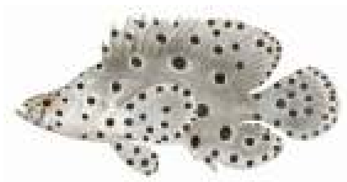

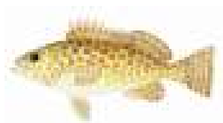

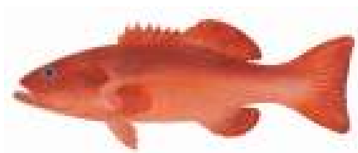

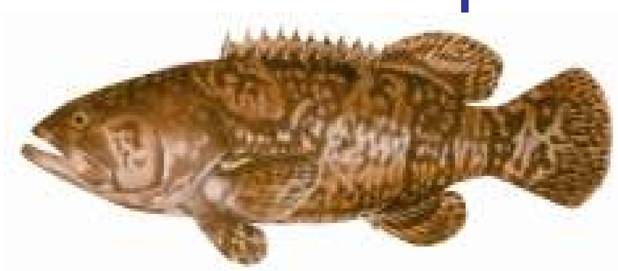

1st SPC Marine Finfish Hatchery Training

Krabi CFRDC, Thailand
14 May – 1 June 2007

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SPC Aquaculture Officer

SPC - Aquaculture section

Original text: English

Secretariat of the Pacific Community Cataloguing-in-publication data

Teitelbaum, Antoine

SPC Marine Finfish Hatchery Training (1st : 14 May – 1 June 2007 : Krabi CFRDC, Thailand) / Antoine Teitelbaum.

1. Fish hatcheries. 2. Fish culture. I. Teitelbaum, Antoine. II. Title III. Secretariat of the Pacific Community.

639.321
AACR2
ISBN: 978-982-00-0226-5

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Prepared for publication at
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Acknowledgements

The author wishes to thank Mr Ben Ponia, SPC Aquaculture Adviser, for releasing the funds to organise this course and for supporting the development of marine finfish training in the Pacific region.

The author also acknowledges NACA for designing the course and for the valuable administrative work with the Thailand Department of Fisheries. Mr Sih Yang Sim in particular is gratefully thanked for sharing his regional experience with SPC participants and for his hard work and commitment in organising the event.

Warm thanks are extended to the KCFRDC director, Mr Paiboon Bunlipatanon, and biologist staff: Mr Samart Detsathit, Mr Arkom Singhabun, Mrs Ampai Longloy and Mrs Nid Klingsukklai. Their kindness and willingness to share their knowledge made the course invaluable. The friendship demonstrated during the course also contributed to making it an extremely productive exercise. Other staff of KCFRDC are also acknowledged.

Finally, the SPC participants (Mr Thierry Tamata, Mr Jean Tu, Mr Gideon Pama, Mrs Vaiana Joufoques and Mr Maciu Lagibalavu) are acknowledged for their willingness to learn and participate as well as their help in making the course worthwhile for everyone.

Figure 1. Back row, left to right: Mr Thierry Tamata (French Polynesia), Mr Gideon Pama (PNG), Mr Jean Tu (New Caledonia), Mr Maciu Lagibalavu (Fiji), Mrs Vaiana Joufoques (French Polynesia), Mr Sih Yang Sim (NACA). Front row: Mr Antoine Teitelbaum (SPC), Mr Paiboon Bunlipatanon (KCFRDC), Mr Arkom Singhabun (KCFRDC).

Contents

Common name	*Scientific name*
abalone	*Haliotis diversicolor*
areolated grouper	*Epinephelus areolatus*
bar-cheeked coral trout	*Plectropomus maculatus*
batfish	*Platax* spp.
blue ring angelfish	*Pomacanthis annularis*
clownfish or anemonefish	*Amphiprion* spp.
cobia	*Rachycentron canadum*
fingermark snapper	*Lutjanus johnii*
giant grouper	*Epinephelus lanceolatus*
green grouper or gold-spot grouper	*Epinephelus coioides*
leopard coral trout	*Plectropomus leopardus*
lobster or crayfish	*Panulirus* spp.
malabar grouper	*Epinephelus malabaricus*
mangrove jack or red snapper	*Lutjanus argentimaculatus*
milkfish	*Chanos chanos*
mouse grouper or humpback grouper	*Cromileptes altivelis*
mud crab	*Scylla* spp.
Napoleon wrasse	*Cheilinus undulatus*
seabass or barramundi	*Lates calcarifer*
seahorse	*Hippocampus* spp.
silver angelfish	*Monodactylus argenteus*
tiger grouper or brown marble grouper	*Epinephelus fuscoguttatus*
trevally	*Caranx* spp.
white shrimp	*Litopenaeus vannamei*

Acronyms and abbreviations

µm	micrometre(s)
CHARM	Coastal Habitats and Resources Management project
COC	Code of Conduct
d (1, 2, 3)	day (1, 2, 3)
DO	dissolved oxygen
DOF	Department of Fisheries
EUS	epizootic ulcerative syndrome
FCR	food conversion ratio
GAP	Good Aquaculture Practices
ha	hectare(s)
HCG	human chorionic gonadotrophin
HUFA	highly unsaturated fatty acid
KCFRDC	Krabi Coastal Fisheries Research and Development Center
ml	millilitre
NACA	Network of Aquaculture Centres in Asia-Pacific
NPK	nitrogen (N) phosphate (P) potassium (K)
PL	post larvae
PNG	Papua New Guinea
ppm	part(s) per million
ppt	part(s) per thousand
t	ton(s)
sp., spp.	species
SPC	Secretariat of the Pacific Community
SPE	Service de la Pèche de Polynésie Française

1 Introduction

Several Pacific Island nations are in the process of developing their marine finfish industry, for various commercial purposes. The Secretariat of the Pacific Community (SPC) was requested by some of its member countries to source and organise the best possible marine finfish hatchery training.

Thanks to its linkage with the SPC Aquaculture Section, the Network of Aquaculture Centres in Asia-Pacific (NACA) agreed to organise a marine finfish hatchery training course. The training was based on the regular three-week NACA Grouper Hatchery Production training course but wsa specifically designed for a smaller group of Pacific Island aquaculturists with various professional backgrounds, from either private sector or government.

The Krabi Coastal Fisheries Research and Development Center (KCFRDC) in Thailand was identified as a suitable facility for the training because of its ability to mass-produce tropical species in hatchery (mostly grouper, seabass and cobia) and:

- its accessibility (direct flights to Krabi from Bangkok);
- its large size and available space for training purposes (both theoretical and practical);
- its skilled staff and their ability to communicate in English;
- the variety of tropical finfish that are being cultured at the Center; and
- the number of relevant commercial and governmental aquaculture facilities within a convenient distance of KCFRDC.

The overall design of the training followed a balance of practical work, theoretical work and field trips. Most of the theoretical work was dispensed using PowerPoint presentations on relevant fish farming/hatchery topics. Lecturers from KCFRDC and other research centres were involved in this part of the training. Fifteen presentations were given.

The main goal of the training was to carry out hands-on practical work in finfish hatchery techniques, with an emphasis on grouper. This work involved spawning induction, incubation and larval rearing until day 12 and through the critical stages at days 4, 5 and 6 and after the dorsal spine development of the larvae, when each trainee was assigned to a larval rearing tank. Simultaneously, the group was trained in mass production of live prey and live algae. Many other practical topics were discussed and demonstrated during the training.

Although most theoretical sessions and field trips were done according to the workload in the larval rearing room, KCFRDC staff managed to organise 13 field trips to a wide range of aquaculture operations in Krabi, Satun, Songkhla, Phuket and Phang Nga provinces. As a result, the group was exposed to commercial and governmental ventures in fish hatchery and grow-out (as well as crustaceans and molluscs), from small to industrial scale.

The training programme is described in Table 1.

Table 1: Marine finfish hatchery training programme

Date	**Time & Contents**		
	08:30-10:30	***11:00-12:30***	***14:00-16:30***
Mon May 14	• **Welcome/Opening address - Krabi CFRDC** • **NACA speech** • **Introduction to Krabi CFRDC (Mr Paiboon Bunlipatanon)** • **Brief information on NACA (Mr Sih Yang Sim)**		• Brief on the training programme • Tour Krabi CFRDC facilities
Tue May 15	• Spawning induction of tiger grouper *E. fuscoguttatus*	• **Biology of grouper (Paiboon Bunlipatanon)** • **Status of marine finfish aquaculture in Thailand (Paiboon Bunlipatanon)**	• On-the-job training • Discussion and briefing on next day's activities
Wed May 16	Field trip to Koh Yao Noi (marine fish floating cages and lobsters) - boat trip		
Thu May 17	• Spawning of tiger grouper and egg collection	• **Live feed production (phyto- and zooplankton) (Mawit Assava Aree)**	• **Fish health management (hatchery and nursery stages) (Janejit Kungkumnerd)**
Fri May 18	• Hatching and stocking of larvae in tanks • *Larvae d1*	• **Site selection, system design, equipment and set-up (Samart Detsathit)**	• On-the-job training • Discussion and briefing on next day's activities
Sat May 19	• Rotifer culture and algae inoculation • *Larvae d2*	• **Broodstock management (Samart Detsathit)**	• On-the-job training • Discussion and briefing on next day's activities
Sun May 20	• First feeding of larvae • *Larvae d3*		• On-the-job training • Discussion and briefing on next day's activities
Mon May 21	• Routine hatchery work, feeding, inoculation, observation, measurements • *Larvae d4*	• **Egg handling, morphological and behavioural development of grouper larvae (Samart Detsathit)**	• Abalone hatchery field trip (*H. diversicolor*) • Prawn hatchery field trip (*L. vannamei*)
Tue May 22	• Routine hatchery work, feeding, inoculation, observation, measurements • *Larvae d5*	• **Tiger and mouse grouper (*E. coioides* and *C. altivelis*) lecture (Paiboon Bunlipatanon)**	• Fish cages in Krabi field trip (mangrove jack, grouper, barramundi and cobia)
Wed May 23	• Routine hatchery work, feeding, inoculation, observation, measurements • *Larvae d6*	• **Green grouper *(E. coioides)* culture in Thailand (Paiboon Bunlipatanon)**	• On-the-job training • Discussion and briefing on next day's activities
Thu May 24	• Routine hatchery work, feeding, inoculation, observation, measurements • *Larvae d7*	• **Marine ornamental fish breeding (Samart Detsathit)**	• Visit to prawn farm (*L. vannamei*)

Date	Time & Contents		
	08:30-10:30	***11:00-12:30***	***14:00-16:30***
Fri May 25	• Field trip to Satun to visit the government aquaculture station, seabass (*L. calcarifer*) hatchery and prawn hatchery • Field trip to Khao Yai broodstock fish cage holding facilities		
Sat May 26	• Field trip to Songkhla aquaculture research centre, seabass hatchery and coastal fisheries management • Visit to Koh Yao, Songkhla Lake, seabass cage farming, over 1000 farmers		
Sun May 27	***Day off***		
Mon May 28	• Routine hatchery work, feeding, inoculation, observation, measurements • *Larvae d11*	• **Nutrition and feed development (hatchery and nursery stages) (Pitchaya Chinark)**	• On-the-job training • Discussion and briefing on next day's activities
Tue May 29	• On-the-job training • Larvae harvest and restocking in a new tank • *Larvae d12*		• On-the-job training • Discussion and briefing on next day's activities
Wed May 30	• Field trip to Phuket Aquarium • Field trip to a large abalone hatchery (*H. diversicolor*)		
Thur May 31	• Field trip to Phuket sea cage farm where numerous species of fish are grown • Visit to Phuket aquaculture centre (seabass and cobia hatchery, ornamental fish hatchery and polychaete worm hatchery) • Visit to Phang Nga national aquaculture station (molluscs: giant clam, goldlip oyster and abalone; fish: grouper, clownfish cobia and seabass)		
Fri Jun 1	• **PowerPoint presentation on the CHARM project (Sanchai Tandavanitj)** • *Larvae d15*	• **Lecture on cage culture** • **Lecture on shrimp certification (Sanchai Tandavanitj)**	• **Lecture on marine finfish hatcheries and culture in SE Asia (Sih Yang Sim)** • Closing and presentation of certificates • Farewell dinner
Sat Jun 2	Departure of participants for home		

2 Introductory presentations and tour of the KCFRDC facilities

2.1 General presentation of the training

On arrival the group was welcomed by NACA grouper specialist Mr Sih Yang Sim, who gave a presentation on NACA, and by Mr Paiboon Bunlipatanon, head of Krabi CFRDC, who gave a presentation on the centre's activities and Thailand's Department of Fisheries (DOF).

The group was informed that researchers from several provinces would be giving lectures during the training:

- Mr Paiboon Bunlipatanon (Head of Krabi CFRDC and grouper aquaculture specialist)
- Mr Samart Detsathit (Senior Biologist at KCFRDC and finfish aquaculture specialist)
- Mr Mawit Assava Aree (Head of the Songkhla Aquaculture Research Centre and live prey production specialist)
- Mrs Janejit Kungkumnerd (Senior Biologist at Songkhla Aquaculture Research Centre and health and disease specialist)
- Mrs Pitchaya Chinark (Senior Biologist at Phang Nga Aquaculture Research Centre; nutrition and feed development for early stages)
- Mr Sanchai Tandavanitj (CHARM project manager, based in Bangkok)

The technical staff of KCFRDC in charge of the SPC group were:

- Mr Samart Detsathit (Senior Biologist and finfish aquaculture specialist – ornamental fish hatchery manager)
- Mr Arkom Singhabun (Senior Biologist and finfish aquaculture specialist – grouper hatchery manager)
- Mrs Ampai Longloy (Biologist – shrimp hatchery manager)
- Mrs Nid Klingsukklai (Biologist– fish hatchery technician)

SPC participants introduced themselves to the rest of the team (see Table 2).

Table 2: Participants in the Marine Finfish Hatchery course

Name / Country	Position / Organisation	(a) Specialisation and (b) specific interest
Mr Antoine Teitelbaum New Caledonia	**Aquaculture Officer** SPC	a. Tropical bivalve (pearl oyster and giant clam) hatchery and grow-out and marine finfish hatchery, nursery and grow-out (sea bass, sea bream and mulloway) b. Ornamental trade and marine finfish hatchery
Mr Jean Tu New Caledonia	**Commercial fisher** TUMAT	a. Fishing for tuna and sea cucumber b. Starting a commercial grouper hatchery and grow-out facility
Ms Vaiana Joufoques French Polynesia	**Marine finfish hatchery technician** SPE	a. Marine finfish hatchery: broodstock management and grow-out of batfish (*Platax orbicularis)* b. Develop knowledge on aquaculture of other finfish, and other species

Name / Country	Position / Organisation	(a) Specialisation and (b) specific interest
Mr Thierry Tamata French Polynesia	**Marine finfish hatchery technician** SPE	a. Marine finfish hatchery, weaning and nursery (batfish, threadfin, grouper or other species) b. Develop knowledge of other finfish species hatchery and grow-out
Mr Gideon Pama Papua New Guinea	**Aquaculture Officer** National Fisheries Authority	a. Gift tilapia hatchery and grow-out (cages and ponds); PNG Inland Fishery Management Plan b. Marine finfish hatchery and grow-out (grouper, barramundi and seabass)
Mr Maciu Lagibalavu Fiji	**Head of Aquaculture** Ministry of Fisheries and Forests	a. Supervises the aquaculture section of Fiji Fisheries, has some experience in aquaculture b. Wishes to acquire technique in grouper hatchery and husbandry

Paiboon Bunlipatanon introduced the SPC group (also referred as 'the group') to the activities of DOF in Thailand generally and those of Krabi CFRDC in particular, which are:

- increasing aquatic production by releasing seabass and shrimp seeds
- inspection and certification of fisheries products
- marine aquaculture research and development:
  - crabs, shellfish and seaweed aquaculture
  - high-value food finfish culture
  - ornamental fish culture (clownfish, seahorses, other species)
- extension and services
- aquatourism

NACA was presented by Sih Yang Sim, who provided details of the following core activities:

- shrimp farming and the environment
- Asia-Pacific Marine Fish Aquaculture Network
- aquatic animal health
- genetics and biodiversity
- culture-based fisheries
- support to regional aquatic resource management
- special programme in response to the tsunami
- training and study tours

2.2 KCFRDC facilities tour

Water is pumped at high tide from a coastal tidal flat in front of KCFRDC to a well. Two pumping systems are operated simultaneously: one for hatcheries and broodstock areas, and one for earthen ponds.

For the hatcheries and the grow-out area, there are four 60,000-litre tanks that are used for chlorination and dechlorination processes. Dechlorinated water is pumped into a header tank and gravity-fed to broodstock areas and hatcheries.

At KCFRDC there are several fish hatcheries and nursery halls, divided into a hatchery, nursery room and broodstock areas for food fish (grouper, seabass, cobia); a shrimp hatchery and nursery room; and an ornamental fish hatchery and grow-out area (Figures 2 and 3).

Several earthen ponds are also used for broodstock holdings of large species (*E. lanceolatus*), and cage culture systems are placed in some of the ponds for holding broodstock and juvenile fish. Prior to flowing through the ponds, water transits through a settlement pond.

Figure 2: Broodstock and grow-out area for anemonefish at KCFRDC

Figure 3: Nursery tanks for prawns at KCFRDC

Table 3: Krabi CFRDC facilities

Denomination of the area	Tanks: number/type	Size of tanks / type of system	Species/stages cultured
Food fish culture area			
Larval rearing room	16 square, concrete	4t - flow-through	Grouper and seabass larvae
Nursery room	8 circular, concrete	15t - flow-through	Grouper and seabass juveniles
Outside broodstock area	6 square, concrete	15t - flow-through	Grouper broodstock (mouse and tiger)
Outside broodstock area	3 square, concrete	60t - flow-through	Grouper (giant and green)
Ornamental fish culture area			
Clownfish hatchery			
Broodstock tanks	50 aquariums, glass	50 litres - recirculated	*Amphiprion* spp. (11 species) broodstock
Grow-out tanks	15 square, concrete	3t - recirculated	*Amphiprion* spp. (11 species) juveniles
Larval room	16 conical, fibreglass	1t - static	*Amphiprion* spp. (11 species) larvae
Other ornamental fish area (seahorse, silver angel, damsel, batfish)			
Multipurpose outdoor area	40 square, concrete	4t - flow-through	Larval, nursery and broodstock area for all other species of ornamental fish
Outdoor grow-out systems and broodstock holding			
Floating sea cages 1	50 square, 3*3*2	In a pond	Nursery, grow-out and broodstock handling for all fish species
Floating sea cages 2	50 square, 3*3*2	In a pond	Nursery, grow-out and broodstock handling for all fish species
Floating sea cages 3	5*5 square	In a pond	Broodstock holding and species demonstration, including Napoleon wrasse, coral trout, trevally and many others
Ponds	1ha	Flow-through	Broodstock holding for giant grouper

Live prey area			
Rotifers culture area	30 raceways, concrete	20t - flow-through	*Brachionus rotundifera*
Algae culture area	30 raceways, concrete	20t - flow-through	*Nannochloropsis* spp.

3 Theoretical aspects of the training

The following is a short summary of the most important lectures given during the training. The chronology of these presentations is in the programme (see Table 1).

3.1 Biology of groupers (Paiboon Bunlipatanon)

Each grouper species suitable for aquaculture was described, with information on habitat, feeding, size and size at maturation. The following species were described: *Cromileptes altivelis*, *Epinephelus fuscoguttatus*, *E. malabaricus*, *E. lanceolatus*, *E. coioides*, *Plectropomus leopardus* and *P. maculatus*.

To be suitable for aquaculture purposes, finfish species must satisfy the following criteria: fast growth, short food chain, efficient food conversion ratio (FCR), readily accept pellets, good table qualities and disease resistance. The species must be easy to breed, have an early maturation and high fecundity, and tolerate water quality fluctuation as well as crowding.

3.2 Status of marine finfish aquaculture in Thailand (Paiboon Bunlipatanon)

This presentation outlined the general context of aquaculture development in Thailand, its constraints, advantages and main characteristics. Although grouper culture technology is accessible throughout the nation, seabass remains the most important fish cultured in Thailand for local consumption. Competition for grouper species is high with neighbouring countries (Vietnam, for example) and the market, which is rather small, fluctuates a lot.

In Thailand most grouper seeds are either captured from the wild (mostly *E. coioides* and *E. areolatus*), produced in government stations or exported from hatcheries overseas (Indonesia, Taiwan). Commonly cultured species are grouper (gold-spot, mouse, areolated, giant, tiger, malabar and coral trout), cobia, seabass, milkfish and mangrove jack.

In 2004 more than 17,000 tons of seabass and groupers were produced, coming from over 8000 farms scattered across the country from the east coast of the Thai Gulf (30%) to the west coast of the Thai Gulf (20%) and the Andaman Sea (50%).

Figure 4: Juvenile *Cromileptes altivelis*, ready for cage culture transfer

Figure 5: Cage culture set-up near Krabi area, in Koh Yao Noi

3.3 Live feed production, phyto- and zooplankton (Mawit Assava Aree)

Various live prey is available for marine finfish production in Thailand. The techniques used to mass-produce zooplankton and phytoplankton were outlined.

Phytoplankton: used to feed live prey or cultured species directly; can be mass-cultured outdoors either in batches or continuous cycle.

- Green algae: *Tetraselmis* spp. and *Nannochloropsis* spp. (usually used for rotifer cultures)
- Diatom: *Skeletonnema* spp. and *Chaetoceros* spp. (usually used for zoea stages in shrimps)

Zooplankton: used for feeding directly to cultured species

- Rotifer SS: *Brachionus rotundiformis*
- *Artemia nauplii*
- Adult artemia
- *Moina* spp.
- *Diaphanosoma*

Figure 6: Outdoor mass culture area for marine chlorella (*Nannochloropsis* spp.)

Marine yeast culture was also described, as an alternative feeding source. Methods used for enriching live zooplankton were also thoroughly described.

3.4 Diseases and fish health management (Janejit Kungkumnerd)

Here, the group was provided with a general reminder of fish diseases, with an emphasis on stress management in husbandry. Diagnosis procedures were reviewed.

Onsite procedure:
- observing changes in behaviour
- monitoring environmental and physical factors

Laboratory inspection for:
- surface symptoms
- internal symptoms

The different groups of disease (parasites, bacterial, fungus and viral) were discussed, with symptoms, diagnosis, treatment and prevention described for each particular disease.

Parasites: Trichodinosis, Amyloodinium, white spot, Chilodonella, Epistylis, myxosporean and crustacean
Bacteria: Vibriosis, Flexibacter and streptococcus
Viral: Nodavirus, iridovirus, lymphocystis and EUS

Emphasis was put on prevention and control of disease through stress management, good hygiene practices, adequate diagnosis and disease prevention.

3.5 Site selection, system design and set-up (Samart Detsathit)

This practical presentation was designed like a 'shopping list'. After a review of site selection for a grouper hatchery (i.e. water quality, protection against natural hazards), a thorough description of the tanks used in a grouper hatchery was given, including chlorination/dechlorination tanks, header tanks, broodstock tanks, larval rearing tanks and live food production tanks. Requirements such as air, water and electricity supply were presented and discussed, and laboratory and hatchery equipment were illustrated.

Figure 7: Air blower at KCFRDC

Figure 8: KCFRDC staff catching *C. altivelis* with various types of hatchery equipment available from hardware/kitchen stores: baskets, scoops, tubs

3.6 Broodstock management (Samart Detsathit)

One of the advantages of broodstock captured from the wild is that the gene pool is generally more diverse than hatchery-reared broodstock. Also, wild-caught broodstock fish are usually mature, while it takes a long time for hatchery-reared fish to grow to adult size. However, broodstock from hatchery can be selected for good morphological characteristics and growth potential, and these fish usually mature a lot faster.

The spawning seasons in Thailand are outlined in Table 4.

Table 4: Spawning time of four fish species in Thailand

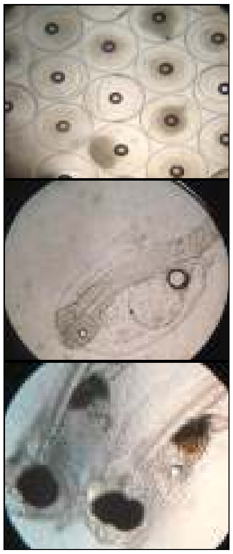
	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr
E. coioides								←	—	—	—	→
C. altivelis	←	—	—	—	—	—	—	—	—	—	—	→
E. fuscoguttatus		←	—	—	—	→						
Cobia				←	—	—	—	—	→			

Source: KCFRDC

The morphological differences between males and females were outlined. Feeding practices were detailed: broodstock females' feed is supplemented with vitamin E, mixed vitamins, spirulina and fish oil. Squid is fed to broodstock once a week. Sex ratio is maintained at about 2-3 females per male grouper. Generally, stocking densities should be around 1-3 kg of fish according to species, but some species have minimum tank size requirements.

Anaesthetics used for broodstock are quinaldine, MS222, clove oil and 2-phenoxy ethanol. Hormones used to inject the fish can be Suprefact and Motilium-M, HCG, Puberogen and pituitary gland.

3.7 Egg handling, morphological and behavioural larval development of grouper (Samart Detsathit)



This presentation exposed the group to the techniques used in observing, sampling, counting and measuring marine fish eggs.

Topics reviewed were: oogenesis, assessment of eggs and sperm, ovarian biopsy procedure, and spawning factors affecting egg quality.

Embryonic and larval development were thoroughly explored and explained, as were the techniques related to egg selection, disinfection and incubation.

A document called 'Embryonic and larval development of brown marble grouper, *Epinephelus fuscoguttatus*' was given to all participants to illustrate the presentation.

Figure 9: Eggs, newly hatched and day 5 stages of *E. fuscoguttatus* larvae

3.8 Grouper culture in KCFRDC (Paiboon Bunlipatanon)

This presentation was divided into three lectures that summarised the experiments carried out at KCFRDC on these species:

- tiger grouper culture (*E. fuscoguttatus)*
- mouse grouper culture (*C. altivelis*)
- gold-spot grouper culture (*E. coioides*)

The technique used for the three species are similar; however, each has specificities. The results from and progress made on each species at KCFRDC throughout the years were shared and discussed.

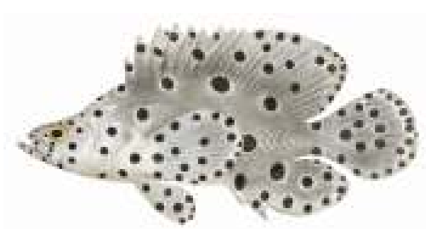


Figure 10: Mouse or humpback grouper (*Cromileptes altivelis*)

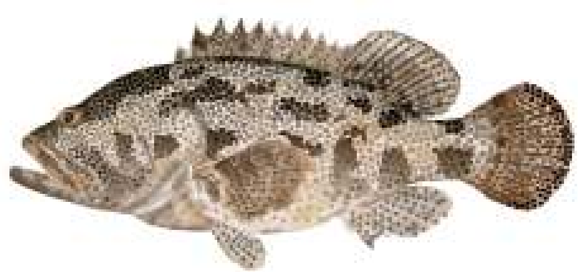


Figure 11: Brown marble or tiger grouper (*Epinephelus fuscogutattus*)

3.9 Marine ornamental fish breeding (Samart Detsathit)

A large part of this presentation was about the biology and taxonomy of anemonefish (*Amphiprion* spp. and *Premnas biaculateus*). System design and live stock management for ornamental fish are relatively simple, as water volumes are a lot lower than for grouper and other larger species.


Figure 12: Incubating clownfish eggs on a slate using aeration

Samart Detsathit, the officer in charge of the ornamental hatchery at KCFRDC, described the breeding techniques and life cycle of anemonefish, silver angel (*Monodactylus argenteus*), batfish (*Platax orbicularis*) and seahorses (*Hippocampus* spp.).

In ornamental fish culture, efforts are made to domesticate the species and care for its wellbeing, as the final product must be visually attractive (shape of body and fins, bright colours, etc.), exhibit friendly behaviour and not be scared of humans, and have the ability to feed on artificial diets.

3.10 Nutrition and feed development (Pitchaya Chinark)


Figure 13: Whole squid used to feed grouper broodstock


Figure 14: Small fresh carangids used as 'trash fish'

The major challenges related to nutrition and feed development are the increase in aquaculture production and the reduction of the use of human food-grade feed sources in feed formulation, including fisheries products ('trash fish'). Overcoming the safety issues and reducing the impact of aquaculture on the environment are also being closely investigated.

Terrestrial feedstock such as plant and animal products/by-products, fisheries by-products and single-cell protein appears to be a more reliable source of aquafeed, and ongoing research is focusing on these products.

In larval rearing, major research topics are the enrichment of traditional live prey with essential unsaturated fatty acids and the development of micro-diets to substitute traditional live prey (labour intensive). The micro-diets are being improved along with: (i) the use of predigested protein sources (hydrolysed); (ii) free amino acids and peptides; and (iii) chemical and physical stimuli.

3.11 Marine finfish hatcheries and culture in Southeast Asia (Sih Yang Sim)

Marine fish farming in Southeast Asia has been developing at a rapid pace, especially in Indonesia, Malaysia and Vietnam (see Table 5). This is a result of the improvement of farming techniques (hatchery) and the inclusion of the activity in government strategic plans. International markets are healthy and most of the production aims at exporting.

Table 5: Comparison between three countries' hatchery and farming practices

Country	Hatchery practices	Farming practices
Indonesia	– small-scale low-investment and low-cost backyard hatcheries – fast return – increasingly capital intensive: medium- and large-scale hatcheries established – grouper (humpback, tiger, orange-spotted, coral and coral trout), milkfish, trevally, snapper, etc.	– mainly floating cages – medium to large scale – concrete tank culture – capital intensive and high investment – mix of trash fish and artificial diets
Malaysia	– capital intensive – medium and large scale – mix of tank and pond systems – limited species produced – majority of marine finfish species farmed rely on imported fingerlings	– floating cages and ponds – medium to large scale – relatively capital intensive – mix of trash fish, artificial diets, bakery products, etc.
Thailand	– commercial production limited to seabass – grouper species from government stations – many marine fish species farmed – still rely on imports or wild seeds	– mix of floating cages and ponds – small to medium scale – low-investment capital – mainly trash fish

Source: Sih Yang Sim (NACA)

Although new aquaculture practices seem to be making their way through the SE Asia region, it appears that most of them might not be suitable in the SE Asia context, e.g. floating cages of large volume that require cranes for handling, or high-tech hatchery equipment that is hard to replace/maintain.

The marine finfish sector, especially grouper production, is facing constraints related to (i) seed production (some species have low survival, supply can be inconsistent and seasonal, seed supply still relies a lot on wild-caught juveniles); (ii) the availability of feed (whether it is trash fish or artificial feed); (iii) the problems linked to low-tech farming methods; and (iv) prices and the market (excess supply, price fluctuation, niche markets, seasonality).

Issues related to grouper as an export commodity are: (i) fluctuation in demand and supply; (ii) competition within Asian countries (e.g. Vietnam is more competitive than Thailand); and (iii) the potential impact of the increase in production on the global market: how much grouper can the market actually absorb, given the current yearly increase in production?

4 Practical aspects of the training

4.1 Hormone stimulation and spawning induction

This was demonstrated and practised on **day 2 (15 May 2007)** of the course.

– Preparation of the hormonal injection chemicals: **Motilium-M** and **Suprefact** are mixed to a given concentration in the laboratory. The group is invited to mix the hormone that will stimulate gamete release in the induced fish.
– *Epinephelus fuscoguttatus* broodstock are fished in the 15t tank by lowering the level of the tank. They are caught with an old blanket and placed in a small tank where they are anaesthetised using quinaldine.
– The individuals are then checked for gonad ripeness by (i) stripping (Figure 16) or (ii) cannulation for females. A cannula is introduced into the oviduct and eggs are sampled for texture and shape, which will indicate their maturity. If the belly is soft and round, it is likely to be a female. Generally, males are bigger than females; most fish in this tank are mature.
– Several mature broodstock are injected with the hormone preparation. Each trainee has a chance to try. The needle is placed at a 45-degree angle between the dorsal fin and the lateral line, in the middle of the back half of the fish (Figure 15). A calculated amount of hormone is injected, according to the weight of the fish.
– Normally, only a few fish need to be injected as their spawning/courtship behaviours will induce the rest of the fish in the tank. Most of the time, natural spawning is practised in this hatchery as the quality of the eggs and the fertilisation rates are usually better.
– On the same day, two other species of grouper are also injected, including *Cromileptes altivelis* and *Epinephelus coioides*.
– Once the fish are induced, they will spawn within 40–48 hours.

Figure 15: Injecting *E. fuscoguttatus* with a solution of Suprefact and Motilium-M

Figure 16: Male *E. fuscoguttatus* being stripped

4.2 Spawning and egg harvesting and incubation

Demonstrated and practised on **day 4 (17 May 2007)** of the course.


Figure 17: Harvesting grouper eggs floating on the surface of the spawning tank, with a seine net


Figure 18: Flow-through incubator used prior to hatching

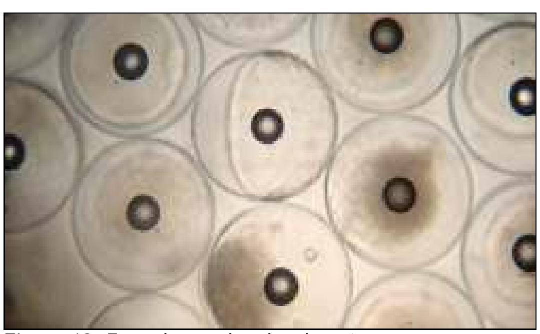


Figure 19: Eggs observed under the microscope, at harvesting. This is early gastrula stage.

– The tiger grouper have spawned during the night and a large number of eggs are observed floating on the surface of the tank.

– The group is invited to help collect the eggs using a seine net. Aeration of the tank is stopped, allowing the good-quality eggs to float. These are sieved from the surface with a 300µm-mesh seine (Figure 17).

– Good-quality eggs are collected and transferred to the hatchery, then inspected under the microscope (Figure 19). Although there is a good fertilisation rate, they are still at an early development stage. This means that the fish have spawned early in the morning instead of late at night, which might harm the future development of the larvae.

– Once harvested, the eggs are placed in a 200-litre tank. They are stirred thoroughly and any sinking eggs are siphoned out of the tank. Weed and other debris are removed from the tank. After that, several samples are taken from those tanks to estimate the number of eggs. The mean is 2.5 million eggs.

– The eggs are dipped in iodine for disinfection for 10 minutes.

– After disinfection, the eggs are harvested in a sieve and placed in the incubator, on flow-through, with gentle aeration (Figure 18). They are left to incubate for 24 hours and will be placed in the larval rearing tank the next day.

– In the afternoon, a second batch of eggs is harvested from the tank by staff from the station and placed in a second incubator.

– Larval rearing tanks are prepared. Each participant is assigned to a 4-ton tank. The tanks are thoroughly cleaned with iodine and domestic detergent and then rinsed with fresh water. Aeration is installed in the tanks.

4.3 Hatching and stocking of larvae

This was demonstrated and practised on **day 5 (18 May 2007)** of the course.

– On the morning of day 5, the larvae have hatched. This is day 1 after hatching for the larvae. They are gently transferred to the larval rearing tanks using plastic containers at a density of 80 larvae per litre (Figure 20). Each tank is stocked with 250,000–300,000 larvae.

– Aeration is set low, to stir the water without damaging the larvae (Figure 21). Six air stones were previously placed in the tank before stocking.

– A second eye count (using 100ml) is done directly in the tank after the larvae are stocked. However, introducing glassware to the tank stresses the larvae, so no more counts are done until later larval rearing.

– The tanks are then shaded with 50% shade cloths to reduce direct light and decrease stress on the larvae.

– Larvae are observed under microscope to calculate yolk size, lipidic globule size and total length (volume of yolk size = $4/3\pi(r1)^2r2$).

– For at least two days, the larvae will feed on yolk. No external feeding is needed at this stage.

Figure 20: Two participants stocking a larval rearing tank on day 1 after hatching

Figure 21: PNG participant adjusting the aeration in the larval rearing tank

4.4 Live feed production for early larval rearing

This was demonstrated and practised on **day 2 (15 May 2007)** of the course.

Green micro-algae (Nannochloropsis spp.)

– For grouper culture in Thailand, green water technique is used. For this technique, it is necessary to mass-produce green micro-algae, either *Tetraselmis* spp. or *Nannochloropsis* spp. (chlorella). At KCFRDC, only chlorella is used. They will feed the zooplankton (rotifer) and tint the water, reducing the stress level of the fish. However, to keep the algae population in a larval tank, new algae have to be inoculated every day.

Figure 22: Stock culture of green algae at Phang Nga research centre (Phang Nga province)

– A practical session is organised to familiarise the group with mass culture of chlorella. Six 400-litre tanks are filled with 5µm filtered seawater at 300 litres and 100 litres of chlorella (concentration = 2.5*10(-6) cells per ml).

– The group prepares NPK solution (Figure 23). Three fertilisers (A, B and C) with different NPK concentrations are diluted and introduced to the algae culture tank (A: 21-0-0; B: 16-20-0; C: 46-0-0).

Figure 23: PNG participant preparing fertiliser for green algae mass culture

– Aeration is set high.

– Algae concentration in the starter tank is estimated using a hemacytometer. The starter concentration is 2.5*10(-6) cells per ml.

– In the afternoon, the group observes algae for protozoa development and adds chlorine to kill foreign organisms at 1ppm.

– Later, the algae tanks are checked for protozoa contamination and the culture is treated with 1ppm of chlorine. If contamination is high, the process can be duplicated. Algae culture is safe to feed to rotifers at least 10 hours after the treatment.

Figure 24: Inoculating chlorella in a 500-litre tank for mass culture

– Chlorella growth is exponential. As it is an outdoor culture, light and heat induce a fast bloom.

SS rotifer (Brachionus rotundiformis)

– Rotifers are cultured in the same tanks as the green algae. Once the algae bloom, rotifers are introduced at a density of 10 per ml. They will bloom up to 30–50 individuals per ml and are then ready for harvest; otherwise, they will consume all the chlorella and the population in the tank will crash.

– The SS strain of rotifer is a brackish-water strain, and salinity is maintained between 15 and 20 ppt in the culture tanks. At KCFRDC, rotifers are cultured in 'continuous cycle' in 15-ton concrete raceways. 'Continuous cycle' means that there is no dry-out between culture cycles. Once the rotifer population reaches the required density, half of the volume in the tank is harvested and the tank is refilled with fresh chlorella.

– For a starter culture, rotifers are stocked at around 30 per ml.

– It is not necessary to enrich the rotifers as chlorella naturally has high levels of highly unsaturated fatty acid (HUFA), required by the grouper larvae.

– To estimate the density of a rotifer population, a ml is sampled from the culture tank and placed on a Sedgewick slide with a drop of formalin to kill the rotifers (if they don't move, they are easy to count). They are counted using the microscope; the process is repeated several times and the mean result is expanded to the volume of the culture tank (Figure 27).

– For the first days of the grouper larvae feeding, only the smallest section of the rotifer population is harvested. Rotifer are harvested and sieved through a 100µm mesh (Figure 25). Small rotifers and rotifer eggs will be used for the first feeding of the grouper larvae.

Figure 25: Harvesting rotifers from a mass culture tank

Figure 26: Rotifers stocked in a bucket at high density

Figure 27: PNG and French Polynesia participants estimating the rotifer density in the culture tank

4.5 Early larval development: days 1-2

Demonstrated and practised on **days 5-6 (18-19 May 2007)** of the course.

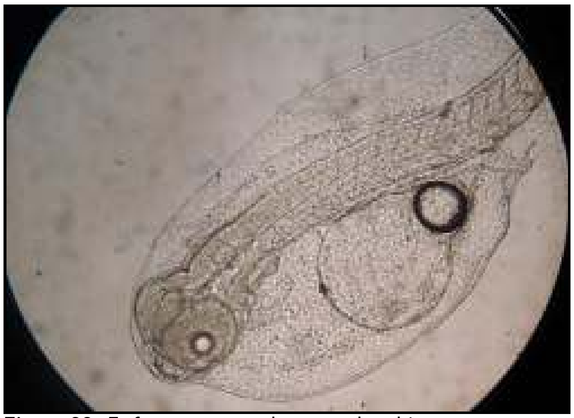


Figure 28: *E. fuscogutattaus* larvae at hatching

– The very early stages of larval development require little care and attention.

– The larvae are lecithotrophic. It takes around two days for them to absorb the yolk and for the mouth to open. The size of the larvae is measured.

– For the first two days of the larval rearing, the group measures the volume of the yolk sac and the size of the lipidic globule in order to evaluate the absorption of the yolk and estimate the time of the mouth opening.

– On day 2 of the larval rearing, chlorella is introduced to the larval tanks.

– Introduction of 0.5 million cells/ml to the tank. Algae is pumped from the mass culture tank to a 200-litre tank and the debit is evaluated. One hundred litres of algae are inoculated in each larval tank.

– There are no rotifers in the tanks yet; if there were, the algae concentration inoculated would be higher (1 million cells/ml).

– First feeding will be on day 3 after hatching.


Figure 29: Day 2 larvae for *E. fuscogutattus*

4.6 Early larval development: days 3-5

Demonstrated and practised on **days 7-9 (20-22 May 2007)** of the course.

– The group checks on the larvae tank on day 3, adding chlorella to keep the concentration up to 1 million cells/ml.

– The group adds five rotifers per ml, from the section below 100μm. (Small rotifers are sieved to 100μm for small size.)

– After the tank inoculation, the group works in the laboratory to measure mouth gap using the following formula: **mouth gap = √2*length of the upper jaw**. (Mouth gap between 250 and 500 μm.)

– A potential problem is suspected in the larval rearing tanks. As the spawning was late (between 3 a.m. and 5 a.m.), hatching was delayed and the first feeding is likely to be later as well (as first feeding is at 66 hours). We will reach 66 hours at 2-3 p.m. on day 3, which means that the larvae will only have a short amount of daylight time for feeding (we are six hours behind).

Figure 30: The black spots are patches of floating dead larvae in the rearing tank

– On day 4, the grouper larvae enters critical development stage (days 4-5-6). A lot of larvae die and get trapped at the surface. This is not starvation, as the larvae still have their yolk sacs. Causes of mortality can be various.

– During these three days, the algae are inoculated daily and the rotifer population is maintained at around 10 per ml.

– Larvae are observed under the microscope to check ingestion of rotifers. The group is taught how to count the mandibles of a rotifer inside a larva's stomach.

– On day 5, high mortality is observed again. The mortality should stop on the next day.

4.7 Early larval development: days 6-12

Demonstrated and practised on **days 10-16 (23-29 May 2007)** of the course.

– On day 6, mortality has stopped but survival is low. Chlorella is inoculated and the rotifer population in the tank is estimated.

– Larvae are observed under the microscope. The first dorsal spine starts to appear.

– On day 7 the tanks are cleaned as rotifer bloom might generate an increase in the ammonia level. A box with 500µm mesh is placed in each tank and a siphon is placed inside the box (Figure 32). The tank is refilled with 5µm water and chlorella to meet 1 million per ml; the rotifer population is still high at 30/ml.

– Between days 8 and 10, routine rotifer and algae inoculation is practised and larval development is observed under the microscope.

Figure 31: Day 12 grouper larvae are visible in the water columns and very active

Figure 32: Siphoning mesh boxes used for water exchange

Figure 33: KCFRDC biologist demonstrating siphoning of sediment at the bottom of the larval tank

– On day 11, the bottom of each tank is siphoned to remove sediment in preparation for tank transfer and larvae count on day 12 (Figure 33).

– On day 11, larvae are observed under the microscope. The swim bladder is now developed, as well as three dorsal spines and a ventral spine.

– On day 12, all the tanks are harvested using plastic scoops and containers (Figure 35). The larvae from all tanks are counted and stocked into one tank. Larvae are stocked at 10 per litre; approximately 10,000 larvae survived until day 12. Survival until weaning will now be high.

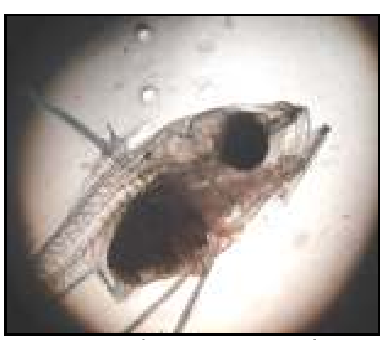


Figure 34: *E. fuscoguttatus* larvae on day 12

Figure 35: Participants harvesting larvae on day 12

4.8 Larval rearing: day 13 to metamorphosis (~d40)

Figure 36: Harvesting freshly hatched *Artemia nauplii*

Figure 37: Enriching artemia with INVE Selco

- Usually, survival of grouper larvae is higher than 10–12% after day 12.

- The group studies the following stages of larval development: hatching, first feeding, critical stages at days 4-5-6, spinal development, bladder development, until day 14.

- Larval rearing from day 14 up to weaning stage is not as problematic as the early stages, and mortality lowers during the second half of grouper larval life.

- Routine feeding with chlorella and rotifers continues until days 15–20, after which *Artemia nauplii* are fed to the larvae.

- At KCFRDC, artemia cysts are immersed in fresh water for 20 minutes with heavy aeration and then chlorine is added for 10 minutes.

- Once washed, the artemia cysts are left to incubate in a covered 350-litre tank with dark sides and a clear bottom.

- Twenty-four hours later, the nauplii have hatched and must be enriched with INVE Selco or another enrichment solution that has high HUFA. This is compulsory for grouper larval development.

Weaning is done by using either artificial food or minced trash fish.

Table 6: Feeding schedule of *E. fuscoguttatus* larvae

Day	3	15	20	30	40	50	>60
Rotifer and chlorella	←	—	→				
Artemia		←	—	→			
Adult artemia				←	—	→	
Minced fish and pellets					←	—	→

Source: KCFRDC

4.9 Nursery

Although nursery wasn't the main focus of this course, participants had daily exposure to nursery practices, including (a) grading and sorting for deformities; (b) feeding; (c) culture methods and culture tanks; and (d) packaging and transporting.
While the group was at KCFRDC, numerous *Cromileptes altivelis* of around 5 grams were stocked in the nursery tanks and the group could observe and assist in all the handling activities.

a. Grading for size and deformities is done manually. Groupers are fished out of their culture tanks and placed in 500-litre tubs. They are then inspected for deformities and sorted according to their size.

b. Feeding juvenile grouper at KCFRDC is done with an artificial diet. Because mouse grouper are fairly slow-moving and gregarious animals, the food has to be dispensed slowly and to satiety. Feeding too much and too quickly would result in a decrease of the water quality in the tank. When the nursery stages are carried out in cages, in small-mesh nets, a plastic box is placed upside down in the cage so the pellets do not float away through the mesh.

c. Juvenile groupers are cultured in 10–15 ton tanks at low stocking density of around 1–4 fish per litre when they weigh around 5 grams. Most grouper are very gregarious and will gather around any structure the tank can offer (sides, stand pipes). Shelter is provided to juvenile grouper by submerging PVC structures in the tanks for the fish to aggregate and hide (Figure 39).

d. Packaging and transporting is done in plastic bags. Two to four litres of fresh seawater is placed in each bag with 20–25 juvenile fish. The bag is then inflated with pure oxygen and sealed with a rubber band. The fish will stay alive in the bag for several hours. If the fish are transported from the indoor culture area to nearby floating cages, they are placed in buckets with a compressor blowing air through multiple airlines and air stones.

Figure 38: Nursery floating cages in a pond at KCFRDC (used for all fish species)

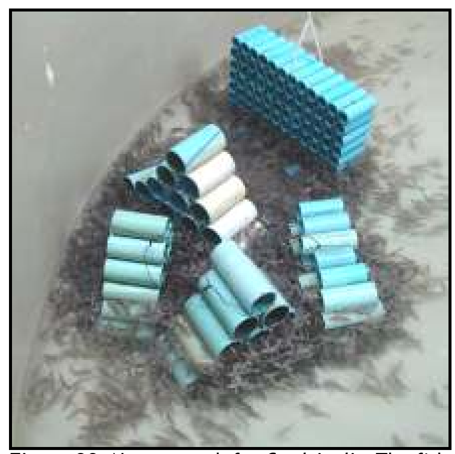


Figure 39: Nursery tank for *C. altivelis*. The fish aggregate and hide in the PVC pipes.

Figure 40: Chopping fresh fish for juvenile grouper

4.10 Grow-out

Thai grow-out techniques were thoroughly examined during the numerous field trips around Krabi and to other provinces. The participants observed the following grow-out methods (most of which were cages) for grouper during the training:

- floating single square cages in ponds (5*5*2): KCFRDC
- floating multiple square cages in ponds (3*3*2): KCFRDC
- floating multiple square cages at sea (5*5*2 and 3*3*2): Koh Yao Noi, Koh Yai, Phuket, Krabi River
- floating circular cages at sea (10 metres diameter, Norwegian-made): Phuket
- fixed cages (5*5*2 or variable sizes): Songkhla Lake

There is a large number of grow-out farm designs, which vary according to the **species cultured** (e.g. cobia – large cages vs grouper – smaller cages), the **capital investment** available (industrial vs small-scale company), **environmental conditions** (current, waves, cyclones) and **farming area** (pond, lake, river mouth, open ocean).

In Thailand, most fish are grown out using trash fish. ‘Trash fish’ are generally good-quality fresh small fish from the carangid, clupeid, leiognathid and other families. The FCR with trash fish is very low and the number of trash fish consumed is high. Sometimes trash fish are not available, and their price fluctuates a lot, leaving little freedom to smaller farmers. It appears that switching from trash fish to pellets is a viable option for the fish farming industry.

Figure 41: Floating cages for grouper grow-out at Koh Yao Noi, Krabi Province

Figure 42: Floating cages for cobia grow-out in Phuket Province

5 Field trips: the diversity of aquaculture in Southern Thailand

Table 7: Field trips organised during the training

Date	Field trip
Wed May 16	√ Field trip to Koh Yao Noi (marine fish floating cages and lobsters) – boat trip
Mon May 21	√ Abalone hatchery field trip (*H. diversicolor*) √ Prawn hatchery field trip (*L. vannamei*)
Tue May 22	√ Fish cages in Krabi field trip (mangrove jack, grouper, barramundi and cobia)
Thu May 24	√ Visit to prawn farm (*L. vannamei*)
Fri May 25	√ Field trip to Satun, visit to the government aquaculture station, seabass (*L. calcarifer*) hatchery and prawn hatchery √ Field trip to Khao Yai broodstock fish cage holding facilities
Sat May 26	√ Field trip to Songkhla aquaculture research centre, seabass hatchery and coastal fisheries management √ Visit to Koh Yai, Songkhla Lake, seabass cage farming, over 1000 farmers
Wed May 30	√ Field trip to Phuket Aquarium √ Field trip to a large abalone hatchery (*H. diversicolor*)
Thu May 31	√ Field trip to Phuket sea cage farm where numerous species of fish are grown √ Visit to Phuket aquaculture centre (seabass and cobia hatchery, ornamental fish hatchery and polychaete worm hatchery) √ Visit to Phang Nga national aquaculture station (molluscs: giant clam, goldlip oyster; abalone; fish: grouper, clownfish, cobia and seabass)

Field trip 1: Floating fish farms in the Krabi area

Figure 43: Chopping trash fish for juvenile groupers

On 16 May, the group visited floating farms on Koh Yao Noi, an island located between Krabi and Phuket. Most of the cages were destroyed by the 2004 tsunami, but some farmers were financially helped by Thailand's king's daughter to re-establish their farms.

The area is protected, in a large channel where there seems to be a lot of current. The water is shallow and murky and seems to be productive as there are a lot of fishing activities around the cage farms.

Figure 44: farmer displaying lobster in a cage (P*anulirus ornatus)*

The floating set-ups are similar and each farm has around 50–60 nets of 3*3*2. Most fish grown in the cages have been collected from the wild as juveniles (*Epinephelus areolatus*, *E. coioides*), but others were purchased in hatcheries (cobia, seabass).

Lobsters (*Panulirus ornatus*) seem to be attracting the most interest for these cage farmers (Figure 44). Although it takes 18 months for a lobster to grow to 1 kg (commercial size), they are currently better value than grouper. Juvenile lobsters are caught thumb-sized near Phuket Island.

Lobsters and finfish are fed trash fish (mostly leiognathids – ponyfish) caught around the cages. Young fish are fed chopped-up fish (Figure 43) while adults are fed whole fish.

* * *

On 22 May, the group visited some floating cage set-ups in the mouth of the Krabi River. Those set-ups have up to 100 3*3*2 net cages (Figure 45). Fouling is high as the water is murky but it seems very productive. Nets spend only a short immersion time and are sun-dried before being reused. The farm grows cobia, red snapper, grouper, seabass and other miscellaneous species of fish. Two tons of trash fish are fed to the stock every other day. The farm was affected by the tsunami in 2004 but government aid money was made available to restart it.

Figure 45: Floating net cages in the Krabi River area – 100 rooms for grouper, cobia, seabass and red snapper

Field trip 2: KCFRDC ornamental hatchery

KCFRDC is currently successfully breeding 11 species of anemonefish: 10 *Amphiprion* spp. (*ocellaris, percula, ephippium, sebae, polymnus, clarkii, frenatus, melanopus, akallopsios* and *perideraion*) and *Premnas biaculateus* (Figure 47).

All species are being reared using traditional larval-rearing protocols: rotifer and chlorella, artemia and weaning on artificial diets. Most fish are sold at a small size to Thai ornamental operators before being exported. The centre has successfully carried experimentation with pond and cage grow-out of anemonefish.

Three species of seahorse are also cultured at KCFRDC: *H. monhikei, barbouri* and *spinosissimus.* Larval rearing protocols follow an *Artemia nauplii* feeding schedule, and as the juveniles grow, the artemia are grown out to adult stages using rice starch. Mysid shrimps are also fed to juvenile and adult seahorses.

Silver angel (*Monodactylus argenteus*) and batfish (*Platax orbicularis*) are being reared at KCFRDC using green-water larval rearing protocols. Silver angel is reared in either fresh brackish or salt water, and batfish is stocked at low density to enhance fin growth as this species is sold for ornamentals.

Larval rearing protocols are also being developed for other species, such as damselfish (*Chrysiptera* spp.) and blue ring angelfish (*Pomacanthus annularis*; Figure 49). So far, experimentation has had limited success. The mesocosm technique is used for larval rearing trials on 'difficult' species.

Figure 46: Four-ton tanks used for ornamental culture at KCFRDC

Figure 47: Breeding pair of *Premnas biaculateus* (large = female; small = male)

Figure 48: Larval rearing tanks used for clownfish larviculture

Figure 49: Broodstock *Pomocanthus annularis* in a 4t tank at KCFRDC ornamental hatchery

Field trip 3: Abalone hatcheries and farms in Krabi and Phuket

Figure 50: Over one-year-old abalone hiding on a tile in a grow-out tank

Figure 51: Nursery raceways for abalone

On 21 May, the group visited an abalone hatchery and grow-out farm in the Krabi area.

The species cultured is *Haliotis diversicolor*, which has a high market value in Taiwan and relatively fast growth rates. The abalone broodstock are fed *Gracilaria* spp. for conditioning and then induced to spawn. Larvae are lecitotrophic and at settlement they are fed with artificial feed.

After incubation, the larvae are stocked directly in grow-out tanks with corrugated tiles (Figure 50) to increase, and are harvested at commercial size. The set-up is fairly basic, with flow-through concrete raceways (15–20 tons) (Figure 51).

* * *

The Phuket abalone farm (visited on 30 May) is a very large hatchery of *Haliotis diversicolor*. There is a strong market for this producer, who exports all over Asia. Here, broodstock is also fed with *Gracilaria* spp. and *Ulva* spp., whereas artificial feed is used for grow-out purposes.

Narvicula spp. and *Nitschia* spp. are mass-cultured for the post-settlement stage of the abalone. Diatoms are bloomed in nursery tanks with corrugated plastic sheets (Figure 52). Spat settles on the fertilised substrate and a month later is transferred to grow-out tanks with clay tiles. Commercial size is reached in about a year.

The whole system is recirculated and biosecurity is considered seriously at this farm: it is not open to the public, and drastic precautions are taken to prevent disease introduction.

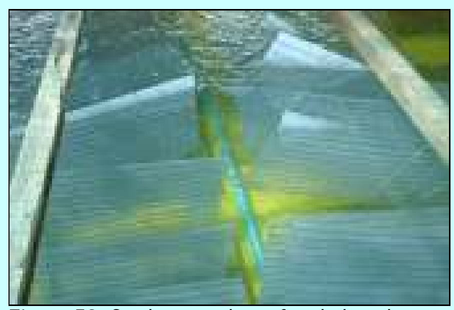


Figure 52: Settlement plates for abalone larvae. They have been inoculated with diatoms.

Figure 53: Juvenile abalone (2–3 months old)

Field trip 5: Intensive white shrimp farming in the Krabi area

The Lookmee prawn hatchery in the Krabi area (visited on 21 May) exclusively produces white shrimp (*L. vannamei*). The hatchery shows extremely thorough hygiene practices. The group was taken through the broodstock area where shrimps are induced to spawn with eyestalk ablation, and nauplii larvae are reared. The larval rearing area has several 5-ton concrete tanks with different stages of shrimp larvae. Zoea stages are fed with diatoms (*Chaetoceros* spp. or *Skeletonnema* spp.) while mysis stages are fed with artemia and artificial food. The hatchery produces 200,000,000 PL per year and sells mostly to farms in the surrounding area of Krabi.

Figure 54: The group visits the nursery hall at the Lookmee hatchery

Figure 55: Owner showing white shrimp PLs

Figure 56: Larval shrimp feed

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On 24 May, the group visited an intensive ***L. vannamei*** farm in the Krabi area that has been operating for 20 years. The productivity at this farm is high; there are seven ponds of 1ha each and each pond can produce around 400 tons per crop. There are two crops a year and partial harvest methods are practised. There are nine full-time staff and each technician is assigned to a pond. Wages are low but production bonuses are high.

Figure 57: A culture pond at the prawn farm with paddle aerators; staff house in the back ground

Because of global environmental problems in the shrimp industry, the farm is very cautious about environmental issues. There are three settlement ponds ahead of the system and a large buffer pond where the water sits before being ejected into the river. No antibiotics are used along the culture cycles.

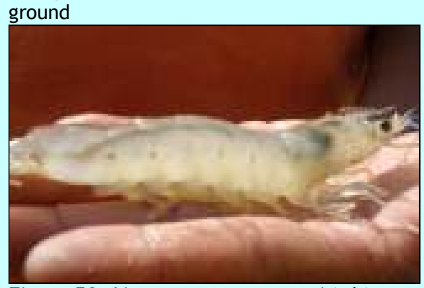

Figure 58: *Litopennaeus vannamei* (white shrimp) cultured at the farm, ready for sale

Numerous paddle aerators and air injectors are placed in the ponds to keep the DO level high (4ppm in the morning and 5ppm in the evening).

Market prices are checked by the manager every day and prawns are harvested accordingly. The farm used to produce *P. monodon*, but low yield, disease problems and high competition encouraged the manager to switch species.

Field trip 6: Aquaculture activities in Satun Province

Figure 59: The group and Satun station staff standing by the outdoor barramundi larval rearing/nursery raceways

On 25 May, the group visited the Satun government aquaculture station. This station mostly produces **seabass** (3 million per year) and **white shrimp** (22 million PL per year). It is a large station with numerous concrete tanks, which has handed over most of the technology to the private sector. The group observed two large outdoor larval rearing tanks (Figure 59). The culture is a static tank with very strong aeration; larvae are 21 days old and fed with *Artemia nauplii*. The fish are weaned with trash fish from day 31.

Polychaete worms are reared in this hatchery to feed broodstock shrimp. When mature, both males and females are placed in a tray where they spawn and fertilise the eggs. The fertilised eggs are placed in an incubator for four days and then placed in tanks filled with sand/gravel with under-sand aeration (Figure 60). They take five months to grow to the appropriate size.

Figure 60: Tanks for rearing polychaete worms, used to feed shrimp broodstock

Figure 61: Broodstock cobia in a cage at Satun's sea cage set-up

Later, the group travelled by boat to Khao Yai Island on the border of Malaysia; Langkawi Island can be seen from there. This is the **broodstock holding station** for the Fisheries Department. There is a floating cage set-up of about 50 rooms holding cobia, seabass, gold-spot grouper, trevally (two species), fingermark snapper and other miscellaneous species. The fish are fed twice a week on trash fish.

There are lines of **winged pearl oyster** (*Pteria penguin)*, and the staff from the station have been doing mabe experiments. The French Polynesians from the group demonstrated the principle of grafting, which was greatly appreciated by the station staff (Figure 62).

On the way back to the wharf, many floating cage set-ups were observed by the group. Most commonly, seabass were being grown.

Figure 62: SPC participant Jean Tu explains the grafting process to Satun station staff

Field trip 7: Aquaculture activities in Songkhla Province

On 26 May, the group visited Songkhla Coastal Aquaculture Research Institute, located near the economically important Songkhla Lake. The Institute was a gift from Japan and was inaugurated by the King in 1981 (www.nicaonline.com). It has 54 employees, including 19 biologists. Its main missions are seed production, coastal aquaculture systems and management, a Songkhla Lake restoration project (shrimp enhancement), raw product inspection and aquaculture standardisation.

The centre produces about one million fry of seabass yearly, which are sold at 1 baht each to farmers of Songkhla Lake. There are thousands of farmers and this has sometimes caused management problems (DO can get really low in summer, and there is mass mortality of fish). The centre is certifying shrimp farms of the area with GAP and COC, but there are no such labels for fish farms yet.

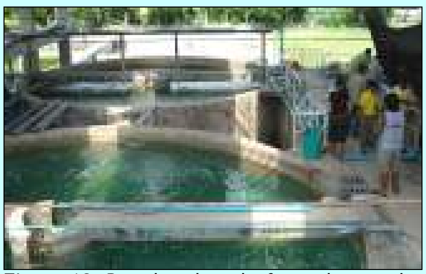

Figure 63: Broodstock tanks for seabass and grouper at Songkhla centre

Figure 64: Twenty-day-old seabass larvae at Songkhla centre

The group visited the hatchery, where there are large tanks for larval rearing of seabass and zoo-/phytoplankton production. Broodstock tanks (Figure 63) are recirculated and use skimmers and biofilters. Water quality in these tanks remains stable for about three months.

Koh Yao Island has a small government centre exclusively focusing on management of the lake. It deals with matters related to cage farming, traditional fish trapping and prawn enhancement. The group visited a large cage farm in Songkhla Lake (Figure 65) that had numerous fixed cages with mostly seabass inside, grown to about 2–3kg (this takes 18–24 months).

Seabass are fed trash fish and pellets. A PVC piping system runs along the cages to flow water through when DO gets low in the lake. Water quality in the lake is one of the major issues for farmers. Mud crabs are also trapped in the lake, then kept and fattened in individual baskets under the cages (Figure 66).

Figure 65: Group observing fixed sea cages for seabass at Songkhla Lake

Figure 66: Farm staff displaying mud crabs (*Scylla* spp.) at Songkhla Lake fixed sea cage set-up

Field trip 10: Floating fish farms around Phuket

Figure 67: Five-kilogram cobias in a Norwegian-style circular floating cage

On 31 May, the group visited a floating cobia farm comprised of three large circular cages (10-metre diameter), each stocked with 4–5 kg fish (Figure 67). The farm is run by a Norwegian company that cooperates with a Thai company; similar cages are used for salmon in Norway. Cobia are fed artificial feed and commercialised in approximately a year. They are mostly filleted and exported. The operation is quite new but seems to be doing well.

Handling the cages is not easy as there is no mechanical equipment, such as cranes. It takes 15 people to lift the nets or to carry out any major operation (harvesting, changing the net).

The farm buys fingerlings from government hatcheries in Krabi, Phuket and Phang Nga. At the time of our visit, there was not yet a commercial hatchery operating with cobia.

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Near the Norwegian farm, there is a co-owned Thai/Taiwanese floating farm. This company operates approximately 200 square cages (5*5*2) and a large floating work house. Fingerlings are mostly imported from Taiwanese and Indonesian hatcheries. Once the fish reach market size, most of them are exported live to Taiwan. This cage farm mostly focuses on high-value species such as coral trout (*P. maculatus*), gold-spot grouper, giant grouper, mouse grouper and *E. areolatus*. The group observed freshwater bathing of fish: five days of treatment once a month to ensure that the fish are free of parasites (Figures 68 and 69). If diseases are seen, the fish are dipped in a tub of oxytetracyclin antibiotic in the floating house.

Figure 68: Inspecting juvenile *E. lanceolatus* for parasites and diseases

Figure 69: Freshwater bathing of *E. lanceolatus* for parasites

Because dealing with fouling takes a lot of work and manpower, workers on the farm change the nets very often (after less than a month).

As scallop recruitment is high around the area, the farm has installed some spat collectors and a long-line grow-out system nearby.

Field trip 11: Government hatcheries in Phuket and Phang Nga

The Phuket centre (visited on 31 May) mostly focuses on fish hatcheries for cobia and seabass. The group observed a cobia nursery (three-month-old cobia were observed that weighed between 40 and 100 grams).

Cobia broodstock is held in large floating cages and brought onto land during the spawning season. Cobia larval stages seem to be similar to those of seabass (30 days).

The Phuket centre uses a flow-through water system and is very large in terms of land area and tank volume. Only a small portion of it seems to be operating. The centre also runs an anemonefish hatchery and a polychaete worm hatchery; products of the former are sold to a commercial prawn hatchery.

Figure 70: Larval rearing tanks at Phuket aquaculture centre

Figure 71: Nursery tanks used for cobia at Phuket aquaculture centre

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The Phang Nga centre is a flow-through system with no filtration, as the intake sits in deep clean water. The centre has a bivalve hatchery (giant clam, volute, abalone and goldlip pearl oyster). It is carrying out trials with these species without making them a priority; other centres in the country emphasise the species.

Again, seabass larvae are produced in the centre, using classic larval rearing protocols with outdoor culture of chlorella and rotifers. Seabass seeds are sold to local farmers in the Phang Nga and Phuket area.

A number of anemonefish are also produced in Phang Nga, most of which serve restocking and conservation purposes (wild-caught ornamental trade is banned from Thailand).

Many species broodstock are kept in tanks, such as grouper (*E. coioides, E. lanceolatus).* In Phang Nga, a lot of research is being done on nutrition, with an emphasis on broodstock nutrition.

Figure 72: 2t larval rearing and nursery tanks at Phang Nga research centre

Figure 73: Small floating cages in a large tank, used for clownfish nursery at Phang Nga

6 Conclusions

6.1 Validity of the training

Overall, the marine finfish hatchery training course was a success. All participants were required to fill in a feedback questionnaire, and the results showed that participants felt there was a good balance of theoretical and practical training and the right number of field trips. Some aspects, such as feed manufacturing, cage culture and stock algae culture, could have been approached in more detail.

Generally, participants were enthusiastic about the hospitality of their Thai counterparts and thought the logistics and organisation were well coordinated. No one had communication problems or felt that they were restricted in using the facilities or equipment.

Besides the SPC Aquaculture Officer, there were four types of participants in the training:

1. hatchery technician (2);
2. entrepreneur with little background in aquaculture (1);
3. government policy-maker/adviser (1); and
4. government aquaculture officer (1).

According to the background of the participants, different levels of success were achieved during the training, ranging from fine-tuning and sharing of hatchery techniques between KCFRDC staff and participants, to a more general approach to marine finfish farming when participants had less experience in working in marine finfish hatcheries.

The **hatchery technicians** were able to share knowledge and observe Thai techniques for fish farming, such as water quality management, eggs and larvae handling. Having access to different grow-out systems for various species was a prime opportunity for the technical trainees because they were able to compare farming practices, always mindful of how to improve their own aquaculture in the Pacific.

The **entrepreneur with little background in aquaculture** was able to have access to a broad range of aquaculture systems, whether grow-out or hatchery. It was an excellent introduction to the whole industry for someone who had no academic or professional experience in aquaculture.

For the **government adviser/policy-maker**, the course helped to focus on aquaculture strategies by using Thailand's example. What species and markets are of interest for PICTs? Which practices are labour intensive? Which facilities are cheap to run? The wide range of examples encountered during the trip were very valuable for this category of participant.

For the **government aquaculture officer**, it was very good general training that complemented the freshwater skills of the participant. Having access to such knowledge was invaluable and being able to transmit it upon returning home will be an essential task.

In the future, the SPC Aquaculture Officer would advise that trainee types 1, 2 and 4 should do this type of course. It does not seem as relevant for type 3 participants to do such technical training. Study tours are probably a more appropriate way of training in this case.

6.2 Applicability of marine finfish farming to the Pacific Islands

Carrying out training in Southeast Asia is of high relevance to Pacific Islanders for the following reasons (Thailand example):

– Culture systems are simple and do not involve high-tech equipment, thus they are highly replicable in the Pacific. Most of the set-ups are made of concrete, PVC and other fairly basic equipment that is readily available throughout the Pacific.

– The techniques used in Thailand base their success on low input, low output. The survival rates of some delicate species remain low, but the costs of producing them are low as well.

– Mechanisation of aquaculture facilities in Thailand is basic and every step is done by hand. As a result, the processes are more labour intensive but costs and risks are kept low.

– The local market in Thailand is big. For finfish species, Thai producers seem to be targeting the domestic market rather than the export market. If they targeted the export market, they would put themselves in competition with other countries (Vietnam, China).

Pacific Island nations should follow the Southeast Asia model in terms of producing marine finfish:

- √ **Low capital input**
- √ **Labour intensive**
- √ **Semi-intensive culture systems**
- √ **Low mechanisation and no high-tech equipment**
- √ **Local markets targeted where possible**

In the Pacific context, it seems relevant that marine finfish production is primarily oriented towards the domestic market for local consumption. Growing populations and stability in demand will help reduce the risks of exporting.

Because the demand for high-quality products remains high in some export markets, exporting might also be considered for Pacific Island nations, bearing in mind that competition is high and production costs are higher than in Southeast Asian countries.

Good water quality, availability of land and sea area for farming, availability of labour, (relatively) low labour costs, and availability of broodstock from valuable species are assets to the Pacific region. Developing marine finfish aquaculture seems a viable option for the near future.

Annexes

Annex 1: Awarding certificates

Paiboon Bunlipatanon awards certificates to Maciu Lagibalavu (top left), Vaiana Joufoques (top right), Jean Tu (centre left), Thierry Tamata (centre right), Gideon Pama (bottom left) and Antoine Teitelbaum (bottom right).

Annex 2: Certificate