FINAL REPORT TO

OCEAN PARK CONSERVATION FOUNDATION OF HONG KONG

Exploitation history, mariculture and trade status of the threatened Hong Kong grouper (*Epinephelus akaara*) throughout its geographic range

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The University of Hong Kong

December 2009

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Acknowledgements

We are most grateful to the Ocean Park Conservation Foundation of Hong Kong (OPCFHK) for funding the project. This first ever comprehensive study on the exploitation history, mariculture and trade status of the threatened Hong Kong grouper *Epinephelus akaara* throughout its geographic range would not have been possible without the contributions of a great number of people (**Appendix I**) who established contacts, provided published or unpublished data and report and assisted in field surveys and interviews. We would like to thank to those fishers, farmers and traders who kindly contributed their time, shared their knowledge and answered our questions patiently. Finally, we are also grateful to the Swire Institute of Marine Science, the School of Biological Sciences and the Financial Office of The University of Hong Kong for general logistic support.

Abstract

In 2003, the Hong Kong, or red-spotted, grouper *Epinephelus akaara* was listed as threatened on the IUCN Red List of Threatened Species based on data available at the time. The need for more information was highlighted. In this study, exploitation history, mariculture and trade status of *E. akaara* were investigated and documented, for the first time, throughout its geographic range. *Epinephelus akaara* has a relatively small geographic range from southern China [China includes mainland China, Hong Kong Special Administrative Region (Hong Kong SAR or Hong Kong) and Taiwan Province of China (Taiwan POC or Taiwan) in this report if no specified] to southern Japan and southern South Korea. This study documented the past and current status of its wild stocks and identified a number of the problems that should be addressed with further action to attain sustainable use of this highly-valued marine fish species and achieve both biological and economic benefits. The results clearly support the global threatened status of *E. akaara* and call for action throughout its range to ensure that populations are viable in the future.

Information was collected from both formal and informal (interview and anecdotal) sources by visiting all the major areas in mainland China, Hong Kong and South Korea, where this species is or was caught and/or cultured (i.e. grown to market size in captivity) from the 1960s. Information from Japan and Taiwan was collected by literature review and personal communication. Almost all of the production of *E. akaara* is taken from the wild as both adults for luxury food and as juveniles for grow-out. Although the species has been produced in small quantities in a few hatcheries, the seed is never used for grow-out and food fish trade.

The results of this study clearly and consistently show that, in all areas where *E. akaara* was exploited, heavy exploitation is indicated from the 1960s, declining in the 1970s and 1980s until they were no longer significant by the 1990s throughout its geographic region. In Japan,

landings of *E. akaara* dropped by 50–90% between the 1960s and the 1990s. In Jeju Island, South Korea, exploitation of *E. akaara* was recorded in the 1960s and 1970s; catches were no longer significant by the 1980s. In mainland China, catches of *E. akaara* declined dramatically over even shorter time periods, and showed a marked skew towards young and small fish. In Zhejiang Province, capture volumes declined 63–94% and CPUE by at least 90% over just one decade between the 1980s and 1990s. In Fujian Province, the trade volume for *E. akaara* has declined 60–95% since the 1980s, as an indirect indicator of declines in capture volume with no indication of the decline of fishing effort for groupers. In Fujian and Guangdong Provinces, exploitation on *E. akaara* is largely focused on juveniles because the progressively smaller fish being taken in catches and scarcity of larger fish, due to overfishing between the 1970s and the 1990s, made grow-out the only option to get marketable size fish. All grow-out of *E. akaara* are fed on mixed fish feed in mainland China. Subsequently, the progressive decline in even the juveniles (over 90% declines overall) with progressive growth and recruitment overfishing led to large reduction in *E. akaara* grow-out during the 1990s. Instead, other species of marine fishes, including other groupers increasingly became the focus. In Hong Kong, *E. akaara* fisheries had already shown depletions by the 1970s, with further typical signs of overfishing noted including a shift of fishing grounds. In Taiwan, *E. akaara* fisheries are little known but remain low capture volume likely due to naturally low abundance in the area.

Epinephelus akaara is a highly considered marine fish species that fetches good prices particularly when sold live throughout its geographic range, but the supply cannot meet the demand. In China, interest and market for the species in the live food fish trade originated in Hong Kong and Macau in the 1960s and expanded into southern mainland China, especially Guangdong, Fujian and Zhejiang Provinces. Wild-caught, marketable size individuals are now rare and attain much higher prices than before. Grow-out of wild-caught juveniles is also no longer viable at a large scale given the lack of juveniles. Although hatchery-production of *E.*

akaara was first achieved in the 1980s in mainland China, it has never been commercially scaled-up evidently due to poor broodstock management and larviculture, and lack of research funding. Moreover, attempts to recover wild population of *E. akaara* by restocking in the 1980s and 1990s were not successful due to little understand the ecology and biology of the species in mainland China. In Seto Inland Sea, Japan, although the restocking of *E. akaara* has been conducted since the 1980s, it has not led to stock recovery evidently. Hatchery-production of *E. akaara* has been conduced in the last decade in South Korea, but it is still in experimental scale. Therefore, wild stocks of *E. akaara* will continue to be the only source for the commercial market. This means that for populations to be viable in long term they are in urgent need of management and regular monitoring.

Currently, *E. akaara* is not managed. A number of management options can be considered for the recovery of *E. akaara* wild stocks and the long term persistence. Mainland China has the most abundance of *E. akaara* based on capture volume and hence is of key importance to its global stock status and conservation issue. Although mainland China has established a fishing moratorium in the East and South China Seas, since 1995 and 1999 respectively, the moratorium only prohibits trawling in deep waters where *E. akaara* does not inhabit. The gears commonly used to catch *E. akaara*, such as hook-and-line, trap and gill net, are not regulated and can be operated year-round. For species like *E. akaara* that inhabit shallow waters, occur along the coast, have no clear evidence of long-distance migration post-settlement, and are not hatchery-produced at commercial levels to take pressure off wild stocks, one possible management measure is to establishing marine protected areas. In addition, fishing effort on the species will have to be reduced to a sustainable annual quota and particular attention paid to ensuring that enough adults survive to reproduce and replenish wild stocks. The maintenance of wild stocks will also be important for ensuring persistence of genetic diversity of this species.

To management *E. akaara* sustainably, several steps need to be taken. First, establish protected areas for *E. akaara*, ecological studies on abundance, habitat association and settlement are needed. Such studies for the species have never been conducted. In this study, several fishing grounds such as Nanji Islands, Mazu Island, Penghu Islands and the Taiwan Bank Fishing Grounds are known to be good for *E. akaara* capture based on volume and can be good places to study; consideration might be given to protect spawning and nursery areas, for example. Second, an assessment of the wild stocks is needed to determine a fishery management plan, to establish a sustainable annual quota and to ensure that sufficient spawning biomass is retained in wild stocks. Third, legislation is needed for threatened marine fish species in mainland China and Hong Kong so that the species can be appropriately protected. Fourth, if hatchery production becomes commercially viable, then efforts need to be made to focus on hatchery production as a means to reduce dependence on wild-caught juvenile grow-out as a means to restore the reproductive capacity of natural stocks.

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1. Introduction

Groupers (Family Serranidae, Subfamily Epinephelinae but recently revised as Family Epinephelidae) are distributed in tropical and sub-tropical waters globally, and most are of commercial importance (Heemstra and Randall, 1993; Craig and Hastings, 2007). By 2007, 20 groupers (out of a total of 161 species and 15 genera globally) were listed on the International Union for Conservation of Nature (IUCN) Red List as threatened, mainly due to overfishing and lack of management. Among these, 3 groupers were listed as 'Critically Endangered (CR)', 5 as 'Endangered (EN)' and 12 as 'Vulnerable (VU)' (IUCN/GWSG, 2007; http://www.iucnredlist.org/) (**Table l.1**). Historic landings or capture volumes are a powerful indicator for the trends and current statuses of wild stocks or populations and were an important criterion used in the assessments of groupers (IUCN, 2001).

The Hong Kong, or red-spotted, grouper *Epinephelus akaara* was listed as the threatened category of 'EN' in 2003 (Cornish, 2003) (**Table l.1**). This species has a limited geographic distribution and only occurs in the northwestern Pacific, from southern China [China includes mainland China, Hong Kong Special Administrative Region (Hong Kong SAR or Hong Kong) and Taiwan Province of China (Taiwan POC or Taiwan) in this report if no specified] to southern Japan and southern South Korea (Heemstra and Randall, 1993; Abe and Honma, 1997; Fish Database of Taiwan: http://fishdb.sinica.edu.tw/2001new/english.asp) (**Figure 1.1**). The occurrence of *E. akaara* in the Gulf of Dongjing (i.e. the Gulf of Beibu or the Gulf of Tonkin) and around Hainan Province (Hu, 1979; Tseng and Ho, 1979a, 1988; Tuan et al., 2001; Huang et al., 2007; Chen et al., 2008a) has been reported but needs confirmation through specimen examination because of its similarity to several congeners. For example, reports of *E. akaara* in Viet Nam (**Figure 1.1**) were attributed to the rock grouper *E. fasciatomaculosus*; both species share most morphometric features (Heemstra and Randall, 1993) (**Plate 1.1**).

Biology of *E. akaara* has been documented. Along the coastal waters of Fujian (**Figure 1.1**), body size and age of first female sexual maturation were about 231–295 mm standard length (SL) (average of 260 mm), 238–663 g body weight (BW) / fish (average of 432 g) and three years old (Cai et al., 1988; Dai et al., 1988; Zhang et al., 1988; Zhang and Hong, 1992; Wang, 1997). Body size and age of first male sexual maturation were about 340–400 mm SL (average of 371 mm), 900–1700 g BW / fish (average of 1350 g) and six years old (Cai et al., 1988; Dai et al., 1988; Zhang et al., 1988; Zhang and Hong, 1992; Wang, 1997). The maximum sizes recorded for *E. akaara* were 510 mm TL and 4,800 g in Hong Kong SAR (Chan, 1968; Tseng and Ho, 1988; Heemstra and Randall, 1993), 580 mm TL and 5,250 g in Fujian Province (Cai et al., 1988; Dai et al., 1988; Zhang and Hong, 1992) and 500 mm TL in Japan (Tamaki, 2000). *Epinephelus akaara* is one of the only two groupers showing bi-directional sex-change, as demonstrated with captive animals (Tanaka et al., 1990; Okumura, 2001).

Epinephelus akaara is a highly-priced and well-favoured marine food fish throughout its geographic range (Li et al., 1988; Tseng and Ho, 1988; Zhang et al., 1988; Wilson, 1997; Lee et al., 2008; Fish Marketing Organization of Hong Kong, FMO: http://www.fmo.org.hk/index/lang_tc/page_price-sea; Shimane Prefecture of Japan: http://www.pref.shimane.lg.jp/industry/suisan/shinkou/umi_sakana/sakana/2/2-15.html). Severe declines, based on formal and informal landings data, have been recorded for this species. In several areas of Japan, landings dropped by 50-90% between the 1960s and 1990s (Cornish, 2003), while in mainland China, *E. akaara* has been heavily exploited since the 1960s, particularly for the live food fish trade (LFFT) centred in Hong Kong, with marketable sizes of > 400 g BW / fish (Li et al., 1988; Tseng and Ho, 1988; Xu and Yu, 1989; Bo et al., 1995; Wang, 1997; Wilson, 1997). As adult wild stocks of *E. akaara* declined, catches became dominated by below marketable-size juveniles and sub-adults (< 300 g BW / fish). Grow-out of wild-caught juveniles and sub-adults of *E. akaara* to marketable sizes, defined as capture-based

aquaculture (CBA), subsequently developed in the 1970s (Tseng and Ho, 1988; Sadovy de Mitcheson and Liu, 2008a). This operation added further fishing pressure on exploited wild stocks. However, information on capture and trade for both *E. akaara* adults and juveniles has not been documented in detail from anywhere within its geographic range.

Hatchery-based aquaculture (HBA) has been widely considered as a tool to reduce fishing pressure on wild stocks and to rebuild overfished natural resources. However, in neither goal has there been progress, and mariculture must, more realistically, be viewed as an additional means of production rather than alternative to fishing, for *E. akaara* as for any fish species. Despite initial successful hatchery production of *E. akaara* in the 1960s in Japan, the late-1970s in China and the 1990s in South Korea, this species still cannot be mass-produced in hatcheries (Ukawa et al., 1966; Tseng and Ho, 1979a, b, 1988; Maruyama et al., 1994; Wang, 1997; Hong and Zhang, 2003; Lee et al., 2008; Liu and Sadovy de Mitcheson, 2008a). The main challenges include mass production of fertilized eggs and larviculture. Therefore, wild-caught *E. akaara* juveniles continue to be the only source of seed for grow-out operations, and fishing pressure on wild stocks of the species, therefore, continues. In addition to the capture fishery on adults, therefore, it is also necessary to evaluate the catch of juveniles for grow-out in *E. akaara* in terms of volumes of wild-caught juveniles used and grow-out production that results from these juveniles.

In this 16-month study (September 2008 to December 2009), exploitation history, mariculture and trade status of *E. akaara* were investigated and documented, for the first time, throughout its geographic range. Literature and unpublished data reviews, personal communications, field surveys and interviews were conducted in mainland China, Hong Kong SAR and South Korea. In Taiwan POC and Japan, literature reviews, personal communications and unpublished data further contributed to our understanding of the overall status of the species.

The specific objectives of this study were: (1) to clarify the occurrence of *E. akaara* in the Gulf of Dongjing; (2) to investigate capture volumes and fishing grounds for *E. akaara*, in order to evaluate exploitation history and to understand the trend and current status of wild stocks of both adults and juveniles; (3) to assess *E. akaara* mariculture status in terms of the volumes of wild-caught juveniles used for grow-out and production; (4) to document the trade status of *E. akaara* as food and seed; (5) to collect information on management measures for *E. akaara* fisheries, mariculture and trade; and (6) to develop recommendations for sustainable use of *E. akaara*.

2. Definitions

The terms used in this report were defined:

- **Aquaculture / Mariculture:** Aquaculture is the farming of aquatic organisms including fishes, molluscs, crustaceans and aquatic plants. Farming implies some sort 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 cultured. For statistical purposes, aquatic organisms which are harvested by an individual or corporate body which has owned them throughout their period contribute to aquaculture (FAO, 1997). **Mariculture** refers to the farming organisms that live in marine or brackish environment.

  In the FAO definition for 'Aquaculture' (FAO, 1997), the sources of the aquatic organisms used for grow-out or rearing were not defined; they can be from either wild-caught or hatchery-produced. It was estimated that wild-caught organisms for mariculture practices contributed to 20% of total mariculture production in the world, indicating their importance on environmental, social and economic issues (Lovatelli and Holthus, 2008). Therefore, clear definitions for distinguishing wild-caught from hatchery-produced aquatic organisms

are necessary and will provide a better understanding of the role of capture fisheries and wild stocks in mariculture and in relation to fisheries management.

- **Capture-based aquaculture (CBA):** The practice of collecting 'seed' (see below) from the wild and subsequently growing-out them in captivity until marketable sizes using aquaculture techniques (Ottolenghi et al., 2004).

- **Hatchery-based aquaculture (HBA):** The practice of using hatchery-produced 'seed' and subsequently growing-out them in captivity until marketable size using aquaculture techniques (Sadovy de Mitcheson and Liu, 2008a). Hatchery-produced seeds can be obtained through manipulation of broodstock maturation, larviculture and juvenile grow-out to marketable size.

- **Fisheries / Capture fisheries / Seed fisheries:** The practice of capturing aquatic organisms which are typically a common property resource, with or without appropriate licenses (FAO, 1997). **Capture fisheries** (i.e. the conventional 'Fisheries') are distinguished from **Seed fisheries** by the different destinations of captured aquatic organisms; to markets directly in capture fisheries and to aquaculture operations before entering markets in seed fisheries (Sadovy de Mitcheson and Liu, 2008a). 'Capture fisheries' and 'seed fisheries' were used in this report when they could be identified.

- **Seed:** The general term that refers to a wide range of life history stages (e.g. larva, juvenile or adult) of aquatic organisms, either wild-caught or hatchery-produced, used for aquaculture (Sadovy, 2000; Sadovy de Mitcheson and Liu, 2008a). The term is used in this report when a more precise life history stage was unavailable or unnecessary.

- **Larva:** The life history stage from post-hatching to the attainment of fully external meristic characters (i.e. the completion of metamorphosis) and the loss of temporary specializations

for pelagic life (Leis and Trnski, 1989). For some benthic fishes, such as groupers, the end of the larval stage approximately coincides with the end of pelagic stage and start of substrate-associated stage (i.e. settlement). Grouper species including *E. akaara* take about 25–60 days to complete the larval stage at which time body sizes have reached about 25–35 mm total length (TL) (Hussain and Higuchi, 1980; Tseng and Chan, 1985; Fukuhara and Fushimi, 1988; Kitajima et al., 1991; Heemstra and Randall, 1993; Abe and Honma, 1997; Sawada et al., 1999; Wang et al., 2001; Yeh et al., 2003).

- **Juvenile:** The life history stage from after attainment of fully external meristic complements to prior to first sexual maturation (Sadovy de Mitcheson and Liu, 2008a).

- **Adult / Sub-adult:** Adult refers to the life history stage after attainment of first sexual maturation (Sadovy de Mitcheson and Liu, 2008a). **Sub-adult** refers to late stage juveniles that will soon reach their first sexual maturation. The age of first sexual maturation varies among grouper species; some small size species mature at less than two years old and some large size species after 3–4 years old (Heemstra and Randall, 1993; Lau and Li, 2000; Chan and Sadovy, 2002; Yeh et al., 2003; Liu and Sadovy de Mitcheson, 2009). The sexual patterns in groupers are diverse including gonochorism, protogynous hermaphroditism and bi-directional sex-change (Sadovy de Mitcheson and Liu, 2008b).

- **Recruitment:** The body size at which individuals join the exploited stock, i.e. are available to the fishery. This term is here used in the fishery, rather than ecological sense. Size of recruitment to the fishery can be controlled by size limits as a conventional management measure.

- **Fry / Metamorphosed fry / Fingerling:** These are general terms. Fry (or tiny) is used for advanced larvae or early juveniles of 10–25 mm TL; metamorphosed fry for early juveniles of 25–75 mm TL and fingerling for juveniles of 75–125 mm TL (Helfman et al., 1997;

APEC/SEAFDEC, 2001). In this report, we use larva or juvenile when these could be identified or were specified.

3. Methodology

In mainland China (from north to south including Zhejiang, Fujian, Guangdong, Guangxi and Hainan Provinces), Hong Kong SAR and South Korea, fishing grounds, hatcheries, mariculture zones and trade markets for *E. akaara* were identified through literature reviews and personal communications and subsequently visited. Interviews were conducted with grouper fishers, farmers, fish hatchers and traders through semi-structured questionnaires (**Appendix II**). During interviews, it was essential to be flexible depending on local circumstances. Emphasis was given to single individual or small group interviews; large group interviews were avoided to reduce the influence on answers from opinions of others. Due to limitation on budget and difficulty on visa application, field surveys and interviews were not conducted in Taiwan POC and Japan. However, literature reviews and personal communications for collecting unpublished data were conducted to address the same specific objectives listed above.

In each trip, provincial or civil fisheries departments were visited to organize field surveys and interviews and to understand the general status of *E. akaara* fisheries, mariculture, hatchery and trade in the region. Groupers from fisheries, hatcheries, grow-out facilities and markets were collected and examined for species identification and photos were taken. Information on fisheries, mariculture, trade and management of groupers or marine fishes in general was also collected if available in the areas visited. In this report, these are presented as boxes in relevant sections.

Taxonomic studies of the genus *Epinephelus* in mainland China were mainly conducted before the 1990s (Hu, 1979; Chu, 1985; a full listing in Huang, 1994) and some species names are no longer valid (Heemstra and Randall, 1993). Therefore, there is a necessity to update the listing

of *Epinephelus* species in mainland China based on Heemstra and Randall (1993) and the IUCN / GWSG Listing (2007) (**Table 1.1**). Such information can provide an important guideline for future studies and confirm species identifications.

4. Results

4.1 Mainland China

4.1.1 An updated listing of all *Epinephelus* groupers in mainland China

Among the total of 98 *Epinephelus* grouper species confirmed globally (**Table 1.1**), 37 valid species are confirmed to occur in mainland China, including the Yellow, East China and South China Seas and Taiwan Strait, and in Hong Kong waters (Hu, 1979; Chu, 1985; Heemstra and Randall, 1993; Huang, 1994; this study; http://www.iucnredlist.org/) (**Table 4.1; Figure 1.1**). There are four remarks pertinent to the listing:

First, in 11 species, their names should be corrected to the valid ones; *E. cometae* to *E. morrhua*; *E. diacanthus* to *E. stictus*; *E. fario* to *E. trimaculatus*; both *E. hoedtii* and *E. kohleri* to *E. cyanopodus*; *E. megachir* to *E. quoyanus*; *E. microdon* to *E. polyphekadion*; *E. moara* to *E. bruneus*; *E. rhyncholepis* to *E. rivulatus*; *E. truncates* to *E. retouti*; and *Promicrops lanceolatus* to *E. lanceolatus*.

Second, *E. trallcatus* is not a valid species.

Third, the record of *E. summana* in the South China Sea is likely to be *E. coeruleopunctatus*, since *E. summana* is only known to occur in the Red Sea and the Gulf of Aden.

Fourth, *E. coioides* and *E. radiatus* were not reported in the Chinese literature (Hu, 1979; Chu, 1985; Huang, 1994). For *E. coioides*, its absence may due to the misidentification of *E. malabaricus*, which is very similar. The occurrence of *E. coioides* in the Gulf of Dongjing and along the coastline of eastern Guangdong (**Figure 1.1**) is confirmed in this study; juveniles of

50−100 mm TL are commonly caught between July and October in shallow coastal waters with rocky habitats for CBA in the Gulf of Dongjing (this study) (**Plate 4.1**). For *E. radiatus*, its apparent absence may due to misidentification as *E. morrhua*.

4.1.2 Grouper fisheries and mariculture in mainland China–a summary

Box 1 *Grouper capture fisheries in mainland China*

Grouper capture fisheries (excluded grouper seed fisheries) mainly operate in the coastal waters of Zhejiang, Fujian, Guangdong, Guangxi and Hainan Provinces (**Figure 1.1**). The estimated total annual grouper capture production from mainland China was about 3,000 t in the early-1980s, and increased to about 30,200 t in 1997 (Song, 1999; FAO, 2007; Liu and Sadovy de Mitcheson, 2008a). In 2007, the estimated total grouper capture production from Fujian, Guangdong and Hainan Provinces was about 69,300 t (this study). The grouper capture production from Zhejiang and Guangxi Provinces in 2007 were not available but likely to be low. Therefore, the estimated total annual grouper capture production from mainland China was around 70,000 t in 2007 (this study).

Box 2 *Grouper seed fisheries in mainland China*

The estimated total annual demand for grouper seeds of all grouper species combined, for grow-out operations in mainland China, was more than 150 million in the late-1990s. However, the supply of wild-caught seed locally was only about 7.5 million, contributing just 5% of the total demand (Zou and Wu, 2002). The importation of grouper seeds from Taiwan, Thailand, Malaysia and other Southeast (SE) Asian countries to southern mainland China was reported in the 1990s. These imported seed were either wild-caught or hatchery-produced.

Box 3 *Grouper mariculture in mainland China*

Marine fish culture in floating cages in mainland China first started in the 1970s in Guangdong Province by grow-out of wild-caught larvae and juveniles of groupers and sea breams to

marketable sizes (Liu and Sadovy de Mitcheson, 2008a). For groupers, the marketable sizes were commonly > 400 g BW / fish. The estimated total annual grouper mariculture production was about 8,000 t in 1997 and increased to 33,000 t in 2004, contributing about 50–60% of total annual grouper mariculture production in the entire Asia-Pacific region. To date, the main areas for grouper mariculture are Fujian, Guangdong and Hainan Provinces, southern China, with smaller production in Zhejiang and Guangxi Provinces. In Zhejiang, the major limitation for grouper mariculture is the low water temperature in winter (about 8°C); in Guangxi, grouper culture starts developing in the last 5 years. The estimated total grouper mariculture production in 2007 from the three main grouper mariculture Provinces was about 36,600 t (this study), roughly 50% of the capture production of grouper in the same area (**Box 1**). Grouper mariculture systems are diverse, and include intertidal and on-land ponds, floating cages and a combination with floating cages inside the intertidal ponds. Indoor recirculating systems on land for grouper mariculture have been developed in recent years (e.g. in Tianjin in the north) (**Figure 1.1**) (this study).

4.1.3 Zhejiang Province (Zhejiang)

In this study, field surveys (five fishing grounds, two hatcheries, two mariculture zones and three fish markets) and interviews (six fishers, eight farmers, six hatchers and four traders) were conducted in October and November 2008 and in November 2009 in Zhejiang Province (**Figure 4.1**).

Box 4 *Grouper species examination in Zhejiang Province*

Epinephelus akaara and *E. awoara*, reported to be the most common groupers in Zhejiang waters, have been studied in relation to hatchery and restocking since the 1980s (Bo et al., 1983, 1990; Zhou et al., 1994; Bo and Zhou, 1999, 2002; Mao et al., 2004). External morphology of the two species were re-examined with the authors in the publications (this study) (**Plate 4.2**). It is confirmed that the reported *E. awoara* was a misidentification of *E.*

akaara. A separate study using molecular analyses further confirmed this conclusion; they are the same species, *E. akaara* (H.C. Cai, personal communication). Therefore, the only common grouper species in Zhejiang waters is *E. akaara*.

4.1.3.1 Distribution

Epinephelus akaara is distributed along the coastal waters of Zhejiang including near- and off-shore islands (e.g. Shengsi, Zhoushan, Liuheng, Dongxing, Dongtou and Nanji) and is particularly associated with rocky habitats (Liu, 1981; Gui et al., 1984; Wang, 1988; Xu and Yu, 1989; Bo et al., 1995; Mao et al., 2004; Ye et al., 2006; this study) (**Figure 4.1; Plate 4.3**).

Epinephelus akaara is known to occur from shallow waters down to 30 m. Juveniles (as small as 30–50 g BW / fish or < 100 mm TL) and adults (up to 2,000–2,500 g BW / fish) live around the same areas; small individuals live in shallow and large ones in deep waters (this study). Smaller individuals such as < 30 g BW / fish are rarely found in the same areas and the settlement (i.e. end of pelagic stage and start of substrate-associated stage) patterns of *E. akaara* in Zhejiang waters are unknown.

4.1.3.2 Fisheries

Epinephelus akaara is the only common and dominant species in grouper fisheries in Zhejiang waters based on fishers, traders and fisheries officers interviewed and literatures (this study) (**Box 4**). Therefore, the exploitation history of groupers in Zhejiang waters represents that of *E. akaara* and demonstrated (1) the change from non-targeted to targeted species fisheries concomitant with the increase of grouper fishing vessels, (2) the decline of volume and capture per unit of effort (CPUE) in capture fisheries, (3) the shift from capture fisheries to seed fisheries due to the decline of body sizes in catches, and (4) the shift of fishing grounds.

First, *E. akaara* was not a targeted species in Zhejiang waters in the 1960s and 1970s; it was mainly caught by hook-and-line in multi-species fisheries and sold as part of a mixed fish

fishery and fresh dead (this study). There were less than 100 Zhejiang-licensed fishing vessels using hook-and-line along coastal waters in the 1960s and 1970s; therefore, fishing pressure on *E. akaara* was relatively low (Bo et al., 1983, 1995; Gui et al., 1984; Xu and Yu, 1989; Zheng et al., 1996) (**Table 4.2**).

Epinephelus akaara was heavily exploited between the late-1970s and 1990s due to the LFFT centred in Hong Kong and Macau and an important seasonal fishing species. The fishing season was between May and December, mainly between May and August (i.e. around its reproductive season) (Bo et al., 1995). No evidences indicate that *E. akaara* forms spawning aggregations in Zhejiang waters. The fishing season in coastal fisheries for *E. akaara* and other marine fishes is commonly between May and December with less fishing activities in cold winter (December to February) when water temperature can drop below 10–15 °C (this study). Fishing pressure on *E. akaara* increased dramatically in the mid-1980s. For example, more than 1,000 Zhejiang-licensed fishing vessels used hook-and-line and targeted groupers specifically using hook-and-line (Wang, 1988; Xu and Yu, 1989; Bo et al., 1995) (**Table 4.2**).

Besides hook-and-line, gill-nets and traps are other major fishing gears used for *E. akaara* fisheries (this study) (**Plates 4.4** and **4.5**) and gill-nets are considered to be the main contributor to the decline of its wild stocks. During low tide, fishers used the gill-nets to cover shallow water rocks where *E. akaara* juveniles could be found; juveniles were caught when came out of the rocks (G.M. Mao, personal communication. The gill-nets were also known to capture *E. akaara* adults during the reproductive season; for example, the gill-nets were operated from May to August in northern Zhejiang with about 30% of total catches were *E. akaara* (Gui et al., 1984; Y.D. Zhou, personal communication) (**Plate 4.5**).

Second, capture volume and CPUE of *E. akaara* in Zhejiang waters showed declines between the 1980s and 1990s. The peak of the total capture volume was around 187 t in 1985 and

declined to < 40 t in 1994 in Zhejiang (Wang, 1988; Xu and Yu, 1989; Bo et al., 1995) (**Table 4.3; Figure 4.2**). In another study (Wang, 1988), the total capture volume of *E. akaara* was around 260 t in 1984 and subsequently declined (**Table 4.3**). In northern Zhejiang, the total capture volume of *E. akaara* reached a peak of about 87 t in 1985; capture declined by 63% in one decade from 1985 to 1994 (**Table 4.3; Figure 4.2**). In southern Zhejiang, *E. akaara* capture volume reached a peak of about 100 t in 1985; capture declined dramatically by 94% over one decade from 1985 to 1994 (**Table 4.3; Figure 4.2**).

Epinephelus akaara fishery is no longer significant in Zhejiang (this study). The current capture volumes of *E. akaara* (both capture and seed fisheries) were estimated from the traditional fishing grounds visited; < 2 t from Liuheng Island in both 2007 and 2008, and about 10 and 4 t from Nanji Islands in 2007 and 2008, respectively (**Table 4.3**). Grouper fishers (four out of six) interviewed shifted to mariculture operations in the 1990s due to declines in grouper catches; currently, species include *E. akaara*, sea breams, sea basses, red drum, large yellow croaker, and invertebrates such as octopus (this study).

CPUE (kg / vessel / year) for *E. akaara* declined about 92% between 1982 and 1986 in a period of five years in southern Zhejiang and about 90% between 1986 and 1994 in less than one decade in northern Zhejiang (Xu and Yu, 1989; Bo et al., 1995) (**Table 4.2**). A hook-and-line fisher interviewed in Liuheng Island caught up to 5 kg / vessel / day of groupers (mainly *E. akaara*) in the 1960s, which declined to < 2 kg / vessel / day in the 1980s; he eventually quit fishing in the 1990s because marketable size grouper catches had become so low and shifted to marine fish culture of various species. From an indirect perspective, a trader in Nanji Islands had the annual *E. akaara* trade volume (both adults and juveniles, caught by fishers locally) of about 1 t / day in the peak season in the 1980s that declined to about 200 kg / day in the 1990s and < 100 kg / day during the same season in recent years, indicating a 90% decline in about two decades.

Third, declines in body sizes in *E. akaara* capture were reported. In the 1980s, *E. akaara* capture was dominated by body sizes of 500–1,500 g BW / fish, which contributed to 57% of the total catch of the species; fish of < 250 g BW / fish contributed only to 3% (Xu and Yu, 1989; Bo et al., 1995). By the mid-1990s, the body sizes of *E. akaara* capture had declined; the proportion of 500–1,500 g BW / fish had declined to 33% of the total catch while that of < 250 g BW / fish had increased to 27% (Xu and Yu, 1989; Bo et al., 1995). Grow-out of *E. akaara* subsequently developed due to the high proportion of below marketable sizes in catches. Currently, more than 90% of *E. akaara* caught in Liuheng Island, Dongtou Island and Nanji Islands are juveniles and sub-adults ranging 30–300 g BW / fish (dominated by 100–200 g BW / fish), all kept in floating cages for CBA (**Plate 4.6**).

Fourth, the shift in fishing grounds for *E. akaara* were found from south to north in Zhejiang waters and also along coastal waters of Mainland China, indicating serial over-exploitation of the species in various targeted areas. The high fishing pressure on *E. akaara* in the 1980s in Zhejiang primarily started with the arrival of the fishers and traders from Fujian and Guangdong Provinces where *E. akaara* fisheries collapsed after exploitation in the 1960s and 1970s (Wang, 1988; Xu and Yu, 1989; Bo et al., 1995; Z.L. Bo, J. Xin and G.M. Mao, personal communications) (**Figure 4.3**). High demand on live *E. akaara* in Hong Kong and Macau and high profit from the LFFT drove fishers and traders to unexploited fishing grounds in Zhejiang waters.

In summary, the capture volumes of *E. akaara* in Zhejiang waters declined overall by 63–94% and CPUE (kg / vessel / year) by at least 90% over one decade of exploitation between the 1980s and 1990s. Captures became dominated by juveniles of 100–200 g BW / fish in the 1990s; CBA subsequently developed to grow-out. Currently, *E. akaara* fishery is no longer significant and the capture volumes maintain at a lower level.

4.1.3.3 Mariculture

Hatchery

Zhejiang was the first Province in mainland China that conducted grouper hatchery work and started in 1980 for *E. akaara* (Bo et al., 1990; Ye et al., 2006). Hatchery-produced *E. akaara* juveniles were first obtained in 1986 with body sizes attained of 65–91 mm TL and 6.7–15.5 g BW / fish and age of 3 months after hatching (Bo et al., 1990). In 1987–1995, the *Epinephelus akaara* hatchery continued to produce juveniles annually between 1987 and 1995 but it never reach a mass production and all juveniles were used for restocking (Zhou et al., 1994; this study) (see **Section 4.1.3.5**).

Hatchery production of *E. akaara* did not continue after 1995 due to lack of research funding (this study). Government fisheries authorities have renewed their interest in *E. akaara* hatchery production because the species is highly valued in the LFFT, not only in Hong Kong but also in local markets and therefore, it is a good candidate for mariculture. There is also an interest in *E. akaara* because that government is considering promoting 'endemic' species for mariculture, such as *E. akaara*, which has demonstrated good survival rate, cold water temperature tolerance (as low as 8 °C) and good disease resistance. The major challenges in its hatchery and larviculture formerly were the limited egg production each spawning season and the inability to control simultaneous spawning among the broodstock.

Broodstock were caught from local waters, reared in ponds, and spawned naturally in indoor tanks or floating cages between June and August, as the natural spawning season in the wild with water temperatures of 23–24°C (Gui et al., 1984; Zhou et al., 1994; Mao et al., 2004) (**Plate 4.7**). *Epinephelus akaara* of 2–3 years old (around their first sexual maturation) and about 400 g BW / fish were used as female broodstock. Males were obtained through sex-change by implanting 17α- methyltestosterone (17α-MT) in April, i.e. prior to spawning season

(Ye et al., 2006). Broodstock maintained in deep-water submerge cages produced more eggs and gave higher fertilization and larval survival rates than in shallow water cages and indoor tanks (Ye et al., 2006).

Grow-out

Marine fish culture in floating cages in Zhejiang was first conducted in 1982 by holding *E. akaara* for a short period before export to Hong Kong and Macau for the LFFT. The interest in growing-out *E. akaara* developed in the late-1980s when catches were mainly dominated by below marketable size juveniles and sub-adults (Xu, 1996; Zheng et al., 1996) (**Plate 4.6**). Mixed fish feeds have been the main food used for *E. akaara* grow-out. The feed conversion ratio (FCR, feed weight used / fish weight gained) is about 6–10 (i.e. 6–10 parts feed to the production of 1 part of fish) (Xu et al., 1994; Zheng et al., 1996). The size of the floating cages was initially about 3 m × 3 m × 3 m. More recently, the sizes of the floating cages have increased to 6 m × 3 m × 3 m or 6 m × 6 m × 3 m by connecting two or four cages in order to increase space for fish movement (this study).

Survival rate for *E. akaara* juveniles during grow-out was around 95% (this study). Juveniles are usually mixed with other marine fish species in floating cages due to the relatively low number of seed available (**Plate 4.6B**); the only exception is in Nanji Islands where single species of *E. akaara* grow-out can be found (**Plate 4.7C**). *Epinephelus akaara* juveniles with body sizes of 100–200 g BW / fish are favoured by farmers in Zhejiang and they take about one and half years to reach marketable size (e.g. 500 g BW / fish).

The volumes of wild-caught *E. akaara* juveniles used for grow-out in Zhejiang were estimated (this study). Based on available information such as the dominant body sizes of 100–200 g BW / fish in seed fisheries and stock volume of about 90 kg juveniles / cage and number of cages (about 1,000 in 1994) (Xu, 1995, 1996; Zheng et al., 1996), the estimated annual total volume

of wild-caught *E. akaara* juveniles for grow-out was about 90 t (i.e. 450,000–900,000 juveniles) in the mid-1990s. Based on the available information on survival rates (i.e. 95%) and marketable size (i.e. 500 g BW / fish), the estimated annual mariculture production of *E. akaara* was about 213–428 t in the mid-1990s, all relied on wild-caught juveniles.

4.1.3.4 Trade

In the 1960s and 1970s, *E. akaara* was mainly sold along with other fishes as mixed fishes and fresh dead. The live *E. akaara* trade started in the late-1970s, mainly exported to Hong Kong and Macau; the marketable sizes were mainly ≥ 500 g BW / fish (Wang, 1988; Zhang et al., 1988; Xu and Yu, 1989; Xu, 1995). Both fresh dead and live *E. akaara* are sold locally. Although the prices of fresh dead *E. akaara* are lower that those of live ones for the same species, it is still higher than many other marine food fish species sold as fresh dead (**Table 4.4; Plate 4.8**). *Epinephelus akaara* has always highly valued in the LFFT and prices vary with body sizes (Xu and Yu, 1989; Xu, 1995; this study) (**Table 4.4**). The marketable sizes showed a decline from about 500 g BW / fish before the 1990s to about 300 g BW / fish to date. The destinations of *E. akaara* exported from Zhejiang have being mainly to Hong Kong and Macau; however, the trade is indirect, i.e. via the traders from Guangdong and Fujian (this study). *Epinephelus akaara* is also exported to Japan and Taiwan, either by air or sea (this study).

Trade volumes of *E. akaara* in Zhejiang were estimated through interviews and literature reviews (this study) (**Table 4.5**). First, in Liuheng Island (northern Zhejiang), the trade volumes from the major *E. akaara* trader were about 20–30 t / year (all for the LFFT and marketable sizes) in the mid-1980s; there were 5 traders in the Island at the time but four of them only dealt with *E. akaara* on a small-scales. In the 1990s, the trader shifted to mariculture, and the annual trade volumes for *E. akaara* in 2007 and 2008 years were < 500 kg / year (mainly for grow-out due to being below marketable sizes). Another trader in Liuheng had about a 1 t *E. akaara* trade volume annually in 2007 and 2008, mainly for grow-out.

Second, in Xiangshan Bay, about 4.7 t *E. akaara* were grown-out in 81 floating cages and exported to Hong Kong in 1989; about 2.1 t with body sizes > 500 g BW / fish and 2.6 t with 250–500 g BW / fish (Lu, 1990) (**Table 4.5**). In recent years, there is little *E. akaara* trade from the Bay (this study).

Third, in Nanji Islands, the annual trade volume from all *E. akaara* traders was estimated to be about 10 t in 2007 and 4 t in 2008 (this study). The trade volumes included both marketable sizes for the LFFT and below marketable size juveniles for grow-out (particularly from 100–200 g BW / fish) (**Plate 4.6B**). In the mid-1980s, the annual trade volumes of *E. akaara* juveniles and sub-adults (< 250 g BW / fish) to Fujian and Guangdong for grow-out were about 122 t (Wang, 1988). Smaller *E. akaara* juveniles (30–50 g BW / fish), caught in Nanji Islands, are usually sold to Fuding, Xiapu and Ningde, northern Fujian for grow-out (this study) (**Figure 4.4**).

4.1.3.5 Management

Management measures on *E. akaara* fisheries were proposed in the 1980s and 1990s in Zhejiang based on its biology (e.g. protogynous hermaphroditism and age and size of sexual maturation), fishery and the declines in wild stocks indicated from 1979 to 1994 (Wang, 1988; Xu and Yu, 1989; Bo et al., 1995). The proposed measures included (1) to a establish non-fishing season in June and July (spawning season for *E. akaara* with high capture), (2) to prohibit live grouper export during the spawning season, (3) to set minimum and maximum body sizes for capture (i.e. 210 mm SL and 250 g BW / fish, and 400 mm SL and 1,750 g BW / fish, respectively), (4) to reduce fishing pressure by limiting the number of non-Zhejiang-licensed fishing vessels operating in Zhejiang waters, (5) to promote *E. akaara* restocking, and (6) to prohibit small shrimps as baits that particularly favoured by *E. akaara* juveniles. However, none of all these management measures were put in place, except for restocking.

The Zhejiang fisheries authorities focused on restocking hatchery-produced *E. akaara* juveniles between 1987 and 1995; about 164,000 *E. akaara* juveniles from hatchery-produced were released, mainly at less than one year old and at 30–70 mm SL (Bo and Zhou, 2002). Juveniles released in 1987 and 1991 were tagged by ink injection for evaluating the recapture rate. However, the recapture rate was zero (Bo and Zhou, 1999), suggesting poor survival rates of hatchery-produced juveniles in the wild and an unsuccessful restocking programme.

Box 5 *Management measures in Zhejiang Province*

Blasting fishing is prohibited in Zhejiang waters; however, it has been reported to be particularly associated with the decline in capture volumes of fishes (Xu and Yu, 1989; Bo et al., 1995). This type of fishing was common; for example, about 25 blasts were recorded in two hours within an area of 600 m^2 in southern Zhejiang in 1985 (Xu and Yu, 1989).

A fishing moratorium in the East China Sea started in 1995; trawler fishing is prohibited in June, July and August. The fishing moratorium, however, is unlikely to protect wild stocks of groupers because the main fishing gears for groupers such as hook-and-line, traps and gill-nets are not managed.

4.1.4 Fujian Province (Fujian)

In this study, field surveys (nine fishing grounds, five hatcheries, seven mariculture zones and three fish trade markets) and interviews (seven fishers, six grouper hatchers, sixteen mariculturists and seven traders) were conducted between October 2008 and May 2009 in Fujian.

4.1.4.1 Distribution

As in Zhejiang waters, *E. akaara* juveniles and adults are distributed along the coastal waters of Fujian, around near- and off-shore islands (e.g. Mazu, Pingtan, Nanri, Xiamen and Dongshan),

and on the Taiwan Bank Fishing Grounds (Lin, 1988; Zhang et al., 1988; Fu, 2003; this study) (**Figure 4.4**). The species inhabits rocky substrate and boulders.

Spawning grounds of *E. akaara* are predicted to be in off-shore waters of Fujian and located in northwestern and western waters of Taiwan based on three pieces of evidence. First, ripe females were never caught in coastal waters of Fujian during the reproductive season between April and September (Cai et al., 1988; Dai et al., 1988; Zhang et al., 1988). Second, most of large individuals were caught off-shore included the largest recorded fish of 580 mm TL (Cai et al., 1988; Dai et al., 1988; Zhang and Hong, 1992). Third, larvae and small juveniles of *E. akaara* (< 50 mm TL) have been caught off-shore waters in locations of 26° N / 121° E in May, 25°30′ N / 121° E and 24°30′ N / 120° E in August, and 24°30′ N / 120° E in September, from north to south (Zhang et al., 1988) (**Figure 4.4**). One *E. akaara* specimen with body size of 23.3 mm TL was caught in the Penghu Islands with capture time unknown (http://fishdb.sinica.edu.tw/2001new/english/english.asp) (**Figure 4.4**).

4.1.4.2 Fisheries

In Fujian, *E. akaara* was the most common species taken in grouper fisheries in the north (Chu, 1985; Zhang et al., 1988; Zhang and Hong, 1992; this study) (**Plate 4.9**). In the south, grouper species in capture fisheries are diverse, such as *E. akaara*, *E. awoara*, *E. quoyanus* and *E. trimaculatus*; *E. awoara* is the most common (Chu, 1985; this study) (**Plate 4.9**).

Epinephelus akaara fisheries in Fujian waters are seasonal, from April to November, and both adults and juveniles can be caught by hook-and-line, gill-net, trap and bottom trawling (Chu, 1985; Cai et al., 1988; Lin, 1988; Zhang and Hong, 1992; Fu, 2003; this study) (**Plate 4.10**). Similar to Zhejiang waters, the bait commonly used for hook-and-line is shrimps, which are known to be favoured by grouper juveniles; polychaetes are also used as bait (this study). Hook-and-line is used when water is clear and traps when water visibility is low.

Epinephelus akaara fisheries in Fujian waters demonstrated (1) the decline of capture volume from the 1970s to 1990s, (2) exploitation of juveniles, (3) decline in age group and body size taken from wild stocks, and (4) shifting of fishing grounds to maintain catches.

First, grouper capture volumes (with a large proportion of *E. akaara* and *E. awoara*) showed declines from the 1970s to 1980s. The estimated annual grouper capture volume was > 400 t in the 1970s and mid-1980s and declined in the late-1980s; groupers were mainly for the LFFT in Hong Kong and Macau (Chu, 1985; Zhang et al., 1988; Zhang and Hong, 1992) (**Table 4.6**). Although no data on *E. akaara* capture volumes were available for the 1990s, it was reported that its seasonal fisheries, for both adults and juveniles, were no longer significant (Zhang and Hong, 1992).

Second, *E. akaara* fisheries in the coastal waters are essentially juvenile fisheries as opposed to off-shore waters. The age groups of *E. akaara* caught in the coastal waters came to be dominated mainly by one year old juveniles, followed by two and three years old with the three age classes contributing 69.4% of the total *E. akaara* catch; another 28.0% came from ages classes 4–6 years old mainly from off-shore fishing grounds, such as the Taiwan Bank Fishing Grounds (Cai et al., 1988; Dai et al., 1988; Zhang et al., 1988; Zhang and Hong, 1992). In 2001, between April and June, a record of 206,500 *E. akaara* juveniles with body sizes of 50–100 g BW / fish (about 18.55 t) were caught for grow-out in Nanri and adjacent waters, southern Fujian (Fu, 2003) (**Figure 4.4**).

Third, a reduction in age group and body size caught in wild stocks of *E. akaara* was recorded. In the mid-1980s, the age groups taken in catches had a wide range between less than one year and 19 years old and dominated by age groups of 2 to 6 (Cai et al., 1988; Dai et al., 1988; Zhang et al., 1988; Zhang and Hong, 1992). Body sizes were between 77 and 580 mm TL, and 12.8 and 5,250.0 g BW. By the early-1990s, after less than one decade of exploitation, the age

groups had declined dramatically. The age groups typically taken were only up to four years old with body sizes up to 320 mm TL and 870 g BW / fish. Furthermore, catches from the age groups of one to three years old contributed to 98.0% of the total catches (Zhang and Hong, 1992). The fishers and traders interviewed mentioned that the body sizes of 2,500–3,000 g BW / fish were commonly caught in the 1980s; while nowadays, individuals > 1,500 g BW / fish are rare, with only a few larger individuals per year per fisher or trader (this study).

Fourth, shift of fishing grounds over time to maintain catches was noted. In the 1970s, *E. akaara* fisheries operated mainly along the coastal waters of Fujian (Chu, 1985; Zhang and Hong, 1992). Fishers moved further away to southern Zhejiang in the late-1970s and to northern Zhejiang in the early-1980s due to over exploitation in Fujian fishing grounds (Xu and Yu, 1989; Bo et al., 1995). In recent years, fishers have focused on off-shore fishing grounds such as Mazu Island, Penghu Islands and the Taiwan Bank Fishing Grounds for *E. akaara* (this study) (**Figure 4.4**).

Box 6 *Common* Epinephelus *groupers in Fujian Province*

A total of 12 *Epinephelus* grouper species were once commonly caught along the coastal and near- and off-shore fishing grounds such as the Taiwan Bank Fishing Grounds; the fisheries and trade importance of these species is summarized (Chu, 1985) (**Table 4.7; Figure 4.4**). Among these, *E. awoara* and *E. akaara* were the first and second common species in grouper fisheries based on capture volumes; the former in the south and the latter in the north.

Box 7 *Grouper capture fisheries in Fujian Province*

Between 2003 and 2007, the estimated total annual grouper capture volumes (not species-specific) from official statistics data was at a level of about 10,145–15,420 t (this study) (**Table 4.6**). Whether the local fishing grounds have the carrying capacity to support such high landings need to be evaluated. Five out of seven grouper traders interviewed shifted to mariculture in the

late-1980s and early-1990s; all mentioned that grouper fisheries are no longer significant (this study) (**Table 4.8**). Therefore, over-reporting of grouper capture volumes in Fujian in recent years is a possible explanation for the high landings reported.

Box 8 Epinephelus awoara *seed fisheries in Fujian Province*

Epinephelus awoara is common not only in capture fisheries but also in seed fisheries. Wild-caught juveniles of 30–100 mm TL, from local and off-shore waters, are commonly used for CBA in floating cages and ponds in southern Fujian (this study) (**Plate 4.9C**).

4.1.4.3 Mariculture

Hatchery

Epinephelus akaara hatchery production was first conducted in the early-1980s; however, hatchery-produced *E. akaara* juveniles, of a body size of about 40 mm TL, were first obtained in 1995 (Wang, 1997; H.S. Wang, personal communication). Since then, only a few hundred or thousand *E. akaara* juveniles have been produced annually; broodstock can spawn naturally without hormone manipulation (this study; H.S. Wang, personal communication).

The major challenge in *E. akaara* hatchery production and larviculture is that it is difficult to obtain large amounts of fertilized eggs over short periods, which limits the development of mass larviculture (Wang, 1997; H.S. Wang, personal communication). An average of 850,000 eggs can be produced by a female with body size of 325–355 mm TL and 590–1,140 g BW and age of 3–4 years during a spawning season, and only 47% of eggs are fertilized (Wang, 1996). This is very low compared to results from Japan, where a female of 690 g BW produced 2.5 million eggs in one spawning season (Maruyama et al., 1994). This indicates that more studies on *E. akaara* reproductive biology and spawning behaviour are needed.

The reproductive season in Fujian waters for *E. akaara* was between April and September with a peak between May and June when water temperatures are about 22.5–28 °C (Cai et al., 1988;

Zhang et al., 1988; Wang, 1997); spawning was generally earlier than in Zhejiang waters where it peaked between June and August (Bo et al., 1995). Broodstock were mainly selected from grow-out cages, around 2–3 years old (i.e. around the age of first sexual maturation) were used; larger juveniles (i.e. sub-adult) and females of 2–4 years old were selected for male induction using 17α-MT manipulation through feeding (Fang and Lin, 1993; Hong et al., 1994; H.S. Wang and Q.S. Fang, personal communications).

Box 9 *Grouper hatchery in Fujian Province*

Hatchery production of *E. coioides* has been conducted in recent years. To date, *E. coioides* juveniles can be produced at a mass scale for grow-out with fertilized eggs from local hatcheries or bought from Guangdong (Zhou and Lin, 2002; this study). Hatchery production of *E. lanceolatus* and *E. bruneus* have been conducted in recent years; fertilized eggs of *E. lanceolatus* are bought from Taiwan and Hainan, and broodstock of *E. bruneus* are selected following wild-caught juvenile grow-out (Lin et al., 2005; this study).

Grow-out

Epinephelus akaara grow-out in Fujian first developed in the 1970s using individuals that were below marketable sizes (i.e. < 400 g BW / fish). The development of grow-out of *E. akaara* juveniles during the 1990s was main a result of highly captures of 30–250 g BW / fish. Small juveniles of 30–70 g BW / fish, mainly caught from local waters or in southern Zhejiang (e.g. Nanji Islands), are commonly used for grow-out in floating cages in northern Fujian (e.g. Fuding and Xiapu) (**Figure 4.4**). Due to the lack of commercial success of *E. akaara* hatchery production, wild-caught juveniles to date are still the only source for grow-out.

Stocking densities for *E. akaara* grow-out in Fujian were usually about 300–400 kg / ha in intertidal ponds and 80–135 kg / cage (3 m × 3 m × 3 m each cage) (Lin, 1988); the latter was similar to that of Zhejiang (i.e. about 90 kg / cage) (Zheng et al., 1996). To date, *E. akaara*

juveniles are usually mixed with other fish species in floating cages for grow-out in Fujian (this study). For example, *E. akaara* (e.g. about 200 juveniles) and the red seabream *Pagrus major* (e.g. 600 juveniles) are usually grown together in a cage of 3 × 3 × 3 m. The sizes of floating cages used for *E. akaara* and other marine fish grow-out have increased over time by connecting two, four, six or nine cages of 3 × 3 × 3 m.

Mixed fish feed is the only feed source for *E. akaara* grow-out in Fujian (this study) (**Plate 4.11**). Because of the high value of groupers in trade, groupers are mainly fed on good quality mixed fishes, such as sardines. Mixed fishes are either caught by trawlers from local waters or the Yellow Sea (**Figure 1.1**). The FCR of mixed fish feed is around 8–9 (Fu, 2003; Li et al., 2004). Although formulated feeds for *E. akaara* have been studied in Fujian since the 1990s, they have not been used in grow-out operations to date (Lin and Zhang, 1996; Li et al., 2004). Farmers prefer mixed fish feed since they give better growth rate and coloration, and higher meat quality (this study).

Mariculture production of *E. akaara* in Fujian was estimated (this study) (**Figure 4.4**). In the 1990s, a major farmer in Fuding had about 20,000 wild-caught *E. akaara* juveniles (about 30–70 g BW / fish) annually for grow-out, i.e. about 1 t; it took about two years to reach marketable size (about 500 g BW / fish) in floating cages. Therefore, the estimated annual mariculture production from him was about 7.5 t based on survival rate of juveniles in captivity (75%). Currently, he does not culture *E. akaara* mainly due to the degradation in water quality locally. In Quanzhou and Dongshan, the estimated annual mariculture production is about 1 t / year in recent years.

Box 10 *Grouper mariculture in Fujian Province*

There are three types of grouper mariculture system in Fujian; intertidal and on-land ponds and floating cages; ponds are those formerly used for shrimp mariculture (**Plate 4.12**). In recent

years, a combination of floating cages held in intertidal ponds is a common system. Grouper grow-out in indoor tanks was conducted experimentally (Lin et al., 1995).

Official statistics on the total annual grouper mariculture production between 2003 and 2007 in Fujian is about 5,750–11,910 t in recent years, contributing to about 31.2–48.2% of the total annual grouper production in Fujian (this study) (**Table 4.6**). The most common grouper species used in grow-out operations in southern Fujian (e.g. Dongshan, Zhangpu, Zhaoan) are *E. awoara* and *E. coioides*; *E. awoara* juveniles are only from wild-caught sources, and *E. coioides* juveniles mainly come from hatchery production (this study) (**Figure 4.4**). In Dongshan, the estimated annual demand for *E. coioides* juveniles for grow-out is about 200 million currently. The mortality of *E. awoara* during grow-out is about 60%; high mortality often occurs in the first three months due to the stress of transportation and infection (this study).

4.1.4.4 Trade

Since the 1970s, *E. akaara* and *E. awoara* have been the major two grouper species for the LFFT into Hong Kong and Macau (via traders from Guangdong) in terms of trade volume and value (Chu, 1985; this study). *Epinephelus akaara* is also sold alive in local markets (**Plate 4.13**).

The trade volumes for *E. akaara* were estimated from the traders interviewed with declines from 60 to 95% since the 1980s, as indicated indirectly by declines in capture production (this study) (**Table 4.8; Figure 4.4**). In Fuding, one grouper trader interviewed (the major one in the area) traded about 20–30 t of *E. akaara* annually in the 1980s, almost all to Hong Kong. The trader shifted to mariculture included *E. akaara* and other marine fishes in the 1990s but no longer does grow-out of *E. akaara*. In Xiapu, the estimated total annual trade volume for *E. akaara* was about 50 t in the late-1980s, from about six traders, and declined to about 12 t in

2008, i.e. a decline about 75%. One trader reported about 5 t trade volumes for *E. akaara* annually in the late-1980s with a decline since the 1990s to about 2 t in both 2007 and 2008, i.e. a decline of about 60%. Another trader had about a 15 t trade volume for *E. akaara* annually in the late-1980s with a decline to about 9 t in 2007 and 2 t in 2008, i.e. a decline of 87%. In Lianjiang, the trader interviewed (the first one established in the area) started *E. akaara* trade in the early-1980s and the trade volume annually was about 5 t. The trader shifted to marine fish culture in 1989 and there has been no significant grow-out of *E. akaara* (< 200 kg in both 2007 and 2008) in his cages. In Pingtan, the estimated total annual trade volume for *E. akaara* (with a small proportion of *E. awoara*) in the 1980s was about 100–150 t from about 20 grouper traders in the area. Many traders in Pingtan have shifted to mariculture since the 1990s. Currently, there are only about 5 t trade volumes of *E. akaara* annually in the area, i.e. a decline of at least 95%. The two traders interviewed in Pingtan had trade volumes of about 15–20 t for *E. akaara* annually in the 1980s. They shifted to marine fish culture in the 1990s but there is no significant grow-out of *E. akaara* in their cages currently. In Quanzhou, the trader interviewed (the first one established in the area) had the trade volumes of 3–5 t *E. akaara* annually in the 1970s. He shifted to marine fish culture in the 1990s and there is no significant grow-out of *E. akaara* (< 100 kg in both 2007 and 2008) in his cages currently. The reason for the shift from grouper trade to mariculture in different places in Fujian was similar, i.e. there was no significant capture of *E. akaara* in the 1990s.

Retail prices for *E. akaara* varied with body sizes in Fujian (this study) (**Table 4.4**). Compared to the prices in Zhejiang, two differences were noted. First, retail prices in Fujian were higher than those in Zhejiang in the 1980s. This was because prices in Zhejiang in the 1980s were controlled by the traders from Guangdong and Fujian who first introduced the live grouper trade into Zhejiang (see **Section 4.1.3**). Second, the prices in Fujian have been lower than those in Zhejiang since the 1990s. Most of *E. akaara* in the LFFT were from grow-out of wild-caught

juveniles since the 1990s. In Fujian, farmers stocked relatively smaller juveniles to grow; therefore, they took longer to reach marketable sizes, which led to the less desirable in texture and coloration and lower prices (**Plate 4.9A**).

Box 11 *Grouper importation in Fujian Province*

Grouper import particularly for establishing mariculture operation, has been widely reported in Fujian in recent years. For example, about 900 *E. malabaricus* individuals of 3–5 years old were imported to Dongshan by boat from Taiwan as broodstock in 2001 (Zou et al., 2003). Fertilized eggs of *E. lanceolatus* from Taiwan hatcheries were imported to Ningde and Zhangpu by boat for larviculture in 2002 (Gong et al., 2004; Lin et al., 2005).

4.1.4.5 Management

There is no specific management for *E. akaara* or for other grouper fisheries, their mariculture or trade in Fujian.

Box 12 *Management measures in Fujian Province*

Blasting and other dynamite fishing have been prohibited in Fujian waters since the 1950s (Liu, 1988). However, in Nanri Island (**Figure 4.4**), blasting was intensive in the late-1980s and early-1990s and there remained almost no wild-caught *E. akaara* in the area by the mid-1990s (this study). Blasting was eventually brought under control in the mid-1990s and the wild stocks of *E. akaara* have recovered in recent years with a report of about 18.55 t *E. akaara* juveniles caught between April and June in 2001 in Nanri Island and adjacent waters (Fu, 2003).

As in Zhejiang, Fujian fisheries have been managed through the fishing moratorium conducted in the East China Sea since 1995; no trawling between June and September. In addition, in southern Fujian and the Taiwan Bank Fishing Grounds (**Figure 4.4**), set-net fishing has been prohibited in May and June since 1999 (Xiao, 2005).

4.1.5 Guangdong Province (Guangdong)

In this study, field surveys (five fishing grounds, three hatcheries, six mariculture zones and five fish trade markets) and interviews (seven fishers, sixteen farmers, six grouper hatchers and five traders) were conducted between December 2008 and July in 2009.

4.1.5.1 Distribution

Epinephelus akaara is confirmed as distribute along coastal waters of eastern Guangdong and near-shore islands, such as Chaozhou (e.g. Yaoping, the Nanao Island), Shantou, Shanwei, Huizhou and Shenzhen (e.g. in the Daya Bay), Zhuhai, Yangjiang, Maoming and Zhanjiang (e.g. the Naozhou Island) based on reported catches (Hu, 1979; Li et al., 1988; Shu et al., 2005; Zhou, 2008; this study) (**Figures 1.1** and **4.5**). The species is particularly associated with rocky habitats and inhabits water depths down to 50 m (this study).

The occurrence of *E. akaara* in the Gulf of Dongjing was reported (Hu, 1979; Tseng and Ho, 1979a; Zhong and Zhong, 2005; Huang et al., 2007) (**Figures 1.2**). Fishers, farmers and traders in Xuwen and Techeng (Guangdong), Beihai and Qinzhou (Guangxi) (see **Section 4.1.6**), and Haikou, Lingao, Lingshui and Wenchang (Hainan) (see **Section 4.1.7**) were interviewed (this study). Fishers reported the rarity of *E. akaara* in their catches and that the species in only caught from eastern Hainan Strait; farmers and traders reported no *E. akaara* individuals in floating cages for grow-out. This information indicates that the southern limit of *E. akaara* occurrence is in southern Guangdong and that it does not enter the Hainan Strait.

4.1.5.2 Fisheries

The main fishing grounds for *E. akaara*, both juveniles and adults, are in northern Guangdong such as Nanao, Yaoping, Shantou, Shanwei and Daya Bay, and off-shore fishing grounds such as the Taiwan Bank Fishing Grounds, Penghu Islands and the Wanshan Islands; the fishery for

the species is much less important in the south, such as at Yangjiang, Maoming and Zhanjiang (**Figures 4.4** and **4.5**).

The main fishing seasons for *E. akaara* and other groupers in Guangdong are from April to November; *E. akaara* juveniles were mainly caught between March and July (Tseng and Ho, 1988; Guangdong Province Survey Report, 1995; this study). The main fishing gears are hook-and-line and long-line; others include bottom trawlers, gill-nets, fix-nets and traps (Guangdong Province Survey Report, 1995; Zhou, 2008; this study) (**Plate 4.14**).

Epinephelus akaara fisheries in Guangdong waters underwent a shift in fishing grounds and coastal fisheries of the species have not been significant since the 1980s (this study). Fishers and traders moved to Fujian and Zhejiang in the 1970s and 1980s due to the high demand for live *E. akaara* in Hong Kong and Macau and the decline in local wild stocks (**Figure 4.3**). In the last decade, *E. akaara* fisheries mainly operate in off-shore fishing grounds such as the Taiwan Bank Fishing Grounds and Penghu Islands (**Figure 4.4**).

Wild-caught *E. akaara* juveniles showed a dramatic decline in Guangdong (in Fujian and Zhejiang as well) waters in the 1980s and 1990s, which had a direct effect on the scale of *E. akaara* grow-out operations (this study). In Yaoping, the estimated annual volumes of wild-caught *E. akaara* juveniles for grow-out were about 25 t in the 1980s, mainly caught in local and adjacent waters with sizes of 50–250 g BW / fish. Currently, the annual volumes are about < 2 t (i.e. decline by 92%), and juveniles are mainly from the Taiwan Bank Fishing Grounds and Penghu Islands (this study) (**Plate 4.15A**). In Huizhou, the estimated annual numbers of *E. akaara* juveniles for grow-out were about 171,000–187,000 (body sizes of 70–150 g BW / fish and about 18 t) in the 1980s, partly from Daya Bay and adjacent waters but mainly from Fujian (e.g. Pingtan); currently, *E. akaara* grow-out is no longer significant (Ai et al., 2001; this study) (**Figure 4.4**).

Box 13 *Grouper capture fisheries in Guangdong Province*

E. awoara, *E. coioides* and *E. quoyanus* are the most common species in *Epinephelus* fisheries along the coastal waters of Guangdong and near-shore islands over the last three decades (Hu, 1979; Guangdong Province Survey Report, 1995; this study) (**Plate 4.16**). The estimated annual grouper capture volumes (not species-specific) in Guangdong were between 14,704 and 21,120 t in 2000–2008, contributing to 1–2% of the total Guangdong marine fish capture volume from the same year (this study) (**Table 4.9**).

In Huizhou, the statistics dataset on grouper capture volumes indicated landings of < 10 t in 1979 and 1980, peaking in 1995 with > 1,100 t, and declining significantly by 92% in 2006 (this study) (**Table 4.10**). Two comments are on the dataset from Huizhou. First, the captures in the 1970s and 1980s were mainly from Daya Bay and adjacent waters and had a high proportion of *E. akaara* among the groupers. Second, the capture volumes since the 1990s were mainly from off-shore fishing grounds in the South China Sea, and there were no *E. akaara*.

Box 14 *Grouper seed fisheries in Guangdong Province*

Currently, the main grouper species in juvenile fisheries in Guangdong is *E. awoara*; wild-caught juveniles (mainly 80–200 mm TL) go to local food markets directly or to grow-out in floating cages or ponds (**Plates 4.15** and **4.16**). There were about 10,000 cages (out of the total 110,000 cages) growing-out *E. awoara* juveniles in 1997 in Guangdong; 60% caught in local waters and 40% imported (e.g. from Taiwan) (GDFDC, 1999). *E. awoara* juveniles from Taiwan were also likely to be wild-caught since there were no any reports on conducting *E. awoara* hatchery (Liao et al., 2001). Based on stocking density of 200–300 juveniles / cage for growing-out, the estimated wild-caught *E. awoara* juveniles from local waters in 1997 were about 2–3 million individuals (this study). In the recent years, the estimated annual volumes of wild-caught *E. awoara* juveniles are about 50 t in Yaoping, mainly from the Taiwan Bank

Fishing Grounds (this study). Other groupers such as *E. bleekeri* and *E. bruneus* can also be caught in Guangdong waters including the Gulf of Dongjing (this study).

4.1.5.3 Mariculture

Hatchery

In Guangdong, *E. akaara* hatchery was first operated in 1983 but it was not until 1986 that 8 juveniles with average body size of 143 mm TL were obtained (Ma et al., 1987). Broodstock were selected from floating cages where wild-caught juveniles were grown-out or caught directly from local waters; males with body size > 2,000 g BW / fish and females with 500–1,200 g BW / fish. Human chorionic gonadotropin (HCG) and luteinizing hormone-releasing hormone (LHRH) injection were applied for final maturation. Spawning season of *E. akaara* is from May to September with a peak in May and June. Male broodstock of *E. akaara* can also be obtained by 17α-MT implantation to two years old juveniles (Li et al., 2006).

Since the 1980s, *E. akaara* hatchery production was conducted occasionally when there was research funding available and the techniques did not change (this study). In 1999, about 11,000 juveniles were hatchery-produced with body size of 30 mm TL and a survival rate of less than 0.1% from the fertilized egg stage (GDFDC, 1999). In 2007, about 21,000 juveniles were hatchery-produced with a body size of 60–120 mm TL (Zhou, 2008).

Hybridization of *E. akaara* males and *E. coioides* females was conducted (Song and Xu, 1987; Liufu et al., 2007). The reason for the study was to look for good combinations of hybrids, such as for red colour from *E. akaara* and fast growth rate from *E. coioides*.

Box 15 *Grouper hatchery in Guangdong Province*

E. coioides, *E. lanceolatus* and *E. malabaricus* hatcheries have been conducted in Guangdong since the 1990s (Yang and Liang, 2002; Zou and Wu, 2002; Zhang et al., 2005; Liu and Sadovy de Mitcheson, 2008a; this study). For *E. lanceolatus*, hatchery-produced juveniles were

imported from Taiwan and grown-out in ponds for at least 5 years before being selected as broodstock (Yang and Liang, 2002; Zhang et al., 2005). For *E. coioides*, fertilized eggs are usually bought from Hainan (e.g. Lingshui and Wenchang) for larviculture. The hybridization of *E. coioides* and *E. malabaricus* is likely because broodstock of the two species maintained in the same tanks and ponds were commonly observed; some hatchery operators even considered the two as the same species (this study). *Epinephelus awoara* and *E. bleekeri* hatcheries were also operated but no at commercial scales.

Grow-out

E. akaara grow-out, all wild-caught, has been conducted throughout the coastal waters of Guangdong since the 1980s (Zhang, 1990; Ai et al., 2001; Yang and Wu, 2005; this study). Today, *E. akaara* grow-out is only conducted in Yaoping and is no longer significant in other areas such as Daya Bay, Yangjiang, Maoming and Zhanjiang (this study) (**Figure 4.5**). Diseases have caused mass losses in *E. akaara* and other grouper mariculture in Guangdong since the 1980s (Zhang, 1990; Huang et al., 2005; Yang and Wu, 2005).

In Daya Bay, there were more than 400 floating cages (3 m × 3 m × 3 m each) for *E. akaara* grow-out in the 1980s and 1990s, and *E. akaara* juveniles for stocking were about 30–300 g BW / fish (Ai et al., 2001; this study) (**Figure 4.5**). The grow-out periods were between 9 and 22 months depending on seed sizes at the start of the grow-out period, with average survival rate of 75% and FCR of 7 using mixed fish feed. Based on stocking densities of *E. akaara* juveniles in the 1980s and 1990s (average about 450 juveniles / cage), the estimated number of wild-caught juveniles for grow-out were about 180,000 (this study). There was a decline in juvenile stocking density for *E. akaara* grow-out from the 1980s to 1990s; mainly due to the decrease of seed availability and degradation of water quality in the 1990s due to the high culture density and the development of industries in the Bay (Ai et al., 2001; this study). Based on body sizes for marketable fish (about 500 g / fish in the 1980s and 1990s), the estimated

annual mariculture production of *E. akaara* was about 68 t in Daya Bay in the 1980s and 1990s, less than the reported statistics in 1990 (**Table 4.10**).

Box 16 *Grouper mariculture in Guangdong Province*

Epinephelus awoara and *E. coioides* are the most common grouper species in grow-out in Guangdong, with other species including *E. bleekeri*, *E. bruneus*, *E. fuscoguttatus*, *E. lanceolatus* and *E. malabaricus*. Juveniles are either wild-caught (e.g. from the Gulf of Dongjing, eastern South China Sea and Taiwan Bank Fishing Grounds) or hatchery-produced (e.g. locally or from Hainan and Fujian hatcheries) (this study) (**Plate 4.15**). Other grouper species such as the humphead grouper *Cromileptes altivelis* and the spotted coralgrouper *Plectropomus maculatus* are also grown-out in floating cages in Zhanjiang; farmers reported imports of both species from Viet Nam (this study) (**Figure 4.5; Plate 4.15**). Groupers are grown-out in floating cages and ponds.

In 1999, the estimated grouper mariculture production in Guangdong was about 2,500 t, i.e. less than 1.5% of the total marine fish culture production (180,000 t) (this study). The estimated statistics on annual grouper mariculture production (not species-specific) in Guangdong in 2003–2008 were between 13,636 and 22,745 t, contributing to 7.0–9.8% of total marine fish culture production and 42.0-54.7% of total grouper production for the same year. These figures demonstrate the importance of grouper mariculture in Guangdong (this study) (**Table 4.9**).

4.1.5.4 Trade

The *E. akaara* trade was mainly destined for Hong Kong and Macau between the 1970s and 1990s; today, the major consumers are local, centred in Guangzhou, Shenzhen, Yaoping and Zhuhai (this study) (**Figure 4.5; Plate 4.17**). Retail prices for *E. akaara* vary with body sizes (Ai et al., 2001; this study) (**Table 4.4**). Wild-caught *E. akaara* individuals that are caught at marketable sizes fetch higher prices than the same species that are grown-out from wild-caught

juveniles. The coloration of *E. akaara* from the two sources can be easily distinguished; wild-caught individuals are in golden red and grow-out ones are in gray red (**Plate 4.17A, B**).

Box 17 *Grouper food trade in Guangdong Province*

Groupers in the food trade are mainly sold alive and are species-diverse in Guangdong; either from grown-out or wild-caught, and from local or other Provinces or imported, sources (**Plate 4.17**). Other common *Epinephelus* species include *E. awoara*, *E. bleekeri*, *E. coioides*, *E. fasciatus*, *E. fuscoguttatus* and *E. lanceolatus*; *E. awoara* and *E. bleekeri* that develop mainly from grown-out wild-caught juveniles, *E. fasciatus* from wild-caught (i.e. marketable size when caught), and *E. coioides*, *E. fuscoguttatus* and *E. lanceolatus* mainly from grown-out hatchery-produced juveniles. Groupers such as the blacksaddled coralgrouper *Plectropomus laevis*, the leopard coralgrouper *P. leopardus* and the spotted coralgrouper *P. maculatus* are also common in the LFFT and all come from wild caught (**Plate 4.17**).

Box 18 *Grouper seed trade in Guangdong Province*

Currently, wild-caught *E. awoara* juveniles in Guangdong are delivered to Fujian (e.g. Ningde, Quanzhou) for grow-out (this study) (**Figure 4.4**). Hatchery-produced *E. coioides* juveniles are sold from Guangdong to Fujian or from Fujian to Guangdong for grow-out (this study).

4.1.5.5 Management

There is no management of *E. akaara* and other grouper fisheries, of mariculture or of trade in Guangdong.

Box 19 *Management measures in Guangdong Province*

Since 1999, a fishing moratorium has been imposed annually between 1st June and 31st July in the South China Sea and the Gulf of Dongjing when all trawling is prohibited (**Figure 1.1**). Fishing gears such as long-line, hand-line, trap and gill net can continue during the moratorium, even though the damage from gill nets to fish stocks is considered equivalent to that of trawlers

(http://www.gxfishery.com.cn/yuyenews2/200605/news06051001.htm). In 2009, the fishing moratorium extended from 16th May to 31st July and two-layered gill nets were, for the first time, prohibited (this study).

Since 1985, Guangdong has conducted restocking; the diversity of restocking species and financial support for restocking increased annually; by 2008, a total of 73 million of marine fish seeds (no groupers recorded) have been released (GDOFA, 2008; this study). The release activities are mainly conducted in the beginning of the fishing moratorium. Since 2000, the spawning grounds of more than 10 fish species and 9 typical ecological habitats such as coral reefs and mangroves have been protected (GDOFA, 2008). Since 2002, the provincial council has promoted artificial reefs to recover and improve marine environment and fish habitats, and to protect threatened species efficiently (GDOFA, 2008). In the 10-year project planned, a total of 100 million US$ will be invested for 100 artificial reefs. By 2008, about 26 artificial reef zones have been established with 88 abandoned fishing vessels and 12,000 concrete artificial reefs.

4.1.6 Guangxi Zhuang Autonomous Region (Guangxi ZAR or Guangxi)

In this study, field surveys (two fishing grounds, two hatcheries and two mariculture zones) and interviews (six fishers, six mariculturists and three traders) were conducted in September 2008 and July 2009.

4.1.6.1 Distribution

Epinephelus akaara is absent from the Gulf of Dongjing (see **Section 4.1.5.1**) (**Figure 1.1**).

4.1.6.2 Fisheries

No *E. akaara* fisheries, for either adults or juveniles, are recorded in the Gulf of Dongjing.

Box 20 *Capture fisheries in the Gulf of Dongjing ZAR*

Guangxi marine capture fisheries mainly operate in the Gulf of Dongjing, together with Guangdong and Hainan Provinces and Viet Nam (**Figure 1.1**). The estimated marine fish maximum sustainable yields (MSY) in the Gulf were 600,000–700,000 t; however, the estimated total annual capture production of marine fishes from Guangdong, Guangxi and Hainan had already exceeded the MSY in the 1990s (Guangxi Fishery Net: http://www.gxfishery.com.cn/yuyenews2/200605/news06051001.htm; http://www.china1931.cn/newse/fgry/200607/3161.html).

Natural resources in the Gulf has shown a decline since the early-1980s indicated by the CPUE declines, capture size and age reduces and species composition changes (http://www.gxfishery.com.cn/gxyy/06081001.htm; http://www.gxfishery.com.cn/dzbk/20081/04.htm; http://www.gxfishery.com.cn/yuyenews2/200605/news06051001.htm). However, fishing pressure has not been reduced from excessive levels. For example, there were about 14,385 fishing vessels totally in 2005, compared to 1,158 in 1980; the total engine power increased from 82,491 kW in 1980 to 697,422 kW in 2005. The number of fishing vessels (> 300 horsepower) in Beihai increased from 40 in 2001 to about 150 vessels in 2006.

Box 21 *Grouper seed fisheries in Guangxi ZAR*

The most common species in grouper seed fisheries in Guangxi is *E. coioides* (**Plate 4.1**) with others such as *E. awoara*, *E. bleekeri* and *E. bruneus* (this study). Grouper juveniles can be caught in the coastal waters of Guangxi, such as Beihai and Qinzhou (**Figure 4.5**). For *E. awoara*, juveniles are commonly caught in seagrass beds with body sizes of 80–120 mm TL; for *E. bruneus* and *E. coioides*, larvae and juveniles are commonly caught in rocky pools during low-tide with body sizes of 20–100 mm TL. The estimated total annual numbers of grouper seeds in Qinzhou was about 10,000,000 seeds over the last decade (this study). The seeds were

mainly sold to Fujian, Guangdong and Hainan for grow-out with small amounts used for local grow-out (this study) (**Plate 4.18**).

The fishing gears for grouper seeds are hook-and-line, hand-net and trap (**Plate 4.18**). The main fishing seasons are year-round for *E. awoara*, mainly in April and May for *E. bruneus*, and between July and October (particularly associated with specific lunar phases) for *E. bleekeri* and *E. coioides* (this study). In Qinzhou, during the new and full moon phases, a trader could buy about 20,000–30,000 *E. coioides* seeds of 20–50 mm TL per day, and a fisher could catch about 200-300 seeds per day.

4.1.6.3 Mariculture

Hatchery

No *E. akaara* hatchery is conducted in Guangxi ZAR.

Box 22 *Grouper hatchery in Guangxi ZAR*

Grouper hatchery operation was first conducted in 2002 in Beihai for *E. coioides*; today, the hatchery is still with small scales (this study). Hatchery-produced *E. coioides* juveniles are mainly sold to Fujian and Guangdong for grow-out and the demand for hatchery-produced grouper juveniles from local culture operations is limited.

Grow-out

No *E. akaara* grow-out is conducted in Guangxi ZAR.

Box 23 *Marine fish culture in Guangxi ZAR*

Marine fish culture is conducted in the coastal waters of Beihai, Fangchenggang and Qinzhou (**Figure 4.5**). The estimated total marine fish culture production in 2006 in Guangxi was about 27,500 t, contributing to about 3% of the total mariculture production of Guangxi ZAR (http://www.gxfishery.com.cn/dzbk/20081/04htm). Due to the extremely cold winter (about

4–5 °C), especially between January and March 2008, a large proportion of marine fishes, including groupers in floating cages, died. Most floating cages were newly-stocked with hatchery-produced red drum *Sciaenops ocellatus*, Japanese seaperch (*Lateolabrax japonicus*) and pompano *Trachinotus blochii*, similar to previous operations; the latter is mainly fed commercial pellets (**Plate 4.18**).

Box 24 *Grouper mariculture in Guangxi ZAR*

Grouper grow-out in Guangxi ZAR started less than one decade ago; species include *E. awoara*, *E. bleekeri*, *E. bruneus* and *E. coioides* and seeds are mainly wild-caught locally (this study) (**Plate 4.18**). Groupers are grown-out in both floating cages and ponds and only fed on mixed fish feed. In Qinzhou, about 176,000 *E. awoara* juveniles (50–120 mm TL), mainly caught in local waters, were cultured in ponds in 2006; mortality was about 30–50% during grow-out. Grouper mariculture is currently expanding due to the desirable prices. The estimated total annual grouper mariculture production in one mariculture zone visited in Qinzhou was about 50 t in recent years (this study). In Beihai, there are about 50,000 m^2 of floating cages for grouper grow-out (this study).

4.1.6.4 Trade

No *E. akaara* trade is conducted in Guangxi ZAR.

Box 25 *Grouper seed trade in Guangxi ZAR*

Wild-caught grouper juveniles (e.g. *E. awoara*, *E. bleekeri*, *E. bruneus* and *E. coioides*) were mainly sold to Fujian (e.g. Dongshan, Pingtan), Guangdong (e.g. Zhanjiang, Yangjiang) and Hainan (e.g. Shanya) Provinces; mainly delivered by truck and boat (this study).

The highest price for grouper juveniles is for *E. bruneus*, about US$ 0.3 / seed of 30–50 mm TL; by comparison *E. coioides* juveniles sell at about US$ 0.07 / seed of 20–50 mm TL. Traders keep grouper seeds in on-land tanks for a short period of less than months. Mortality of

wild-caught grouper seeds varied in holding tanks; larvae and small juveniles had high mortality up to 30%, and juveniles > 70 mm TL had relatively low mortality. During holding, the grouper seeds were fed on oyster and mixed fish.

4.1.6.5 Management

There is no management for grouper fisheries, mariculture or trade in Guangxi ZAR.

Box 26 *Management measures in Guangxi ZAR*

A fishing moratorium has been in place in the Gulf of Dongjing since 1999 (See **Box 19**). Restocking into coastal waters of Guangxi has been conducted in recent years. In June 2008, about 3,128,000 juveniles of marine fishes such as the crimson snapper *Lutjanus erythropterus* (no groupers were recorded) were released into the Gulf of Dongjing (http://www.gzagri.com/news/gb/content/2008-06/16/content_138649.htm).

4.1.7 Hainan Province (Hainan)

In this study, field surveys (three fishing grounds, two hatcheries, three mariculture zones and four fish trade markets) and interviews (five fishers, two grouper hatchers, six mariculturists and two traders) were conducted in June 2009.

4.1.7.1 Distribution

Epinephelus akaara is absent from the Gulf of Dongjing and around Hainan (see **Section 4.1.5.1**).

4.1.7.2 Fisheries

No *E. akaara* fisheries are reported in Hainan. Four places, Haikou, Lingao, Lingshui and Wenchang along the coast of Hainan were visited, and no *E. akaara* individuals were found in floating cages or in retail and wet markets; fishers reported the absence of *E. akaara* capture (this study) (**Figure 4.5**).

Box 27 *Grouper capture fisheries in Hainan Province*

The main fishing grounds for groupers are the South China Sea (e.g. the Paracel and the Spratly Islands) and the Gulf of Dongjing (this study) (**Figures 1.1** and **4.5**). The estimated statistics on annual grouper capture volumes (not species-specific) in Hainan Province were about 10,811−32,272 t between 1998 and 2008, with a steady increase (this study) (**Table 4.11**). Grouper species in capture are diverse and the most common species include *E. awoara*, *E. bleekeri*, *E. coioides*, *E. fasciatus*, *E. malabaricus* and *E. trimaculatus* (**Plate 4.19**). The fishing gears for groupers are hook-and-line, net and trap and the fishing seasons are year-round (this study).

4.1.7.3 Mariculture

Hatchery

No *E. akaara* hatchery is conducted in Hainan Province.

Box 28 *Grouper hatchery in Hainan Province*

Grouper hatchery was first started in 1998 for *E. malabaricus*; fertilized eggs and larvae were imported from Taiwan for larviculture (Chen and Zhang, 2001a, b). Nowadays, broodstock of *E. malabaricus* are from hatchery-produced juveniles after grow-out to sexual maturation (this study) (**Plate 4.19**). One decade after the first trial in 1998, Hainan has become the most important grouper hatchery centre of mainland China. To date, *E. coioides* and *E. malabaricus* are the most successful species in grouper hatchery based on the number of juveniles produced. In 2005, the estimated total number of *E. malabaricus* juveniles produced was about 5 million (Lei et al., 2005). A hatchery visited produced about 6 million *E. coioides* and *E. malabaricus* juveniles in 2008; fertilized eggs were also sold to other farmers for larviculture (this study) (**Plate 4.19C**).

In 2006, *E. lanceolatus* hatchery production was successful for the first time in Hainan; about 1,000 g of fertilized eggs were imported from Taiwan and 200,000 juveniles were subsequently produced with 32 days old (http://www.gxfishery.com.cn/kzdt/2006/06082101/htm). About one hundred *Epinephelus lanceolatus* juveniles of less than one year old were imported from Taiwan and kept in either floating cages or ponds for years in order to reach sexual maturation as broodstock in future (this study) (**Plate 4.19C,G,H**).

Grouper broodstock feed on good quality mixed fish feed and are reared in both floating cages and ponds (this study) (**Plate 4.19F**). To date, *E. coioides* and *E. malabaricus* broodstock can spawn naturally in ponds whenever water temperature exceeds 24 °C without hormone induction (this study). The hybridization of *E. coioides* and *E. malabaricus* is likely because broodstock of the two species are commonly maintained in the same ponds (this study) (**Plate 4.19E**). *Epinephelus lanceolatus* males have been obtained through sex change using implanting 17α-MT, and spawning has to be induced by hormone manipulation (Shen and Zhang, 2001a; this study).

Grow-out

No *E. akaara* grow-out is conducted in Hainan Province.

Box 29 *Grouper mariculture in Hainan Province*

The common grouper species for grow-out in Hainan are *E. awoara*, *E. coioides*, *E. fuscoguttatus*, *E. lanceolatus* and *E. malabaricus* (this study) (**Plate 4.20**). *Epinephelus awoara* juveniles are almost wild-caught; *E. coioides* and *E. malabaricus* juveniles are mainly hatchery-produced locally; *E. fuscoguttatus* and *E. lanceolatus* juveniles are mainly from hatcheries, both locally and imported from Taiwan. Grouper grow-out uses mixed fish feed only, usually caught in the Gulf of Dongjing by trawlers. The estimated statistics on annual grouper mariculture production (not species-specific) in Hainan Province were about 1,615–11,106 t between 2002

and 2008, and increased dramatically over the 6 year period; mariculture production contributed to 10.2–25.6% of total grouper production (this study) (**Table 4.11**).

4.1.7.4 Trade

No *E. akaara* trade is conducted in Hainan Province.

Box 30 *Grouper seed trade in Hainan Province*

In Hainan, grouper seed trade for mariculture operation has been widely recorded. Fertilized eggs, larvae and juveniles are imported for larviculture and grow-out. Importation is either by boat or by air, and mainly from Taiwan. For example, *E. malabaricus* and *E. lanceolatus* fertilized eggs, larvae and juveniles were imported from Taiwan (Shen and Zhang, 2001a, b; this study; http://www.gxfishery.com.cn/kzdt/2006/06082101/htm). Exportation of hatchery-produced juveniles to Hong Kong for grow-out is also recorded, such as for *E. lanceolatus* and *E. coioides* (this study). Fertilized eggs, larvae and juveniles are commonly sold to Guangdong, Guangxi and Fujian for larviculture and grow-out (**Plate 4.19**).

4.1.7.5 Management

There is no management for grouper fisheries, mariculture and trade in Hainan Province.

Box 31 *Management measures in Hainan Province*

A fishing moratorium has been proposed in the South China Sea and the Gulf of Dongjing since 1999 (See **Box 19**). Restocking together with the development of artificial reef programmes have been conducted in recent years (http://www.gxfishery.com.cn/yuyehb/hb379.htm). The most common marine fish species for releasing is *L. erythropterus*; all juveniles come from hatchery production.

4.2 Hong Kong Special Administration Region (Hong Kong SAR or Hong Kong)

In this study, field surveys (four mariculture zones and four fish trade markets) and interviews (five fishers, seven farmers and three traders) were conducted between September 2008 and May 2009 in Hong Kong.

4.2.1 Distribution

Epinephelus akaara is mainly distributed in eastern Hong Kong waters, such as Basalt Island, High Island, Po Toi Islands, Port Shelter, Plover Cove and the Ninepins Islands (Chan, 1968; Tseng and Ho, 1988; Sadovy and Cornish, 2000; this study) (**Figure 4.6**). A spawning aggregation of *E. akaara* was reported in Hong Kong waters (Bentley, 1999). Spawning aggregations have not bee otherwise reported and only single or up to several *E. akaara* individuals are occasionally seen.

The habitats for *E. akaara* are coral-rich areas and rocky grounds and boulders down to 55 m deep (Chan, 1968; Tseng and Ho, 1988; Sadovy and Cornish, 2000). Adults are usually found in deeper waters of 27–55 m, and juveniles less than 100 mm SL are found in shallow waters of less than 20 m. The maximum sizes recorded were 510 mm TL and 4,800 g in Hong Kong (Chan, 1968; Tseng and Ho, 1988; Heemstra and Randall, 1993)

4.2.2 Fisheries

Epinephelus akaara was caught throughout the year from local and adjacent waters of the South China Sea; juveniles in particular are caught from March to May and adults of 1,000–2,000 g BW can be caught occasionally (Chan, 1968; Tseng, 1983; Sadovy and Cornish, 2000; this study) (**Figure 4.6**). The species was commonly caught by hand-line in the 1960s and maintained alive for a higher price; fish caught at below marketable sizes went to floating cages for grow-out (Chan, 1968; Wilson, 1997; Sadovy and Cornish, 2000). There are no official data available on capture volume of *E. akaara* in Hong Kong.

In the late-1970s, the estimated annual volumes of *E. akaara* juveniles for grow-out in Hong Kong were about 18–45 t, all caught from coastal waters of mainland China such as Guangdong, Fujian and Zhejiang in the East and South China Seas (Tseng and Ho, 1979b, 1988; Tseng, 1983) (see **Sections 4.1.3, 4.1.4** and **4.1.5**). The dominant body sizes in *E. akaara* juvenile fisheries were about 100–200 g BW / fish and 120–200 mm TL (Tseng and Ho, 1988; Tseng, 1983). Therefore, the estimated total annual capture numbers of *E. akaara* juveniles were about 120,000–300,000 in the late-1970s based on the average body size of 150 g BW / fish (this study).

To examine the accuracy of the above estimated volume of *E. akaara* juveniles for grow-out, the total annual numbers of *E. akaara* juveniles captured were estimated based on mariculture production in Hong Kong (this study). Based on the estimated annual grow-out production of *E. akaara* of 500 t in the 1970s and preferred marketable body size of about 500 g BW / fish (Tseng and Ho, 1979a, b; Liu and Sadovy de Mitcheson, 2008a; this study) (**Table 4.12**), the estimated total annual numbers of *E. akaara* for grow-out were about 1,333,000 juveniles, after considering 25% mortality during grow-out around the region (see **Section 4.1.5**). The estimation is higher than the above data.

Epinephelus akaara fisheries in Hong Kong had already shown depletion by the 1970s. Overfishing and water pollution were considered to be the major factors (Tseng and Ho, 1979b; Tseng and Poon, 1983). Fishers and traders travelled to Guangdong, Fujian and Zhejiang Provinces for capture and trade in the 1970s and 1980s also indicated depletion of *E. akaara* wild stocks locally (this study) (**Figure 4.3**). Information obtained from all fishers, farmers and traders interviewed has indicated the rarity of the species in Hong Kong waters since the 1990s (this study).

Box 32 *Grouper capture fisheries in Hong Kong SAR*

The estimated total annual landing volumes of groupers (fresh dead only and not species-specific) by Hong Kong-licensed fishing vessels were about 361–1,490 t between 1985 and 2007, showing a decline trend over time (**Table 4.13**). Data were collected by the Fish Marketing Organization of Hong Kong (FMO); all fresh dead marine fishes (excluded live marine fish and fish in transhipment) caught by the Hong Kong-licensed fishing vessels are required to be landed and sold at the seven retail fish markets (**Figure 4.6**). The capture volumes of groupers contributed to < 2.5% of total marine fish capture (**Table 4.13**). Groupers were commonly caught by hand-line, long-line, gill net, spear and trawler in local and adjacent waters of the South China Sea and species included *E. akaara*, *E. awoara*, *E. bleekeri*, *E. bruneus*, *E. fasciatomaculosus*, *E. lanceolatus*, *E. merra*, *E. quoyanus* and *E. trimaculatus* (Chan, 1968; Sadovy and Cornish, 2000; To and Sadovy de Mitcheson, 2009; this study) (**Table 4.1; Plate 4.21**).

4.2.3 Mariculture

Hatchery

Epinephelus akaara hatchery was conducted experimentally by academic in the late-1970s and 1980s due to the decline of wild stocks and high demand for juveniles for grow-out (Tseng and Ho, 1979a, b, 1988). Both female and male broodstock were given HCG injections to induce spawning; females matured from April to June with the minimum size and age for sexual maturation of about 230–240 mm SL and 3 years. Males matured from March to July with size and age of about 390 mm SL, 1,000 g BW and four years (Tseng and Ho, 1979a, b, 1988). Since the 1980s, no *E. akaara* or other grouper hatcheries have been conducted in Hong Kong (this study).

In the late-1970s, *E. akaara* males and *E. amblycephalus* females were hybridized experimentally using HCG injection to induce spawning (Tseng and Poon, 1983). The reason for conducting the hybridization study was to combine the red colour from *E. akaara* and fast

growth rate from *E. amblycephalus*; both were the common grouper species in grow-out in the 1970s (Tseng and Poon, 1983).

Box 33 *Grouper hatchery in Hong Kong SAR*

There is no commercial grouper hatchery in Hong Kong, and the city has never had one (Tseng and Ho, 1988; this study). Farmers are interested in developing grouper hatchery locally because imported grouper seeds for grow-out have high mortality up to 90% (Liu and Sadovy de Mitcheson, 2008a; this study). In recent years, broodstock of *E. cyanopodus* (wild-caught juveniles imported from Taiwan for grow-out) have been kept in floating cages. Taiwan hatchery experts come to Hong Kong and induce broodstock spawning by hormone injection due to the lack of expertises locally (this study) (**Plate 4.22A**). Fertilized eggs were exported to Taiwan for larviculture in private sectors.

Grow-out

Grouper grow-out first started in Hong Kong in the late-1960s by keeping wild-caught *E. akaara* alive in floating cages for higher prices. This was the most important grouper species for grow-out in the 1970s due to its high value and demand. The estimated annual grow-out production of *E. akaara* was about 500 t in the 1970s, contributing about 70–80% of the total marine fish culture production in the same period (Tseng and Ho, 1979b, 1988; Tseng, 1983; Liu and Sadovy de Mitcheson, 2008a; FishBase: http://fishbase.org/Summary/speciesSummary.php?ID=5158&genusname) (**Table 4.12**).

Grow-out production of *E. akaara* showed a decline from the 1980s to the 1990s; today, *E. akaara* grow-out is almost none (**Table 4.12; Plate 4.22**). The decline was mainly due to the low availability of wild-caught and hatchery-produced *E. akaara* juveniles, water pollution, disease, high operation cost (e.g. high seed price, slow growth rate and long turnover), and the

growing-out of other grouper species (Tseng and Poon, 1983; Tseng and Ho, 1988; Wilson, 1997; Sadovy, 2000; Liu and Sadovy de Mitcheson, 2008a).

Mixed fish feed gave *E. akaara* a better growth rate compared to formula feed and the species prefers crustaceans compared to fish (Tseng and Ho, 1988). When water temperatures dropped below 20°C from November to March, *E. akaara* fed less; fish tolerate a wide range of salinity between 15 and 45‰, and the critical minimum water temperature was 9°C (Tseng and Ho, 1988).

Box 34 *Grouper mariculture in Hong Kong SAR*

Grouper mariculture first started in Hong Kong in the late-1960s, then spread into Taiwan, mainland China, Japan, Malaysia, the Philippines and Singapore, mainly because the strong demand for live marine fishes, the increase in the standard of living, the decline of wild stocks and the increase in fuel prices (Tseng and Ho, 1988; Chu, 1993; Yu, 1994; Wilson, 1997; Sadovy, 2000; Pomeroy et al., 2002). Although the total marine fish culture production in Hong Kong declined in the last decade, grouper grow-out is still an important component in this sector (**Table 4.12**) (Yu, 1994; Wilson, 1997; Sadovy, 2000; Liu and Sadovy de Mitcheson, 2008a; http://www.afcd.gov.hk/textonly/english/fisheries/fish_aqu/fish_aqu_mpo/fish_aqu_mpo.html). In the last decade, grouper grow-out production volume contributed 22.4–55.8% of the total marine fish culture production in Hong Kong SAR (**Table 4.12**).

Other grouper species are also grown-out in addition to *E. amblycephalus*, *E. bruneus*, *E. areolatus*, *E. awoara*, *E. bleekeri*, *E. coioides*, *E. cyanopodus*, *E. lanceolatus* and *E. malabaricus*. The seeds of these species are almost all imported, from either hatchery-production or after being wild-caught (Tseng and Poon, 1983; Tseng and Ho, 1988; Yu, 1994; Wilson, 1997; Sadovy, 2000; Liu and Sadovy de Mitcheson, 2008a;

http://www.afcd.gov.hk/textonly/english/fisheries/fish_aqu/fish_aqu_mpo/fish_aqu_mpo.html; this study) (**Plate 4.22**). Most grouper species are grown-out in floating cages and fed on mixed fish feed; *E. lanceolatus* and *E. coioides* are also grown-out in indoor recirculation tanks and ponds (Chau and Sadovy, 2005; Liu and Sadovy de Mitcheson, 2008a; this study).

4.2.4 Trade

Grown-out *E. akaara* in Hong Kong was mainly consumed locally between the 1970s and the 1990s (this study) (**Table 4.12**). Due to the high demand, *E. akaara* has been imported from mainland China such as from Zhejiang, Fujian and Guangdong Provinces since the 1970s (see **Sections 4.1.3, 4.1.4** and **4.1.5**). However, the import volumes of *E. akaara* have been little documented; 4.7 t from Xiangshan (Zhejiang) in 1989 (see **Section 4.1.3.4**) (**Table 4.5**) and 57 t *E. akaara* from mainland China in 1995 (Leung, 1997). Currently, traders in Hong Kong only import *E. akaara* after they receive orders or only import small amounts each time due to the high price of the species; *E. akaara* is mainly imported from Shenzhen by boat (this study). *Epinephelus akaara* has the highest price among *Epinephelus* grouper species in the LFFT in Hong Kong; the species is preferred because it is a symbol of fortune due to its red colour and is mainly served as fine dishes in restaurants, particularly at wedding dinners; it has good quality of flesh (Tseng and Ho, 1979a, b, 1988; Wilson, 1997; Cesar and Hempel, 2000; http://www.hk-fish.net/chi/market_price; http://www.fmo.org.hk/index/lang_tc/page_price-sea; this study) (**Table 4.14**).

Two concluding comments on *E. akaara* trade in Hong Kong can be made. First, the preferred marketable sizes were about 1,000–1,200 g BW / fish in the 1970s; however, since the 1990s, the marketable sizes have reduced to about 400–500 g BW / fish and fish mainly from wild-caught juveniles that have been grown-out. This infer over exploitation of adult wild stocks. Second, wild-caught individuals have a higher price than grown-out ones even though the latter uses wild-caught juveniles; similar pattern reported in Guangdong (**Table 4.4**)

Wild-caught juveniles of *E. akaara* were not only imported from mainland China but also from the Penghu Islands (Taiwan) for grow-out before the 1990s (Sadovy, 2000; this study) (**Figure 4.4**). Today, there are virtually no *E. akaara* seed imports for grow-out into Hong Kong (this study).

Box 35 *Grouper food trade in Hong Kong SAR*

Grouper species in trade in Hong Kong is diverse; fishes are sold fresh dead and live and both adults and juveniles are traded (**Plates 4.21** and **4.22**). In the 1960s, the main grouper species in trade were *E. akaara* and *E. awoara*; mainly from local and adjacent waters (this study). Since the 1970s, grouper species diversity in the trade has increased and now groupers are mainly from mainland China, Southeast Asian countries, Pacific Island countries and Australia (Sadovy et al., 2003).

Estimates of the volumes of live groupers in Hong Kong are available from two sources; by air and non Hong Kong-licensed vessels monitored through Census and Statistics Department (CSD), and by Hong Kong-licensed vessels monitored through AFCD under a volunteer questionnaire survey (**Table 4.15**). In the CSD data, the main import countries/areas are Australia, Indonesia, Malaysia, Maldives, Marshall Islands, the Philippines, Taiwan, Thailand and Viet Nam; in the AFCD data, the main import countries/areas are mainland China, Taiwan, Indonesia, Maldives, Malaysia, the Philippines, Nansha Islands, Shisha Islands and Taiwan. The estimated total imported grouper volumes (include CSD and AFCD) have been stable at about 5,500–8,900 t over the last decade.

Re-export of groupers were recorded by CSD, mainly to mainland China, Taiwan and Macau (**Table 4.15**). Re-export by Hong Kong licensed-vessels is not available. Wild-caught groupers, particularly *Plectropomus* species, were re-exported to mainland China by boat to Shenzhen then by air to other cities in mainland China (this study).

Grown-out groupers such as *E. lanceolatus* and *E. coioides* with juveniles mainly from Taiwan hatcheries are exported to mainland China such as Beijing, Shanghai, Guangzhou and Shenzhen; by air either directly or indirectly by boat first to Shenzhen (Liu and Sadovy de Mitcheson, 2008a; this study).

Box 36 *Grouper seed trade in Hong Kong SAR*

The reason for grouper seed import is mainly due to their limited supply from local waters and the lack of a local hatchery (Tseng and Ho, 1988; Wilson, 1997; Sadovy, 2000; Sadovy de Mitcheson and Liu, 2008a; this study). In the 1990s, grouper juveniles of *E. coioides*, *E. malabaricus*, *E. areolatus* and *E. bleekeri* were mainly imported from mainland China and the Philippines, all were wild caught. There were small proportions of hatchery-produced *E. malabaricus* juveniles imported from Taiwan and Thailand (Wilson, 1997). Today, the main grouper species imported as seed are *E. coioides*, *E. lanceolatus* and *E. bleekeri*, mainly from mainland China, Taiwan, Indonesia, Malaysia, the Philippines and Thailand (this study). Imports of grouper seeds (or fry) by air has been monitored since 1999 by value and since 2002 by both value and weight through CSD; mainly from Taiwan, Philippines and Thailand (Census and Statistics Department of Hong Kong, 2002–2007) (**Table 4.16**). The estimated total annual imports by number of grouper seeds was about 8,700,000–16,600,000 between 2002 and 2007.

4.2.5 Management

There is no management for *E. akaara* in Hong Kong SAR.

Box 37 *Management measures in Hong Kong SAR*

Destructive fishing practices such as the use of explosives, toxic substances, electricity, dredging and suction devices for the purposes of fishing are prohibited under the Fisheries Protection Ordinance Chapter 171 (http://www.afce.gov.hk/english/fisheries/fish_cap/fish_cap_fpo/fish_cap_fpo.html). Joint

efforts with the Police Force are made to enforce the regulations under the Ordinance. Offenders are prosecuted and subject to a maximum fine of about US$ 25,640 (HK$ 200,000) with six months' imprisonment upon conviction.

There are less than 1% of marine waters in Hong Kong protected. This area includes four marine parks and one marine reserve since 1996; although permits are needed to fish in marine parks, hundreds of fishers have permits. Fishing is only prohibited in the marine reserve and the core area of marine park (http://www.afcd.gov.hk/english/country/cou_vis/cou_vis_mar/cou_vis_mar_des/cou_vis_mar_des_mar.html). There are no other regulations of capture fisheries and seed fisheries locally, nor of their import or export. This makes it impossible to control overfishing of any species. Moreover, there is no existing legislation in Hong Kong to protect threatened marine fishes.

Unregulated development of marine fish culture resulted in water quality problems in the 1970s and almost every sheltered bay was occupied by floating cages. This led to the development and implementation of marine fish culture legislation, i.e. Marine Fish Culture Ordinance Chapter 353 in 1980 (http://www.hklii.org/legis/en/ord/353.txt). Since 1980, mariculturists can be only operatd their business in 26 gazetted culture zones (**Figure 4.6**).

All fresh dead marine fish (all live marine fish and fish in transhipment are not included) are required to be landed and sold at the seven wholesale fish markets operated by the FMO according to Marine Fish (Marketing) Ordinance Chapter 291 (http://www.fmo.org.hk/index/lang_en/page_fmo-fishlaw) (**Figure 4.6**). Permits are needed to transport fresh dead marine fish on land or in the waters of Hong Kong in quantities in excess of 60 kg. Any person who contravenes these two regulations commits an offence and is liable to a maximum fine of US$ 1,280 (HK$ 10,000) and imprisonment for six months.

Marine fish restocking programmes in Hong Kong waters were conducted between 2000 and 2004, with about 57,000 juveniles were released in marine parks (licensed fishing still allowed), artificial reefs and others (fishing allowed) by AFCD (http://www.afcd.gov.hk/english/fisheries/fish_cap/fish_cap_con/fish_cap_con.html). The species released were snappers (*Lutjanus* species) and groupers (*Cromileptes altivelis*, *E. coioides* and *E. lanceolatus*). All were from hatchery-produced and imported with body sizes of 50–255 mm TL. Underwater visual censuses, fishing surveys and fisherman interviews were conducted after releasing; small numbers of released fishes were observed or caught but there is no available report of this work and no indication that releases helped to restore or assist the fishery.

4.3 Taiwan Province of China (Taiwan POC or Taiwan)

4.3.1 Distribution

According to the locations of the specimens caught, *E. akaara* is confirmed to occur along the western waters of Taiwan, from Keelung in the north, to Taichung, and to Kaohsiung and Pingtung in the south, and around the off-shore islands such as Penghu Islands and Jinmen Island (Dai et al., 1988; Zhang et al., 1988; http://fishdb.sinica.edu.tw/2001new/english/english.asp) (**Figures 1.1** and **4.4**). *Epinephelus akaara* inhabits water depths of 4–30 m with body sizes ranging between 23.3 and 312 mm TL; the smallest specimen was from Penghu Islands (http://fishdb.sinica.edu.tw/2001new/english/english.asp).

4.3.2 Fisheries

Epinephelus akaara capture fisheries are little documented in Taiwan POC. The species can be caught occasionally and is sold live or fresh dead in wet markets; the peak season for capture is between April and June in Penghu Islands (this study) (**Figure 4.4; Plate 4.23**).

Box 38 *Grouper capture fisheries in Taiwan POC*

Groupers can be caught along coastal and off-shore waters of Taiwan including Penghu Islands (Taiwan Fisheries Yearbook 1993–2007; Taiwan Fishery Agency: http://www.fa.gov.tw/eng/statistics/yearbooks). The fishing gears include hook-and-line, gill net, set net, drag net, trap, pair and bottom trawlers. The estimated total annual capture volumes of groupers were about 434–4,350 t between 1993 and 2007, showing a declining trend and remaining at a low level of <500 t in recent years (**Table 4.17**). The contribution to these landings of *E. akaara* is unknown.

Box 39 *Grouper seed fisheries in Taiwan POC*

Grouper seed fisheries for grow-out purposes were first conduced in Penghu Islands in the mid-1970s; the estimated annual volumes of wild-caught grouper seeds were about 1.5–3 million (Chen, 1990; Sadovy, 2000). Due to the development of grouper grow-out in other areas of Taiwan, wild-caught grouper seeds from Penghu Islands were insufficient and therefore, grouper seeds were subsequently imported in the mid-1980s, mainly from Southeast Asian countries (Lin et al., 1988; Chen, 1990; Sadovy, 2000; Pomeroy et al., 2002; Chen et al., 2006).

The main fishing season for grouper seeds was from May to October in Taiwan POC (Lin et al., 1988; Chen, 1990; Sadovy, 2000). Fishing gears used to take grouper seeds included hook-and-line, trap, hand net, seine net, set net and sodium cyanide; advanced larvae and small juveniles were caught at around 15–30 mm TL. Sodium cyanide was first used in Penghu Islands in the 1970s then spread to other Southeast Asian countries, and set nets and seine nets took considerable by-catch and discards (Sadovy, 2000).

4.3.3 Mariculture

Hatchery

Epinephelus akaara hatchery is not conducted in Taiwan POC; the species spawns between March and May (Liao et al., 2001; Yi et al., 2005).

Box 40 *Grouper hatchery in Taiwan POC*

Grouper hatchery production in Taiwan POC first started in the late-1970s in Penghu Islands. To establish a hatchery, broodstock were first caught from the wild and reared in captivity until reaching sexual maturation; today, they are selected from hatchery-produced individuals after grow-out (Huang et al., 1986; Lin et al., 1988; Liao et al., 2001). Most grouper species in Taiwan spawn between April and August with the peak between May and July (Chu, 1993). Full-cycle mariculture (i.e. hatchery-based) has been established in two grouper species, *E. coioides* and *E. fuscoguttatus* (Cesar and Hempel, 2000; Sadovy, 2000; Pomeroy et al., 2002).

Hormone manipulation was applied for broodstock final maturation and spawning and nowadays broodstock can spawn naturally without hormone manipulation in captivity (Huang et al., 1986; Lin et al., 1988; Liao et al., 2001). Males can be obtained by 17α-MT manipulation of both juveniles and functional females (Yeh et al., 1987; Liao et al., 2001).

In the early- and mid-1980s, fertilized eggs and new-hatched larvae of groupers were mainly from hatcheries in Penghu Islands (http://www.miobuffer.com.tw/fishworld/199903/09.htm). Grouper hatchery development in Taiwan POC started in the late-1980s right after the collapse of the shrimp mariculture industry (Liao et al., 2001; Pomeroy et al., 2002; Liao, 2005; Chen and Hsu, 2006). The peak production year for hatchery-produced grouper seeds was in 1999, with more than 280 millions (advanced larvae and small juveniles of 10–30 mm TL). This was maintained around 38–65 millions (small juveniles of 50-60 mm TL) since 2001 (Taiwan Fisheries Yearbook 1993–2007; http://www.fa.gov.tw/eng/statistics/yearbooks) (**Table 4.18**).

Several reasons contributed to the grouper hatchery achievements in Taiwan POC. It was possible to obtain mass fertilized eggs through broodstock management, improve larviculture

techniques to enhance larval and juvenile survival rates and establish specialized supply chains from broodstock sources, different stages from larviculture, feed supply, and juvenile grow-out to marketing (Liao et al., 2001; Chen et al., 2006). Since 2001, there have been about 600–800 grouper hatcheries and grow-out farms, and 10 grouper broodstock farms in Taiwan POC; more than 10,000 people are directly or indirectly involved in grouper hatchery and grow-out (Pomeroy et al., 2002; Chang et al., 2008).

The main hatchery-produced grouper species are *E. coioides*, *E. malabaricus*, *E. fuscoguttatus* and *E. lanceolatus* (Liao et al., 2001). Among these, *E. coioides* is the most successful species and its hatchery can be conducted year-round. The estimated total annual seed production of *E. coioides* was about 40 million juveniles of 60 mm TL in recent years; *E. fuscoguttatus* about 20 million and *E. lanceolatus* about 5 million in recent years (Chang et al., 2008; http://www.miobuffer.com.tw/fishworld/199903/09.htm; http://ind.ntou.edu.tw/~jklu/homePAGE/web/seminar/3.pdf).

Grouper hatchery production in Taiwan POC faces challenges. First, mass mortalities during larviculture and grow-out are often caused by viral infection, such as viral nervous necrosis virus (VNNV) and iridovirus-like infection (Liao et al., 2001; Chang et al., 2008). VNNV disease occurs between April and September with the peak between June to August when water temperature is around 30–32°C (Liao et al., 2001). To date, various drugs (e.g. antibiotics) and dyes (e.g. malachite green) are used to control bacterial, fungal and viral diseases. Vaccination of broodstock and specific pathogen-free larviculture techniques from fertilized eggs, feed and water are being developed (Chang et al., 2008). Second, over-production of grouper seeds has been recorded. Grouper seeds from hatcheries were sometimes released into the sea due to over-production; for example, the recorded release of about 3 million grouper seeds of 50 mm TL (Sadovy, 2000). The effect of these on wild stocks are unknown but there is potential for disease spread into the wild and no follow up studies of released fish.

Grow-out

Epinephelus akaara grow-out was the original interest in Penghu Islands in the early-1970s using wild-caught seeds; the species was favoured because of the high quality of its flesh and tolerance to low temperature (Sadovy, 2000). However, due to its slow growth rate and the availability of other fast-growing grouper species for grow-out, *E. akaara* became less attractive (Sadovy, 2000). Grow-out production of *E. akaara* is unknown.

Box 41 *Grouper mariculture in Taiwan POC*

Grouper grow-out have developed along coastal waters of southern Taiwan, e.g. Pingtung, Kaohsiung, Ilan, Tainan and Chiayi since the 1980s (Yeh, 2000; Sadovy, 2000; Chen and Hsu, 2006; Chen et al., 2006; http://www.shs.edu.tw/works/essay/2006/10/2006101411420926.pdf) (**Figure 4.4**).

There are about 15 grouper species in grow-out operations today and the most common ones are *E. amblycephalus*, *E. coioides*, *E. fuscoguttatus*, *E. lanceolatus* and *E. malabaricus* (Chen, 1990; Yeh, 2000; Pomeroy et al., 2002; Chang et al., 2008; available at: http://ind.ntou.edu.tw/~jklu/homePAGE/web/seminar/3.pd). The estimated total annual production from grouper mariculture increased steadily since the 1990s, exceeding 17,000 t in 2007 (Chu, 1993; Taiwan Fisheries Yearbook 1993–2007; http://www.fa.gov.tw/eng/statistics/yearbooks) (**Table 4.17**). The contribution of *E. akaara* is unknown. Grouper grow-out is mainly conducted in ponds (both on land and intertidal) with some in floating cages (near coast and off-shore) (Taiwan Fisheries Yearbook 1993–2007; http://www.fa.gov.tw/eng/statistics/yearbooks). Groupers are fed on either mixed fish feed or formula feed in Taiwan POC (Chen, 1990; Chu, 1993; Yeh, 2000; Pomeroy et al., 2002). The seed and feed are the most expensive expenses in the total cost of grow-out production, about 76% (Chen et al., 2008b). Therefore, reducing feed waste and improving survival rate are the top priorities in grouper grow-out.

4.3.4 Trade

Epinephelus akaara is not a common grouper species in food trade in Taiwan POC (Yu Shyi-Liang, personal communication, April 2009). The prices are about US$ 13 / kg (the New Taiwan dollar, NT$, was pegged to the US$ at approximately 30:1) for fresh dead and at least US$ 17 / kg for live; lower than prices in Hong Kong and mainland China (**Tables 4.4** and **4.14**). Seed trade data on *E. akaara* were unknown.

Box 42 *Grouper food trade in Taiwan POC*

Groupers are mostly sold alive in Taiwan POC with body sizes of 300–400 mm TL and 500–1,000 g BW preferred (Chen, 1990). Main cities for live grouper consumption are Taipei, Taichung and Chiayi, and grouper farmers can sell groupers to retail traders and fish stall owners (Chen et al., 2006).

Live grouper export and import for food have been recorded since 1993. The estimated total annual grouper export volumes were about 26–328 t between 1993 and 2007 with < 50 t from import (Taiwan Fisheries Yearbook 1993–2007; http://www.fa.gov.tw/eng/statistics/yearbooks) (**Table 4.19**). The export volumes were < 5.5% of total grouper production (including capture fisheries and grow-out); indicating that the main consumption of groupers is domestic (**Tables 4.17** and **4.19**). The main export cities and countries are Hong Kong, Singapore, Japan and mainland China such as Shanghai, Chongqing, Chengdu, Wuhan and Xian (Chen et al., 2006; http://ind.ntou.edu.tw/~jklu/homePAGE/web/seminar/3.pdf).

Box 43 *Grouper seed trade in Taiwan POC*

Wild-caught grouper juveniles (about 30 mm TL) were about US$ 3 / seed in the mid-1980s (Chen, 1990). The prices of grouper seeds declined after the development of hatcheries; prices for hatchery-produced advanced larvae and small juveniles of 20–30 mm TL declined from US$ 1.3 / seed in the early-1990s to US$ 0.30–0.48 / seed in 1998 and for juveniles (60–80 mm

TL) declined from US$ 2–4 / seed in the late-1980s and early-1990s to US$ 0.90–1.20 / seed in 1998 (Cesar and Hempel, 2000). In recent years, hatchery-produced *E. coioides* and *E. fuscoguttatus* juveniles of 60 mm TL are about US$ 0.6–0.9 / seed and US$ 3.3 for *E. lanceolatus* (http://ind.ntou.edu.tw/~jklu/homePAGE/web/seminar/3.pdf).

Grouper seed imports first started in 1982. In the 1990s, advanced larvae and juveniles of 10–30 mm TL, almost all wild-caught, were imported from Hong Kong, Indonesia, Malaysia, the Philippines, Singapore, Sri Lanka, Thailand and Viet Nam (Sadovy, 2000; Liao et al., 2001; Taiwan Fisheries Yearbook 1993–2007; http://www.fa.gov.tw/eng/statistics/yearbooks) (**Table 4.19**). Despite high seed production from hatcheries in Taiwan POC, grouper seed import continues. This is partly because of the lower price of imported seeds compared to those of local hatchery-produced, and partly, to fill short-term shortfalls due to the seasonal variation in hatchery production, such as between January and March (Sadovy, 2000).

Taiwan POC started grouper seed export in 1996; grouper fertilized eggs and hatchery-produced larvae and juveniles were mainly exported to Hong Kong, mainland China such as Hainan, Fujian and Guangdong Provinces), Indonesia, Malaysia, the Philippines and Viet Nam, and maintained at about 33–81 t in recent years (Sadovy, 2000; Pomeroy et al., 2002; Taiwan Fisheries Yearbook 1993–2007; this study; http://www.fa.gov.tw/eng/statistics/yearbooks; http://ind.ntou.edu.tw/~jklu/homePAGE/web/seminar/3.pdf) (**Table 4.18**). In recent years, there were about 2 million hatchery-produced *E. coioides* juveniles exported to Hong Kong, Indonesia, Malaysia, the Philippines and Viet Nam annually; 15 million *E. fuscoguttatus* to Malaysia and Viet Nam, and about 800,000 juveniles of *E. lanceolatus* to mainland China, Hong Kong, Viet Nam and Malaysia (http://ind.ntou.edu.tw/~jklu/homePAGE/web/seminar/3.pdf).

4.3.5 Management

There is no management for *E. akaara* in Taiwan POC.

Box 44 *Management measures in Taiwan POC*

In the Fisheries Act amended on December 2002, toxic substances including cyanide, explosives or other dynamites, and electricity or other narcotics are prohibited from use in catching aquatic organisms (http://www.fa.gov.tw/eng/laws/fshacte.php). In the Penghu Islands, fishers are not permitted to catch any grouper seeds < 60 mm TL (Sadovy, 2000).

There are concerns of *E. lanceolatus* seed trade in Taiwan POC. For example, more than 40,000 hatchery-produced *E. lanceolatus* juveniles were confiscated by Taiwan Customs when they were smuggled to mainland China in 2007 by boat (http://www.epochtimes.com/b5/7/8/8/n1795915.htm). Concerns included the spread of *E. lanceolatus* hatchery techniques into mainland China and re-export to Taiwan at cheaper prices after grow out to marketable size from mainland China; this will affect the livelihoods of Taiwan fishers (http://www.epochtimes.com/b5/7/8/8/n1795915.htm).

4.4 Japan

4.4.1 Distribution

Epinephelus akaara occurs in southern Japan, from Kyushu in the south up to Shikoku, and to about 38° N on both coasts of Honshu; it does not occur in Okinawa (Heemstra and Randall, 1993) (**Figures 1.1** and **4.7**). It is commonly found in Seto Inland Sea and also known to occur north up to Aomori (i.e. around 40° N) (Yokogawa, 1997; Bentley, 1999; Tamaki, 2000; Kobayashi, 2004; Y. Obata, personal communication, 2009).

Epinephelus akaara is commonly found on rocky reefs; small juveniles of 70–80 mm TL live in shallow waters around 5 m deep and large fish of 200–500 mm TL move to deep water of 15–20 m (Tamaki, 2000). In Seto Inland Sea, body sizes of captured *E. akaara* were around

110–325 mm TL and 85– 495 g BW, i.e. both juvenile and adult phases (Yokogawa, 1997; Kayano, 2001).

4.4.2 Fisheries

Epinephelus akaara capture is a seasonal fishery and the landings have shown a decline over time (Maruyama et al., 1994; Abe and Honma, 1997). In Okayama, the estimated annual landings of *E. akaara* were about 8–18.5 t in the 1950s and 1960s and declined to 1–3 t in the 1990s, i.e. a decline of 62–95% in three decades (Okumura et al., 2002). In Shimane, *E. akaara* can be caught year-round with most catches between June and September (around the spawning season between July and September), contributing to about 60–80% of total annual catch of the species (Shimane Prefecture: http://www.pref.shimane.lg.jp/industry/suisan/shinkou/umi_sakana/sakana/2/2-15.html). The total catch volume of *E. akaara* in Shimane in 2000 was 3 t; 2 t from hook-and-line and 1 t from gill net and trawler. The fishing gears for *E. akaara* are gill nets, small trawlers and hook-and-line (Abe and Honma, 1997; Yokogawa, 1997; Lee et al., 2002; this study; http://www.pref.shimane.lg.jp/industry/suisan/shinkou/umi_sakana/sakana/2/2-15.html).

Box 45 *Grouper capture fisheries in Japan*

Grouper capture production in Japan is only known from Okinawa (**Figure 1.1**); the estimated annual capture production of groupers and basslets (Family Serranidae) were around 480–1,000 t in 1974–1994, showing a consistent decline since 1988 (Okinawa Statistical Yearbook of Agriculture, Forestry and Fishery, 1974-1994).

4.4.3 Mariculture

Hatchery

Epinephelus akaara hatchery in Japan first started in the 1960s and developed quickly in the late-1980s mainly because of finding smaller live zooplankton (i.e. smaller rotifer strain) for

larval first feed (Ukawa et al., 1966; Maruyama et al., 1994; this study). The estimated total annual numbers of hatchery-produced *E. akaara* advanced larvae and juveniles (22–53 mm TL) in Japan were about 10,000–480,000 since the 1980s; all used for restocking instead of grow-out (Kayano et al., 1993; Maruyama et al., 1994; Wang, 1997; this study) (**Table 4.20**; **Plate 4.23**). The viral disease outbreak in the early- and mid-1990s led to a dramatic decline in *E. akaara* seed production in some hatcheries; the number of hatchery-produced juveniles increased in recent years after the control and prevention of the virus (Maruyama et al., 1994; this study; Y. Obata, personal communication).

In Seto Inland Sea, *E. akaara* spawns between July and September (Shimane Prefecture: http://www.pref.okayama.jp/soshiki/detail.html?lif_id=31275). Broodstock of *E. akaara* used in hatcheries were usually wild-caught, maintained in captivity and fed on mixed fish feed or formula pellets; mature fish could spawn naturally (Ukawa et al., 1966; Fukuhara, 1989; Kayano and Oda, 1994; Maruyama et al., 1994; this study; Y. Obata, personal communication). In captivity, *E. akaara* spawns from May to September at water temperatures of 20–27 °C; fish reached first sexual maturation at two years or earlier in captivity, while wild stocks mature at three years old (Ukawa et al., 1966; Zhang et al., 1988; Fukuhara, 1989; Tanaka et al., 1990; Kayano and Oda, 1994; Maruyama et al., 1994). A female of 690 g BW spawned 2.5 million eggs in a spawning season (Maruyama et al., 1994).

Box 46 *Grouper hatchery in Japan*

Hatcheries of *E. bruneus* (= *E. moara*), *E. coioides*, *E. fasciatus*, *E. malabaricus* (= *E. salmonoides*), *E. polyphekadion* (= *E. microdon*), *E. septemfasciatus* and *Plectropomus leopardus* have been conducted in Japan (Fukuhara, 1989; Soyano et al., 2008). However, there is little information on seed numbers produced.

Grow-out

There are some studies on *E. akaara* juvenile growth in captivity. Juveniles of 3 months old were about 81 mm TL and 9.6 g BW, reached to 145 mm TL at one year old, to 217 mm TL at two, to 293 mm TL at three, 318m mm TL at four and 335 mm TL at five; similar to its wild stocks (Kayano and Oda, 1994). No *E. akaara* grow-out for food has been recorded in Japan.

4.4.4 Trade

Epinephelus akaara is a highly-valued fish species for food (Okumura et al., 2004). The prices were between US$ 25−85 / kg since the 1990s, higher than for red sea bream *Pagrus major* (Sparidae) (about US$ 11.5−12 / kg) and bastard halibut *Paralichthys olivaceus* (Paralichthyidae) (about US$ 22−22.5 / kg); note that the Japanese Yen was exchanged to the US$ at approximately 103:1 (this study).

In 1993, about 4,400 *E. akaara* individuals, wild-caught from Ch'ungmu (South Korea), were imported for release purposea (Yokogawa, 1997) (**Figure 4.7**). Subsequent studies on population genetics and external morphology revealed significant differences at population and morphology levels from the two countries, which may be due to the barriers of the Korean Strait and Japan Sea (Yokogawa, 1997). No more importation of *E. akaara* juveniles has been reported since then.

Box 47 *Grouper seed trade in Japan*

Although some groupers can be hatchery-produced in Japan, grouper grow-out depends almost entirely on imported wild-caught seeds (Fukuhara, 1989; Wakabayashi, 1996; Soyano et al., 2008). For example, wild-caught grouper seeds of *E. septemfasciatus* and *E. octofasciatus* were imported from South Korea, Hong Kong, Indonesia and the Philippines for grow-out (Nakai, 1996; Wakabayashi, 1996).

4.4.5 Management

Restocking of hatchery-produced *E. akaara* juveniles has been mainly conducted in the Seto Inland Sea to enhance natural resources of the species (**Figure 4.7**). In Okayama, *E. akaara* restocking was conducted annually between 1991 and 1997, resulting in 54,400 hatchery-produced juveniles being released in the Seto Inland Sea; most (>95%) were less than one year old and around 51–81 mm TL, and the rest more than one year old and around 136–440 mm TL (Kayano et al., 1998). In 1998, a total of 53,000, hatchery-produced, *E. akaara* juveniles were released in Japan (Okumura et al., 2002). Restocking has continued and a few hundreds or thousands of *E. akaara* juveniles have been released in the Seto Inland Sea annually depending on the availability of hatchery-produced juveniles since 1998 with body sizes of 78–120 mm TL and 9–20 g BW (Kayano et al., 2001; Okumura et al., 2003; Y. Obata, personal communication).

Since the mid-1990s, studies have focused on releasing hatchery-produced *E. akaara* juveniles onto artificial reefs for improving retention and survival rate; all conducted in Seto Inland Sea (Kayano et al., 1998, 2001; Okumura et al., 2004). Although releasing juveniles older than one year *E. akaara* have shown higher retention rates in artificial reefs, most released juveniles were less than one year old and about 51–100 mm TL in practices due to the high risk and cost of keeping juveniles longer in captivity. The artificial reefs have shown promising results; up to 20% retention rate in the artificial reefs where *E. akaara* juveniles released 5 months (Okumura et al., 2004). However, restocking has not led to the population recovery despite considerable effort and money provided for this activity in the Seto Inland Sea.

Box 48 *Management measures in Japan*

The principal law regulating fishery activities is the Fisheries Law for fishing rights and licenses (http://www.fao.org/fishery/legalframework/nalo_japan). Japan has a long tradition of coastal community based fisheries management to ensure sustainable fisheries (Schmidt, 2003). Coastal fisheries management includes input and output controls, such as the total allowance

efforts (TAEs), closures of area and season, fishing gear control, mesh size restriction, and total allowable catches (TACs) (Yagi, 2002). Fish seed (including eggs, larvae and juveniles) import is not managed; the only exception is the import of eyed eggs of salmonids fish from USA and Canada that require an inspection report from the export country authority (Wakabayashi, 1996).

4.5 South Korea

In this study, field surveys (two mariculture farms and four hatcheries) and interviews (one fishery officer, three marine biologists and one fish trader) were conducted in December 2009 in Jeju Island, South Korea.

4.5.1 Distribution

Epinephelus akaara is distributed along the southern (e.g. Ch'ungmu and Gwangyang) and southwestern coastal waters of South Korea, and around Jeju (Cheju) Island (Heemstra and Randall, 1993; Lee and Kim, 1996; Yokogawa, 1997; Hwang et al., 1998; Kim et al., 2001; Lee et al., 2008; S.R. Oh, personal communication) (**Figures 1.1** and **4.7**). Both adults and juveniles with body sizes of 190–465 mm TL and 95–1,020 g inhabit rocky reefs at water depths of 5–60 m (Lee et al., 1997; Yokogawa, 1997; Hwang et al., 1998; Kim et al., 2001).

4.5.2 Fisheries

There are no official fishery data on *E. akaara* and/or on any other groupers in South Korea. In Jeju Island (**Figure 4.7**), based on interviews, a decline in capture production for *E. akaara* was recorded in the 1980s and there has never been any apparent recovery (this study). The estimated capture production in recent years in Jeju is very low, about 100 kg annually (S.R. Oh, personal communication). Based on the common capture size for *E. akaara* (about 500 g / fish) in Jeju, the estimated annual capture number for *E. akaara* is about 200 individuals in Jeju (this study). The only fish trader interviewed reported fewer than 10 *E. akaara* individuals

traded each month in recent years, inclusive of fish collected around the entire island (this study). The main capture season for *E. akaara* is between May and August, using long-line and gill net (this study).

Box 49 *Grouper fisheries in South Korea*

The grouper species commonly caught in Jeju Island are *E. bruneus* and *E. septemfasciatus*, with lower catches of *E. akaara*, *E. awoara*, *E. chlorostigma* and *E. fasciatus* (**Plate 4.24**) (this study). Capture production of groupers has shown a decline, in particular for *E. bruneus* (Song et al., 2005); however, there are no official statistics data available. In recent years, the estimated annual capture production for *E. bruneus* is about 3–5 t in Jeju (S.R. Oh, personal communication). The main capture season for groupers is between May and December, using long-line and gill net (this study). *Epinephelus bruneus* can be caught at water depths of 30–100 m, with small juveniles at water depths of 10 m (S.R. Oh, personal communication).

4.5.3 Mariculture

Hatchery

Epinephelus akaara has been one of the most heavily promoted grouper species for hatchery and grow-out since the mid-1990s in South Korea because of its high value (Lee et al., 1997, 2008). However, juvenile production from hatchery has been small and unstable and insufficient for commercial-scale grow-out (**Plate 4.25**) (this study). The challenges faced by *E. akaara* hatchery production are the mass mortality caused by failure to adapt to the initial food, VNNV infection and deformity (Lee et al., 2008).

Epinephelus akaara broodstock are wild-caught. In captivity, the gonadosomatic index (GSI%) for females began to increase from February and reached a peak in August with vitellogenic stage oocytes (Hwang et al., 1998). Natural spawning in captivity occurred almost daily from mid-July to mid-August when water temperatures were around 23–28°C; a female of about

1,000 g BW released 380,000 eggs in a spawning season (Lee et al., 1997). Androgen (17α-MT) manipulation is applied to obtain sex-changed males (Hwang et al., 1998; Lee et al., 2008). However, hormone manipulation follow by artificial fertilization is still the only method applied in hatchery production practices to ensure that large amount of eggs can be obtained in short periods for larviculture (Y.D. Lee, personal communication). Hatchery-produced juveniles have been kept in captivity for years (about four years after hatched) for use as broodstock in the near future (**Plate 4.25**) (this study).

Box 50 *Grouper hatchery in South Korea*

Other groupers such as *Epinephelus bruneus*, *E. septemfasciatus* and *E. fasciatus* are also of interest for hatchery and grow-out development in South Korea, particularly in Jeju Island (Lee et al., 2008; Y.D. Lee, personal communication) (**Plate 4.26**). In recent years, juveniles of *E. bruneus* and *E. septemfasciatus* can be produced from hatchery; however, juvenile production has been small and unstable and insufficient for commercial-scale grow-out (this study). Grouper broodstock are wild-caught. Hatchery production involves broodstock management and sexual maturation through 17α-MT manipulation for obtaining males and HCG manipulation for spawning, cryopreservation of sperm and larviculture techniques (Lee and Kim, 1996; Lee et al., 1996, 2008; Song et al., 2005). Hatchery production of *E. bruneus* and *E. septemfasciatus* faces the same challenges as for *E. akaara* (Lee et al., 2008). Hatchery-produced juveniles of *E. bruneus* and *E. septemfasciatus* have also been kept in captivity for use as broodstock in future (this study).

Box 51 *Ornamental marine fish hatchery in South Korea*

Hatchery-production of anemonefish *Amphiprion* species for the ornamental fish trade in South Korea, particularly in Jeju Island, is conducted at a commercial-scale (**Plate 4.27**). Markets are mainly domestic and exports to Japan and USA are also recorded (this study). Full life-cycle hatchery from anemonefish has been achieved. Hatcheries of seahorse *Hippocampus* are

conducted on an experimental scale. Broodstock are either caught from local waters or imported from SE countries.

Grow-out

Commercial grow-out of groupers (including *E. akaara*, *E. bruneus* and *E. septemfasciatus*) has never been conducted in South Korea. Growth performance of *E. akaara* juveniles (ranged 178–203 g BW and 243–254 mm TL) was studied in floating cages (Moon et al., 1997). The results showed that the best growth was obtained when water temperatures were above 20°C with feeding frequency of twice a day or once a day. Indoor re-circulation systems are the only option in South Korea for grouper mariculture development in future due to the low seawater temperatures in winter (this study).

Box 52 *Marine fish culture in South Korea*

The common marine fish culture species in South Korea are the Bastard halibut *Paralichthys olivaceus*, the red seabream *Pagrus major* and the Japanese pufferfish *Fugu rubripes*; all juveniles for grow-out are hatchery-produced (**Plate 4.28**). Jeju Island is the most important marine fish culture area in South Korea, contributing to about 50% of the total national marine fish culture production in recent years (Y.J. Park, personal communication). The most important marine fish culture species in Jeju is *P. olivaceus*; about 24,000 t in 2008, contributing to about 97% of the total marine fish culture production in Jeju and to about 50% of the total national production for the same species (Y.J. Park, personal communication). All marine fish culture operations are conducted in indoor re-circulation systems (**Plate 4.28**). Commercial feeds are the only food source for marine fish during grow-out.

4.5.4 Trade

All *E. akaara* in food fish trade in South Korea are wild-caught because there are no commercial grouper mariculture operations in the country (this study). *Epinephelus akaara* is a

highly-valued marine food fish in South Korea (Lee et al., 1997, 2008); it is one of the most expensive food fishes; the price at port is about US$ 100–140 / kg and restaurant price about US$ 220 / kg in Jeju (S.W. Hur, personal communication).

Export of *E. akaara* was only reported in 1993; about 4,400 wild-caught *E. akaara* juveniles from Ch'ungmu were exported to Japan (Yokogawa, 1997).

Box 53 *Marine food fish trade in South Korea*

Groupers are the most expensive food fishes in South Korea and commonly found in the live food fish trade (this study) (**Plate 4.24**). Like the high retail prices for *E. akaara* given above, the restaurant prices for *E. bruneus* and *E. septemfasciatus* are about US$ 200 / kg in Jeju with *P. olivaceus* about US$ 70 / kg (S.W. Hur, personal communication). Marine fishes are either sold alive or fresh dead in Jeju Island (this study) (**Plate 4.29**).

Marine fish export such as *P. olivaceus* and *F. rubripes* from mariculture has been reported; the main countries are Japan and USA (S.W. Hur and Y.J. Park, personal communications; this study).

4.5.5 Management

There is no management for *E. akaara* fisheries, mariculture and trade in South Korea.

Box 54 *Management measures in South Korea*

Various fisheries management measures have been carried out in South Korea since the 1950s; however, none have focused on groupers specifically. Fishery input controls include various limitations such as fishing gear, vessel and mesh size, season and area closure and capture size (Food and Agriculture Organization of the United Nations, FAO: http://www.fao.org/fi/fcp/en/KOR/body.htm). Fishery output controls have focused on the TACs since 1998 (Schmidt, 2003; Ryu et al., 2006). By 2004, TACs had been set for nine

marine species including pelagic fishes, crustaceans and molluscs (Ryu et al., 2006) but no demersal species, such as groupers, are included. The importance of import and export controls of live fish and the quarantine of aquatic organisms imported with indication of country of origin have been addressed but not yet implemented (http://www.fao.org/fishery/legalframework/nal_korea).

5. Discussion

The aim of this study was to take first ever detailed look at various practices from capture and seed fisheries, hatchery, grow-out, food and seed trade, to management measures, of the threatened *E. akaara* throughout its geographic region. This study has provided an understanding of the current status of the wild stocks and problems encountered by the species, at both small and large spatial scales, and enabling the identification of actions that need to be taken actions to attain its sustainable use and, thereby, ensure both biological and economic benefits.

5.1 Distribution, abundance and population structure

The geographic region of *E. akaara* was re-evaluated in this study. The species, most likely, does not occur in the Gulf of Tongking and all specimens in Taiwan were only caught from western waters, inferring its absence from eastern waters (**Figure 1.1**). Therefore, the region of *E. akaara* is smaller than previously thought.

Based on the historic capture volumes for *E. akaara*, the species has the highest abundance in China. Nanji Islands, Mazu Island, Penghu Islands and Taiwan Bank Fishing Grounds, all off-shore, are the few remaining fishing grounds still with considerable captures of *E. akaara*. These fishing grounds should be the first priorities for conducting underwater surveys and other studies to understand juvenile settlement patterns, determine adult population density and

identify habitat association. These data are very useful to set capture quotas, consider spatial protection, and establish a sustainable development plan.

Understanding the population structure of a fish species can provide a scientific basis for establishing management and conservation at appropriate spatial scales. Throughout the geographic region of *E. akaara*, population genetics sub-structuring has been studied. For example, a molecular analysis revealed significant differences between populations in Japan and South Korea; however, detailed results are not available (Yokogawa, 1997). In another study from mainland China, mitochondrial DNA variations in *E. akaara* from different sites, Zhejiang (Zhoushan), Fujian (Pingtan and Xiamen) and Guangdong (Shantou and Zhanjiang), were not detected using DNA sequence data from the 5' end of the control region (Chen et al., 2008a). To understand the population structure of *E. akaara*, further studies should focus on the genealogy among populations from Zhejiang, Fujian and Guangdong by using more sensitive techniques such as microsatellite loci analysis. Studies can look at a larger scale such as comparing the population differences throughout the whole geographic distribution region (i.e. China, Japan and South Korea) to understand the connectivity of the species.

5.2 Fisheries and trade

Epinephelus akaara was listed as the threatened category 'EN' in the IUCN Red List due to its estimated declines of 50-90% in capture volumes in several areas of Japan and because of notable depletions of wild stocks in Hong Kong SAR and mainland China (Cornish, 2003). However, it was recognised that more information was needed and this study provides the necessary information to confirm this listing throughout the range of this species. As an endangered species, there is a need to have closer monitoring and regular assessment to understand status and trends in its wild stocks, and to be able to respond in a timely fashion to manage it for long term benefits while ensuring sufficient spawning biomass for population persistent.

This study provides strong evidence to confirm severe depletions in *E. akaara* wild stocks in China and support the global 'EN' listing in the IUCN Red List. Quantitative evidence includes declines in capture and seed fisheries volumes and in CPUE for *E. akaara*. For example, estimated declines in *E. akaara* catches were about 63% in northern Zhejiang and 94% in southern Zhejiang between 1985 and 1994; today, *E. akaara* capture is no longer significant in Zhejiang. The decline in CPUE for *E. akaara* was > 90% in less than one decade in Zhejiang where *E. akaara* is no longer a targeted species. In Guangdong, grow-out scales for *E. akaara* declined largely due to low wild-caught seed volumes. For example, in Yaoping, the estimated seed volumes for *E. akaara* grow-out declined by 92% since the 1980s. In Huizhou, the decline was more severe and *E. akaara* grow-out is no longer significant. The same trend was recorded in Hong Kong; *E. akaara* grow-out has not been significant since the 1990s mainly due to the unavailability of wild-caught seed, either locally or imported (Liu and Sadovy de Mitcheson, 2008a; this study). Other evidence such as shift of fishing grounds for *E. akaara*, shift of grouper fishers and traders to become farmers because of decline in *E. akaara*, the change from *E. akaara* to other species grow-out and the reduction in age group and sizes of wild *E. akaara* stocks also indicated depletions in *E. akaara* throughout China.

Trends in capture volumes over time are an important criterion for species red listing assessment (IUCN, 2001). However, obtaining capture data for *E. akaara* (as for many groupers) is a particular challenge due to incomplete or unavailable statistics datasets from official departments, or lack of academic studies throughout its geographic region. The lack of capture data for *E. akaara* limits the evaluation of the current status of wild stocks and the identification specific problems that would assist in formulating appropriate solutions.

In this study, for the first time, trade data for *E. akaara* were collected. Eestimated trade volumes for *E. akaara* declined by 60–95% over the last three decades throughout the coastal waters of Fujian. Nonetheless, market demand, and hence fishing pressure, on the species

remains high. Of particular importance, wild-caught marketable-sized *E. akaara* fetches higher prices than those from grow-out of wild-caught juveniles (**Tables 4.4** and **4.14**), a reflection of the rarity of *E. akaara* wild stocks, since increased rarity tends to bring higher prices for highly valued goods.

5.3 Mariculture

Mariculture was commonly considered to be the measure to maintain and/or increase total fisheries production after capture fisheries collapsed for many commercially important species. Specifically, grouper mariculture is considered to contribute to the protection and sustainable use of grouper wild stocks, to create jobs and incomes for coastal populations and to bring foreign exchange (Cesar and Hempel, 2000). Today, groupers are the most diverse fish group in the marine fish culture sector in mainland China, Hong Kong and Taiwan, which, in addition to *E. akaara*, includes *E. awoara*, *E. bleekeri*, *E. bruneus*, *E. coioides*, *E. fuscoguttatus*, *E. lanceolatus*, *E. malabaricus*, *E. tauvina* and *E. tukula* (Liao et al., 2001; Chang et al., 2008; Chen et al., 2008b; Liu and Sadovy de Mitcheson, 2008a).

However, with the rapid development of mariculture based on wild stocks (i.e. grow-out of wild-caught juveniles) of *E. akaara*, lack of management of either grouper fisheries or mariculture practices, and inability of restocking to recover wild stocks, two major concerns have arisen. First, even *E. akaara* seed can be hatchery-produced, grow-out continues to rely only on wild-caught juveniles and sub-adults. This increased fishing pressure on wild stocks, which formerly focused on the adults. Today, adults (e.g. > 1500 g BW / fish) are seldom caught from the wild and even the capture of juveniles has shown massive declines; this is a clear sign of serious growth and recruitment overfishing and severely reduces the value of this species for livelihoods and the economy. Due to the high value of *E. akaara* in the LFFT, its capture fisheries for food and seed fisheries for grow-out persist, even as the wild stocks decline, as in Zhoushan and Nanji (Zhejiang), Xiapu, Pingtan and Dongshan (Fujian), and

Yaoping (Guangdong). The high value will mean the even when fish numbers are extremely low, fishing will continue, further threatening the species. It is critical to reduce grow-out for *E. akaara* until the species can be hatchery-produced in mass production, or until wild stocks are appropriated managed.

Second, cultured marine fishes in mainland China and Hong Kong that are carnivorous are largely fed with mixed fish feed. For broodstock condition, better quality feed is needed to good quality of eggs and the use of mixed fish is an additional and heavy pressure on wild stocks. Given the mariculture production of groupers in mainland China (36,600 t) in 2007, the estimated volume of mixed fish feed used for grouper grow-out was about 292,800 t, based on the FCR of 8. Grouper mariculture can be only sustainable is the seed are sustainably produced and sustainably maintained (Sadovy de Mitcheson and Liu, 2008a).

Although *E. akaara* seed from hatchery has been produced annually in Japan since the 1980s, it has not been fully developed (T**able 4.20**); the hatchery techniques have not been fully established in mainland China, Hong Kong, Taiwan or South Korea. Hatcheries of *E. akaara* in mainland China and South Korea continue to face challenge partly because there is no research focusing on understanding reproductive biology and feeding ecology in the wild. Such information could greatly help to improve the condition of the broodstock in captivity, the quality of eggs they produced and survival rate during larviculture. There is a clear need to conduct fundamentally biological studies on *E. akaara*. For restocking, information would be needed on the best times, places and sizes for restocking and to tag fish to evaluate whether restocking is worth the time and energy investment involved (Bell et al., 2008).

5.4 Management

To date, there is no management for *E. akaara* fisheries, mariculture and trade throughout its geographic region. In mainland China, although a fishing moratorium on trawling has been

applied since 1995 and 1999 in the East and South China Seas, respectively, this is unlikely to protect *E. akaara* wild stocks because fishing gears such as hook-and-line, gill-net and trap are still permitted and these are the main gears to catch *E. akaara*, are still allowed to operate.

Restocking, as one of the fishery management tools, has been conducted widely to boost overfished wild stocks and much money and effort expended to this end. *Epinephelus akaara* restocking programmes have been conducted in mainland China and Japan for about two decades. In mainland China, the programmes showed little success because released juveniles did not survive well in the wild (see **Section 4.1.3.5**). In Japan, considerable studies have been conducted to improve juvenile survival rates after release in the Seto Inland Sea (see **Section 4.4.5**). After more than two decades, however, there is still no evidence of wild stock recovery. Today, the activity of restocking is being widely discussed internationally and there are many doubts and concerns over its actual contribution to depleted capture fisheries, or to ecosystem or economy. In mainland China, even large-scale and long-term marine restocking programmes did not show promising results for some marine fishes; restocking is often practiced in an *ad hoc* without sufficient understanding of the study species and is typically conducted without solving the original and root causes for declines; practiced in this way, it is destined fail and waste much money and effort (Liu and Sadovy de Mitcheson, 2008b).

Since the fishing moratorium and restocking cannot contribute to rebuild overfished wild stocks of *E. akaara*, other management tools need to be considered. Establishing marine protected areas (MPAs) can be one of the options. From this study, the last remaining important fishing grounds for *E. akaara* have been identified as Nanji Islands, Mazu Island, Penghu Islands and Taiwan Bank Fishing Grounds. These grounds could be a first priority for establishing MPAs for *E. akaara*. Therefore, studies on adult population density and mating behaviour, juvenile settlement pattern and adult and juvenile habitat preferences in these grounds should be conducted urgently. In addition, a fishery management plan needs to be developed to establish a

sustainable quota and reduce fishing effort on the species to ensure its long term viability and sufficient spawning biomass.

6. Recommendations

Epinephelus akaara was of high commercial importance between the 1960s and 1990s and is still a highly-priced and well-favoured marine food fish throughout its geographic region. Despite the fact that hatchery production has been possible for *E. akaara* for more than four decades, wild-caught juveniles are still the only source for mariculture operations. When exploitation of both *E. akaara* adults and juveniles continues, populations everywhere have exhibited marked declines with no recovery despite restocking programmes. Therefore, management measures must be introduced to ensure their sustainable uses into the long term. Based on this study, six specific recommendations are proposed to address many of the shortcomings identified by this study:

First, research on population genetics structure throughout the geographic region of *E. akaara* is needed in order to provide a scientific basis for establishing management and conservation at appropriate spatial scales. Microsatellite loci analysis, with its high degree of polymorphism and high mutation rate, is suggested to apply as an appropriate tool.

Second, sustainable use of *E. akaara* wild stocks needs to be achieved. To move towards this goal, data collection on capture volumes of the species, both adults and juveniles, should be conducted regularly at specific fishing grounds to assist sustainable management planning. Since restocking and mariculture do not solve the problem of overfishing in this species, conventional management is needed to ensure that wild stocks persist into the future.

Third, juvenile settlement pattern and adult density assessment of *E. akaara* should be a matter of research priority. These data will help capture quota setting and MPA design as well as

improve the chances of survival of released fish in restocking. Considering the current capture volumes for *E. akaara*, Nanji Islands, Mazu Island, Penghu Islands and Taiwan Bank Fishing Grounds are ideal sites to conduct relevant field surveys.

Forth, research on *E. akaara* mariculture should focus on persistent problems, such as reducing the reliance on mixed fish feed, preventing diseases, enhancing survival rates in larviculture and improving broodstock productivity. These should also be central objectives in grouper mariculture in general.

Fifth, *E. akaara* is a highly-valued seafood with limited supply from the wild and from limited regions and areas. Trade monitoring, such as proper marketing and bio-coding, are proposed.

Sixth, legislation is needed in Hong Kong to protect any marine species of fish that is considered to be threatened.

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8. Appendices

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Appendix II. Questionnaires

Questionnaire for *Epinephelus akaara* survey – for grouper fishers 紅斑問卷调查 (漁民)

Date 日期:	Name of interviewee 受訪者名字:
Age group 年齡組別 (>60, 60-51, 50-41, 40-31, <30):	
How long in the business? Why/How? 從事這行多久? 为何/如何入行?	Address/Location 地址/地點:
Any other business support 有无其他經濟收入?	
Fishing site and how many fishermen fishing there? How do you know the site? 捕撈海域? 多少漁民到此捕鱼? 如何知道那兒?	
Do you have to travel further or spend longer at sea fishing? If yes, why? 會否到較遠海域捕鱼或延長捕鱼時間? 如是, 爲什麼?	
Fishing gear/vessel? Any change by year? If yes, why? 漁具/漁船? 有否隨年份而改變? 如是, 爲什麼?	
Any IUU in fishing site 捕撈地點有无非法的捕撈方式?	
Do you need license/permit for catch *E. akaara* or other fish 捕撈紅斑或其他魚類需要牌照?	
All catch species? Any change by year? If yes, why? 所有捕獲品種?有无隨年份而改變? 如是, 爲什麼?	
Total catch volume? Any change by year? If yes, why? 總捕撈數量?有无隨年份而改變? 如是, 爲什麼?	
Catch volume of *E. akaara*? Any change by year? If yes, why? 捕撈紅斑的數量?有无隨年份而改變? 如是, 爲什麼?	
Catch site of *E. akaara*? Any change by month or year? If yes, why? 捕撈紅斑的地點?有无隨月份及年份而改變? 如是, 爲什麼?	
Catch season of *E. akaara*? Any change by month or year? If yes, why? 捕撈紅斑的季節?有无隨月份及年份而改變? 如是, 爲什麼?	
Any mature *E. akaara* caught? Where/When? 有无捕撈成熟的紅斑? 地點及月份?	
Mortality of *E. akaara* after catch? Reason/Solution? 捕撈后紅斑死亡率?原因/解決辦法?	
Price of *E. akaara*? Any change by years/size/season? If yes, why? 紅斑的價錢? 有无隨年份/大小/季節而改變? 如是, 爲什麼?	
Who/where do you sell to? Any change by year? If no, why? 銷售給誰/哪兒?有无隨年份而变化? 如是, 爲什麼?	
Do you catch *E. akaara* on an order basis or can you sell all you caught 捕撈紅斑的數量是根據訂購的數目, 還是捕撈多少, 銷售多少?	
Any preferred size from mariculturists and traders? Any change by year? If yes, why? 养殖户和商人有无特選的紅斑大小? 有无隨年份改變? 如是, 爲什麼?	
Any monitor? Legislation? Enforcement? 任何監管? 立法? 執行?	
What do you expect grouper fishery in the next 5-10 years 請預計未來 5-10 年石斑鱼捕撈的情況?	
Do you have any questions for me 有沒有問題想知道?	

Questionnaire for *Epinephelus akaara* survey – for grouper mariculturists 紅斑問卷调查 (养殖户)

Date 日期:	Name of interviewee 受訪者名字:
Age group 年齡組別 (>60, 60-51, 50-41, 40-31, <30):	
How long in the business? Why/How? 從事這行多久? 为何/如何入行?	Address/Location 地址/地點:
Any other business support 有无其他經濟收入?	
Mariculture site? How did you choose the site? Any site change by year? If yes, why? 养殖区? 如何选点? 有无养殖区变化? 如是, 爲什麼?	
Mariculture scale (numbers of mariculturists and cages)? Any change by year? If yes, why? 养殖规模(养殖户人数及网箱数)? 有无隨年份而变化? 如是, 爲什麼?	
Mariculture species in your cages and the proportion of *E. akaara*? Any change by year? If yes, why? 养殖品种及紅斑的比例? 有无隨年份而变化? 如是, 爲什麼?	
Type of fish feed and price? Any change by year? If yes, why? 鱼饵及价格? 有无隨年份而变化? 如是, 爲什麼?	
Price and size of wild-caught *E. akaara* juveniles for mariculture? Any change by year? If yes, why? 野生紅斑鱼苗价格及大小? 有无隨年份而变化? 如是, 爲什麼?	
Price and size of hatched *E. akaara* juveniles for mariculture? Any change by year? If yes, why? 人工培育紅斑鱼苗价格及大小? 有无隨年份而变化? 如是, 爲什麼?	
Which type of *E. akaara* juveniles, either wild-caught or hatched, and size you prefer for mariculture? 喜好野生或人工培育紅斑鱼苗,及鱼苗大小?	
What is your stock season for *E. akaara* mariculture? Any change by year? If yes, why? 紅斑鱼苗放养季节? 有无隨年份而变化? 如是, 爲什麼?	
Can you buy enough *E. akaara* juveniles for mariculture? Any change by year? If yes, why? 能不能买到足够的紅斑鱼苗? 有无隨年份而变化? 如是, 爲什麼?	
Mortality of *E. akaara* in mariculture period? Reason/Solution? 养殖中紅斑死亡率?原因/解决辦法?	
Price and size of *E. akaara* for market size? Any change by year? If yes, why? 售卖价格及大小? 有无隨年份而变化? 如是, 爲什麼?	
Any mature *E. akaara* found in cages? Which month? 网箱中有无成熟的紅斑? 月份?	
Who/where do you sell to? Any change by year? If no, why? 紅斑卖给谁/哪里? 有无隨年份而变化? 如是, 爲什麼?	
Do you need license/permit to buy/mariculture *E. akaara* 购买及养殖紅斑需要牌照?	
Any monitor? Legislation? Enforcement? 任何監管? 立法? 執行?	
What do you expect grouper fishery in the next 5-10 years 請預計未來 5-10 年石斑鱼养殖的情況?	
Do you have any questions for me 有沒有問題想知道?	

Questionnaire for *Epinephelus akaara* survey – for grouper traders 紅斑問卷调查 (魚類批發商)

Date 日期:	Name of interviewee 受訪者名字:
Age group 年齡組別 (>60, 60-51, 50-41, 40-31, <30):	
How long in the business? Why/How? 從事這行多久? 为何/如何入行?	Address/Location 地址/地點:
Any other business support 有无其他經濟收入?	
Business scale and base? Any change by year? If yes, why? 生意规模及基地? 有无隨年份而变化? 如是, 爲什麼?	

How many grouper traders in the area? Any change by year? If yes, why? 多少魚類批發商? 有无隨年份而变化? 如是, 爲什麼?
Trade species and grouper species? Proportion? Any change by year? If yes, why? 批發魚种類及石斑魚种類及紅斑? 比例多少? 有无隨年份而变化? 如是, 爲什麼?
Do you sale either dead or live grouper or both? Proportion? Any change by year? If yes, why? 批發死的或活的石斑魚种類或两者? 比例多少? 有无隨年份而变化? 如是, 爲什麼?
Price/Size of *E. akaara* for sale (dead or live)? Any change by year? If yes, why? 紅斑(死的或活的)的价格及大小? 有无隨年份而变化? 如是, 爲什麼?
Any mature *E. akaara* found? Which month? 有无成熟的紅斑? 月份?
High season for *E. akaara* sale? Any change by year? If yes, why? 哪季是紅斑銷售高峰? 有无隨年份而变化? 如是, 爲什麼?
Can you buy enough groupers? Any change by year? If yes, why? 可否收購足夠的石斑作供應? 有无隨年份而变化? 如是, 爲什麼?
Transportation? Any change by year? If yes, why? 交通運輸? 有无隨年份而变化? 如是, 爲什麼?
Mortality of *E. akaara* during holding and transportation? Reason/Solution? 運送及暫养紅斑期間, 其死亡率是怎樣? 原因/解決辦法?
Who/Where do you sell to? Any changes by yea? If no, why? 銷售給誰/哪兒? 有无隨年份而变化? 如是, 爲什麼?
Any export 有无出口貿易?
Preferred size for *E. akaara* in market? Any change by year? If yes, why? 市場有沒有喜好的紅斑大小? 有无隨年份而变化? 如是, 爲什麼?
Do you need license/permit for *E. akaara* or other fish species trade? 紅斑及其它鱼貿易需要牌照?
Any monitor? Legislation? Enforcement? 任何監管? 立法? 執行?
What do you expect grouper fishery in the next 5-10 years 請預計未來 5-10 年石斑鱼貿易的情況?
Do you have any questions for me 有沒有問題想知道?

Questionnaire for *Epinephelus akaara* survey – for grouper hatcheries 紅斑問卷调查 (育苗户)

Date 日期:	Name of interviewee 受訪者名字:
Age group 年齡組別 (>60, 60-51, 50-41, 40-31, <30):	
How long in the business? Why/How? 從事這行多久? 为何/如何入行?	Address/Location 地址/地點:
Any other business support 有无其他經濟收入?	
How many grouper hatcheries in the area? Any change by year? If yes, why? 多少石斑魚類育苗场? 有无隨年份而变化? 如是, 爲什麼?	
Hatchery scale and species? Any change by year? If yes, why? 育苗规模及基地? 有无隨年份而变化? 如是, 爲什麼?	
How many grouper species hatchery conducted? Any change by year? If yes, why? 多少种石斑魚類育苗? 有无隨年份而变化? 如是, 爲什麼?	
Number of grouper juveniles (size and season) produced each year? Any change by year? If yes, why? 石斑魚年育苗量(大小/季节)? 有无隨年份而变化? 如是, 爲什麼?	

Number/Price/size/season of produced *E. akaara* each year? Any change by year? If yes, why? 紅斑年育苗量/价格/大小/季节? 有无隨年份而变化? 如是, 爲什麼?
Where grouper broodstock came from? How many? Any change by year? If yes, why? 石斑鱼亲鱼来源及数量? 有无隨年份而变化? 如是, 爲什麼?
Can you sale hatchery-produced grouper juveniles easily? Any change by year? If yes, why? 石斑鱼苗销路? 有无隨年份而变化? 如是, 爲什麼?
Transportation? Any change by year? If yes, why? 交通運輸? 有无隨年份而变化? 如是, 爲什麼?
Mortality of grouper hatchery? Reason/Solution? 石斑鱼育苗期間死亡率是怎樣? 原因/解決辦法?
Who/Where do you sell to? Any changes by yea? If no, why? 銷售給誰/哪兒? 有无隨年份而变化? 如是, 爲什麼?
Any export 有无出口贸易?
Preferred size for *E. akaara* juveniles from buyers? Any change by year? If yes, why? 买主喜欢的紅斑鱼苗大小? 有无隨年份而变化? 如是, 爲什麼?
Do you need license/permit for *E. akaara* or other fish species hatchery? 紅斑及其它鱼育苗需要牌照?
Any monitor? Legislation? Enforcement? 任何監管? 立法? 執行?
What do you expect grouper fishery in the next 5-10 years 請預計未來 5-10 年石斑育苗業的情況?
Do you have any questions for me 有沒有問題想知道?

Table 1.1 The IUCN Red List categories for all groupers (n = 161, Family Epinephelidae) (data from IUCN/GWSG, 2007). CR, critically endangered; DD, data deficient; EN, endangered; LC, least concern; NT, near threatened; VU, vulnerable

No.	Species	Category	No.	Species	Category
1	*Aethaloperca rogaa*	DD	81	*E. itajara*	CR A2d
2	*Alphestes afer*	LC	82	*E. labriformis*	LC
3	*A. immaculatus*	LC	83	*E. lanceolatus*	VU A2d
4	*A. multiguttatus*	LC	84	*E. latifasciatus*	DD
5	*Anyperodon leucogrammicus*	LC	85	*E. lebretonianus*	DD
6	*Cephalopholis aitha*	DD	86	*E. longispinis*	LC
7	*C. argus*	LC	87	*E. macrospilos*	LC
8	*C. aurantia*	DD	88	*E. maculatus*	LC
9	*C. boenak*	LC	89	*E. magniscuttis*	DD
10	*C. cruentata*	LC	90	*E. malabaricus*	NT
11	*C. cyanostigma*	LC	91	*E. marginatus*	EN A2d
12	*C. formosa*	LC	92	*E. melanostigma*	DD
13	*C. fulva*	LC	93	*E. merra*	LC
14	*C. hemistiktos*	NT	94	*E. miliaris*	LC
15	*C. igarashiensis*	DD	95	*E. morio*	NT
16	*C. leopardus*	LC	96	*E. morrhua*	LC
17	*C. microprion*	LC	97	*E. multinotatus*	LC
18	*C. miniata*	LC	98	*E. mystacinus*	LC
19	*C. nigri*	LC	99	*E. nigritus*	CR A2d+3d
20	*C. nigripinnis*	DD	100	*E. niphobles*	DD
21	*C. oligosticta*	LC	101	*E. niveatus*	VU A2d+3d
22	*C. panamensis*	LC	102	*E.octofasciatus*	DD
23	*C. polleni*	LC	103	*E. ongus*	LC
24	*C. polyspila*	LC	104	*E. perplexus*	DD
25	*C. sexmaculata*	LC	105	*E. poecilonotus*	LC
26	*C. sonnerati*	LC	106	*E. polylepis*	NT
27	*C. spiloparaea*	LC	107	*E. polyphekadion*	NT
28	*C. taeniops*	DD	108	*E. polystigma*	DD
29	*C. urodeta*	LC	109	*E. posteli*	DD

30	*Cromileptes altivelis*	VU A4cd	110	*E. quernus*	NT
31	*Dermatolepis dermatolepis*	LC	111	*E. quoyanus*	LC
32	*D. inermis*	LC	112	*E. radiatus*	LC
33	*D. striolata*	DD	113	*E. retouti*	DD
34	*Epinephelus acanthistius*	LC	114	*E. rivulatus*	LC
35	*E. adscensionis*	LC	115	*E. septemfasciatus*	LC
36	*E. aeneus*	NT	116	*E. sexfasciatus*	DD
37	*E. akaara*	EN A2d	117	*E. socialis*	NT
38	*E. albomarginatus*	VU A2d	118	*E. spilotoceps*	LC
39	*E. amblycephalus*	DD	119	*E. stictus*	LC
40	*E. analogus*	LC	120	*E. stoliczkae*	DD
41	*E. andersoni*	NT	121	*E. striatus*	EN A2ad
42	*E. areolatus*	LC	122	*E. suborbitalis*	DD
43	*E. awoara*	DD	123	*E. summana*	DD
44	*E. bilobatus*	DD	124	*E. tauvina*	DD
45	*E. bleekeri*	NT	125	*E. timorensis*	DD
46	*E. bontoides*	DD	126	*E. trimaculatus*	LC
47	*E. bruneus*	VU A4d	127	*E. trophis*	DD
48	*E. caninus*	DD	128	*E. tuamotuensis*	LC
49	*E. chlorocephalus*	DD	129	*E. tukula*	LC
50	*E. chlorostigma*	LC	130	*E. undulatostriatus*	DD
51	*E. cifuentesi*	NT	131	*E. undulosus*	DD
52	*E. clippertonensis*	LC	132	*Gonioplectrus hispanus*	LC
53	*E. coeruleopunctatus*	LC	133	*Gracila albomarginata*	DD
54	*E. coioides*	NT	134	*Mycteroperca acutirostris*	LC
55	*E. corallicola*	DD	135	*M. bonaci*	NT
56	*E. costae*	DD	136	*M. cidi*	DD
57	*E. cyanopodus*	LC	137	*M. fusca*	EN B1ab(v)
58	*E. daemelii*	NT	138	*M. interstitialis*	VU A2d+3d
59	*E. darwinensis*	DD	139	*M. jordani*	EN A2d+3d
60	*E. diacanthus*	NT	140	*M. microlepis*	LC
61	*E. drummondhayi*	CR A2d+3d	141	*M. olfax*	VU D2
62	*E. ergastularius*	LC	142	*M. phenax*	LC
63	*E. epistictus*	DD	143	*M. prionura*	NT

64	*E. exsul*	DD	144	*M. rosacea*	VU A2ad+4ad
65	*E. erythrurus*	DD	145	*M. rubra*	LC
66	*E. fasciatomaculosus*	DD	146	*M. tigris*	NT
67	*E. fasciatus*	LC	147	*M. venenosa*	NT
68	*E. faveatus*	DD	148	*M. xenarcha*	LC
69	*E. flavocaeruleus*	LC	149	*Paranthias colonus*	LC
70	*E. flavolimbatus*	VU A2d+3d	150	*P. furcifer*	LC
71	*E. fuscoguttatus*	NT	151	*Plectropomus areolatus*	VU A4d
72	*E. gabriellae*	VU B1ad(v)	152	*P. laevis*	VU A2d+4d
73	*E. goreensis*	DD	153	*P. leopardus*	NT
74	*E. guttatus*	LC	154	*P. maculatus*	LC
75	*E. haifensis*	DD	155	*P. punctatus*	DD
76	*E. heniochus*	DD	156	*P. oligacanthus*	NT
77	*E. hexagonatus*	LC	157	*P. pessuliferus*	NT
78	*E. howlandi*	LC	158	*Saloptia powelli*	DD
79	*E. indistinctus*	DD	159	*Triso dermopterus*	LC
80	*E. irroratus*	LC	160	*Variola albimarginata*	LC
			161	*V. louti*	LC

Table 4.1 All *Epinephelus* groupers (n = 37, Family Epinephelidae) occurring in mainland China including the Yellow Sea (YS), the East China Sea (ECS), the South China Sea (SCS) and the Taiwan Strait (TS), and in Hong Kong waters (HK) (see **Figure 1.1** for locations). [1], Hu, 1979; [2], Chu, 1985; [3], Huang, 1994; [4], http://www.iucnredlist.org/; [5], this study

No. of species	English common name	*Epinephelus* species
1	Hong Kong grouper	*E. akaara* (ECS, HK, TS, SCS)[1-5]
2	Banded grouper	*E. amblycephalus* (ECS, TS, SCS)[2-4]
3	Areolate grouper	*E. areolatus* (ECS, HK, TS, SCS)[1-4]
4	Yellow grouper	*E. awoara* (ECS, HK, TS, SCS)[1-5]
5	Duskytail grouper	*E. bleekeri* (ECS, HK, TS, SCS)[2-5]
6	Longtooth grouper	*E. bruneus* (ECS, HK, TS, SCS)[2-5]
		(valid name of *E. moara*)
7	Brownspotted grouper	*E. chlorostigma* (ECS, TS, SCS)[1-4]
8	Whitespotted grouper	*E. coeruleopunctatus* (ECS, TS, SCS)[3,4]
9	Orange-spotted grouper	*E. coioides* (ECS, HK, SCS) [4,5]
		E. cometae
		(not valid, see *E. morrhua*)
10	Coral grouper	*E. corallicola* (TS, SCS)[3,4]
11	Speckled blue grouper	*E. cyanopodus* (SCS)[1,4]
		(valid name of *E. hoedtii* and *E. kohleri*)
		E. diacanthus
		(not valid, see *E. stictus*)
12	Dotted grouper	*E. epistictus* (ECS, HK, TS, SCS)[2-4]
		E. fario
		(not valid, see *E. trimaculatus*)
13	Rock grouper	*E. fasciatomaculosus* (ECS, HK, SCS)[3,4]
14	Blacktip grouper	*E. fasciatus* (ECS, HK, TS, SCS)[1,3-5]
15	Brown-marbled grouper	*E. fuscoguttatus* (TS, SCS)[1,3]
16	Starspotted grouper	*E. hexagonatus* (HK, SCS)[1,3,4]
		E. hoedtii
		(not valid, see *E. cyanopodus*)
		E. kohleri
		(not valid, see *E. cyanopodus*)

17	Giant grouper	*E. lanceolatus* (SCS)[1-4]
		(valid name of *Promicrops lanceolatus*)
18	Striped grouper	*E. latifasciatus* (ECS, HK, TS, SCS)[2-4]
19	Snubnose grouper	*E. macrospilos* (HK, SCS)[3,4]
20	Highfin grouper	*E. maculatus* (HK, SCS)[3,4]
21	Malabar grouper	*E. malabaricus* (ECS, HK, TS, SCS)[2-4]
		E. megachir
		(not valid, see *E. quoyanus*)
22	Honeycomb grouper	*E. merra* (ECS, HK, TS, SCS)[1,3-5]
		E. microdon
		(not valid, see *E. polyphekadion*)
		E. moara (ECS, TS, SCS)
		(not valid, see *E. bruneus*)
23	The comet grouper	*E. morrhua* (HK, SCS)[1,3,4]
		(valid name of *E. cometae*)
24	White-streaked grouper	*E. ongus* (TS, SCS)[3,4]
25	Camouflage grouper	*E. polyphekadion* (SCS)[3,4]
		(valid name of *E. microdon*)
26	Longfin grouper	*E. quoyanus* (ECS, HK, TS, SCS)[2-4]
		(valid name of *E. megachir*)
27	Oblique-banded grouper	E. radiatus (SCS)[4]
28	Red-tipped grouper	*E. retouti* (ECS, TS, SCS)[1,3]
		(valid name of *E. truncates*)
		E. rhyncholepis
		(not valid, see *E. rivulatus*)
29	Halfmoon grouper	*E. rivulatus* (ECS, HK, SCS)[2-4]
		(valid name of *E. rhyncholepis*)
30	Convict grouper	*E. septemfasciatus* (YS, ECS)[3,4]
31	Sixbar grouper	*E. sexfasciatus* (SCS)[3]
32	Foursaddle grouper	*E. spilotoceps* (SCS)[1,3]
33	Black-dotted grouper	*E. stictus* (HK, SCS)[3,4]
		(valid name of *E. diacanthus*)
		E. summana
		(not valid, see *E. coeruleopunctatus*)

34	Greasy grouper	*E. tauvina* (SCS)[1,3] *E. trallcatus* (SCS)[3] (not valid)
35	Threespot grouper	*E. trimaculatus* (ECS, HK, TS, SCS)[1-4] (valid name of *E. fario*) *E. truncates* (not valid, see *E. retouti*)
36	Potato grouper	*E. tukula* (SCS)[3]
37	Wavy-lined grouper	*E. undulosus* (SCS)[3]

Table 4.2 *Epinephelus akaara* fisheries status between 1982 and 1994 in Zhejiang Province (Xu and Yu, 1989; Bo et al., 1995) (see **Figure 4.1** for locations). CPUE, the capture per unit effort

Year	No. of Zhejiang-licensed hook-and-line fishing vessels	Capture volume (t)	CPUE (kg / vessel / year)
Southern Zhejiang			
1982	30	39.20	1306.67
1983	390	98.40	252.31
1984	640–740	91.20	132.17
1985	910–1010	99.50	103.65
1986	640–740	68.50	99.28
Shengsi Island, Northern Zhejiang			
1986	90	44.93	499.22
1987	90	25.88	287.57
1988	100	30.45	304.50
1989	100	11.59	115.97
1990	100	30.24	302.42
1991	100	21.42	214.25
1992	100	19.50	195.00
1993	120	14.00	116.67
1994	150	7.50	50.00

Table 4.3 Estimated annual capture volumes (t) for *Epinephelus akaara* in Zhejiang Province between 1979 and 1994 (Wang, 1988; Xu and Yu, 1989; Bo et al., 1995) and in 2007 and 2008 (this study) (see **Figure 4.1** for locations). *, data from Wang, 1988; **, data from the Nanji Islands; ***, data from the Liuheng Island; NA, not available

Year	Capture volume (t)		
	Southern Zhejiang	**Northern Zhejiang**	**Total**
1979	13.86	6.14	20.00 (~7*)
1980	25.30	21.68	46.98
1981	32.80	39.95	72.75
1982	39.20	36.35	75.55
1983	98.40	34.18	132.58
1984	91.20	44.82	136.02 (~260*)
1985	99.50	87.02	186.52
1986	68.50 (~87.4*)	63.00	131.50 (~220*)
1987	51.70	45.33	97.03
1988	41.40	49.90	91.30
1989	41.40	52.40	93.80
1990	31.00	68.00	99.00
1991	24.08	50.21	74.27
1992	21.50	46.90	68.40
1993	16.01	56.87	72.88
1994	6.50	32.25	38.75
1995–2006	NA	NA	NA
2007	< 10**	< 2***	NA
2008	< 4**	< 2***	NA

Table 4.4 Retail prices (US$) for *Epinephelus akaara* over time with different body sizes in Zhejiang, Fujian and Guangdong Provinces (Xu and Yu, 1989; Xu, 1995; Ai et al., 2001; this study) (see **Figure 1.2** for locations). *, marketable size; **, below marketable size and used for grow-out; [a], fresh dead for food; [b], grow-out from wild-caught, below marketable sizes; [c], wild-caught of marketable sizes

Year	Retail price (US$ / kg)	Body size (g BW / fish)	Exchange rate (1 US$ to RMB yuan)
Zhejiang			
1980s	14–32	≥ 500*	3.70
	22	300–500**	
	11	100–300**	
1990s	45–67	≥ 500*	5.34
2008	63–69	> 300*	7.30
	10–15	> 250*, [a]	
	41	200–300**	
	25	100–200**	
	28	< 50 g (or < 10 cm TL)**	
Fujian			
1980s	27–65	> 400*	3.70
1990s	30–35	> 400*	5.34
2008	32–55	≥ 400*	7.30
	19–22	100–150**	
	14	30–70**	
Guangdong			
1980s	19–51	≥ 500*	3.70
	32	250**	
	8–12	70–100**	
1990s	50	≥ 500*	5.34
2000	36	100–150**	8.28
2008	32–55	500–1,200*	7.30
	32–40	400*	
	20–28	100–150**	
	14	30–70**	
2009	44–48	≥ 400*, [b]	6.70
	75	≥ 400*, [c]	

Table 4.5 Estimated trade volumes (t) for *Epinephelus akaara* over years in Zhejiang Province (this study) (see **Figure 4.1** for locations). Numbers in parentheses indicated the traders interviewed. *, trade volume only from the traders interviewed; **, trade volume from in the whole area; LFFT, the live food fish trade; NA, not available

Area	**Annual trade volume (t)**		
	1980s	**1990s**	**2007 / 2008**
Liuheng (1)*	20-30 (for LFFT directly)	Shift to mariculture	< 0.5 / < 0.5 (mainly for grow-out)
Liuheng (1)*	NA	NA	1 / 1 (mainly for grow-out)
Xiangshan**	4.7 (grow-out production for LFFT to Hong Kong in 1989)	NA	No significance
Nanji (2)*	NA	NA	9 / 3 (mainly for grow-out)
Nanji**	122 (for grow-out)	NA	10 / 4 (for LFFT directly but mainly for grow-out)

Table 4.6 Estimated annual capture volumes (t) and mariculture production (t) of groupers in Fujian Province (Zhang et al., 1988; Zhang and Hong, 1992; this study). Data in parentheses indicate the extra capture volumes from long-distance waters. NA, not available

Year	Capture (t)	Mariculture (t)
1970s	> 400	NA
Mid-1980s	> 400	NA
Late-1980s	< 400	NA
1990s	No significance	NA
2003	12,685	5,751
2004	10,145 (1,429)	9,238
2005	11,678 (1,550)	10,941
2006	15,420 (1,665)	11,909
2007	14,496 (334)	8,813

Table 4.7 A summary of fisheries and trade importance of 12 *Epinephelus* groupers (Family Epinephelidae) commonly occurring in the coastal waters of Fujian and the Taiwan Bank Fishing Grounds (Chu, 1985). LFFT, the live food fish trade

No.	Species	Fisheries and trade importance
1	*Epinephelus akaara*	Second common species in grouper fisheries and the most important grouper species in the LFFT to Hong Kong and Macau
2	*E. amblycephalus*	For food
3	*E. areolatus*	For food
4	*E. awoara*	The most common species in grouper fisheries and an important species in the LFFT to Hong Kong and Macau
5	*E. bleekeri*	A highly-valued food species but naturally rare
6	*E. bruneus*	For food
7	*E. chlorostigma*	For food
8	*E. epistictus*	For food
9	*E. latifasciatus*	A highly-valued food species but naturally rare
10	*E. malabaricus*	For food
11	*E. quoyanus*	A common species in grouper fisheries
12	*E. trimaculatus*	A common and important species in grouper fisheries and in the LFFT to Hong Kong and Macau

Table 4.8 Estimated trade volumes (t) for *Epinephelus akaara* over time in Fujian Province (this study) (see **Figure 4.4** for locations). Numbers in parentheses indicate the traders interviewed. *, trade volume only from the traders interviewed; **, trade volume from the whole area; LFFT, the live food fish trade; NA, not available

Area	**Annual trade volume (t)**			
	1970s	**1980s**	**1990s**	**2007/2008**
Fuding (1)*	NA	20-30 (mainly for LFFT directly)	Shift to mariculture	NA
Xiapu (1)*	NA	5 (mainly for LFFT directly)	Decline	2 / 2 (mainly for grow-out)
Xiapu (1)*	NA	15 (mainly for LFFT directly)	Decline	9 / 2 (mainly for grow-out)
Xiapu**	NA	50 (mainly for LFFT directly)	Many traders shift to mariculture	NA / 12
Lianjiang (1)*	NA	5 (mainly for LFFT directly)	Shift to mariculture	< 0.2 / < 0.2 (for grow-out)
Pingtan (2)*	NA	15-20 (mainly for LFFT directly)	Shift to mariculture	NA
Pingtan**	NA	100-150 (mainly for LFFT directly)	Many traders shift to mariculture	5 / 5 (mainly for grow-out)
Quanzhou (1)*	3-5 (for LFFT directly)	Decline (mainly for LFFT directly)	Shift to mariculture	< 0.1 / 0.1 (mainly for grow-out)

Table 4.9 Estimated annual grouper capture volumes (t) and mariculture production (t) between 1999 and 2008 in Guangdong Province (this study). NA, not available

Year	Capture (t)		Mariculture (t)	
	Marine fishes	**Groupers**	**Marine fishes**	**Groupers**
1999	NA	NA	180,000	2,500
2000	1,482,532	14,985	203,168	NA
2001	1,430,772	15,602	230,732	NA
2002	1,400,779	14,704	222,575	NA
2003	1,391,858	18,869	195,542	13,636
2004	1,353,544	19,375	210,106	16,799
2005	1,293,172	19,277	223,526	19,494
2006	1,147,758	18,822	231,504	22,745
2007	1,114,837	19,297	235,595	19,621
2008	1,134,254	21,120	256,680	20,808

Table 4.10 Estimated annual grouper capture volumes (t) and mariculture production (t) between 1979 and 2008 in Huizhou, Guangdong Province (this study) (see **Figure 4.5** for location). *, *Epinephelus akaara* dominant; NA, not available

Year	Capture (t)	Mariculture (t)
1979	4	NA
1980	8	NA
1981	43	NA
1982	20	NA
1983	122	NA
1984	73	NA
1985	44	NA
1986	36	NA
1987	44	NA
1988	72	NA
1989	90	NA
1990	104	100.6*
1992	264	NA
1993	468	NA
1994	997	NA
1995	1,136	NA
1996	518	NA
1998	160	NA
1999	56	NA
2000	192	NA
2001	187	NA
2002	182	NA
2003	183	2,058
2004	96	976
2005	99	886
2006	96	1,274
2007	400	1,295
2008	334	827

Table 4.11 Estimated annual grouper capture volumes (t) and mariculture production (t) between 1998 and 2008 in Hainan Province (this study). NA, not available

Year	Capture (t)	Mariculture (t)
1998	10,811	NA
1999	12,327	NA
2000	13,721	NA
2001	13,633	NA
2002	14,262	1,615
2003	20,274	3,252
2004	23,474	4,099
2005	28,370	5,459
2006	38,932	8,559
2007	35,522	8,149
2008	32,272	11,106

Table 4.12 Estimated total annual marine fish and grouper culture production in Hong Kong SAR since the 1970s (Liu and Sadovy de Mitcheson, 2008a; this study; http://www.afcd.gov.hk). NA, not available

Year	Marine fishes (t)	Groupers (t)	*Epinephelus akaara* (t)
1970s	563-1,000	NA	500
1980	760	NA	NA
1981	962	NA	NA
1982	1,155	NA	NA
1983	960	NA	NA
1984	1,283	NA	130
1985	1,589	NA	135
1986	2,098	NA	210
1987	2,870	NA	401
1988	3,281	NA	164
1989	3,109	NA	150
1990	3,321	365	166
1991	3,860	265	38
1992	3,400	55	10
1993	3,010	632	30
1994	2,990	627	30
1995	2,950	620	30
1996	3,000	1,110	NA
1997	2,960	1,037	NA
1998	1,200	312	NA
1999	1,250	280	NA
2000	1,770	523	NA
2001	2,470	910	NA
2002	1,210	325	NA
2003	1,490	832	NA
2004	1,541	798	NA
2005	1,540	514	NA
2006	1,488	525	NA
2007	1,530	NA	NA

Table 4.13 Estimated total annual marine fish and grouper capture volumes (t) since the mid-1980s by Hong Kong-licensed fishing vessels (Fish Marketing Organization of Hong Kong, FMO). Captures were mainly from local and adjacent waters such as the South China Sea and sold as fresh dead. NA, not available

Year	Marine fishes (t)	Groupers (t)	Grouper %
1985	NA	1,490	NA
1986	NA	1,607	NA
1987	NA	1,719	NA
1988	NA	1,551	NA
1989	NA	1,180	NA
1990	NA	908	NA
1991	71,137	623	0.88
1992	62,015	714	1.15
1993	60,340	789	1.31
1994	57,079	872	1.53
1995	50,883	678	1.33
1996	48,125	678	1.41
1997	45,772	661	1.44
1998	46,064	682	1.48
1999	49,722	621	1.25
2000	52,633	478	0.91
2001	50,840	662	1.30
2002	47,225	1,018	2.15
2003	40,101	713	1.78
2004	40,891	572	1.40
2005	41,024	389	0.95
2006	42,446	408	0.96
2007	40,468	361	0.89

Table 4.14 Retail prices (US$) for *Epinephelus akaara* over time with different body sizes in Hong Kong SAR (this study). *, marketable size; **, below marketable size and used for grow-out; [a], US$ / fish; [b], wild-caught of marketable sizes; [c], grow-out from wild-caught, under marketable sizes; [d], fresh dead for food

Year	Retail price (US$ / kg)	Body size (g BW / fish)	Exchange rate (1 US$ to HK$)
1970s	24–30	1,000–1,200*	5.0
	10	<1,000*	
	1–5[a]	100–200**	
1990s	44–49[b]	500*	8.2
	17[c]	500*	
2008	70–85	≥400*, [b]	7.8
	31–54	≥400*, [c]	
	21	≥400*, [d]	

Table 4.15 Estimated live grouper import and re-export volumes (t) in Hong Kong SAR (this study). CSD (Census and Statistics Department) in which volumes are recorded from transportation modes by air and non Hong Kong-licensed vessels; AFCD (Agriculture, Fisheries and Conservation Department) in which volumes are recorded from transportation mode by Hong Kong-licensed vessels

Year	CSD		AFCD (import)	Total (import)
	Import	Re-export		
1997	5,715	9.3	2,316	8,031
1998	6,555	6.2	1,572	8,127
1999	3,132	9.6	2,398	5,530
2000	4,000	237.1	3,370	7,370
2001	4,078	6.2	1,517	5,595
2002	5,291	31	1,535	6,826
2003	5,916	106	1,270	7,168
2004	5,770	79	1,240	7,010
2005	5,999	64	1,303	7,302
2006	6,473	21	1,238	7,811
2007	7,033	61	1,930	8,963

Table 4.16 Estimated grouper seed import volumes (kg) in Hong Kong SAR since 2002 (data from Census and Statistics Department). Grouper seed weights were estimated by 25% of the total weight recorded; number of seeds is estimated by 3 g BW / seed. NA, not available

Year	Import country					
	Philippines		Taiwan		Thailand	
	Seed weight (kg)	Number of seeds	Seed weight (kg)	Number of seeds	Seed weight (kg)	Number of seeds
2002	1,443	481,000	40,224	13,408,000	1,417	472,300
2003	31	10,300	26,182	8,727,300	NA	NA
2004	807	269,000	18,636	6,212,00	8,848	2,949,300
2005	83	27,700	3,123	1,041,000	709	236,300
2006	24	8,000	4,599	1,533,000	4,572	1,524,000
2007	689	229,700	3,979	1,326,300	120	40,000

Table 4.17 Estimated total annual capture and mariculture volumes (t) of groupers in Taiwan POC between 1990 and 2007 (Chu, 1993; Taiwan Fisheries Yearbook 1993–2007; Taiwan Fishery Agency: http://www.fa.gov.tw/eng/statistics/yearbooks.pdf). NA, not available

Year	Capture (t)	Mariculture (t)
1990	NA	5,386
1991	NA	NA
1992	NA	3,127
1993	2,906	3,942
1994	3,018	1,842
1995	1,771	2,104
1996	2,458	1,882
1997	4,350	562
1998	1,414	3,416
1999	1,265	4,122
2000	1,202	5,052
2001	1,610	5,385
2002	933	12,376
2003	1,201	11,565
2004	707	12,512
2005	434	13,582
2006	480	9,500
2007	316	17,370

Table 4.18 Estimated total annual numbers of grouper seeds from hatcheries and volumes (kg) of seed trade (export and import) in Taiwan POC between 1993 and 2007 (Taiwan Fisheries Yearbook 1993–2007; Taiwan Fishery Agency: http://www.fa.gov.tw/eng/statistics/yearbooks). NA, not available

Year	No. of hatchery-produced seeds	Seed export (kg)	Seed import (kg)
1993	7,743,000	NA	8,877
1994	3,000,000	NA	8,396
1995	26,189,000	NA	2,110
1996	47,423,000	11,875	16,980
1997	26,472,000	5,496	9,044
1998	229,264,000	3,915	4,906
1999	282,476,000	5,024	7,167
2000	149,124,000	33,181	3,442
2001	52,555,000	62,488	4,166
2002	50,503,000	59,156	185
2003	49,817,000	50,330	243
2004	56,616,000	81,070	496
2005	65,179,000	50,828	864
2006	43,086,000	44,277	347
2007	38,759,000	30,030	308

Table 4.19 Estimated total annual volumes (kg) on grouper food trade (export and import) in Taiwan POC between 1993 and 2007 (Taiwan Fisheries Yearbook 1993–2007; Taiwan Fishery Agency: http://www.fa.gov.tw/eng/statistics/yearbooks)

Year	Export volume (kg)	Import volume (kg)
1993	103,796	49,647
1994	26,138	49,721
1995	66,587	22,056
1996	228,568	9,300
1997	248,695	17,471
1998	44,712	28,566
1999	35,451	21,745
2000	322,701	12,856
2001	272,348	12,738
2002	110,210	9,388
2003	230,693	7,179
2004	327,588	8,099
2005	189,123	6,540
2006	160,193	7,226
2007	160,234	4,196

Table 4.20 Estimated annual numbers and body sizes of hatchery-produced advanced larvae and juveniles of *Epinephelus akaara* since the 1980s in Japan (Maruyama et al., 1994; Wang, 1997; Y. Obata, personal communication)

Year	Number of individuals	Body size range (mm TL)
1980s	10,000–480,000	23-31
1990	222,000	33-34
1991	189,000	26-29
1992	308,000	22-25
1993	271,000	23-34
1994	58,000	24-31
1995	297,000	25-31
1996	341,000	29-33
1997	70,000	35-45
1998	150,000	29-42
1999	18,000	35-38
2000	54,000	28-53
2001	92,000	27-31
2002	80,000	27-28
2003	315,000	25-34
2004	375,000	23-46
2005	276,000	24-39

Figure 1.1 Geographic distribution of the Hong Kong grouper *Epinephelus akaara* in the northwestern Pacific, from southern China to southern Japan and southern South Korea. Red starbursts-the occurrence is confirmed; pink starburst-the occurrence in the Gulf of Dongjing and around Hainan Island are questionable

Figure 4.1 Coastal waters of Zhejiang Province. Various places mentioned in the text are indicated. Red starbursts-the places visited in this study

Figure 4.2 Changes of *Epinephelus akaara* capture volumes (t) and capture per unit effort (CPUE) (kg / vessel / year) in Zhejiang Province. CPUE in northern Zhejiang was only from Shengsi Islands (see **Tables 4.2** and **4.3** for data)

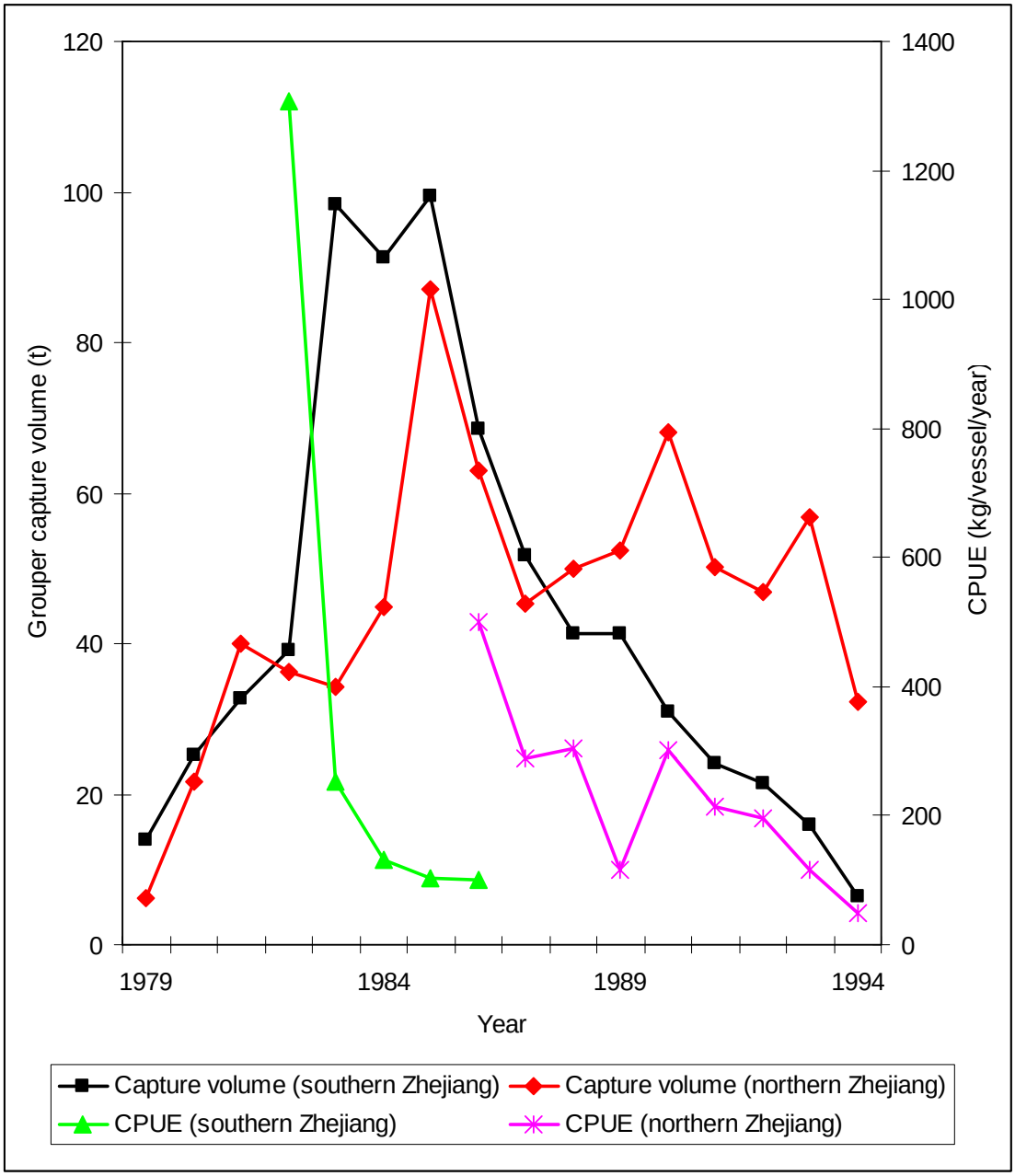

Figure 4.3 The shift of fishing grounds for *Epinephelus akaara* in mainland China, particularly for the live food fish trade, showing the movement from Hong Kong SAR (HK) to the north (red arrows) along coastal waters with first target years indicated in each area

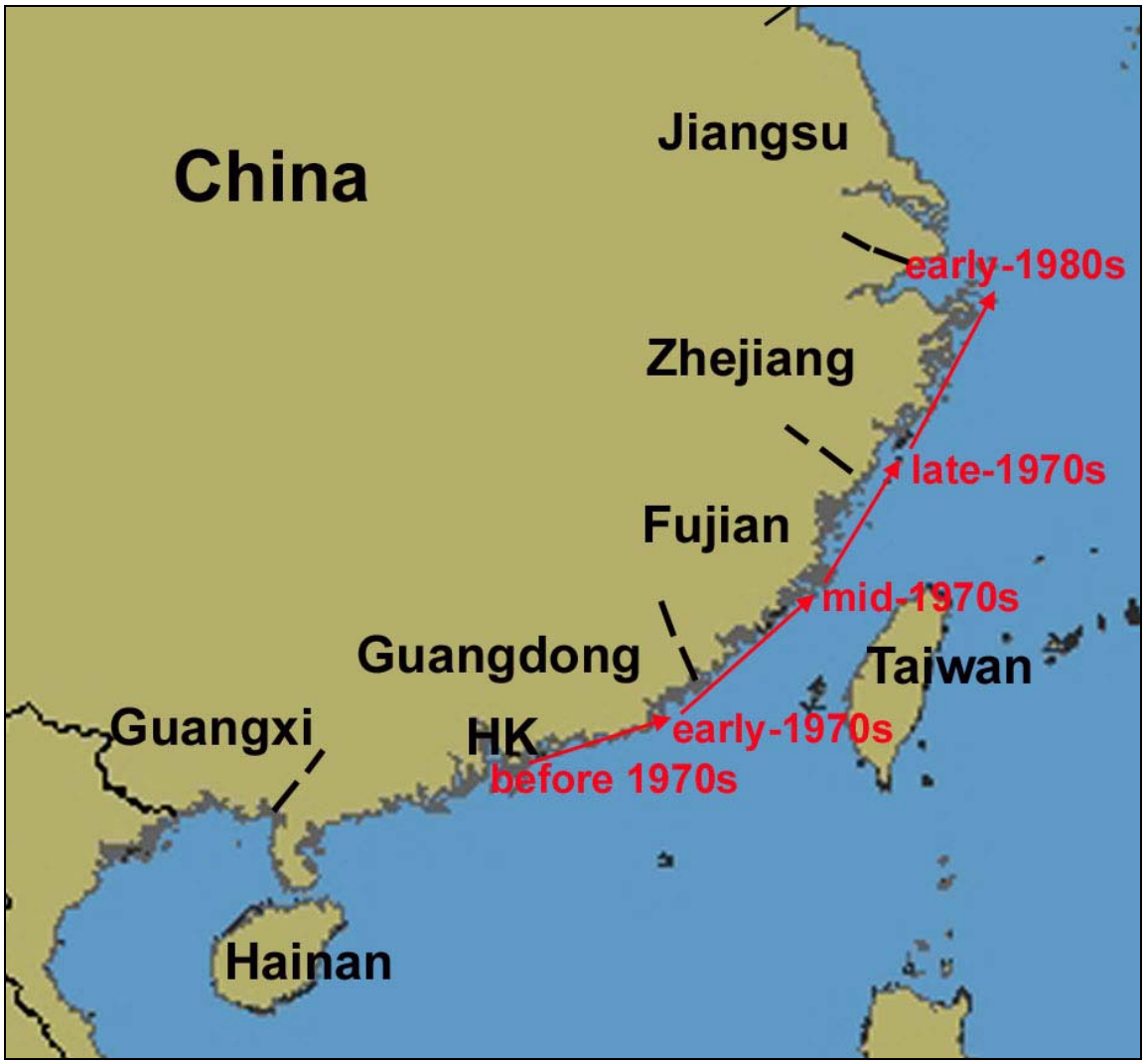

Figure 4.4 Coastal waters of Fujian Province and Taiwan POC with fisheries and trades of wild-caught *E. akaara* juveniles for the purposes of grow-out are indicated (red arrows). Various places, including and near- and off-shore islands, mentioned in the text are indicated. Red starbursts-the places visited in this study; green tiles-the places where advanced larvae and small juveniles (< 50 mm TL) were sampled

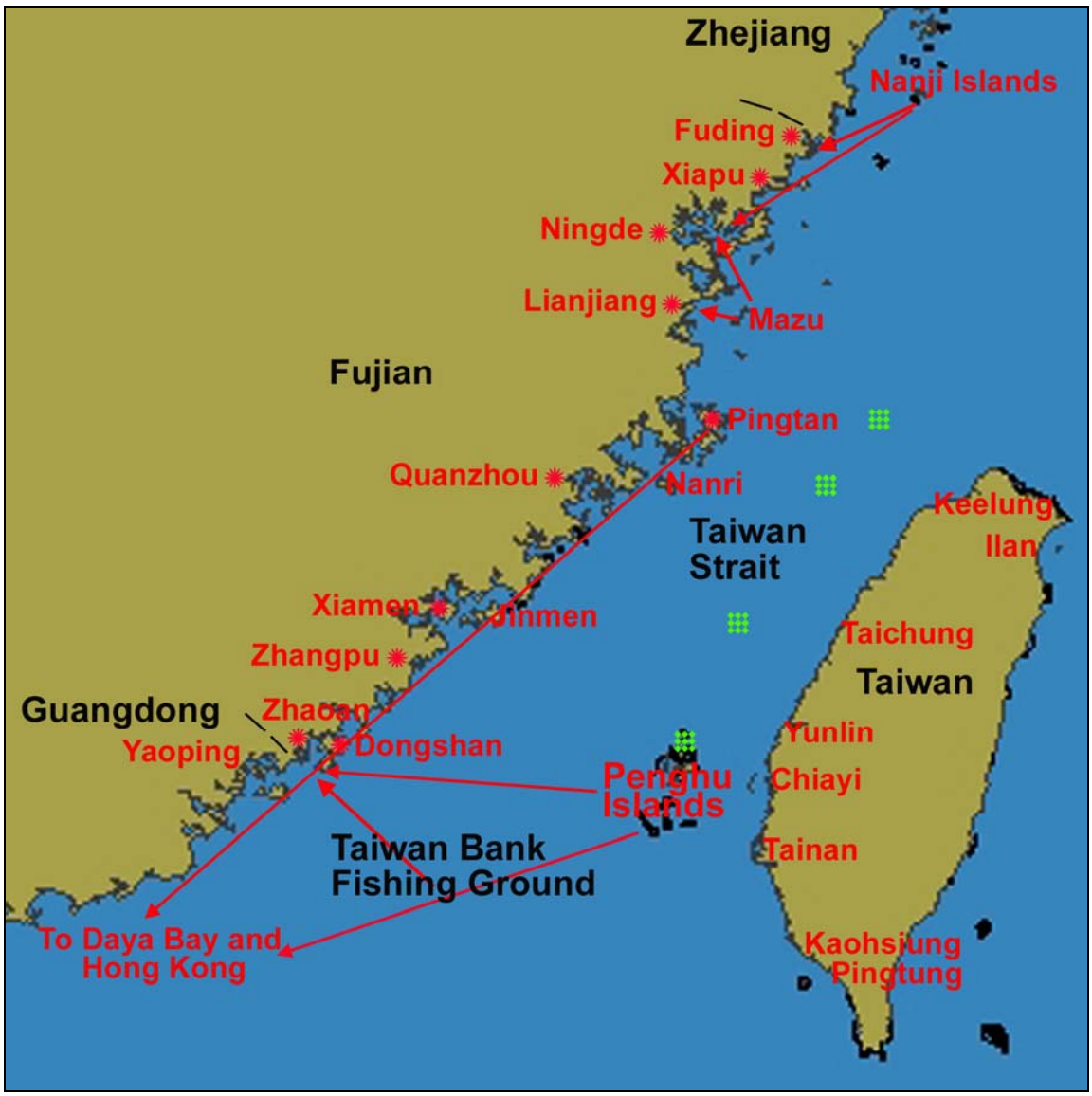

Figure 4.5 Coastal waters of Guangdong, Guangxi and Hainan Provinces. Various places and near-shore islands mentioned in the text are indicated. Red starbursts-the places visited in this study

Figure 4.6 Map of Hong Kong SAR. Various places and near-shore islands mentioned in the text are indicated. Blue starbursts-areas that *Epinephelus akaara* was caught; black dots-marine fish culture zones (n = 26); red tiles-retail markets (n = 7); grey shaded area-ponds for fish and shrimp culture; pink shaded area-oyster culture

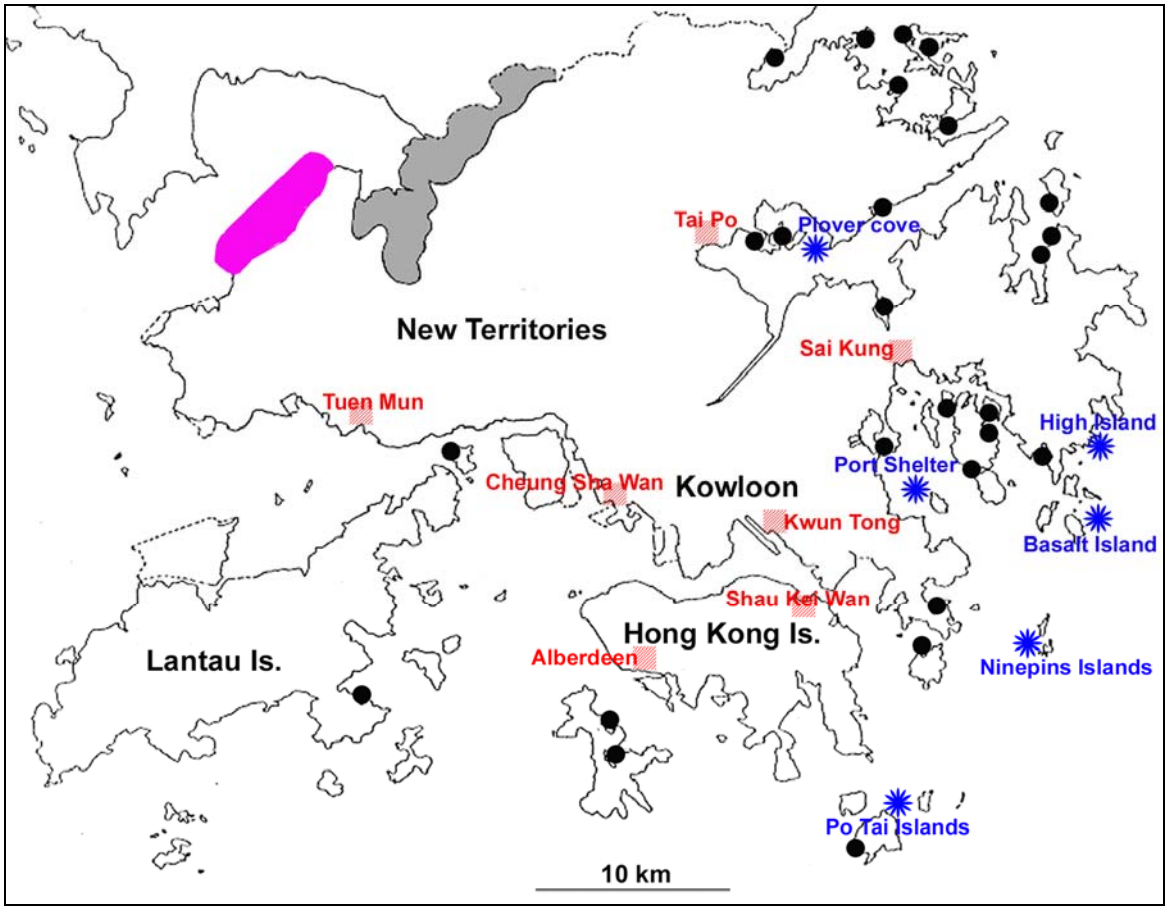

Figure 4.7 Coastal waters of southern Japan and South Korea. Various places mentioned in the text are indicated. Red starburst-the place visited in this study

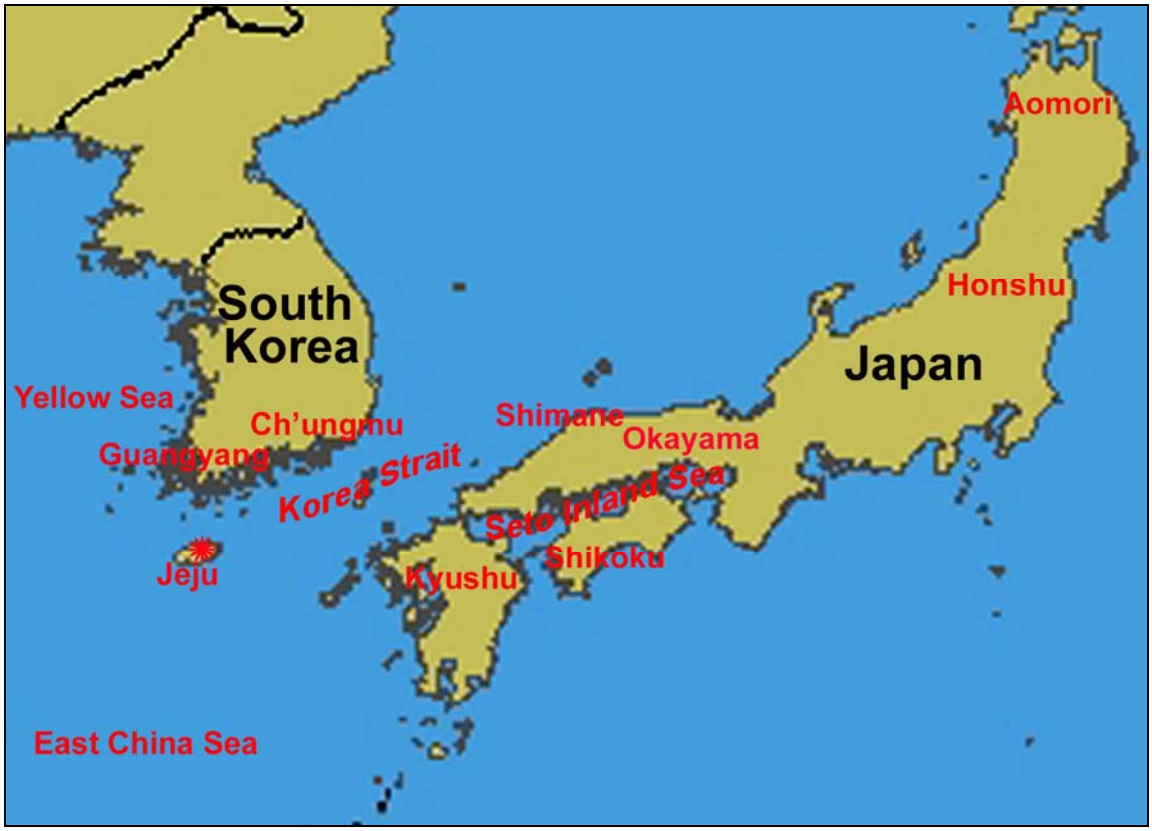

Plate 1.1 External morphology of (A) *Epinephelus akaara* and (B) *E. fasciatomaculosus*. At similar sizes, the later has a slightly larger eye and more slender caudal peduncle

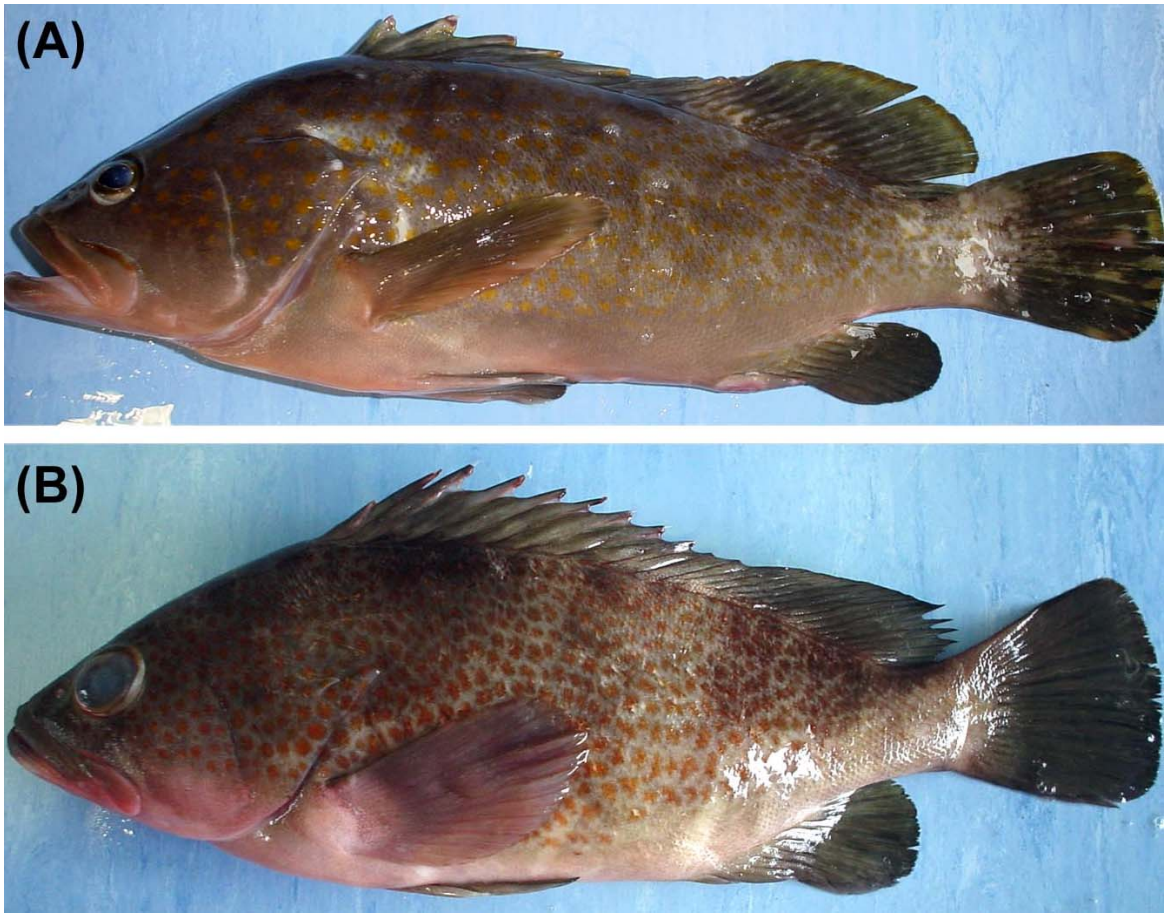

Plate 4.1 A wild-caught *Epinephelus coioides* juvenile about 90 mm TL in the Gulf of Dongjing (see **Figure 1.1** for location). The diameter for the one-yuan RMB coin is 25 mm

Plate 4.2 External morphology of *Epinephelus akaara* and *E. awoara*. (A) *E. akaara* reported in Chinese literature with correct identification; (B) *E. akaara* misidentified as *E. awoara* based on the difference in coloration by Zhejiang researchers; and (C) the valid species of *E. awoara*, uncommon in Zhejiang waters

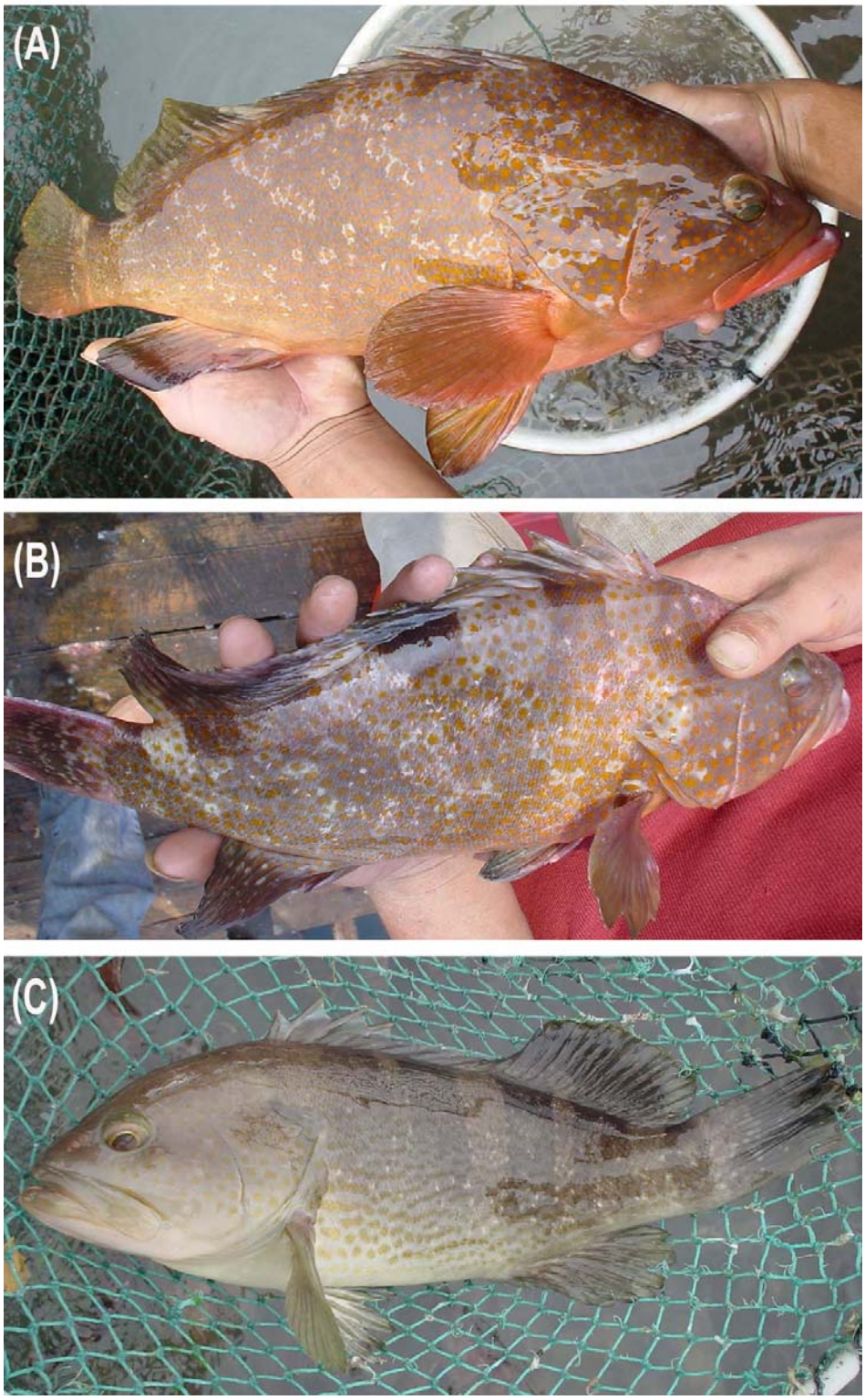

Plate 4.3 Rocky habitats associated with *Epinephelus akaara* in Zhejiang Province. (A) Zhoushan Islands (aerial view); (B) Liuheng Island; and (C) Nanji Islands (see **Figure 4.1** for locations)

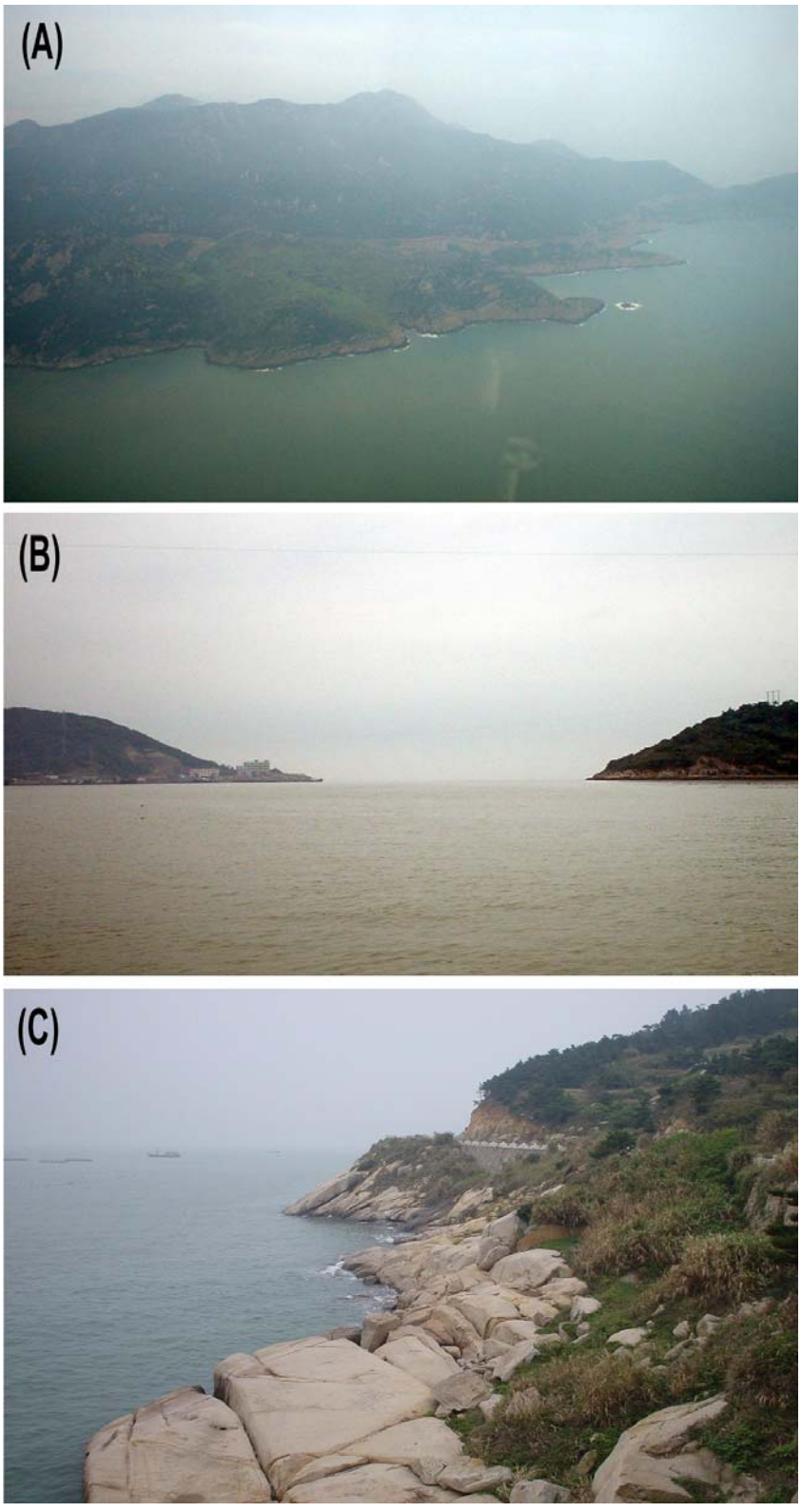

Plate 4.4 Common fishing gears in multi-species fisheries in Zhejiang Province. (A) Single, small-size trap; (B) small traps operated in rocky habitats and shallow waters (a set usually has 50 traps together and a fishing boat with 2 fishers carrying 7 sets); (C) large traps operated in flat and muddy habitats; (D) a fishing boat carrying gill-nets; (E) a set of large traps; and (F) trawling nets mainly operated in deep and off-shore water

Plate 4.5 Fisheries in Zhejiang Province. (A) *Epinephelus akaara* juveniles (< 200 g BW / fish) caught by hook-and-line and for grow-out; (B) a *E. akaara* adult (about 700 g BW / fish) caught by gill-net and sold alive in local wet markets; (C) *Sciaenops ocellatus*, a species from the USA introduced for mariculture purposes in the 1990s, is now a common species in hook-and-line fishery (e.g. about 10 individuals / hour / two fishers); and (D) octopus (species unknown) is commonly caught by traps and for grow-out (e.g. up to capture volume of 1–2 t / day / area)

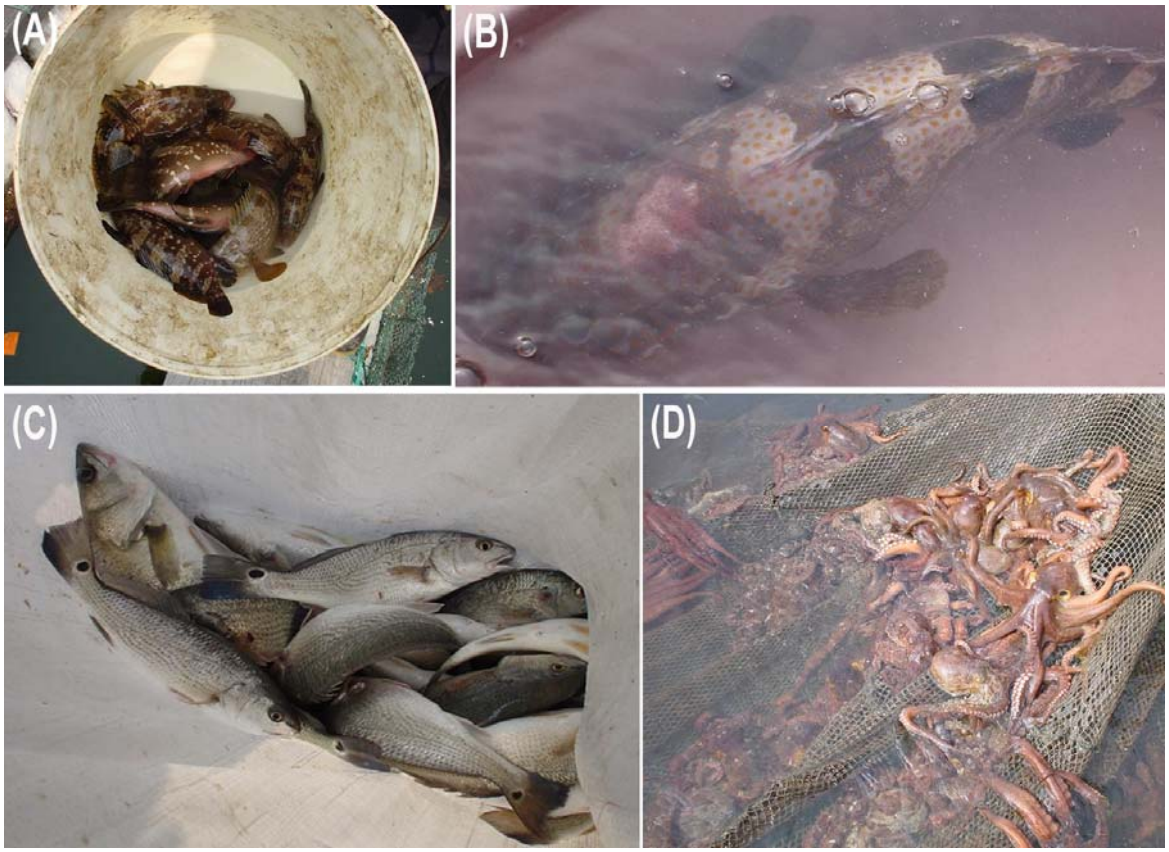

Plate 4.6 *Epinephelus akaara* seed fisheries for grow-out in Zhejiang Province. (A) Juveniles (< 150 g BW / fish); and (B) juveniles and sub-adults (100–300 g BW / fish)

Plate 4.7 *Epinephelus akaara* mariculture in Zhejiang Province. (A) Ponds for broodstock; (B) indoor larviculture tanks; and (C) floating cages for mixed marine fish culture. Red arrows, *E. akaara*

Plate 4.8 Some marine food fishes in wet markets in Zhejiang Province. (A) *Epinephelus akaara* sold alive; (B) *E. akaara* sold fresh dead; (C) – (F) various species

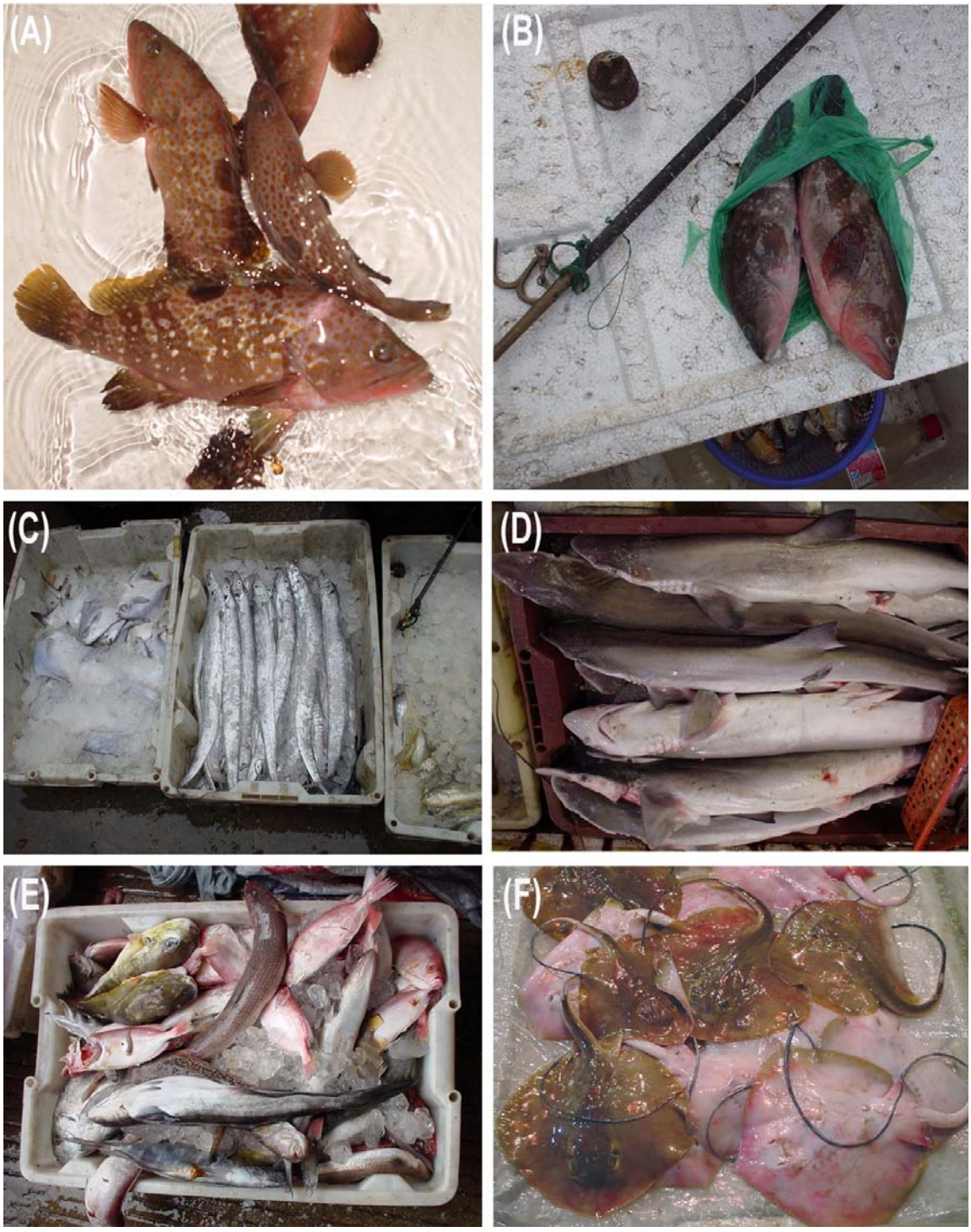

Plate 4.9 Common *Epinephelus* grouper species in capture and mariculture in Fujian Province. (A) Wild-caught *E. akaara* for grow-out in the north; (B) Wild-caught *E. awoara* (red starburst) and *E. quoyanus* (blue starburst) sold fresh dead in a wet market in the south; and (C) wild-caught *E. awoara* juveniles for grow-out in the south

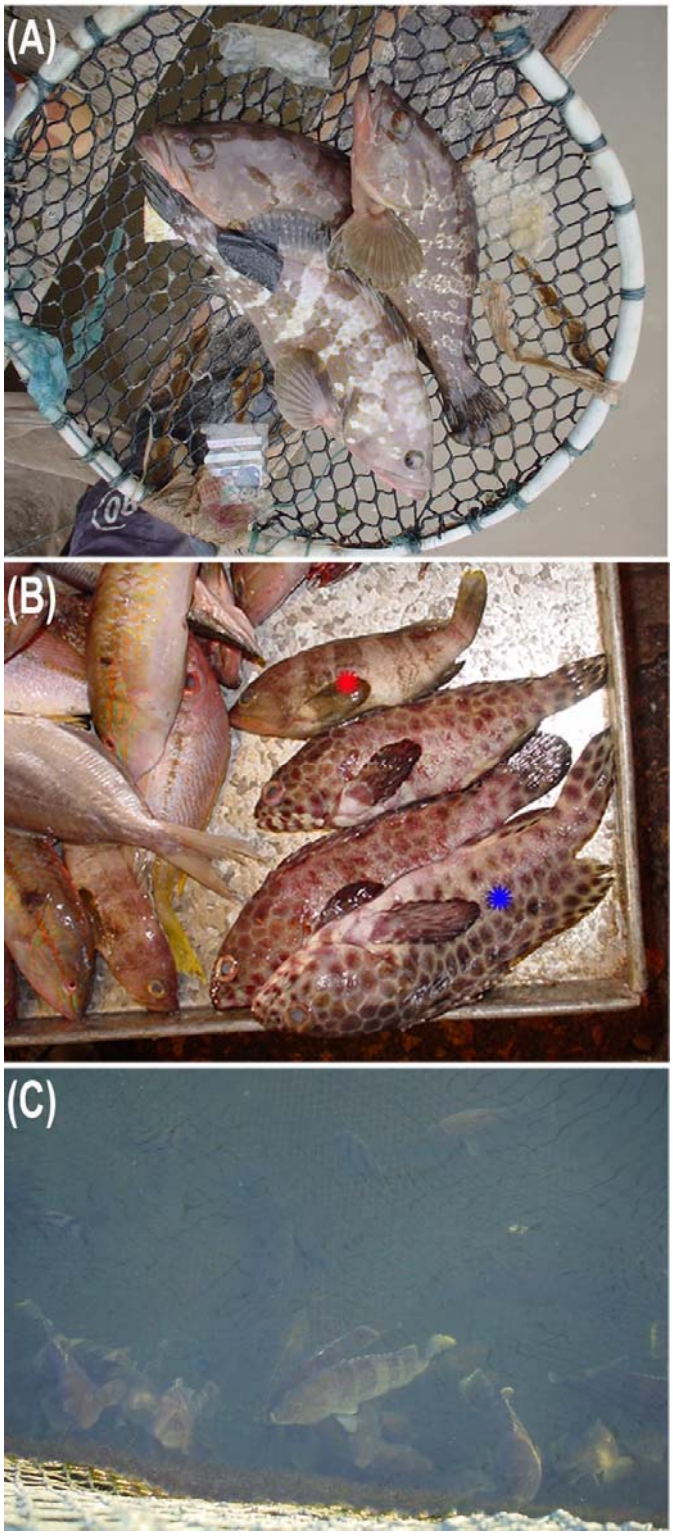

Plate 4.10 Some common fishing gears in multi-species fisheries in Fujian Province. (A) Large-size traps with about 30–40 sets per boat; (B) a large-size trap; (C) gill-nets with about 10 m long per piece and 10 pieces per boat; (D) two-layered gill-nets with different mesh sizes; (E) a fishing vessel with both trawl nets and small-size traps; and (F) a fishing vessel with small-size traps

Plate 4.11 Mixed fish feed used in mariculture in Fujian Province. (A) Feeding preparation on floating cages; (B) poor quality of mixed fish and crustacean feed; and (C) good quality of mixed fish feed such as sardines, mainly used for highly-valued species grow-out such as groupers

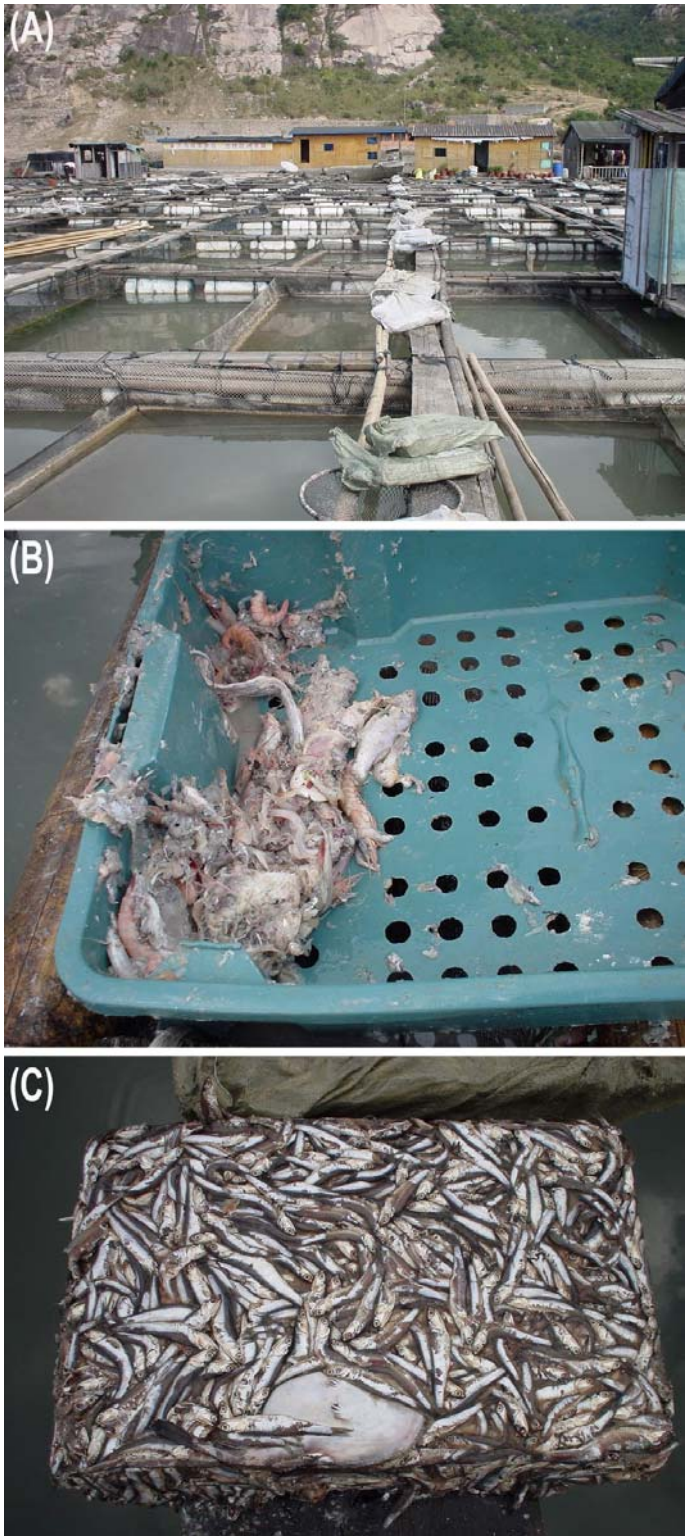

Plate 4.12 Grouper grow-out systems in Fujian Province. (A) Floating cages; and (B) intertidal ponds with floating cages in

Plate 4.13 Some marine food fishes in wet markets in Fujian Province. (A) *Epinephelus akaara* sold alive; (B) – (F) various fishes sold fresh dead. Blue starbursts-*Epinephelus* species; yellow starbursts-*Plectropomus* species

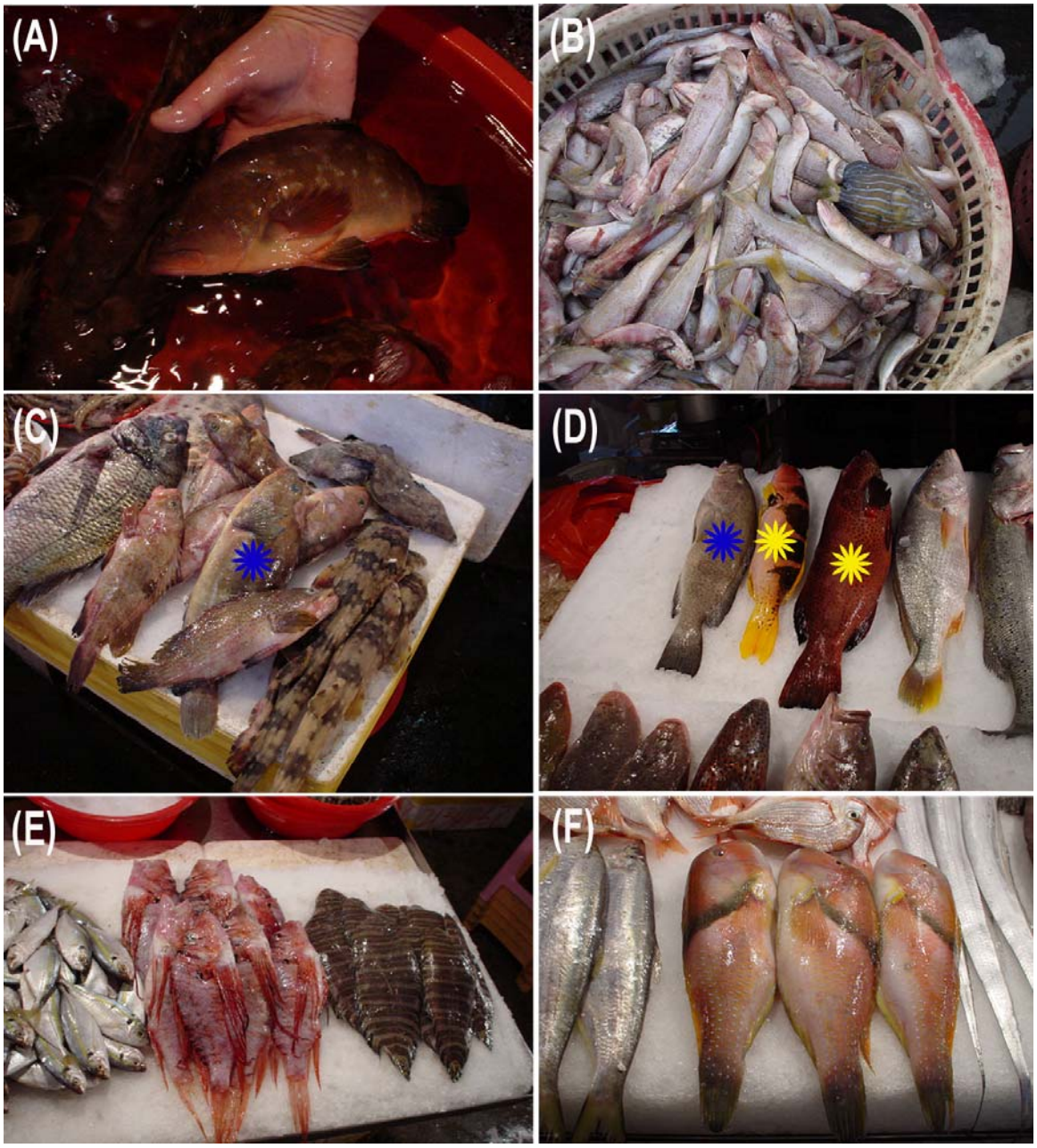

Plate 4.14 Some common fishing gears in multi-species fisheries in Guangdong Province. (A) Fix nets; (B) – (D) Traps; and (E) gill nets

Plate 4.15 Groupers mariculture in Guangdong Province with seed sources indicated. (A) *Epinephelus akaara* (wild-caught); (B) *E. lanceolatus* (hatchery-produced); (C) *E. awoara* (wild-caught); (D) *E. bruneus* (hatchery-produced); (E) *Plectropomus maculatus* (wild-caught); and (F) *E. coioides* (hatchery-produced)

Plate 4.16 Wild-caught *Epinephelus* species sold in wet markets in Guangdong Province. (A) *E. awoara* juveniles about 150 mm TL (blue starbursts); (B) *E. awoara* juveniles about 80–100 mm TL; (C) *E. coioides*; and (D) *E. quoyanus* (blue starburst). The diameter for the one-yuan RMB coin is 25 mm

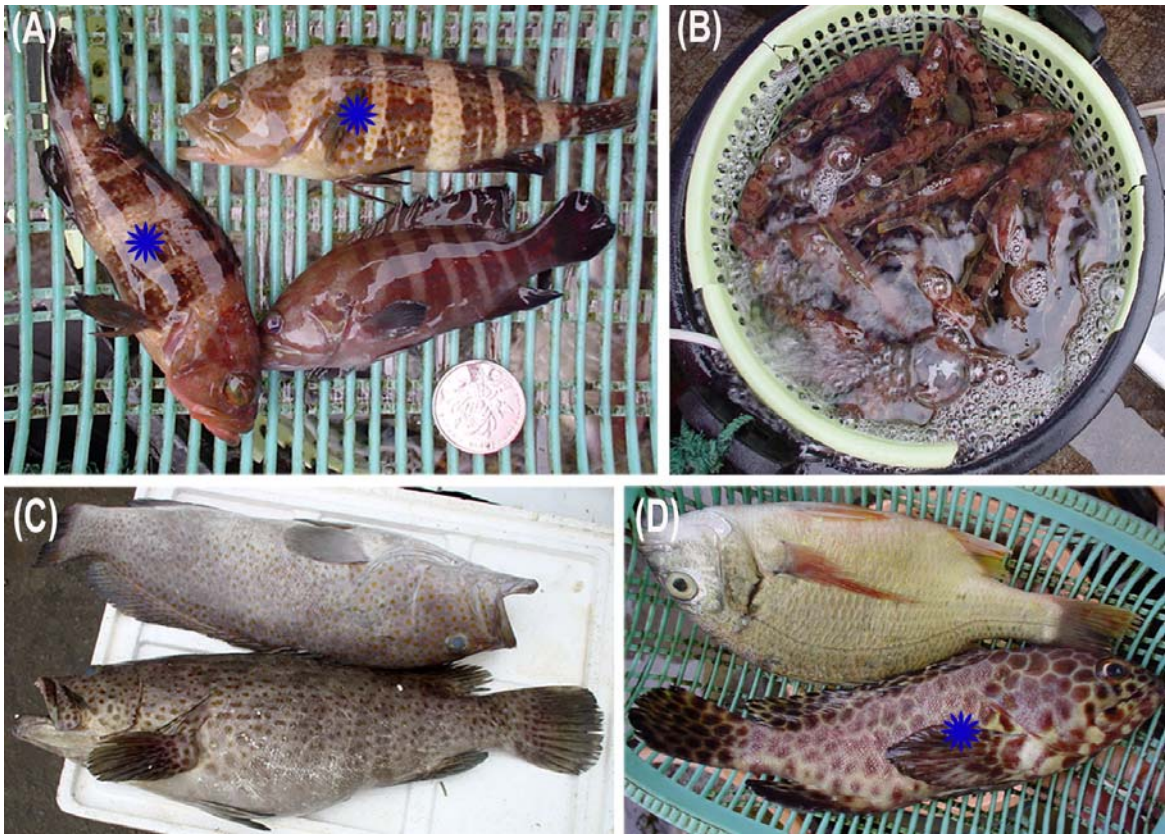

Plate 4.17 Groupers in the live food fish trade in Guangdong Province. (A) Grown-out *Epinephelus akaara* from wild-caught juveniles; (B) Wild-caught *E. akaara*; (C) *E. coioides* (yellow starburst) and *E. fuscoguttatus* (blue starburst); (D) *E. bleekeri*; (E) *E. fasciatus*; (F) *E. awoara*; (G) *E. lanceolatus*; and (H) *Plectropomus maculatus* (yellow starburst) and *P. leopardus* (blue starburst)

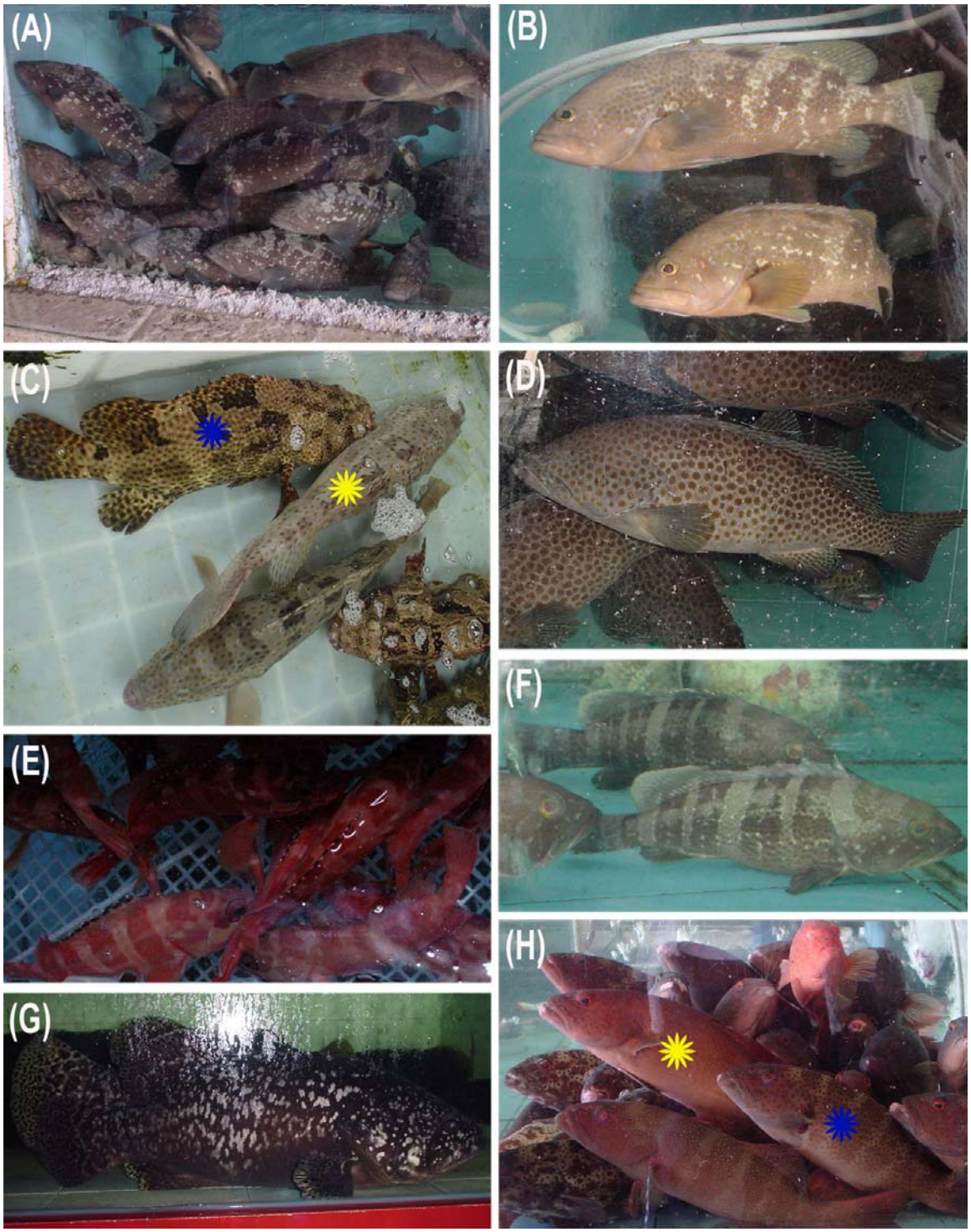

Plate 4.18 Fisheries and mariculture in Guangxi ZAR. (A) Trap fishing; (B) a mariculture zone; (C) *Epinephelus coioides* (yellow starburst) sold alive in a wet market; (D) and (E) wild-caught marine fishes sold fresh dead; and (F) commercial pellets for *Trachinotus blochii* mariculture

Plate 4.19 Grouper fisheries and mariculture in Hainan Province. (A) A wild-caught *Epinephelus trimaculatus*; (B) wild-caught *E. coioides*; (C) *E. coioides* fertilized eggs sold for larviculture; (D) grow-out hatchery-produced *E. lanceolatus* juveniles as broodstock source; (E) *E. coioides* and *E. malabaricus* broodstock in the same pond; (F) good quality of mixed fish feed for grouper broodstock; (G) pond mariculture for both broodstock and juveniles; and (H) floating cage mariculture for both broodstock and juveniles

Plate 4.20 Grouper mariculture with hatchery-produced juveniles in Hainan Province. (A) Grown-out *Epinephelus coioides* to marketable sizes; (B) *E. coioides* (yellow starburst) and *E. lanceolatus* (blue starburst); and (C) *E. fuscoguttatus*

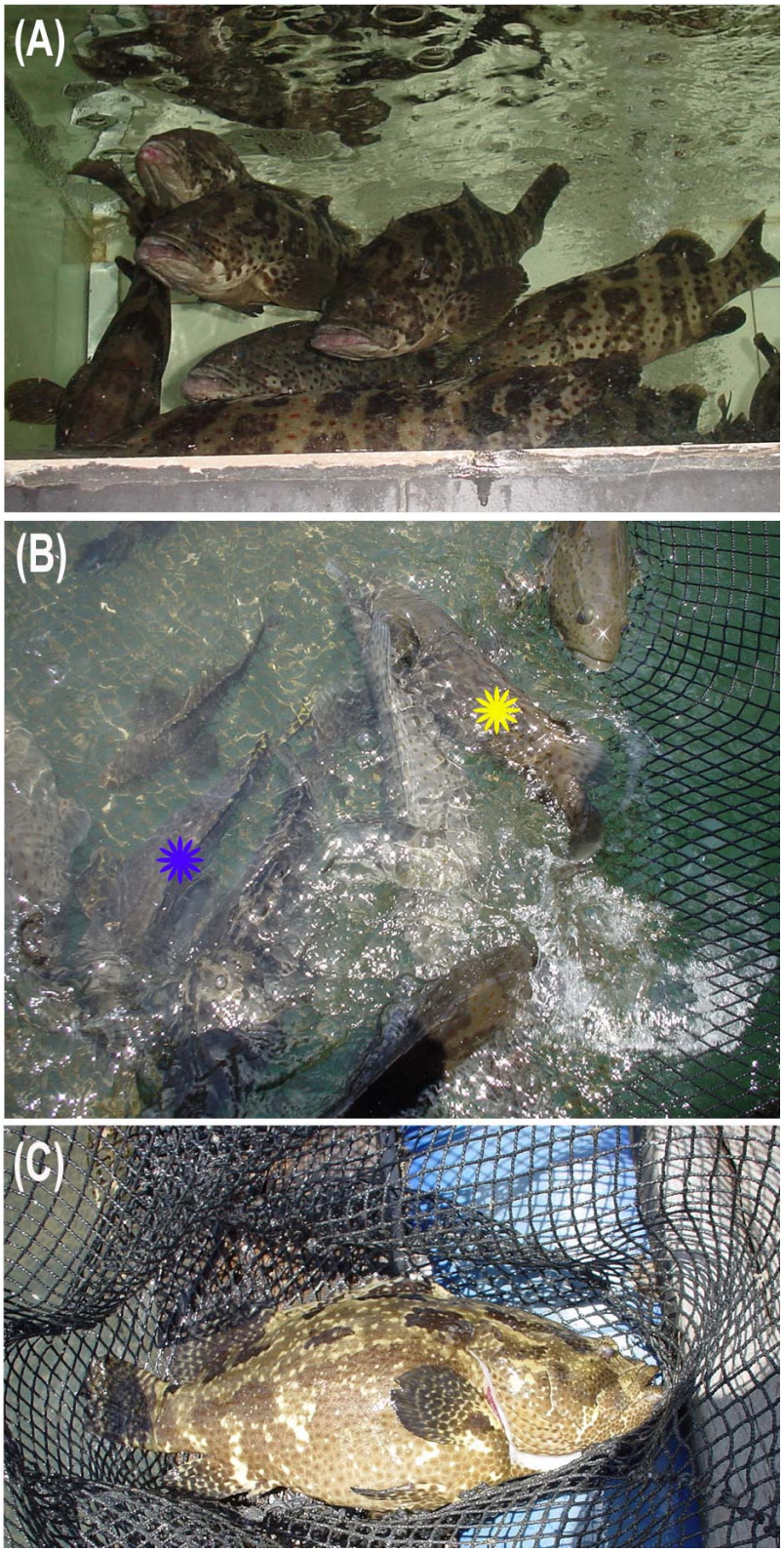

Plate 4.21 Grouper fisheries and food trade (fresh dead) in Hong Kong SAR. (A) *Epinephelus awoara*; (B) *E. bruneus*; (C) *E. malabaricus*; (D) *E. fasciatomaculosus*; (E) *E. lanceolatus*; and (F) *E. bleekeri*

Plate 4.22 Grouper mariculture (A–D) and food trade (live) (E–H) in Hong Kong SAR with sources indicated. (A) *Epinephelus cyanopodus* (seed imported from Taiwan); (B) *E. akaara* (wild-caught seed in Fujian); (C) *E. coioides* (hatchery-produced seed in Taiwan); (D) *E. lanceolatus* (hatchery-produced seed in Taiwan); (E) *E. akaara* (from mainland China); (F) *E. undulosus* (yellow starburst) (imported); (G) *E. merra* (source unknown); and (H) *E. fuscoguttatus* (from mainland China)

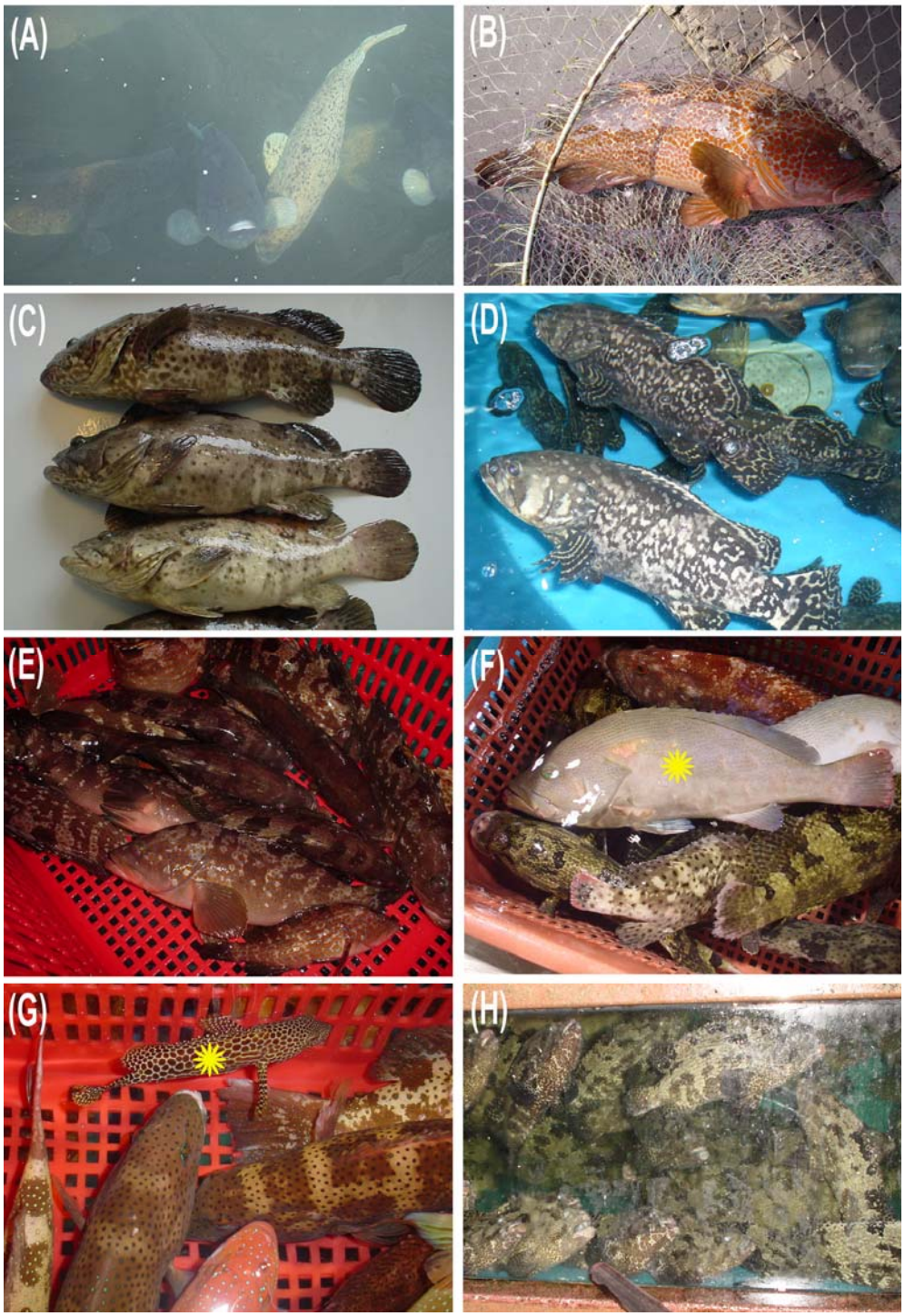

Plate 4.23 *Epinephelus akaara*. (A) A wild-caught individual (~ 250 mm TL) sold fresh dead in a Penghu wet market, Taiwan POC; and (B) hatchery-produced *E. akaara* juveniles with body sizes of around 30 mm TL. TL, total length

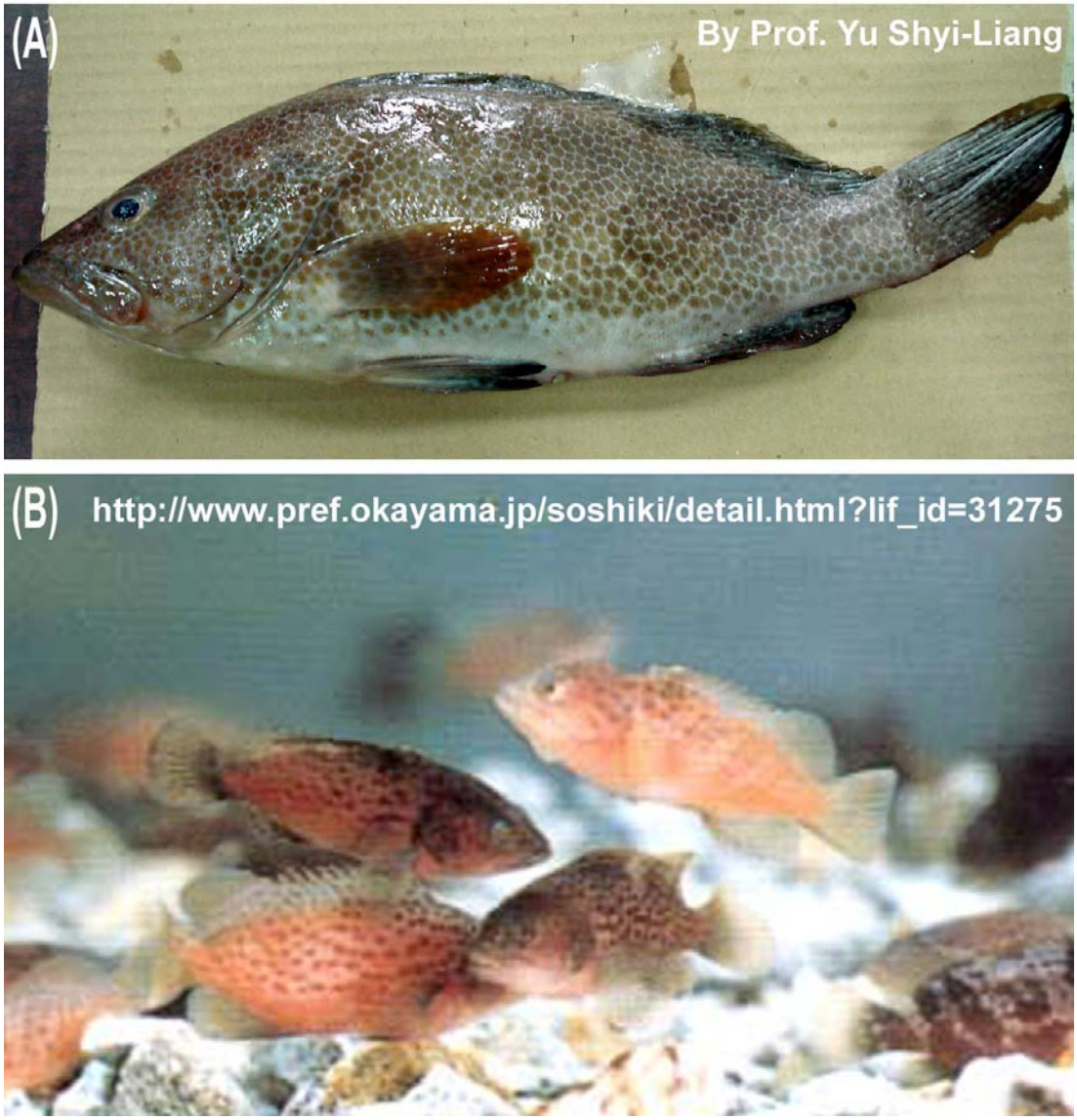

Plate 4.24 *Epinephelus* species in the live food fish trade, all wild-caught, in Jeju Island, South Korea. (A) *E. bruneus* (about 550 mm TL); (B) *E. septemfasciatus* (about 450 mm TL); (C) *E. fasciatus* (about 320 mm TL); (D) *E. chlorostigma* (about 250 mm TL)

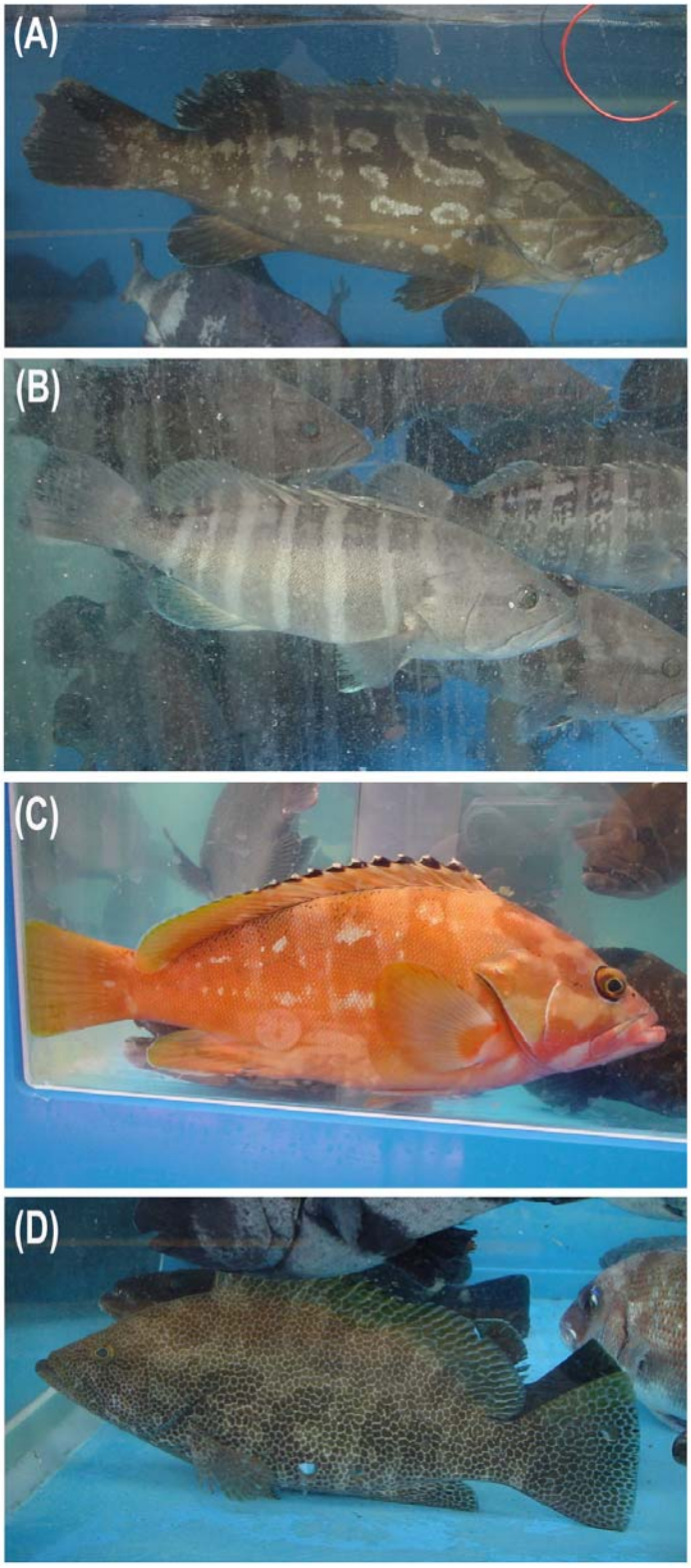

Plate 4.25 *Epinephelus akaara* hatchery in Jeju Island, South Korea. (A) Hatchery-produced juveniles about one and half years old; (B) a hatchery-produced juvenile with about 150 mm TL and one and half years old; and (C) hatchery-produced juveniles kept in captivity for about four years in order to being used as broodstock source in near future

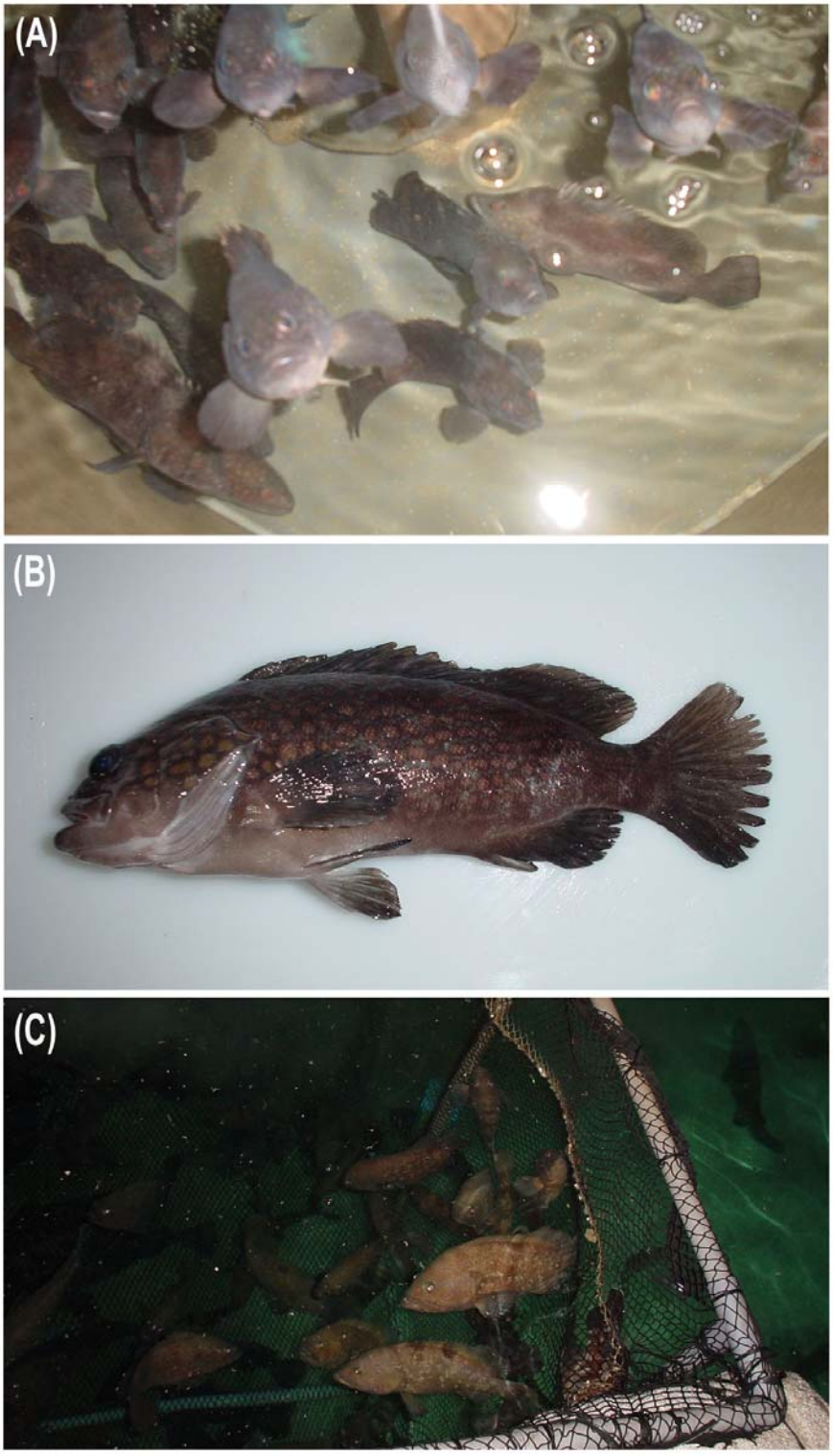

Plate 4.26 Grouper hatchery in Jeju Island, South Korea. (A) A hatchery-produced juvenile of *Epinephelus bruneus* with about 200 mm TL and one and half years old; (B) grouper broodstock tanks with about 3 m in depth and 5 m in diameter (insert a *Epinephelus septemfasciatus* broodstock observed from the window on the wall); and (C) tanks for grow-out experiment of hatchery-produced grouper juveniles

Plate 4.27 Marine fish hatchery for ornamental fish trade in Jeju Island, South Korea. (A) Hatchery-produced juveniles of *Amphiprion phippium*; (B) Hatchery-produced juveniles of *A. frenatus* and *A. melanopus*; (C) a paired female-male broodstock of *Amphiprion* species is taking care of their fertilized eggs (yellow starburst) attached on the tile; (D) fertilized eggs (yellow starbursts) of *Amphiprion* species attached on tiles; (E) broodstock of seahorse *Hippocampus kuda*; and (F) hatchery-produced *Hippocampus kuda* juveniles

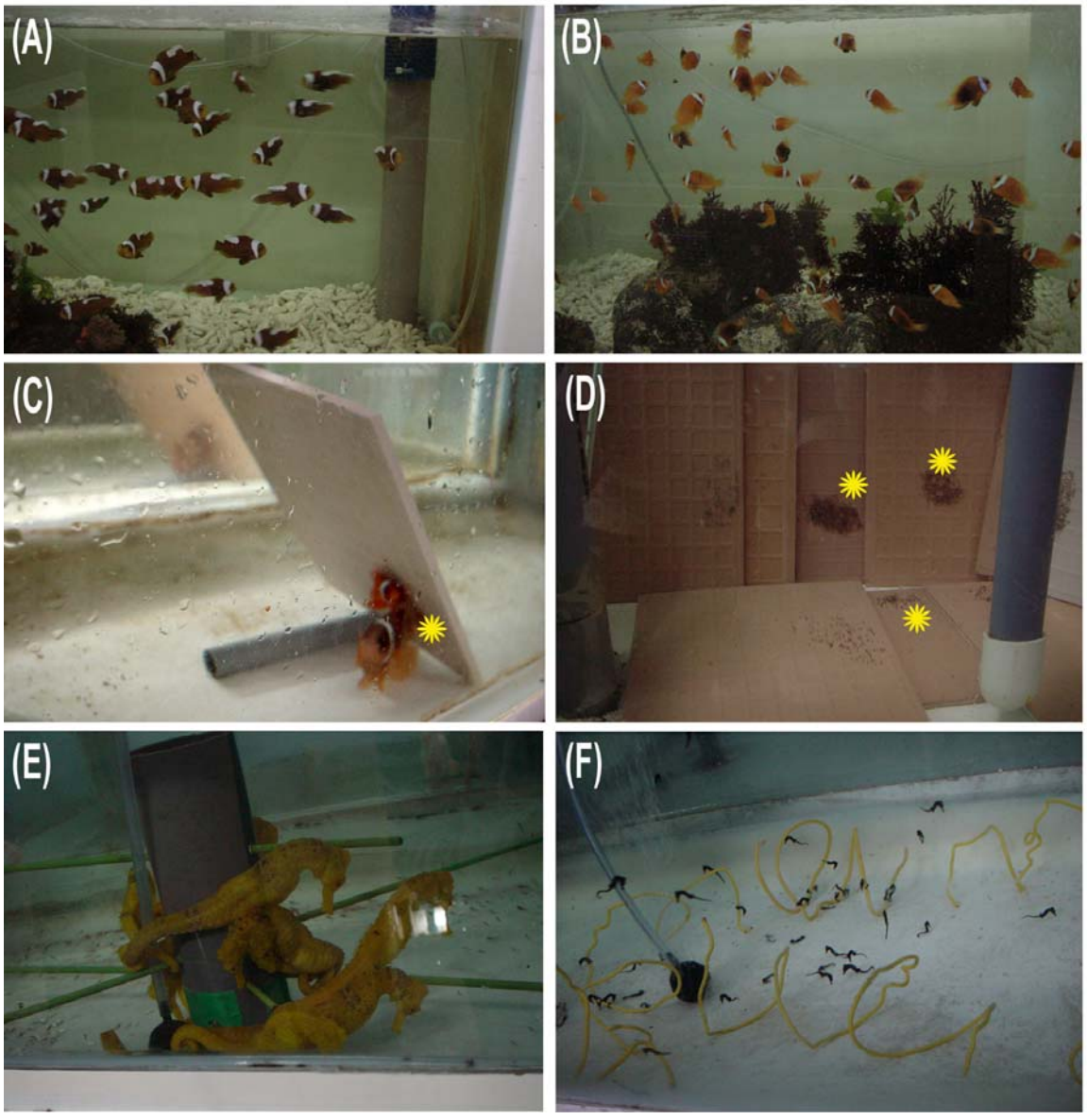

Plate 4.28 Marine fish culture in Jeju Island, South Korea. (A) *Paralichthys olivaceus* indoor culture with marketable size of 1–1.2 kg / fish; (B) hatchery-produced *P. olivaceus* juveniles ready for sale; and (C) a hatchery-produced *P. olivaceus* juvenile with about 110 days old and 150 mm TL; (D) one of the largest *P. olivaceus* hatcheries; (E) one of the largest *P. olivaceus* grow-out farms; and (F) *Fugu rubripes* grow-out

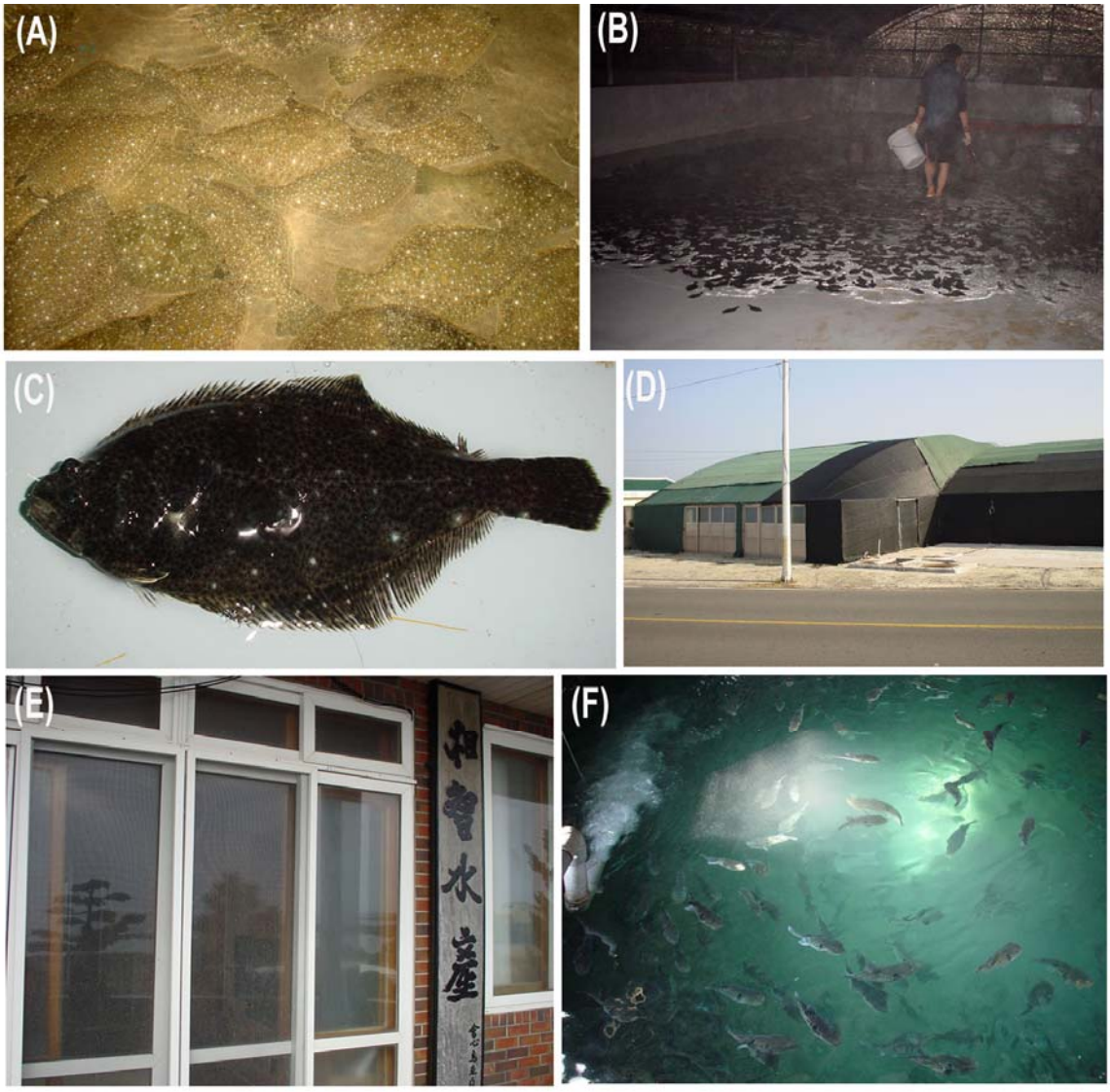

Plate 4.29 Some marine food fishes in trade in Jeju Island, South Korea. (A) – (D) various fishes sold fresh dead included rockfish, croaker, hairtail, damselfish and *Epinephelus septemfasciatus* (yellow starburst); and (E) – (H) various fishes sold alive included porgy, rabbitfish, flounder, ray and filefish