlings were sold at 12-20 cm (75-150 g). In 1978, Hong Kong fish farms purchased 18,000 kg of seed (100-200 g) which numbered from 90,000-180,000 fish. The sales began in May and peaked in July with quantity dropping after July and fry were not purchased during the winter months. In 1979, at least 180,000 kg were purchased by culturists in Hong Kong from China (200,000-450,000 fish of 100-200 g). Some seed was also collected in Hong Kong (*E. akaara*, *E. awoara* and *E. areolatus*) in limited amounts (Johannes and Reipen, 1995; Sadovy and Cornish, 2000). Seed was also brought in from Chinese Taipei and elsewhere in SE Asia (Tseng, 1983). At the time of the Tseng paper there had been no disease problems.

It is still government policy to promote mariculture, however, the poor local water conditions, the heavy development pressure and pollution in coastal areas and the lack of new sites available for fish culture strongly suggest that the industry is unlikely to expand in its current form. There are no established hatcheries due to the shortage of suitable water resources or land (Wong, 1995). Local culturists are increasingly affected by prices and culture activities elsewhere in SE Asia, and continually search for new species with ample supply of fry, fast growth and consumer acceptability to maintain their mariculture operations (Wong, 1995).

Grouper culture has always depended on wild capture of juveniles and the use of trash fish for feed in Hong Kong. In earlier years, grouper fry came into Hong Kong mainly from China and initially the species involved were the Red grouper, *Epinephelus akaara*, the spotted grouper *E. areolatus*, the Green grouper (*E. coioides* and possibly *E. malabaricus*). After the early 1980s it became difficult to obtain the seed of some of these species, and others were sought (Wong, 1995). The most common species now is *E. bleekeri*, a species that has proven a reasonably good substitute for the (true) Red grouper in terms of market demand (Li, 1999). Although a mixture of trash fish and pelleted food is now used in Hong Kong, it is striking to note that a significant proportion of fish taken in Hong Kong waters, comprising juveniles and small species (much of which are considered to be 'trash fish'), supplies mariculture operations (Wilson, 1997; ERM, 1998).

Research Findings

The Hong Kong results are based on the interviews with 9 mariculturists with experience between 3 and 20 years and all own their facility, 5 grouper fry importers and 2 government officers. Site number 44 in Fig. 1a.

1. CAPTURE FISHERIES

There is no grouper fry capture fishery in Hong Kong; all seed are imported.

2. GROW-OUT

Hong Kong mariculture facilities are distributed in 26 gazetted mariculture zones and all depend entirely on grow-out in floating net cages. Of the 9 culturists interviewed, 4 took over the business from their family, and one was formerly a fisher and was encouraged by the Agriculture, Fisheries and Conservation Department (AFCD) (formerly the Agriculture and Fisheries Department) in the 1970s to join the industry. The remaining 4 culturists recognized the economic value of culturing grouper and other marine fishes in Hong Kong. Though 1 mariculturist did invest in grouper hatcheries research of grouper a long time ago, this was done outside of Hong Kong.

Despite the long history of mariculture in Hong Kong, it became clear during the course of the interviews that most culture facilities in Hong Kong are not operating at much capacity for grouper now because of the poor water conditions and also the difficult economic environment. There has been a particularly marked reduction in culture activities in the last two years. Owners are evidently maintaining their cages and license (by keeping a few fishes to avoid cancellation of the license by the government fisheries department [AFCD - Agriculture, Fisheries and Conservation Department]) partly in the hope of receiving ex-gratia allowances if outside activities impinge negatively on the culture zones.

Only a few species are, or have been, successfully cultured in any quantity in Hong Kong. Cultured species (with Cantonese names) are the Brown spotted grouper (*Chee Ma Paan*) *Epinephelus bleekeri* and *E. areolatus areolatus*, and Green grouper (*Chin Paan*), *E. coioides* (but note that this name is also often applied to *E. malabaricus*, the Malabar grouper - *Fa Kwai Paan*—because of similar sources, prices and colours). Although both *E. coioides* and *E. malabaricus* are always mixed for culture, mariculturists clearly distinguished between the two. *E. coioides* has lower mortality in grow-out, while *E. malabaricus* grows more faster than *E. coioides*, but is more sensitive to lower water temperatures. *E. bleekeri* more common than *E. areolatus* in culture. *E. coioides* has higher mortality than *E. bleekeri* in winter and *E. bleekeri* is now preferred in Hong Kong. However, one importer indicated that there had recently been severe disease problems with *E. bleekeri* imported from Thailand.

Several culturists have attempted the grow-out of other grouper species in Hong Kong, with little success. These species include Tiger grouper, *E. fuscoguttatus* (*Lo Fu Paan*), Yellow grouper (*E. awoara* - *Wong Paan*), Coral trout, *Plectropomus leopardus* (*Dung Sing Paan*), Panther grouper *Cromileptes altivelis* (*Lo Xue Paan*) and Giant grouper (*Long Dann*), *E. lanceolatus*, but the first four did not do well in the colder winter months and seeds of the latter two were perceived to be rare and expensive (note that since these interviews were conducted, there has been significant success in Chinese Taipei with Giant grouper culture and culture of Panther grouper is particularly successful in Bali, Indonesia).

Details of the sources of various cultured species were provided. Most culturists cultured *E. akaara* in the 1980s and much of the fry came from Fujian province in southern PRC, as well as Matsu (Cantonese: *Ma Jo*) in Chinese Taipei. All seed were taken from the wild. Several culturists had heard of a hatchery for *E. akaara* in Fujian but could not confirm the rumours. For *E. awoara*, wild seed comes from Fujian and Zhejiang in PRC. For *E. bleekeri*, major sources were the Philippines and Thailand but it was clear that all culturists in Hong Kong considered that seed from the Philippines was much better than that from Thailand, at least in terms of survival rates. They said that salinity of water in Thailand is much lower than in Hong Kong and fry from Thailand do not adapt as well to Hong Kong water as do Philippine seed. However, owing to the lower price of Thailand grouper

seeds, there is still demand for seeds from Thailand. For Green grouper, most of the seed (80-90%) purchased by some Hong Kong importers are wild-caught, the remaining 10-20% come from hatchery sources (but see Chinese Taipei section). Others, however said that most (50-70%) of their seed was from Chinese Taipei, so sources vary across importers. None of the mariculturists or importers thought that there were problems with supply of grouper seed for important cultured species. Other reported sources for this species are Indonesia, Vietnam, Malaysia, Kampuchea and Myanmar. *E. areolatus* comes from the same places as *E. bleekeri* but in smaller numbers; this species evidently grows faster than *E. bleekeri*. For *E. coioides* and *E. malabaricus*, sources of wild-caught fry are mainly from the Philippines and Thailand, while hatchery-produced fry of these species come exclusively from Chinese Taipei. Other more minor sources include Indonesia, Malaysia and Vietnam.

Regarding species of minor culture importance, 4 others were mentioned: *E. fuscoguttatus* is imported from the Philippines and Indonesia, while *E. lanceolatus* comes from the Philippines, Indonesia and Vietnam in small quantities as fingerlings. Supply from Chinese Taipei of hatchery reared Giant grouper appears to be good now (Patrick Chan, pers. comm. 14/12/00); the species is fast-growing, shows excellent potential for culturists and it may replace *E. coioides* as the major culture grouper species in Hong Kong. *Plectropomus leopardus* comes in small quantities from the Philippines, Thailand and Indonesia but seed of this species is not abundant and culture has not been successful outside of Japan. *Cromileptes altivelis* comes from the Philippines and Indonesia, and hatchery-reared seed are available from Indonesia and Chinese Taipei. This species is said to grow slowly in culture.

Although there is a distinct seasonal component to the demand for grouper fry in Hong Kong according to the local growing season (and warmer summer water temperatures), most culturists were not aware of any seasonality in grouper seed supply and felt that seed should be available all year round from more tropical SE Asian countries. Culturists usually request grouper seed only from about March to July, in a few cases even until October of each year. The warmer water temperatures at this time mean that the fish grow faster and reach a larger size by the winter and thereby have a better chance of adapting to local conditions and surviving the lower winter temperatures.

When grouper seed arrive in Hong Kong the treatment is very simple prior to introduction into floating cages. Some culturists sterilize their seed using freshwater or 'yellow powder' (possibly an antibiotic), others use a formalin bath. Bags of seed are then floated for 15-30 minutes to allow the temperature inside the bag to equilibrate with that in the net cage. The grouper are not fed for the first 2 days after introduction and the animals tend to be stressed; often the smaller seed start to eat sooner than the larger ones. Feeding of fish in Hong Kong culture is by 'trash' fish (Plate VIII d), although some culturists also use artificial pellet feed promoted by AFCD.

The major problem of grouper grow-out in Hong Kong is the high levels of mortality and this has become significantly worse recently compared with the situation 10 years ago. Most culturists agreed that the first period of high mortality is in the first few weeks or months after introduction to the net cages; 10 years ago, mortality at this stage was 5%, while now it is 20-30% and sometimes 100%! Handling and quality of the seed were considered to be important factors in this early mortality. The second vulnerable period is when the water temperature changes, which happens quite rapidly twice a year, increasing in April/May and decreasing in November. The time of increasing temperature appears to be the worst of these two periods.

Another cause of mortality is the differential growth rates of individuals leading to cannibalism. So, size-grading is an important and necessary procedure to slow down the mortality caused by cannibalism which is more serious in *E. coioides* than in *E. bleekeri*. When it happens between individuals of similar size, they will both die and close attention to grading is a necessary, but time-consuming, activity.

The high levels of mortality are not only wasteful of resources and expensive but they mean that business planning is difficult and culturists feel that they gain little support or knowledge from the government. Overall, grouper mortality in Hong Kong typically ranges from 80% to 90%, and may be 100% in some cases or for some shipments. Those culturists with extensive experience recall that mortality was closer to 40-50% a decade or so ago but has become progressively worse, the consequence, it was suggested, of poor water quality and disease. Often the disease is 'symptomless' or undiagnosed but there are also problems with *Vibrio* and some strains have been introduced with imported grouper seed (e.g. from Thailand). Antibiotics, such as tetracycline, may be used to treat disease, or other medications are used locally and referred to as *Luk mui so* and *Kun Gue Luk*. Culturists think that the disease or virus strain is now immune to these drugs. In general, the feeling was that culturists received little useful help from the government and that, for some species, the position and water conditions of gazetted culture zones are not the best for certain species (such as *E. akaara*). Their perception was that AFCD has no expert on fish disease (although recent work has begun to address this problem) and their access to drugs for treatment (which are sought in PRC) is limited. However, free disease diagnosis and prescription services are made available to culturists by AFCD.

To put the high levels of mortality into perspective, I have calculated how many fish are necessary to produce the annual production of much of the 1990s (about 3,000 mt for all marine fish culture, of which grouper are about 13%, if the 1999 percentage of grouper applied throughout the 1990s) (Li, 1999; J. Sham, pers. comm.). If we assume that market-size is about 400 g (about 30 cm), then about 1 million seed are needed to produce 3,000 (x 13%) mt fish and about 7.5 million fry would be needed if all 3,000 mt were grouper. There are about 1,500 licensed operators in Hong Kong and one of the largest of these formerly imported about 10 million a year for his own use. This suggests that hundreds of millions of fry are imported annually which ultimately produce a few hundreds to about 1000 mt of fish (depending on the year). These numbers reflect the high mortalities in Hong Kong associated with the culture phase (even despite that fact that much imported fry is re-exported to China).

3. GROUPEL HATCHERIES

There is no established hatchery for grouper in Hong Kong and none are planned according to AFCD personnel. Currently, however, AFCD is conducting a feasibility study on marine finfish fry production (including for groupers). One major importer indicated he had recently sought government assistance in establishing a hatchery in Hong Kong but has not received an encouraging response, although AFCD states it will provide technical assistance for hatchery establishment. However, many of the traders are not keen on the idea of a hatchery because they believe the hatchery-produced seed will significantly reduce the value of their trade. Hong Kong businessmen also have interests in southern China in culture and hatchery of marine fishes but hatchery success with grouper species is low.

4. TRADE

Imports of marine fry by air, and by vessels not licensed in Hong Kong, are recorded with their own commodity code (0301-9912) (since 1997). Since most imports in this category are groupers, the figures collected by the Census and Statistics Department of the government of the HKSAR provide an indication of the monthly volumes (by price) of fry imports as well as the source countries. As an example, in 1997 the total value of marine fry imports was 9,356,000US\$, with most fry coming in between March and May (assuming value is approximately equal to similar unit volume throughout the year). The main source countries were Chinese Taipei and Thailand (about 70%) with about 20% from China and Malaysia. Other source countries are the Philippines, Myanmar, Indonesia, Sri Lanka (Lau and Parry-Jones, 1999). Few grouper seed were imported in 1999

because of poor mariculture conditions. Care is needed in evaluating official import figures into Hong Kong, however, since a significant proportion of this trade continues, unofficially, through into China, and imports from the Philippines appear to be underestimated according to Philippine export figures.

To give an indication of the numbers of seed imported into Hong Kong, examples are available from individual culturists. One of the biggest culturists used to buy 8,000,000 – 10,000,000 *E. bleekeri* and 800,000 – 1,000,000 *E. coioides* per year for culture before 1998. One of the smallest, on the other hand, purchased 3,000 – 4,000 grouper fry per year in 1996 –97 and only 1,000 fry more recently. Another culturist imported 5,000 - 30,000 grouper fry per year in 1998 and one importer indicated that the culture facilities on Lamma Is. purchased 2,000,000 fry (*E. bleekeri* and *E. coioides/E. malabaricus*) in one year in the late 1990s. A significant proportion of seed imported into Hong Kong appears to continue on to the PRC. One of the major Hong Kong importers interviewed, sends about 90% of his imports (90% is about 200,000-300,000 animals) to China (increasingly to Hainan Is.) and retains 10% in Hong Kong.

Most grouper fry are imported to Hong Kong by air, the one exception is boat transport from PRC. According to importers, mortality during air transportation is low and typically less than 20%. Good packing techniques are an important factor in reducing mortalities in transport and involve the appropriate packing density according to fish size: those of 5 cm are packed at 400 seeds per box; those of 7.3-10 cm are packed at about 120 seeds per box, while seed of 15-20 cm are packed at about 40 - 70 seeds per box. No anaesthetic is needed for grouper seed packaging but the fish must not be fed before export. It is considered important to lower the water temperature for transport to 18 – 20°C to inactivate the fry/fingerling in the, aerated, plastic bags and to avoid movement during travel. For relatively longer distance travel, ice may be placed outside the bag of fish in the styrofoam box but care is needed to avoid 'cold-burn'. Seed previously imported from PRC in fishing vessels were stored in an open water tank, with circulation and water exchange to the outside; importers and culturists used to like this method because the fish appeared better able to adapt to the Hong Kong water environment on arrival than those sent by air. However, fish coming in by fishing vessel were not graded for size and needed a long processing time on arrival in Hong Kong.

Grouper seeds are traded in 6 distinct size classes: class 1 (5-7.5 cm); class 2 (7.5-10 cm); class 3 (10-12.5 cm); class 4 (15-20 cm); class 5 (20-22 cm), and class 6 (>25 cm). The preferred purchase sizes are 10-20 cm because fish of this size are not too expensive on the one hand and do not suffer from high mortalities, as do the smaller fish, on the other. All importers indicated that fry from the Philippines are of better quality and gain HK\$ 1-2 more per fish than the same species and size from Thailand.

5. SOCIOECONOMICS

Grouper culture in Hong Kong is not a large-scale activity and is typically carried out on a small, family-size, scale (Plate VIIIa, VIIIc). There are several larger scale net cage operations but these are mainly dedicated to the short-term storage of market-size live fish prior to sale (Plate VIIIb). Most of the culturists interviewed felt that prospects for the future of the culture industry were bleak because of the problem of high mortality during grow-out. They do not see a solution to this problem. All complained about the poor, and worsening, water quality and felt that the only solution would be to turn to pond culture.

Other problems encountered by the small-scale culturists included poaching, high stocking density, disease, lack of cooperation among culturists in some gazetted area and lack of help from the government. Fish poaching is carried out even by neighbours and most fish rafts have one or two dogs (which add to water pollution). Although residing on a culture raft is illegal, watchsheds for watchkeeping purposes are permitted under licence, further polluting the water. The high density of stocking of fish and the close proximity of the

culture rafts to each other mean that there are often problems of low dissolved oxygen and spread of disease; such problems could be alleviated by better cooperation among culturists and better information and guidance from the government. Advice is especially sought on 'technology' to deal with grouper disease, better feed, greater investment into the industry and information on advances and improvements. However, overall it was felt by culturists interviewed that the culture industry has no future, that few young people are considering joining the business and that the main value of a culture license is for possible government ex-gratia allowance to compensate for pollution or disturbance coming from outside of the culture zones.

6. HISTORY

Up until the early 1990s, most culturists preferred the Red grouper (*Epinephelus akaara*) (Cantonese: *Hung Paan*), a highly valued and very tasty fish; more so than others of the same genus. At that time, and since the early 1980s, the Red grouper was imported from southern PRC but, owing to the shortage of seed supply culture activities were shifted to other species for which seed are available, mainly green and Brown-spotted groupers.

Culturists have increasingly diversified the species that they culture and are constantly experimenting with different (non-grouper) species.

7. REGULATIONS

Culturists in Hong Kong must be licensed and operate in one of 26 gazetted culture zones. There are no regulations that apply to the capture of grouper fry or their import or export.

D. DISCUSSION AND RECOMMENDATIONS

The overall aim of this survey of 8 economies in SE Asia was to take a region-wide look at the practices of grouper seed capture, supply and trade with a view to identifying directions for further attention and action to attain a better use of biological resources and greater socio-economic benefits from grouper culture activities. The broad scope of such a survey clearly precludes detailed analyses of any one country but takes a step back from the country level to view the activities related to grouper seed supply on a broader scale in the region. Specific follow-up studies, identified by this survey, are proposed to address several areas where further work is clearly needed. Results from interviews in each country have been summarized and presented as a consensus view, although individual comments are sometimes given, and indicated as such.

The semi-quantitative nature of the data is typical of surveys of this kind, and, while allowing a critical component of grouper mariculture activities in the region, that of seed supply, to be examined on a region-wide basis for the first time, they are limited in identifying specific solutions at the finer scale. The lack of reliable trade and capture data, and reportedly illegal trade, further exacerbate regional evaluations of scale and scope of trade. More detailed studies will be necessary to examine some of the key issues identified during the course of this survey and to resolve the means of achieving some of the recommendations. Given the already acknowledged shortage of grouper seed supply regionally, and the intensely international nature of grouper seed trade, the lack of attention given to seed supply in general stems in part from the tendency to focus on national issues and on production and economics. As the results of this survey show, however, there is clearly a need to also look more closely at the regional foundation on which such production and economics rest by examining their biological resource base and determining how better this can be used to benefit the region, both economically and socially, in a way that is sustainable.

While drafts of each economy surveyed have been reviewed by independent workers familiar with each country (with the exception of Malaysia), the views expressed and the interpretations of the data gathered are my own and entirely my responsibility. These views have as their foundation the belief that regional grouper seed resources from the wild can, and should, be utilized in a much less wasteful way than they are at present and in a way that better benefits the socio-economics of source countries than they do at present. Indeed, it is incumbent upon both supply and demand economies to become more responsible in their use of the increasingly limited marine resources of the region.

Given the increasing global shortages in seafood and problems with many fish stocks in SE Asia, it is critical to promote fishing and culture practices with a long-term view in mind and to recognize the interrelationships between marine culture operations and marine fisheries for many species. This latter issue is important since mariculture is often viewed as an alternative to capture fisheries, when, in many cases, including the case of groupers, the two are intimately linked. These linkages are not only in the fry/adult relationship, but also in the heavy dependence of grouper culture and trash fish (the latter is beyond the scope of this survey but see excellent review article by Naylor et al., 2000 on the general question of linkages).

The original objectives of the grouper fry/fingerling survey are addressed and recommendations arising therefrom are provided below. To understand the framework within which to view these recommendations, we need to keep in mind that a very crude recent estimate of annual regional production of market-size fish through culture is 23,000 mt (this does not include Indonesia – see individual country sections for supporting figures; nor does it include live fish taken from reefs at market-size. Note that the production data at the country level is highly variable and precludes a robust regional estimate of production for most economies). About 20% of this production may be based on hatchery produced fry, the remainder on wild-caught seed. China is the major producer (8,300 mt annually), with Taiwan and Vietnam also producing significant quantities of cultured market-sized fish. At an average retail value (Hong Kong prices) of US\$25/kg, regional production is worth in the order of 575 million US\$. By contrast, the value of traded fry in one of the major import economies (Hong Kong, which also re-exports to China) was little over 9 million US\$ in one year suggesting a much lower value for the regional fry trade. Such crude estimates of the values of fry trade and market-size fish suggest that if reductions in international fry trade lead to improvements in the production of market-size fish (through better use of available fry) then there should be overall economic gains to the region.

Results from this survey indicate that there is ample scope to increase that value and much opportunity to reduce wasteful and damaging practices.

Availability, capture and trading practices 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-waters 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 (about 8 general categories could be distinguished, some of which may be used with or without lights: fixed large nets; traps and shelters; hook and line; scoop/push nets; artificial reefs; fish attractors; tidal pools; chemicals) 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 may often be taken year-round. Although a wide range of species is taken and 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, to a lesser extent, *E. malabaricus*. It is interesting to note that the two most commonly cultured species (plus the recent success with *E. lanceolatus*) involve species that have a strong estuary-associated life-history phase; perhaps such species are particularly tolerant and thus able to withstand many of the rigours of culture.

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 1 year of age (Fig. 2b). All of these fish are likely to be juveniles since sexual maturation in the most common species, *E. coioides*, is not attained until above 25 cm TL. Most capture, however, focuses on fish up to about 15 cm (about one year of age). The smallest size classes of fish, 1-2 cm fry, are caught by the million over short periods each year while smaller quantities of large 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 may broadly be divided into passive (e.g. traps and shelter) and active (e.g. hook and line and scoop net) types, while some gears, especially of the 'fish shelter' type, have been specially developed to take fish seed and show some potential for taking seed sustainably and should be further examined. 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 that are dragged across the substrate, like the scoop net, can cause habitat damage and for this reason is controlled or banned in several places. Cyanide, although not widely reported for seed capture is also destructive of habitat and produces bycatch. When lights are used to enhance the catches taken in fish shelters, the mortality of the seed is significantly higher than when no light is used, and high mortality is also associated with fyke nets (again, 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 (one of the few conducted to investigate bycatch and catch characteristics of a grouper fry fishing gear) demonstrated that a very high percentage of total catch taken in artificial reefs (*gangos* – see Philippines section for details and caveat regarding *gango* use in the Philippines) are non-target species and the method of harvesting the *gango* can lead to mortality in much of the bycatch unless this is carefully handled (Mous et al., 1999). For many other gears, and during certain periods, bycatch can be high. While some of this bycatch may be used for fish feed or for human food, its impact on local resources cannot be ignored. As an example, wasteful bycatch of small rabbitfish (*Siganus* spp.) juveniles was often high, for example, in areas where 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 and to recommend preferred gears for the capture of grouper fry.

The volumes of seed caught each year and cultured/traded regionally, as indicated by interviews, trade figures and by crude calculations, reaches many hundreds of millions of individuals. The greatest volume is with the smallest size classes (1-3 cm), the catch of which, during peak seasons, can reach several tens of thousands by one gear in one night (e.g. fyke net). Even larger sizes of fish are being taken in massive numbers region-wide each year. It is sobering to realize that the amount of seed often produced in a hatchery (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 suggest crude and wasteful culture practices. To produce 23,000 mt of table-size live fish about 60 million seed are necessary (see Hong Kong section for details of the calculation). Yet, crude estimates of trade around the region suggest that international trade of many hundreds of millions of seed occur annually and it is clear that there is an enormous mortality and wastage of biomass involved in the process. The magnitude of such waste, which does not include mortalities from capture, transport and export, calls for scrutiny of its causes and a significant reduction for better use of wild resources. The major sources of this massive mortality are destructive fishing practices/gears, poor post-harvest handling, poor culture practices and conditions and lack of experience or knowledge at many levels. Given the magnitude of this wastage, it is very important to determine whether it can be significantly reduced and to ensure that better use is made of available

resources.

It was interesting to note that mortality levels were often exacerbated when demand from exporters/buyers was high, causing large volumes of seed to be caught in a short period of time (examples are given in country accounts of such circumstances). Less care was taken in capture, more destructive gears were used and there was generally less interest in delivering animals in good quality. This was also noted when the price of market-sized fish was low, producing a situation of reduced interest in local culture and more interest in rapidly collecting and shipping out large volumes of seed (see Thailand account). Moreover, there was an overall impression that imported fry originate in conditions very different than those in the destination economy, were slow to adapt and had higher mortalities than those fry caught and cultured in the same area. The stress of changing of water conditions and long-distance transport may be key factors in such mortality differences.

The relationship between demand and supply of seed revealed two other patterns of note and relevance to regional trade. Whereas the fishers and local buyers were very aware of annual fluctuations in seed supply and, in some cases, of overall declines in their respective areas, the exporters and the importer/culturists in destination countries were much less so and generally believe that fry should be available throughout much of the year. This suggests that an important link is missing regarding an understanding of, and response to, the status of the resource (grouper seeds) by those towards the upper end of the trading chain. It also means that their businesses should be somewhat immune to major resource depletions in any given source area since they can purchase from a range of alternative source areas. A parallel pattern has been recognized in the trade in market-size live reef food fish whereby businesses were able to move from one fishing ground to the next as resources became successively depleted (e.g., Johannes and Riepen, 1995).

This absence of consequences for (possibly) unsustainable exploitation for the relatively small number of major traders that gain the major economic benefit from these trades, is a serious problem for the long-term persistence of such fisheries. Again, a parallel situation is seen in the live reef fish trade for market-size fish where serial depletions lead to (non-national) businesses simply moving on to the next unfished area until that too is overfished (Johannes and Riepen, 1995). Moreover, it is important to recognize that many higher level traders or exporters of fish fry are diversified in their business interests, often trading in a wide range of seafoods; this again gives such companies some immunity to resource shortages in any one area of trade.

The trade in grouper seed throughout SE Asia is complex and extensive (Fig. 4). Major trade routes for grouper seed involve Hong Kong, China and Chinese Taipei as destination countries and major source countries are Philippines, and Thailand, and, to a lesser extent Indonesia and Chinese Taipei (largely hatchery-reared in the latter case but see the country section). Some trade is probably illegal, as indicated by many interviewees, although such claims could not be substantiated (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 and Vietnam to the PRC). Note also that Chinese Taipei exports both hatchery produced seed and imports and re-exports wild-caught seed. 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 (some of it reportedly through Singapore). 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 do play a small role in various aspects of the live reef fish trade, one that will likely increase for Japan and Korea.

The trade structure can also be complex although much of the international trade appears to be controlled by relatively few companies. Fishers sell seed to culturists/buyers/middlemen and there may be one or more levels of middlemen, the last of which sells to an exporter. It is not common for fishers to sell directly to exporters.

Most of the export businesses are owned by Chinese, Chinese-Filipino/Indonesian, or Taiwanese businessmen and the same large businesses may operate in several countries. The middlemen may sell to the exporter or trade domestically, or both, and many fishers or middlemen may, themselves, be culturists.

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

There is a widely acknowledged shortage of wild-caught seed of grouper compared to seed demand for grouper culture and strong indications that in many areas supplies are declining. From interviews throughout the region, and from lower levels of capture and culture (but not usually traders and exporters, see above), there was a strong and consistent indication that supplies have declined in many areas, especially those that have been long and heavily harvested (see Tables and country accounts for data of changes in catches over time). Reasons for the declines cannot be evaluated without the appropriate careful and controlled studies but likely involve, one or a combination of, the following suggested causes: overfishing of grouper adults and seed, habitat damage and loss, destructive fishing techniques, siltation, pollution, agriculture runoff, and high export demand. However, in evaluating apparent changes in supply, the market situation must always be considered since a depressed market leads to reduced fishing activity and, hence, reduced demand. Nonetheless, examples from throughout SE Asia indicate that real declines in seed supply have occurred with the virtual disappearance of seed of species like *E. akaara* from the northern sector of the South China Sea. Declines have also been noted elsewhere (e.g. this survey and by Johannes and Riepen [1995] in Hong Kong, S. Philippines and NW Indonesia). Hong Kong, Chinese Taipei and China, the major demand centres for live fish, no longer have viable seed fisheries.

Some of these declines may be attributable to overfishing, rather than to other possible causes, others are likely a consequence of multiple impacts (see Banten Bay, Indonesia section). In the northern Philippines, for example, water quality is good but both grouper seed and grouper adults are heavily exploited (by different fishery sectors.). Moreover, there is a strong indication that those seed resources that have been targeted the longest, are those which show signs of the most serious declines (examples are PRC, Chinese Taipei, Hong Kong and Cavite (Roxas, Philippines), while larger fishes generally to be more readily available in more recently established seed fisheries (such as Vietnam). The Red grouper, *E. akaara*, is evidently largely extirpated from most, if not all, of the coast of China, in terms of both juvenile and adult-sized fish.

It is noteworthy that the fishery for, and trade in, grouper seed have received very limited attention despite the interest taken in some areas in seed fisheries of other commercially important fishes such as milkfish (*Chanos chanos*) and rabbitfish (*Siganus* spp.). Apart from a few restrictions on exports (such as in China, Vietnam and Malaysia), there are few controls on the harvest of grouper seed, despite its economic importance and the declines noted in several places. Clearly there is an urgent need for more attention to be given to this fishery and it is suggested that well-designed, long-term, studies be established in a few key areas to examine the fishery over time, inclusive of socioeconomic 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 (suggested areas from this survey are Medan and Lampung in Indonesia, Cagayan, Pangasinan and the Visayas region in the Philippines and SE and SW Thailand). 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).

Despite seed resource shortages and declines, and notwithstanding the theoretical limits to seed supply, it is clear that grouper culture must continue to depend heavily on wild-caught seed for a considerable period and

that certain species have little chance of being successfully hatchery-reared in the foreseeable future. Therefore, serious attention needs to be given to the question of sustainable wild seed supply of groupers, and of other marine species of actual or potential interest for culture, and to determining whether current seed procurement practices are sustainable or could be modified to become so. Moreover, in those economies that have exhausted their own resources due to overfishing, or other impacts, encouragement to develop hatchery production should reduce their impact on resources elsewhere in the region.

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, which are, after all, the future adults of their kind. Groupers are pelagic spawners (the eggs are released into the plankton, hatch and develop into larvae before 'settlement' on the substrate 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 levels drop 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? While this question has yet to be satisfactorily resolved, data from other reef fishes, including a grouper, suggest that the rapid drop in mortality occurs within weeks or a few months of settlement (e.g. Sale and Ferrell, 1988; Koenig and Colin, 1999). Since the sizes of grouper taken for culture typically range from 1-15 cm with ages of up to 1 year (Fig. 2b, 3), this literature indicates that fish older than a few months (larger than about 6 cm) may reasonably be expected to survive to adulthood. This means that removal of 6 cm (approx.), and larger, fish could have a significant impact of adult stock and should be considered a capture fishery; in traditional capture fisheries juveniles are not usually taken because of the impacts of so doing on the adult stock. The country reviews indicate that there is a substantial fishery, and demand, for fish in the 5-10 cm range and that the implications of the removal of this 'seed' needs serious attention for its possible consequences for the future of both adult stocks and the contribution of these adults to the future of the seed fishery itself.

To safeguard regional supplies of grouper seed, there is a need for regulation and management of seed capture, especially those seed in the larger size classes, until we better understand the impacts of seed fisheries on the future of seed fisheries. There is also a need to protect the adult stock, and especially the spawning aggregations where the seed are produced (Johannes, 1998). Given the likelihood of a significant increase in natural mortality in the smallest settling fish, several workers have already proposed fisheries of very early post-settlement, or even pre-settlement, seed (e.g. Dufour, 1999) as a way of gaining benefit from a resource that does not affect long-term persistence of that 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 when how much is 'too much harvest' and how early is 'early enough'. There is a need, therefore to exercise the precautionary principle in developing such approaches on a wide-scale basis.

Given the insufficient supply of seed for regional demand (which is particularly exacerbated by high export demand), the possibly non-sustainable basis of some seed capture practices (especially in the case of larger seed) and the apparent widespread declines in seed resources, it is strongly recommended that export of wild-caught seed throughout the region be banned. This measure is already in place in several economies. It is the best single measure possible to address many of the most pressing problems in the grouper culture industry in

the region. Not only will it help to preserve seed for source countries to culture locally (note that local seed supply is probably sufficient for local demand but that both Thailand and the Philippines export most to their grouper seed), it should significantly reduce the risk of disease transfer around the region, places responsibility and accountability for local resources in the hands of local governments and stakeholders, and enhances the economic value of local resources to the source economy 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. Finally, reduced trade should restrict the introduction of genotypes around the region into areas where they do not occur naturally *[NOTE: some mention was made during interviews of restocking from hatchery fry, this should only be carried, if carried out at all, as a well-planned, researched and monitored activity, with locally produced seed and into a managed area – see the guidelines of the Re-introduction Specialist Group of the World Conservation Union (IUCN) <http://www.iucn.org/themes/ssc/pubs/policy/transe.htm>].*

Scope and potential for grow-out regionally while evaluating the importance to local fishing communities of juvenile capture, mariculture grow-out practices and the role of hatchery-produced seed

The wild-capture of grouper seed, its grow-out in suitable areas to market-size and the production of seed by hatcheries all have consequences for coastal communities and grouper supply regionally. For example, successful hatchery production in Chinese Taipei has greatly decreased demand and prices in countries that supply wild seed, while the deteriorating water quality in Hong Kong has also led to reduced demand for seed for grow-out. Moreover, with the exception of Chinese Taipei, there are no strong indications that hatchery production is close to meeting demand for seed and for diversity of species in the short-term. It is, therefore, important to examine the conditions for grow-out and consequence(s) of hatchery production in relation to grouper seed production and its possible social and economic implications.

Grow-out culture of grouper seed is practiced throughout SE Asia mainly in set and floating net cages and coastal ponds, many of the latter remaining from failed shrimp culture operations. From this survey, it was clear that culture conditions vary markedly in terms of water quality, security, density, feed quality and mortality levels during grow-out. Water quality conditions are particularly poor in Hong Kong, and parts of China and the Philippines and also when fish density is not well managed, trash fish use is excessive and there are problems with contamination or low dissolved oxygen because of poor placement of cages (see Indonesia section). Under such conditions, mortality was not only high, often exceeding 50%, but this has come to be considered acceptable and, possibly, inevitable. In more northern locations the cold winter water temperatures limit growth, survivorship and species diversity; in southern China, the most northern culture areas move their grouper south for the winter period because of temperature problems (see PRC section).

Higher mortality was also commonly noted in some areas in imported seed than in seed that had been sourced close to the culture area, or was typically higher from some source countries than from others. Seed from Thailand, for example, was often mentioned as having a higher mortality in Hong Kong and China than seed from the Philippines and seed taken closer to culture facilities in Hainan survived better than imported seed of the same species. The reasons for these differences in mortality are likely to be one, or a number of the following, differences in capture methods, differences in transport methods, or greater difficulties in acclimation to the local culture conditions by fish imported from areas distant to the culture area (for example, some culturists in Hong Kong indicated that fry from certain areas in Thailand, which differ markedly in salinity from Hong Kong, have particularly high mortalities after import to Hong Kong). I suggest that the latter is likely to be of some importance, since capture and packing methods seemed similar in the two places, but this factor is not, to my knowledge, factored into decisions on possible source countries and can lead to much wastage of

stressed animals.

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 truly address the best intended regional objectives for mariculture development. These objectives need to be clearly defined, but typically include livelihood options, earnings, sustainable mariculture and better utilization of marine resources. Is the direction that grouper culture is developing likely to fulfill such objectives?

The contribution to production of market-size grouper through culture (compared to wild-caught market-size fish) is significant in SE Asia and cultured fish have the potential to take pressure off wild stocks, be a source of safe-to-eat fish (but see Cesar et al., 2000 and Cesar and Hempel, 2000) and provide livelihood options in coastal communities. Approximately one quarter to one third of the trade in market-size fish is cultured. While it should be kept in mind that most of such ‘culture’ is dependent on the grow-out of wild-caught fish (i.e., not hatchery-supplied fish), cultured fish still represent a significant component of the regional live reef fish (market-size) trade. If practiced sustainably, it therefore has the capacity to take pressure off wild populations and ensure a safe (ciguatera-free) source of fish for human consumption. However, to fulfill this role, the culture sector needs to ensure that it recognizes good culture practices, carries out quality control on production and culture conditions and encourage and reward good practice. To do this, a licensing system could be introduced and internationally accepted guidelines such as Hazard Analysis Critical Control Point (HACCP), adopted to ensure fish are safe for human consumption and is produced sustainably.

Turning to the role of hatchery production in improving the earnings of impoverished 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?

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 and caused a decline in seed prices. Exporters and importers were understandably 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 an interest in the long-term stability of seed production, rather than considering only immediate business goals and constraints. On the other hand, if fry capture is entirely 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 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) difficulty in procuring broodstock in many cases, and low volumes of all but a few species, the potential for large-scale production of a diverse range of high quality reef fishes is unlikely to materialize 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 organization and specializing, not in reducing mortalities, and it is technical and expensive. It, therefore, seems likely that hatchery production will be limited to government institutes and private companies.

There are many tens of thousands of fishers in SE Asia from grouper seed capture. There is, therefore, a compelling reason to ensure that coastal communities benefit from small-scale, low intensity, culture operations and to ensure that seed resources are managed. Government assistance at the community level is also going to be necessary to improve the possibility for fishers to move into suitable culture operations and assist them in breaking away from relationships of indebtedness that characterize some communities. Assistance will also be needed in providing cheap, good quality hatchery-produced seed to make up shortfalls from healthy, limited but managed, wild seed sources and to ensure that supply from hatcheries does not ultimately jeopardize fisher livelihoods.

To develop recommendations, in relation to the seed fishery, 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. This should not only provide the incentive to better manage and utilize grouper resources but should better preserve the livelihood of local fishers/traders who rely on these resources for their livelihood and reduce wasteful practices and overfishing (associated with high export demand). Mortalities due to stress and poor acclimation noted in imported fish in destination countries would also be reduced. Moreover, the higher value of market-sized fish should bring greater foreign currency earnings to source countries. Cessation of exports should also reduce disease transfer around the region and the risks of genetic pollution through the inadvertent introducing of genotypes outside of their natural range. A total prohibition of export of wild-caught seed would be much easier to enforce than a partial prohibition and would reinforce prohibitions already in place in the region. Export prohibitions would also encourage those economies with a high demand for grouper seed but few local seed resources to develop hatchery facilities.

If export continues, adopt the Hong Kong Harmonized Code classifications for live grouper and live marine fry to ensure that international trade is being monitored.

2. Develop and implement careful and controlled studies on selected grouper seed fisheries in major producers of wild grouper seed, whereby information is integrated on catches, socioeconomics, market forces, associated adult fisheries and habitat. Such an approach is holistic and recognizes the linkages, discussed in this report, between different, but related fisheries (adult and juvenile grouper), and different but related activities (capture fisheries and culture). Such studies would have to focus intensively on a few specific areas (several of those visited in this survey would be suitable and are listed above) for 2-3 years and may suit a PhD project or could be integrated into ongoing fishery surveys in key fry production areas. Such surveys would require collaboration between different sectors of capture, trade and culture and could build specifically on the results of the present survey.

3. Reduce or eliminate the use of destructive (of habitat) or particularly wasteful (producing high mortality in, or damage to, target and/or non-target species) fishing gears or methods (like adding lights) and carry out studies on preferred gears to ensure that their operation does not incur greater waste or damage than is absolutely

necessary. Recognize and endorse the use of regionally approved gears.

4. Ensure better use of existing resources and reduce wastage of grouper seed biomass (and bycatch) arising from unnecessary mortality from harvest, transport and culture. Specific action might include agreement within the region on acceptable capture methods for seed and market-size fish and broodstock, seasonal or other bans to protect specific size classes or species and restrictions on numbers or sizes taken.

5. Examine, scientifically, the possibility of focusing the capture fishery on the smallest seed available (see arguments about natural mortality, above) and improve the means of nursing this phase to one suitable for widespread, small-scale culture. The techniques for nursing have been well-developed in Chinese Taipei and may be transferable to coastal communities. One possible approach might be to establish 'nursing' stations in areas where there is a 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). Marine protected areas might incorporate key settlement and nursery areas.

7. Provide government assistance both 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, and in terms of training in post-capture handling to reduce mortalities, and in nursing (see 5 above).

8. Develop certification systems for quality and good practice. For example, a distinction between hatchery-produced and wild-caught and reared (see Appendix - Definitions) seed could provide incentives for producing good seed quality and good-quality cultured (i.e. ciguatera-free, not caught with cyanide, etc.) fish, as well as for good aquaculture practices. It may be possible to develop tests to determine seed quality prior to purchase, thereby increasing incentives to produce good quality seed. Adopt guidelines for food safety, such as HACCP. Classify 'live fish' as a food item in Hong Kong under the law such that it is subject to normal and formal food health and safety procedures; ultimately high quality, certified, fish might command higher prices.

9. Examine the role of hatcheries in supplying grouper seed for culture. What are the precise objectives of government hatchery production (if seed are not exported is hatchery production necessary; should hatcheries specialize on ensuring small quantities of a range of species for market diversity or on high volumes of easy to rear species, etc.?) and how might these address the objectives (see 10 below) of grouper culture development in the region?

10. Develop clear objectives for mariculture development in the region and a plan that specifically addresses those objectives (i.e. what are the priorities - sustainable resource use, livelihood, foreign earnings, food supply, does coastal development take priority over grouper culture, to support international trade and big business, etc.)?

11. Promote the active application of the precautionary principle in the exploitation of grouper resources and the adoption by APEC member economies of the [FAO Code of Conduct For Responsible Fisheries](#). Identify the role

of APEC in addressing the above recommendations.

E. ACKNOWLEDGEMENTS

This survey would not have been possible without the excellent assistance of Patrick Lau who participated in all aspects of the survey and conducted a number of the field trips. Many others have helped in different ways, from establishing contacts, providing information or unpublished manuscripts, translating and sharing their knowledge and enthusiasm. I am very grateful to: Rooney Biusing, Annadel Cabanban, John Liuph, Boy O Ancog, Rachel Wong, Arpon Meechukant, Joselito and Sonia Somga, Patrick Chan, Renu Yashiro, Michael Phillips, Prof K. T. Shao, John Hambrey, Joe Sham, Siti Nuraini, John Wang, Herman Cesar, Wim Douven, William Cheung, Niels Svennevig, Kimberley Warren, Husni Amarullah, Bob Johannes, Wesley Rosario, Jonathan Nacario, Nephe Ogburn, Amanda Vincent, George Mitcheson, Marcus Phipps, IMA, AFCD, and Tracy Wong and Janet Kwok for help in administering funds. Finally, I wish to thank those who agreed to answer our questions and share their time with us, often when they were busy and could certainly have found better things to do.

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G. TABLE, FIGURE AND PLATE LEGENDS

TABLE LEGENDS

[Table 1 - Fishing gears and catch characteristics from Indonesia survey](#)

[Table 2 – Fishing gears and catch characteristics from Malaysia survey](#)

[Table 3 – Fishing gears and catch characteristics from Thailand survey](#)

[Table 4 – Fishing gears and catch characteristics from Vietnam survey](#)

[Table 5 – Fishing gears and catch characteristics from PRC and Chinese Taipei](#)

H FIGURE LEGENDS

[Figure 1](#) - General areas visited during the surveys are indicated as numbered red dots. Areas for which additional data on fry/fingerling collection areas were provided during country visits, and were later verified, are also given and indicated by green squares but these sites were not visited. For additional sites in the Philippines, see Ogburn and Johannes (1999) and Castanos (1999). See [Fig 1b](#) for the Philippines.

1.Medan

2. Banten Bay
3. Johor/Singapore
4. Georgetown (Penang)
5. Kuala Terengganu
6. Kota Kinabalu (Tuaran is to the north)
7. Kudat
8. Sandakan
9. Semporna
10. Tawau
11. Krabi (Phuket, Phang-gna)
12. Trang
13. Satun
14. Songkhla
15. Yaring, Pattani, Panare, Sai Buri
16. Narathiwat
17. Appari, Cagayan, Buguey
18. San Fernando, Illocos sur, La Union
19. Dagupan, Pangasinan
20. Lingayen, Pangasinan
21. Manila
22. Cavite
23. Daet, Camarines norte, San Miguel Bay
24. Naga
25. PiPi
26. Legaspi, Banao Cove, Bagacay
27. Roxas City, Capix
- 27a. Occidental Mindoro, San Jose, Magsassay
28. Iloilo
29. Cebu City, Cebu
30. Clarin, Tubigon, Tagbilaran, Batasan Is., Pangangan Is. Calape, Bohol
31. Inabanga, Jeta Fe, Bohol
32. Nha Trang
33. Thanh Hoa
34. Hanoi
35. Mong Cai (Quang Ninh Province)
36. Sanya, Hainan Is.
37. Guangdong Province
38. Daya Bay
39. Xiamen, Fujian Province
40. Fuzhou, Zhejiang Province
41. Pescadores Is. (Penghu)
42. Kao-Hsiung
43. Fang-liao
44. Hong Kong, Yantian

[Figure 2 – \(a\)](#) weight-length relationship of *Epinephelus coioides* for conversions between length and weight.

[Fig \(b\)](#) approximate growth curve for *Epinephelus* during the first year of life.

[Figure 3](#) – Theoretical natural mortality curve for settling and post-settlement fish with a pelagic egg/larval phase up to 9 months post-settlement. Current literature indicates that natural mortality in reef fishes has dropped significantly by about 3 months post-settlement.

[Figure 4](#) – Major trade routes for wild-caught grouper seed in SE Asia are shown by the solid lines. The dotted lines indicate trade that is probably illegal. Probably minor, trade routes were identified from Indonesia and the Philippines to Brunei, and from China to Hong Kong. Seed also enter the PRC from Thailand and Chinese Taipei through Hong Kong. Note also that Chinese Taipei exports both hatchery produced and imports and re-exports wild-caught grouper seed.

I PLATE LEGENDS

Plate IA

Plate IAa – Fish trap at Pulau Sembilan, Indonesia

Plate IAb – Fish trap at Pulau Sembilan (small trap) and Jaring Halus (big trap), Indonesia

Plate IAc – Bagnets in flood, Pulau Sembilan, Indonesia

Plate IAd – Bamboo fish trap, Bantem Bay, Indonesia

Plate IAe – Fish traps being deployed close to shore, Bantem Bay, Indonesia

Plate IAF – Fish hook for grouper fingerlings, Bantem Bay, Indonesia

Plate IAg – Scoopnet fishers packed up for the day, the net is rolled and the floating unit is to keep personal belongings and live fish.

Plate IAh – Scoopnet fisher outside his home, Bantem Bay, Indonesia

Plate IB

Plate IBi – Fish trap in boat and black bucket showing how grouper are kept after harvest – one fish inside the bucket fills it.

Plate IBj – As above

Plate IBk – Near Pulau Sembilan – landing area where boats are coming in after a dawn harvest. Grouper fingerlings caught by hook and line are left in plastic containers at the waters edge.

Plate IBl – same as above

Plate IBm – Scoopnet fisher and his catch (one grouper) of a few hours. On right is the species diversity in the same collection area as taken by beam trawl.

Plate IBn – Scoopnet fisher sorting his catch.

Plate IBo – At Jaring Halus the fixed net cages are below the dwelling areas, on the left this is the mooring dock and diesel is stored.

Plate IBp – At Pulau Sembilan, staked net cages offshore from housing area.

Plate IIA

Plate IIAa – Fish trap, *bubu*, Tuaran, Sabah, Malaysia

Plate IIAb – Fish trap, *bubu*, Tuaran, Sabah, Malaysia

Plate IIAc – Fish trap, *bubu*, Tuaran, Sabah, Malaysia

Plate IIAAd – Fish trap, *bubu*, Tuaran, Sabah, Malaysia, with attached branches for shelter

Plate II Ae – Fish traps are set in coastal areas, Sandakan, Malaysia

Plate IIAf – Location for *ranggas* (fish shelter – see sticks) for grouper fingerlings, Tuaran, Sabah, Malaysia

Plate II Ag – *Kilong*, net bag used to catch grouper fingerlings and other fish, set along the edge of the mangrove, Tuaran, Sabah, Malaysia

Plate IIAh – *Gurungon*, bamboo fish traps, Tuaran, Malaysia

Plate IIB

Plate IIBi – *Gurungon*, bamboo fish traps, Tuaran, Malaysia.

Plate IIBj – *Ranggas* – fish shelter gear to catch grouper fingerlings. Tuaran, Sabah, Malaysia.

Plate IIBk – Temarung plant used for making grouper fingerling capture gear, *temarung*, Terengganu, Malaysia.

Plate IIBl – The dried plant (above) for the *temarung* gear, Terengganu, Malaysia.

Plate IIBm – Ribu ribu plant used for *temarung* gear but not as successful as Temarung plant.

Plate IIBn – Harvest of fry by scoop net after pulling in the line (lower picture) deployed in shallow water along the beach and along which are strung the *temarung*. Terengganu, Malaysia.

Plate IIBo – Size of grouper fry collected with the *temarung*. Terengganu.

Plate IIBp – Typical small-scale culture facility at Tuaran, Sabah, Malaysia.

Plate III

Plate IIIa – Fish traps at coast southwest of Trang, SW Thailand.

Plate IIIb – Detail of fish trap at coast southwest of Trang. The width of the trap is approximately 15cm and the mesh is nylon.

Plate IIIc – Cylindrical small-meshed fish traps at fishing community southwest of Trang. The length of the trap is approximately 25 cm.

Plate III d – Poster of fishing gears of Thailand Top left – the triangle shows the triangular shape of a push net

and the photo on the lowest row, second from the right shows the push net being used. A fyke net is shown in the top row, second from the left.

Plate IIIe – Fish shelter (*pum*) seed collection device at Songkhla. Note the sugar sachet to the right for size. The *pum* is made of dried twigs enclosed in a large meshed netting bag.

Plate IIIf – Fry collection area along SE Thailand coast (close to Pattani). Fishing gear is strung along the coast in shallow water of reduced salinity.

Plate IIIg – Small culture facility (the floating structure is loaded with piles of fish traps) in SW Thailand.

Plate IIIh – Small culture facility in SW Thailand. Fishers catch their own seed and manage a small number of nets each in sheltered areas.

Plate IVA

Plate IVAa – Front and side views of bubo (fish trap) used for grouper fingerling capture in San Miguel Bay, Calabanga, Philippines.

Plate IVAb – Bubo (fish trap) used in Inabanga, Bohol, Philippines, for table-sized grouper.

Plate IVAc - Triangular fish trap, Roxas City, Capiz, Philippines. Side and front views. For grouper fingerlings.

Plate IVAd – Rectangular trap used to take grouper juveniles in river mouths, Roxas City, Capiz, Philippines, and cylindrical trap for smaller grouper capture.

Plate IV Ae – Fyke nets in river mouth in western Luzon, Philippines.

Plate IV Af – Fyke nets spread across much of a river mouth in western Luzon, Philippines.

Plate IV Ag - Large scissor net and small scissor net used by children at Clarin, Bohol, Philippines.

Plate IV Ah - Scissor net operation in Bagacay, Legaspi, Philippines and small version of the scissor net.

Plate IVB

Plate IVBi – Flooded miracle hole (just the sticks around the diameter of the hole can be seen), Inabanga, Bohol, Philippines.

Plate IVBj – Grouper seed catch from fyke net at Buguey, Cagayan, Philippines.

Plate IVBk – Size of the smallest grouper fry caught using a *bum bum* with light, San Jose, Occidental Mindoro, Philippines.

Plate IVBl – *E. malabaricus* fingerling caught at Buguey, Cagayan, Philippines. Probably caught by hook and line.

Plate IVBm – Grouper (*E. coioides*, *E. fuscoguttatus*) collected at Clarin, Bohol, Philippines and awaiting collection for transport.

Plate IVBn – Grouper fry capture area, Bohol.

Plate IVBo – Grouper fingerling kept by brokers prior to sale in San Miguel Bay, Calabanga, Philippines

Plate IVBp – Grouper fingerling kept by brokers prior to sale in San Miguel Bay, Calabanga, Philippines

Plate V

Plate Va – Fishing boat carrying bamboo traps used to catch grouper fingerlings. Ha Long Bay, Quang Ninh Province, Vietnam.

Plate Vb – Hook used to catch grouper seed and recently hook-caught grouper at Ha Long Bay, Quang Ning Province, Vietnam.

Plate Vc – ‘Live’ well in boat used to keep grouper seed alive after capture and before transfer to middleman or culture cage, Ha Long Bay, Vietnam.

Plate Vd – Culture facility of a small-scale grouper fry fisherman, Ha Long Bay, Vietnam.

Plate VI

Plate VIa – Fish traps used to catch grouper fingerlings, Fuzhou, Fujian Province, China.

Plate VIb – ‘Live’ well with open-water circulation in bottom of fishing boat for carrying grouper seed and table-sized fish, Xiamen, China

Plate VIc – Light and net balls (fish shelters) for grouper fry capture, Hanhoi mariculture zone, Sanya. On right – trash fish for feed, Xiamen, China.

Plate VI d – Fuo Siu Yu mariculture zone, Xiamen, Fujian province

Plate VII

Plate VIIa – Fish trap at Penghu Is., Chinese Taipei, used to take grouper fingerlings and other species.

Plate VIIb – Fishing boats that capture fingerlings in coastal waters of Penghu Is.; trap and hook and line fishing. Fish are kept in a live well after capture.

Plate VIIIc – Fishing boats at Penghu Is.

Plate VIId – Pond grouper culture facility in southern Chinese Taipei

Plate VIII

Plate VIIIa – Small-scale culturists in Hong Kong. Rafts of suspended net cages and often with a 'guard' hut are typically family-run businesses. Density of the rafts in the 26 gazetted culture zones can be quite high.

Plate VIIIb – Large-scale rafts of net cages largely for holding imported table-sized live reef fish in readiness for sale or until the market price is good.

Plate VIIIc – Water quality is a problem even in the cleaner culture zones (this one is in the cleaner eastern waters). Waste from the culture facility and other pollution has produced poor culture conditions and high mortalities.

Plate VIId – Trash fish purchased from trawlers is a major component of the feed for the grouper culture zones.

Ia APPENDICES

DEFINITIONS

- **Mariculture:** practice of keeping and feeding brackish or marine aquatic organisms until they attain a marketable or consumable size (see FAO definition in Section D).
- **Grouper seed:** is a general term which refers to fry, fingerling or juveniles used for mariculture grow-out to marketable or consumable size and is used in the report when a more precise description is unavailable or unnecessary.
- **Fish larva:** refers to a stage from post-hatching (or birth) and attainment of full external meristic complements and loss of temporary specializations for pelagic life; yolk-sac through post-flexion stage inclusive (Leis and Trnski, 1989).
- **Settlement stage (sometimes referred to as post-larva) or recruitment stage:** developmental stage where the pelagic larva or juvenile is morphologically and physiologically ready to adopt a substrate-associated life style. Often, but not always, associated with larva to juvenile transition. Applicable only to species that are not pelagic as adults (Leis and Trnski, 1989).
- **Grouper fry:** Fish fry is a non-specific term used for advanced larvae or early juveniles, generally 1-2 cm (Helfman *et al.*, 1997; Leong, 1998).
- **Tinies (singular tiny):** used as for fry, but sometimes bigger. In the Philippines, 'tinies' are planktonic stage transparent grouper.
- **Grouper fingerling:** generally 2.5 - 5 cm (Yashiro *et al.*, 1999) but can be larger and overlaps with the juvenile size range.
- **Grouper Juvenile:** generally 3 - 5 inches (about 7.5 - 13 cm) (Yashiro *et al.*, 1999). However juveniles can be larger (depending on the species). A juvenile has not yet attained sexual maturity and larger species generally become sexually mature at a larger size than smaller species. Typically, sexual maturation occurs when the fish attains 50% of maximum length (Sadovy, 1996). Since sexual maturation in most grouper species traded live is over 25 cm TL, then all grouper seed are juveniles.
- **Grouper hatchery:** part of grouper culture which includes hatching of fertilized eggs, their collection and transfer to either cement or fibreglass tanks with moderate aeration, where the newly hatched larvae will grow to about 3 cm TL (Leong, 1998).
- **Grouper nursery ('nursing'):** part of grouper culture practiced after the hatchery, which includes growth of fish from 3 to 10 cm TL; i.e. from fingerling to juvenile, in either tanks or net cages (Leong, 1998). Nursery is also applied to the maintenance of fry up to about 5 cm, often in ponds.
- **Grow-out:** part of grouper culture where juvenile groupers grow in net cages, cement tanks, or earthen ponds, from about 10 cm TL to marketable size.
- **Natural spawning:** one method to obtain eggs for hatchery-rearing by maintaining grouper broodstock which spawns naturally in the captive environment during the natural spawning season. Some authors may also refer to this as "**Voluntary spawning**" (Tucker, 1998).
- **Induced spawning:** spawning of grouper broodstock induced by injection of various hormones such as HCG and LH-RHa (Ruangpanit, 1999).
- **Broodstock:** refers to the parent fish used in either natural or induced spawning to produce fertilized eggs

for hatcheries.

- **Bycatch:** non-target catch-may be used for feed, food or released

Ib APPENDICES

SAMPLE QUESTIONNAIRE (SEE METHODOLOGY FOR DETAILS)

[Note that questionnaires were also designed specifically for: grouper fry middlemen; grouper fry exporter/importers; grouper mariculturists; grouper fry hatcheries]

Questionnaire for Grouper Fry Fishermen

Date

Name

Country

Place of Interview

Experience in fishing [Year]

What did you do before grouper fry fishing and why you join this industry?

Do you own aquaculture facilities (*If Yes, ask also the questionnaire for mariculture*)

What is the size of the fishing vessel you operate? [Length, Engine power]

Where do you catch the grouper fry now? How long have you worked there?

What species of grouper fry or fingerling do you catch in the fishing grounds? [Species, site, habitat and water depth]

What fishing gears do you use for grouper fry/fingerling capture? [Gear (English name)/Local name (size of fry/fingerling catch),

Percentage of bycatch, percentage mortality of grouper]

What other gears do other fishermen in the same place use? [Gear (English name)/local name, percentage of bycatch, percentage mortality of grouper]

What is the harvesting procedure? (specify gear and method)

What is the capture season for grouper season in your fishing grounds? [Overall capture season, Peak capture season]

Do you also catch grouper fry outside the peak capture season? (*If No*, What do you do outside the peak grouper fry capture season?)

How much fry do you catch per daily harvest during the peak and non-peak capture periods? [Gear, Peak capture season, Non-peak capture season]

How many fry of different species do you catch per peak month per fishermen? [Species, No. of fry (size of fry)]

How many fry of different species do you catch per non-peak per fishermen? [Species, No. of fry (size of fry)]

Approximately how many fishers work on the same grouper fry fishing ground?

How many fry were caught in (year or month, *to specify*)?

How did the above harvest compare to 5 years ago and 10 years ago?

Reason for any change

Do you know any other places in your country where grouper fries/fingerling capture occurs ?

What are your target grouper species and what size do you prefer to catch? [Species , Size (reason for this size)]

Do you get bycatch when you catch fry? If so, what do you do with the bycatch?

How do you handle and transport the grouper fry after capture?

..../**continued**

b. SAMPLE QUESTIONNAIRE (continued)

What is the approximate percentage grouper fry mortality during that post harvest handling period and before transportation? [Reason for mortality]

Where do you transport the just-harvested fry to? How long for transportation?

What do they use to accommodate grouper fry caught on a vessel? [Aeration, Water temp, Salinity etc]

What is the percentage mortality during transportation?

What do you usually do to the grouper fry immediately after harvesting?[Transport and sell to the mariculturist directly, Transport and sell to the middlemen, Transport and sell to brokers, Keep in pond/cage until the buyers approach, Keep in pond/cage to grow up before sell to other traders, Others]

If you keep and grow the fry to a larger size before sale, how long is the grow-out period?

What is the percentage mortality during that period?

Does the fisher export any fry directly?

If you sell grouper fry to middlemen, where are the middlemen located?

What is the price of grouper fry, by size, paid by the middlemen recently, and compared with 5 years ago? [Species, Size, Recent price, 5 years ago]

Do you sell grouper fry directly to exporters? If yes, where are the exporters?

How did you learn about the exporters?

What is the price of grouper fry, by size, paid by exporters recently, and compared with 5 years ago? [Species, Size, Recent price, 5 years ago]

How is the price of grouper fry/fingerling determined?

Do you know where exported fry are sent to?

Do you pack the grouper fry yourself for export, or do exporters pack the fry?

How are fry packed? [Water temp, Density, Others]

Do you know whether any fisher uses poisons for catching grouper fry? [if Yes, What poison is used?]

What was your average annual income from grouper fry last year?

What percentage of your total income is from grouper fry?

How did you first come to know of the high value of grouper fry?

What do you expect from the harvest of grouper fry in the next 5-10 years?

Do you have any questions you would like to ask me?

Thank you

Ic APPENDICES

TRIP DATES AND MAIN CONTACTS

13 AUG 1999 - PR China

Mr. Ze Bo, Wu

Person-in-charge, China Aquatic Product Academy of Science

Shenzhen Nanhai Aquatic Products Species Seedlings Development Co.

Shenzhen Shatoujiao Yantian

18 – 20 AUG 1999 – PR China

Mr. Fu, Shi

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Mr. Ginchuan, Shi

Manager, Sanya Hainan Fisheries Co. Ltd

3 – 13 SEPT 1999 - Vietnam

Dr. Le Thanh, Luu

Vice Director, Research Institute For Aquaculture No.1

Ministry of Fisheries

Ninh Bang-Tien Son-Bac Ninh

Mr. Nguyen Huu, Pho

Vice Director

Quang Ninh Seaproducts Export Company

Quang Ninh Province, Vietnam

Dr. Lai Van, Hung

Deputy of International Relationship and Postgraduate Education Department

University of Fisheries

Nha Trang

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12 – 17 OCT 1999: PR China

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