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Australian Centre for
International Agricultural Research

PROJECT SUMMARY

ACIAR Project FIS/2002/077

Improved Hatchery and Grow-out Technology for Marine Finfish Aquaculture in the Asia-Pacific Region

Michael A. Rimmer, N.A. Giri, Usman, Richard M. Knuckey, Clarissa L. Marte, Veronica R. Alava, Mae Catacutan, Inneke F.M. Rumengan, Kevin C. Williams, Michael J. Phillips, Sih-Yang Sim, Simon Wilkinson, Le Thanh Luu

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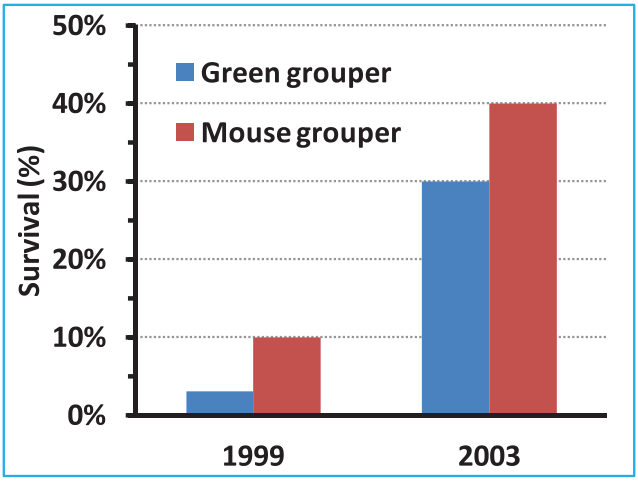
Contents

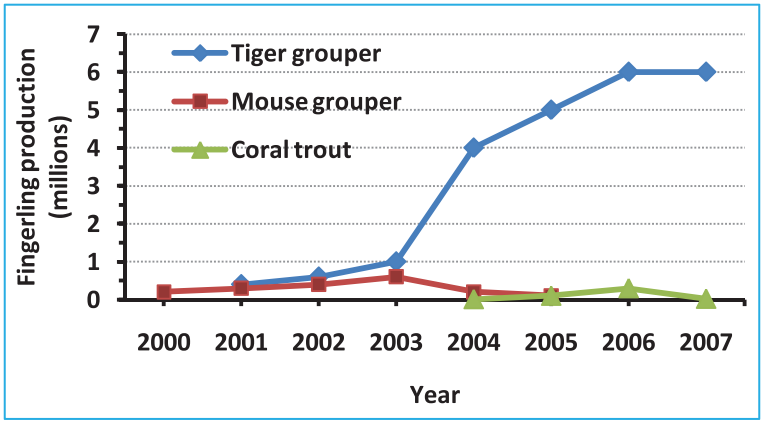
Key achievements

Increased production of seedstock

- The first project (FIS/97/73) produced results that dramatically increased the survival of groupers in the hatchery: survival of green grouper increased from less than 10% to 30%, while survival of mouse grouper was up to 40% by the end of the project.



- Since then there has been a substantial increase in grouper seedstock production, particularly from hatcheries in Indonesia. Indonesia is now a major provider of grouper fingerlings to the rest of the Asia-Pacific region.



- More than 100 hatchery operators and researchers from 22 countries have graduated from the Regional Grouper Hatchery Training Course, held since 2002 in Indonesia. These trainees have spread grouper hatchery technology to other countries including Philippines, Thailand, Vietnam and Australia.

Diet development

- This research has been instrumental in providing the necessary nutritional information to develop compounded pellet diets for groupers. Many feed companies throughout the Asia-Pacific region are now manufacturing pellet diets for groupers.

Extension information

- These projects, and related research, have developed a wealth of extension information. In many cases, extension materials have been translated into local languages, including Indonesian.

Capacity building

- Project staff have built skills in
  - ✓ Larval rearing
  - ✓ High-sensitivity enzyme analysis
  - ✓ Nutrition research
  - ✓ English language
  - ✓ Scientific writing and publication

- The projects have trained farmers, Dinas Kelautan dan Perikanan staff and students from many parts of Indonesia, including South Sulawesi, Kalimantan, Papua and Aceh.

Background

Aquaculture of high-value marine finfish species is developing rapidly in the Asia - Pacific region, primarily in response to the high prices (up to US$70/kg wholesale) and growing demand for species such as groupers (Serranidae, Epinephelinae) in the live markets of Hong Kong and southern China. Marine finfish aquaculture is an important contributor to the economies of coastal communities throughout the region.

However, much of the marine finfish aquaculture in Southeast Asia relies on the capture and grow-out of wild-caught juvenile fish. The trade in wild fry is associated with a number of resource management issues, including: overfishing, use of unsustainable harvesting techniques (including cyanide); high levels of mortality; and inadequate supply to support the demand of a developing aquaculture industry. To meet the demand for seedstock for aquaculture, and to reduce pressure on wild fisheries, there is a recognised need to increase the production of hatchery-reared seedstock, particularly of groupers.

The need for compounded (pellet) feeds is also widespread throughout the region. Most marine finfish aquaculture in Southeast Asia is supported by the use of 'trash' fish as the major feed source. Issues regarding the use of trash fish have been identified in detail in several publications and these include: competition for fishery products with human nutritional requirements and with other agricultural sectors; relatively low efficiency of utilisation of 'trash' fish; localised pollution due to losses of feed material during feeding; and increased prevalence of protozoan infestations associated with feeding 'trash' fish.

With assistance from ACIAR, Australian and Indonesian fisheries agencies have collaborated on two projects to address these issues:

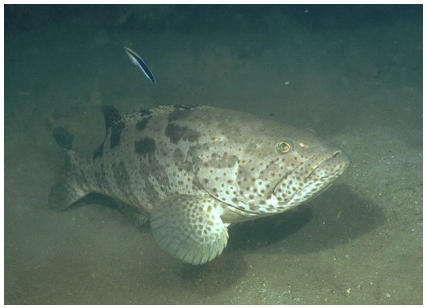
- *FIS/97/73 Improved hatchery and grow-out technology for grouper aquaculture in the Asia-Pacific region, and*
- *FIS/2002/077 Improved hatchery and grow-out technology for marine finfish aquaculture in the Asia-Pacific region.*

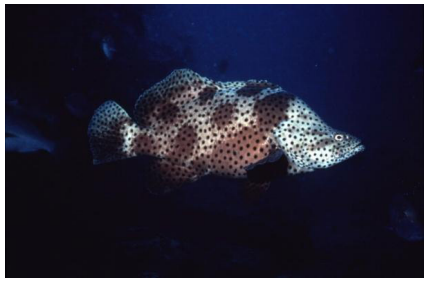
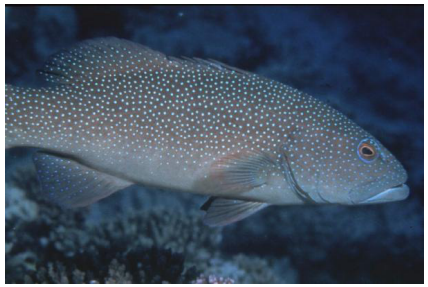
These projects focused on improving the survival of hatchery-reared high-value marine finfish larvae, and increasing the reliability of hatchery production. Research into grow-out diets better defined the nutritional requirements for groupers, and subsequently focused on promoting uptake of compounded pellet diets at the expense of 'trash' fish use.

A third component of the projects developed mechanisms to improve research collaboration and coordination in the Asia-Pacific region, and evaluated the socio-economic constraints to uptake of the technologies (hatchery production, compounded diets).

Groupers

The two projects worked with several grouper species, based on fingerling availability and farmer interest in the various species.

	Common and scientific names	Other names	Comments	Value (live fish trade)
	Tiger grouper *Epinepehelus fuscoguttatus*	Australia: flowery cod Indonesia: kerapu macan	Relatively hardy in culture Indonesia is now the largest supplier of seed Cultured throughout the Asia - Pacific region, particulary in Indonesia.	Medium
	Green grouper *Epinephelus coioides*	Australia: estuary cod Indonesia: kerapu lumpur	Hardy in culture Can be farmed in ponds as well as sea cages. Hatchery production well developed but still most juveniles captured from the wild	Low

	Whitespotted grouper *Epinepehelus coeruleopunctatus*	Indonesia: kerapu pasir	Hatchery production technology developed by RIM Gondol. Little farmer interest because of slow growth rates.	Medium
	Humpback grouper / Mouse grouper / Polkadot grouper *Cromileptes altivelis*	Australia: barramundi cod Indonesia: kerapu tikus, kerapu bebek	Slow growing : 1.5 – 2 years to market size. Subject to disease or mortality if water conditions deteriorate. Indonesia is the major seedstock supplier	High
	Coral trout *Plectropomus leopar-dus*	Indonesia: kerapu sunu	One of the main species in demand by the live fish trade. Good potential for sea cage culture. Indonesia is the major seedstock producer.	High

Project objectives

The overall aim of these projects was to enhance the sustainability of marine finfish aquaculture in the Asia-Pacific region by improving hatchery production technology and facilitating the uptake of compounded feeds for grow-out.

Within this overall aim, specific objectives were to:

1. Improve hatchery production technology for high-value marine finfish, particularly groupers;
2. Develop cost-effective grow-out diets;
3. Improve research collaboration and coordination, and facilitate technology adoption, in the Asia-Pacific region.

Why groupers?

A major stimulus for the development of grouper culture has been the high prices paid for groupers and some other marine finfish in the live fish markets of Hong Kong SAR and China.

Fish are shipped live, either by air or by sea, to markets like the one at left.

Restaurants sell the fish live – diners can select the fish they want, and specify the cooking technique. High-value species such as humpback grouper can sell for US$ 90 per kg in restaurants in Hong Kong.

Summary of results

Objective 1 – Improve hatchery production technology for high-value marine finfish, particularly groupers

Larval nutrition

The project has demonstrated that the use of nutritional supplements that increase the levels of highly unsaturated fatty acids (HUFAs) in the larval diet lead to improved growth, condition and survival of grouper larvae.

This work was undertaken in a structured manner:

1. The nutritional composition of prey organisms at partner laboratories was evaluated.
2. The levels of HUFAs were increased by evaluating several different commercial supplements.
3. The larval requirement for essential fatty acids was evaluated by comparing starved and fed larvae.
4. The response of larvae fed diets high in HUFAs was compared with larvae fed a 'standard' diet.

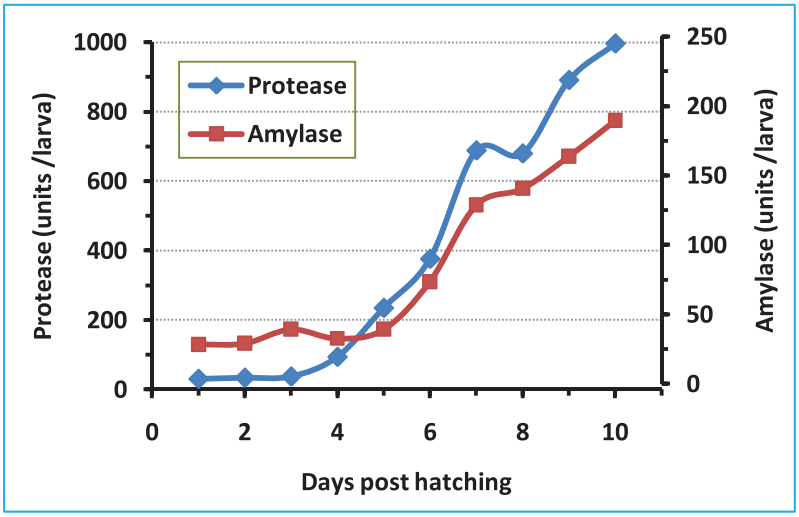
Overall, these experiments showed that grouper larvae have a very high requirement for HUFAs, particularly DHA (22:6n-3), but also for ARA (20:4n-6) and EPA (20:5n-3).

When grouper larvae are fed diets high in these HUFAs, they exhibit faster growth, better condition and higher survival than larvae reared without nutritional enhancement.

Grouper larvae fed diets high in HUFAs show improved growth, condition and survival.

Larval digestion

The projects evaluated the capacity of grouper larvae to digest live prey as well as compounded larval diets by describing the development of digestive enzymes during larval development.



Our results show that early stage larvae have very low levels of digestive enzymes, and thus limited capacity to digest prey and particularly compounded pellets. For example, the adjacent graph shows the ontogenic development of the digestive enzymes protease and amylase in coral trout *(P. leopardus)* larvae.

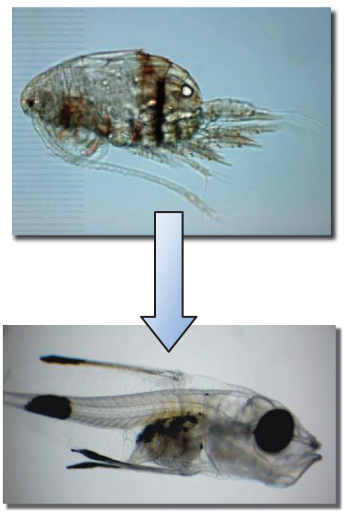
Copepod culture

Copepods are known to improve larval growth, pigmentation and survival when fed to fish larvae. However, they are difficult to culture in the hatchery and usually cannot be cultured in the densities necessary to provide suitable quantities of live feed.

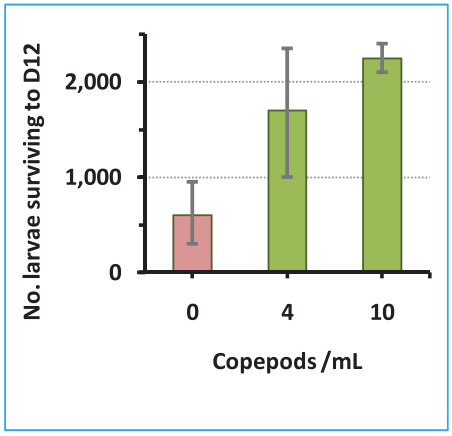
Our research has improved culture techniques for copepods. In particular, the calanoid copepod *Parvocalanus* has demonstrated its suitability for hatchery use:

- *Parvocalanus* nauplii are more suitable food items for marine fish larvae, because they are smaller and slower moving than other copepod species;
- *Parvocalanus* has a simpler diet than other copepod species, so it is easier to rear in the hatchery;
- Because *Parvocalanus* is not cannibalistic, it can be produced at higher densities than other copepods – in our experiments cultures have reached densities of over 20/mL in mass culture.

Parvocalanus has been successfully used in grouper larval rearing at NFC Cairns, demonstrating its suitability for use in grouper hatcheries. In one experiment, grouper larvae fed *Parvocalanus* during the early larval stages showed significantly higher survival to day 12 than those fed only rotifers. The treatment fed *Parvocalanus* at 10/mL had 259% more larvae than the control treatment.

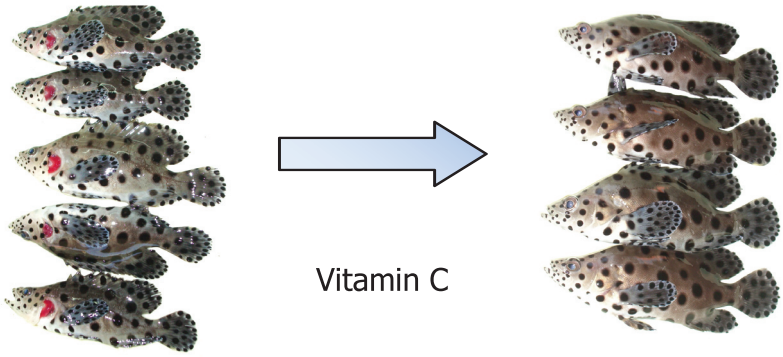


Grouper larvae fed copepods had 259% better survival at day 12.



Rotifer culture

Grouper larvae have small mouths and consequently require small prey at first feeding. Currently, this requirement is met by sieving small ('SS - strain') rotifers *(Brachionus rotundiformis)* to remove larger rotifers. Because a more efficient production system would be to reduce the overall size of the rotifer population, we have evaluated a range of methodologies for decreasing the average size of rotifer populations.



Increased levels of vitamin C in the diet may stop, or even reverse, bone deformities in mouse grouper

Improving fingerling quality

Although production of grouper fingerlings has increased substantially in Indonesia since 2000, there remain problems with fingerling quality. In particular, there are often high proportions of grouper fingerlings with skeletal or opercular deformities.

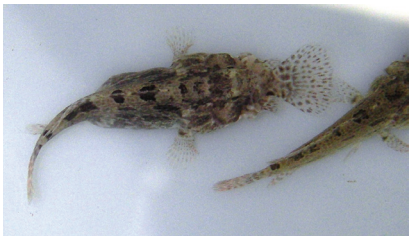
Our research has demonstrated that increasing levels of dietary vitamin C can reduce the incidence of opercular and skeletal deformities. In some cases, it may actually reverse the deformity, allowing full recovery of affected fish.

Nursery culture

Cannibalism is a major cause of mortality during the nursery stage of most grouper species, particularly the *Epinephelus* species. ACIAR-supported research carried out at RIM Gondol has demonstrated that survival in the nursery is improved by:

- Commencing feeding early in the day (i.e. soon after dawn);
- Maintaining light levels at <600 lux.

Some other factors, such as water flow and tank shape, had no effect on survival. Some dietary attractants improved survival, but results were highly variable.

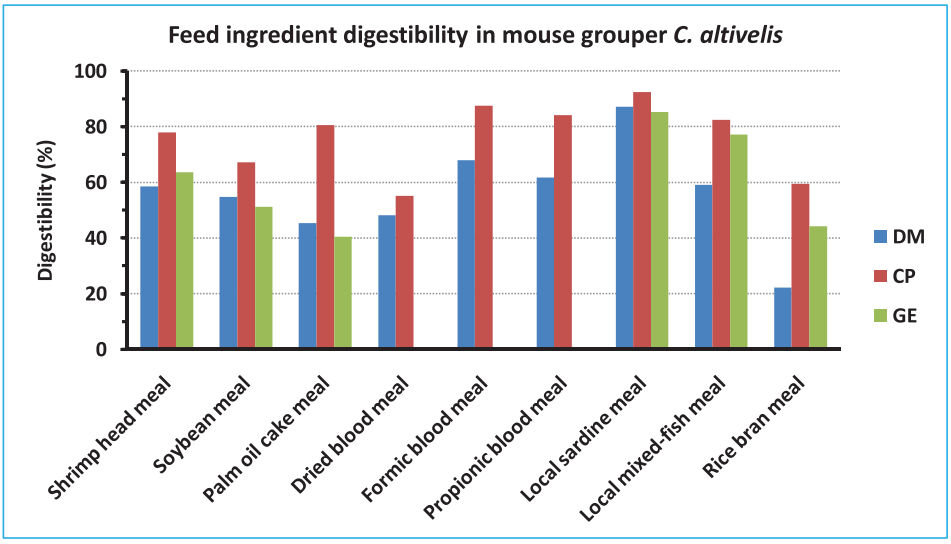


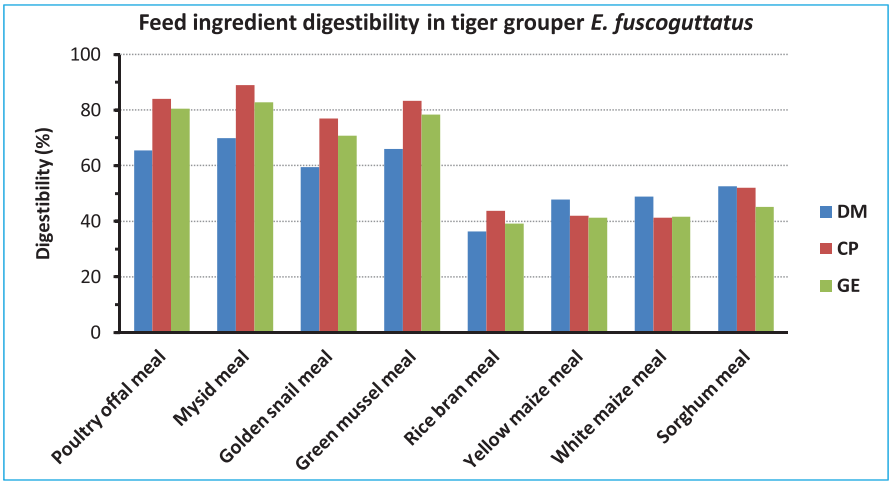
Often both the predator and prey fish will die as a result of the cannibalism attempt.

Objective 2 – Develop cost-effective grow-out diets

Feed ingredients

Research at RICA Maros evaluated the potential for the use of various local feed ingredients in diets for mouse grouper *(C. altivelis)* and tiger grouper *(E. fuscoguttatus)*. The graphs below show the dry matter (DM), crude protein (CP) and gross energy (GE) apparent digestibility coefficients of the feed ingredients tested.





In general, grouper digest animal protein sources more efficiently than plant protein sources. Consequently, it is easier to substitute fish meal with animal meals (such as meat meal) than with plant meals.

Nutritional requirements of groupers

The projects have evaluated the nutritional requirements of groupers, looking at optimal protein, lipid and protein:energy ratios, as well as some minor nutrients such as vitamin C and highly-unsaturated fatty acids (HUFAs). These results, plus those from other published studies, were summarised by Williams (2009) who recommends the following basis for grouper diets:

Factor	Diet specification	Fish size
Protein	~50–52% DM basis	
Lipid	<12–13% DM basis	
Protein:energy	~30 g CP:1 MJ GE	<15 g to ~21 g
	~21 g CP:1 MJ GE	500 – 750 g
n-3 HUFA	>1%	
Docosahexaenoic acid (DHA)	>0.75%	
Vitamin C	>50 mg/kg ascorbic acid equivalent supplied as a heat-stable product	

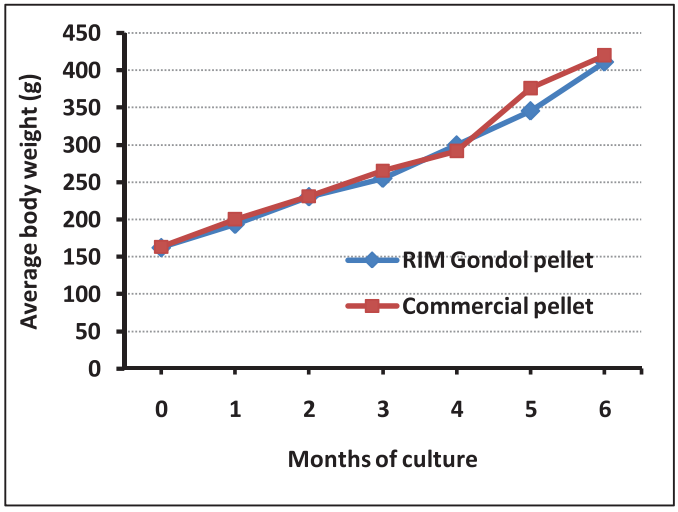
Research results generated by both projects (FIS/97/73 and FIS/2002/077) are now being used by commercial feed companies throughout the Asia-Pacific region to develop pellet feeds for groupers.

Fishmeal substitution

Our research showed that many terrestrial protein meals have potential as partial replacements for fishmeal in grouper grow-out diets. Good quality meat and bone meal can replace more than two thirds of the fishmeal without any adverse effect on grouper performance. Plant protein meals such as soybean and lupin have been shown capable of successfully replacing from one third to half of the fishmeal in grouper diets.

Producing high-quality pellet feeds

Both projects have focussed on producing information to allow commercial feed companies to produce high-quality pellet feeds for marine finfish, particularly groupers.



Trials comparing compounded pellets made at RIM Gondol with pellets made by commercial feed companies showed similar performance when fed to coral trout.

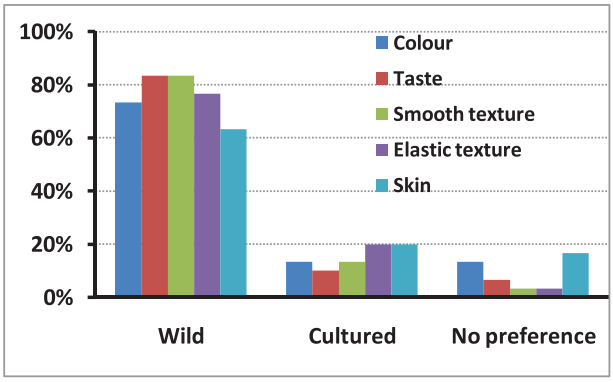
As part of this research, feed pellets manufactured at RIM Gondol were compared with pellets produced by a commercial feed company for grow-out of coral trout *P. leopardus*. As the adjacent graph shows, there were no differences in the growth rate of fish fed the two pellet diets in this trial. This trial showed that coral trout readily accepted pellets and grew well on these diets. However, other trials showed that most compounded pellets are not performing as well as 'trash' fish.

To facilitate the uptake of research results by feed companies in Indonesia, we held a three-day workshop on fish nutrition at the Santika Hotel, Surabaya, 20–22 October 2009, with support from the Research Centre for Aquaculture, MMAF. Indonesian feed companies were invited to send technical representatives, particularly feed formulators, to the workshop to update their knowledge of fish nutrition and to hear the results from research carried out under FIS/2002/077 as well as other research undertaken by the Indonesian Agency for Marine Affairs and Fisheries Research. Feedback on the workshop was generally positive. However, because of the relatively small market for marine finfish feeds, and the very diverse number of species produced, feed companies are not prioritising the development of marine finfish feeds at present.

Dr Igor Pirozzi (James Cook University) and Mr Simon Tabrett (CSIRO) and AMFR staff Mr Ketut Suwirya (RIM Gondol), Mr Usman (RICA Maros) and Mr Reza Samsudin (RIFA Bogor) provided training in fish nutrition to Indonesian feed companies in Surabaya, October 2009.

Farmed product quality evaluation

The effects of feeding groupers with different diets were evaluated with mouse grouper and with tiger grouper by undertaking taste tests in Hong Kong SAR. The evaluation of mouse grouper was undertaken in conjunction with ACIAR Project ADP/2002/105 'Economic and market analysis of the live reef fish food trade in Asia-Pacific'.



Most Hong Kong SAR consumers preferred the taste of wild caught mouse grouper over cultured grouper. However, these results may have been confounded by mixing of the fish fed 'trash' fish with those fed pellets, and the larger size of the wild-caught fish.

There was a definite preference for the colour, taste and texture of the wild-caught mouse grouper among the participants with over 70% preferring the wild-caught product on these criteria. However, the aquaculture product was also found to be highly acceptable to the consumers.

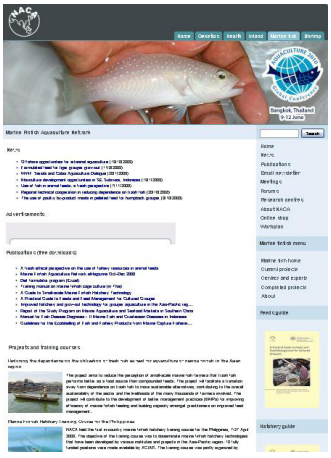
This result may have been confounded by the differential size of the two sample groups (the wild-caught fish being larger and older, which is known to influence flesh texture).

Another study undertaken with tiger grouper *(E. fuscoguttatus)* by RICA Maros, showed that, overall, panellists preferred fish fed a moist pellet diet. The panellists felt that this product had better meat quality than grouper from Taiwan and Thailand. However, the meat quality of tiger grouper fed another moist pellet diet, commercial pellets and 'trash' fish were generally well accepted by the panellists.

Overall, the acceptability of the farmed mouse and tiger grouper to Hong Kong SAR consumers bodes well for the widespread commercial acceptance of farmed groupers fed pellet feeds in the future. However, further research into the effects of pellet diets on consumer acceptance is essential to better evaluate the impacts of different diets on market attributes.

Objective 3 – Networking, coordination, and technology adoption

The first project (FIS/97/73) saw the formation of the Asia-Pacific Grouper Network (APGN) which was formed through NACA. In 2002, this network was expanded to become the Asia-Pacific Marine Finfish Aquaculture Network (APMFAN) and its activities were absorbed into the NACA core program.



Example page of the NACA APMFAN web site.

Web site

APMFAN activities were publicised on the NACA web site (www.enaca.org). The web site was upgraded regularly, most recently to a 'portal' format to increase accessibility. The web site provided news, publications and project information. News items generally average 650 – 1,500 views. Publications are available for download and the most popular are the extension manuals (see Publications, p. 23).

APMFAN also published an e-magazine, which was incorporated in the NACA magazine 'Aquaculture Asia'. Electronic versions of the e-magazine are extremely popular, with around 2,000 downloads per issue.

Hatchery training

The Regional Grouper Hatchery Production Training Course originally started at RIM Gondol in 2002 under ACIAR project FIS/97/73, and has been held annually since 2005 at the Brackishwater Aquaculture Development Centre (BADC) Situbondo. The table below summarises the number of participants and the countries represented in each training course.

Dates	Participants	Countries
1–21 May 2002	14	Colombia, Hong Kong SAR, Indonesia, Malaysia, Philippines, Singapore, Thailand, Vietnam,
1–21 May 2003	14	Australia, Brunei Darussalam, India, Malaysia, Singapore, Vietnam,
18 April – 8 May 2005	17	Australia, Brunei Darussalam, Indonesia, Malaysia, Maldives, Marshall Islands, Singapore, Vietnam
20 November – 9 December 2006	20	Australia, China – Hong Kong SAR, India, Indonesia, Malaysia, Maldives, Myanmar, Qatar, Saudi Arabia, Singapore, Thailand, Vietnam
9 – 29 July 2007	16	Australia, China – Hong Kong SAR, Palau, Philippines, Singapore, Sri Lanka, Thailand, Vietnam
5 – 25 May 2008	19	Australia, China – Hong Kong SAR, Indonesia, India, Iran, Malaysia, Oman, Thailand, Trinidad and Tobago, Vietnam

The 2008 course provided a significant milestone with over 100 graduates now having completed hatchery training through the RIM Gondol and BADC Situbondo courses.

APMFAN also organised a marine finfish hatchery training course for the Secretariat for the Pacific Community (SPC) for a group of six trainees from Pacific Islands Countries (Fiji, French Polynesia, New Caledonia, Papua New Guinea) in May 2007 at Krabi Coastal Fisheries Research and Development Centre of DOF Thailand. One of the DOF trainers (Mr Detsathit) was a graduate of the 2002 training course held at RIM Gondol.

An additional training course was held at SEAFDEC AQD, Tigbauan, Iloilo, Philippines, 6–26 April 2008, with the assistance of trainers from Indonesia (Mr Bambang Hanggono) and Thailand (Mr Detsathit).

Grouper hatchery training course participants gain 'hands-on' experience handling grouper broodstock and feeding grouper larvae.

KKP staff and graduates of the 2007 APMFAN Grouper Hatchery Production Training Course held at BBAP Situbondo.

Farmer training

The project has supported farmer training in Indonesia and in Australia:

Australia

NFC Cairns provided on-farm training to two farmers on culture techniques for grouper with particular reference to methods of cage culture and fish grading. Also, training was provided to a barramundi hatchery operator on the culture of tiger grouper. This training provided the first fingerlings of tiger grouper produced by a commercial operator in Australia.

Indonesia

Sulawesi

RICA Maros has provided training in grouper feed preparation and management to:

- farmers and staff from Yayasan Palu Hijau (Central Sulawesi);
- farmers from Sengata Regency (Kalimantan Timur Province);
- farmers from Mappi Regency, Papua Province.

Bali

- RIM Gondol provided training in grouper hatchery and nursery culture to five staff from Balai Benih Ikan Pantai (BBIP) Nias, North Sumatra, and two staff from BBIP Simeulue, Aceh. This training was supported by the Asian Development Bank's Earthquake and Tsunami Emergency Support Project.

Aceh

- Usman and Neltje Palinggi (RICA Maros) provided training in farm-made feeds for marine and brackishwater finfish aquaculture in Aceh in January 2009, in collaboration with the Aceh Aquaculture Rehabilitation Project (FIS/2006/002). A total of 12 BBAP Ujung Batee staff, 56 farmers, 14 Dinas Kelautan dan Perikanan staff, 2 SUPM Ladong staff, and 4 FAO ARC project staff participated in this training.

RICA Maros staff provided training in farm-made feeds to grouper farmers in Aceh province.

Constraints to technology adoption

To identify constraints to the adoption of improved hatchery and grow-out technologies, Sih-Yang Sim (NACA) interviewed hatchery owners / operators in:

- Situbondo: 16 hatcheries,
- Gondol: 15 hatcheries,

and farmers in:

- Indonesia: 34 grow-out farms (cages and pen systems),
- Thailand: 33 farms (pond and cage systems),
- Vietnam: 42 farms (cage system).

This survey identified the constraints to hatchery production:

- Availability of good quality eggs

  Egg supply is still limited from government centres and larger hatcheries, and quality is variable. Smaller hatcheries cannot afford broodstock facilities.

- Infrastructure

  Suitable sites for hatcheries are often in remote areas with poor infrastructure.

- Price and markets

  The lunar spawning cycle of groupers creates 'floods' in egg and seed supply, driving down prices.

  Many hatcheries try to access international markets, but this is also more risky.

- Price orientation

  Farmer demand is focussed on fingerling price rather than quality.

The survey also identified a number of constraints to adoption of pellet feeds for feeding marine finfish:

- Use of pellet feeds

  In Indonesia most use of pellet feeds is during the nursery stage. Less than 20% of farms were using pellet feeds for growout.

  None of the farms surveyed in Thailand and in Vietnam were using pellet feeds.

- Price

  A basic economic analysis shows that 'trash' fish is generally more cost effective than artificial feed. The 'break-even' FCR for 'trash' fish is 13:1; below this 'trash' fish is more cost-effective than pellets.

  Farmers are more focussed on obtaining cheaper feeds than on efficient feeding practices.

- Accessibility

  Pellet feeds are difficult to get in rural areas. Price is increased by small orders and high transportation costs.

  Farmers may need to access formal credit schemes to purchase pellet feeds. In comparison, 'trash' fish is available locally at a cheap price.

- Performance

  Farmers generally feel that the performance of pellet feeds is inferior to 'trash' fish.

Strategies to improve technology adoption

Hatchery technology

Many constraints (infrastructure, markets) are not related to R&D and must be addressed through other mechanisms. There is a need to establish or further develop national broodstock/egg production centres to supply hatcheries (e.g. the BBIP scheme in Indonesia), and to develop and extend better management practices for improved seed survival and quality.

Compounded feeds

The survey identified a gap between the outcomes of R&D trials and real-world performance. Many R&D trials report FCR<2, but farmers report FCR between 2 and 3. There is a need to close this gap through more on-farm research and farmer training.

Publications

Scientific papers

The two projects summarised here have made a significant contribution to our knowledge of tropical marine finfish larval rearing, and particularly to grouper nutrition. A review of the nutritional requirements for groupers by Williams (2009) included many of the research results from these projects.

Larval rearing

Gonzaga, J., Anderson, A., Richardson, N., Nocillado, J. and Elizur, A. (2010). Cloning of IGF-I, IGF-II and IGF-IR cDNAs in Mullet *(Mugil cephalus)* and grouper *(Epinephelus coioides)*: molecular markers for egg quality in marine fish. Asian Journal of Biological Sciences 3, 55–67.

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Rumengan, I.F.M., Sulung, M., Lantiunga,Z. and Kekenusa, J. (2007). Morphometry of SS-strain rotifer *Brachionus rotundiformis* originated from Minanga and Watuliney brackishwater ponds cultured at different salinities. Jurnal Riset Akuakultur (2)2, 221–229 (in Indonesian).

Sumilat, D.A., Mamesah, J.A.B. and Rumengan, I.F.M. (2003). Preliminary study on the local strain of *Chlorella*-like microalga isolated from a hydrothermal coastal water in Likupang, North Sulawesi. Ekoton 3(1): 7–13.

Toledo, J.D., Caberoy, N.B., Quinitio, G.F., Choresca, C.H. and Nakagawa, H. (2002). Effects of salinity, aeration and light intensities on yolk oil globule absorption, feeding incidence, growth and survival grouper *Epinephelus coioides* larvae. Fisheries Science 68, 478–483.

Wullur, S., Rumengan, I.F.M. and Manu, G. (2004). Fecundity of *Apocyclops* sp in culture media containing microalga, *Nannochloropsi oculata.* Journal of the Faculty of Fisheries and Marine Science, Sam Ratulangi University 27(1): 95–100.

Yoshinaga, T., Minegishi, Y., Rumengan, I.F.M., Kaneko, G., Furukawa, S., Yanagawa, Y., Tsukamoto, K. and Watabe, S. (2004). Molecular phylogeny of the rotifers with two Indonesian *Brachionus* lineages. Coastal Marine Science 29(1): 45–56

Nutrition

Eusebio, P.S., Coloso, R.M. and Mamauag, R.E.P. (2004). Apparent digestibility of selected ingredients in diets for juvenile grouper, *Epinephelus coioides* (Hamilton). Aquaculture Research 35, 1261–1269.

Giri, N.A., Suwirya, K. and Marzuqi, M. (1999). Dietary protein, lipid, and vitamin C requirement of juvenile humpback grouper *(Cromileptes altivelis).* J. Penelitian Perikanan Indonesia V(3), 38–46. (In Indonesian, abstract in English).

Laining, A., Rachmansyah, Ahmad, T. and Williams, K. (2003). Apparent digestibility of selected feed ingredients for humpback grouper, *Cromileptes altivelis*. Aquaculture 218, 529-538.

Marzuqi, M., Suwirya, K. and Giri, N.A. (2006). Pattern of lipid and essential fatty acid changes in early development of tiger grouper, *Epinephelus fuscoguttatus* larvae. Indonesian Aquaculture Journal 1(2), 129–134.

Marzuqi, M., Giri, N.A., Suwirya, K. and Rustini, Y. (2001). The effect of dietary phospholipid on growth of juvenile humpback grouper, *Cromileptes altivelis*. Aquaculture Indonesia 2, 99–102. (in Indonesian, with English abstract).

Millamena, O.M. (2002). Replacement of fish meal by animal by-product meals in a practical diet for grow-out culture of grouper *Epinephelus coioides*. Aquaculture 204, 75–84.

Millamena, O.M. and Golez, N.V. (2001). Evaluation of processed meat solubles as replacement for fish meal in diet for juvenile grouper *Epinephelus coioides* (Hamilton). Aquaculture Research 32(1), 281–287.

Rachmansyah, Usman, Kabangnga, N. and Makmur (2006). Utilization of poultry offal meal silage in tiger grouper, *Epinephelus fuscoguttatus* diets. Jurnal Riset Akuakultur 1(1):87–96.

Smith, D.M., Williams, I.H., Williams, K.C., Barclay, M.C., Venables, W.N. (2005). Oxidation of medium-chain and long-chain fatty acids by polka dot grouper *Cromileptes altivelis*. Aquaculture Nutrition 11, 41–48.

Tuan, L.A. and Williams, K.C. (2007). Optimum dietary protein and lipid specifications for juvenile malabar grouper *(Epinephelus malabaricus)*. Aquaculture 267, 129–138.

Usman, Rachmansyah and Kamaruddin (2006). Substitution of fish meal with golden snail meal *(Pomacea sp)* in diets for grow-out of tiger grouper *(Epinephelus fuscoguttatus)*. Jurnal Riset Akuakultur 1(2): 161–170.

Usman, Rachmansyah, Kamaruddin, Lante, S. and Ahmad, T. (2006). Replacement of fish meal with poultry offal meal in diets for grow-out of humpback grouper *(Cromileptes altivelis).* Indonesian Aquaculture Journal 1(1): 45–52.

Usman, Kamaruddin, Palinggi, N.N. Rachmansyah and Ahmad, T. (2007). Fermented blood meal use for tiger grouper, *Epinephelus fuscoguttatus* grow-out diet. Indonesian Aquaculture Journal 2(1), 7–13.

Usman, Rachmansyah, Laining, A., Ahmad, T. and Williams, K.C. (2005). Optimum dietary protein and lipid specifications for grow-out of humpback grouper *Cromileptes altivelis* (Valenciennes). Aquaculture Research 36, 1285–1292.

Usman, Rachmansyah, Makmur and Ahmad, T. (2005). Substitution of fish meal with soybean meal in humpback grouper, *Cromileptes altivelis* juvenile diets supplemented with phytase. Indonesian Fisheries Research Journal 11, 73–80.

Williams, I.H., Williams, K.C., Smith, D.M., Jones, M. (2006). Polka-dot grouper, *Cromileptes altivelis,* can utilize dietary fat efficiently. Aquaculture Nutrition 12, 379-387.

Williams, K.C. (2009). A review of feeding practices and nutritional requirements of postlarval groupers. Aquaculture 292, 141–152.

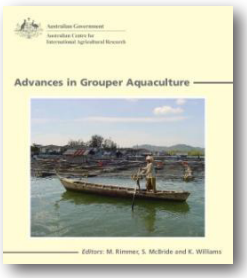
Williams, K.C., Irvin, S. and Barclay, M. (2004). Polka dot grouper *Cromileptes altivelis* fingerlings require high protein and moderate lipid diets for optimal growth and nutrient retention. Aquaculture Nutrition 10, 125-134.

Other

Nguyen, T.T.T., Davy, F.B., Rimmer, M.A. and De Silva, S.S. (2009). Use and exchange of genetic resources of emerging species for aquaculture and other purposes. Reviews in Aquaculture 1, 260-274.

Books and book chapters

The results of FIS/97/73 were summarised in a publication in ACIAR's monograph series.



Rimmer, M.A., McBride, S. and Williams, K.C. (2004). Advances in Grouper Aquaculture. ACIAR Monograph 110. Australian Centre for International Agricultural Research: Canberra. 137 pp.

Project staff are recognised for their expertise in regard to marine finfish aquaculture, particularly grouper aquaculture, and have contributed to a number of reviews and regional summaries.

Rimmer, M.A. and McBride, S. (2008). Grouper Aquaculture in Australia. pp. 177–188. In: 'The Aquaculture of Groupers'. Liao, I.C. and Leaño, E.M. (eds). Asian Fisheries Society, World Aquaculture Society, Fisheries Society of Taiwan, National Taiwan Ocean University. 241 pp.

Rimmer, M.A. and Ponia, B. (2007). A Review of Cage Aquaculture: Oceania. pp. 208–231. In: Halwart, M., Soto, D. and Arthur, J.R. (eds). 'Cage Aquaculture – Regional Reviews and Global Overview'. FAO Fisheries Technical Paper No 498. Food and Agriculture Organisation of the United Nations, Rome. 241 pp.

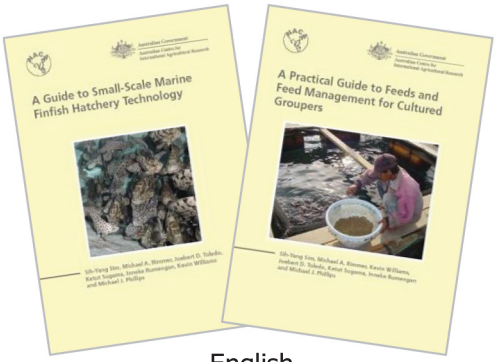
Rimmer, M.A., Williams, K.C., Phillips, M.J. and Kongkeo, H. (2000). An Asia-Pacific Regional Cooperative Network for Grouper Aquaculture Research. In: I.Chiu Liao and C. Kwei Lin (Editors), 'Cage Aquaculture in Asia', pp. 273-279. Asian Fisheries Society, Manila and World Aquaculture Society, Bangkok.

Extension publications

The projects published two practical manuals intended for use by commercial producers, government agencies and other research and development agencies, on 'Small-scale marine finfish hatchery technology' and 'Feeds and feed management for cultured groupers'. These were also translated into Indonesian, Thai and Vietnamese to make them accessible to local farmers.

Sim, S.Y., Rimmer, M.A., Toledo, J.D., Sugama, K., Rumengan, I., Williams, K. and Phillips, M.J. (2005). A Guide to Small-Scale Marine Finfish Hatchery Technology. Network of Aquaculture Centres in Asia-Pacific, Bangkok, Thailand. 17 pp.

Sim, S.Y., Rimmer, M.A., Williams, K., Toledo, J.D., Sugama, K., Rumengan, I. and Phillips, M.J. (2005). A Practical Guide to Feeds and Feed Management for Cultured Groupers. Network of Aquaculture Centres in Asia-Pacific, Bangkok, Thailand. 18 pp.



English

Indonesian

Three more extension publications are currently being produced as outputs from FIS/2002/077:

- Hatchery Management of Tiger Grouper *Epinephelus fuscoguttatus*
- Nursery Management of Grouper
- Grow-out of Marine Finfish

These will be published as 'Best Practice Manuals' by ACIAR.

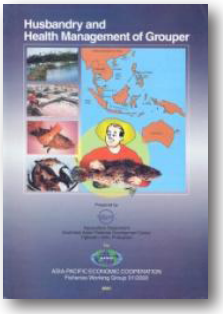
Related publications

The collaboration developed during these projects also supported other lines of research. The following publication, which describes a new method of tagging marine finfish larvae, resulted from a collaboration between James Cook University (Australia) and RIM Gondol (Indonesia) which was facilitated by the ACIAR project.

Williamson, D., Jones, G. and Thorrold, S. (2009). An experimental evaluation of transgenerational isotope labelling in a coral reef grouper. Marine Biology 156, 2517–2525.

Project team members were instrumental in developing other publications, such as the Asia - Pacific Economic Cooperation (APEC) –supported 'Husbandry and Health Management of Grouper' manual. This was translated into Filipino, Indonesian, Thai, Mandarin and (by SUMA) Vietnamese to make it accessible to local farmers.

APEC/SEAFDEC (2001). Husbandry and Health Management of Grouper. Asia-Pacific Economic Cooperation (APEC), Singapore, and South-east Asian Fisheries Development Centre (SEAFDEC), Iloilo, Philippines.



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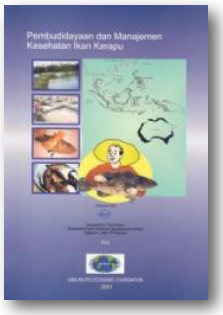

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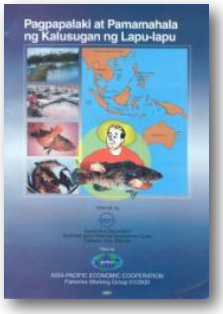
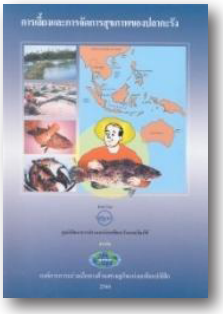


Filipino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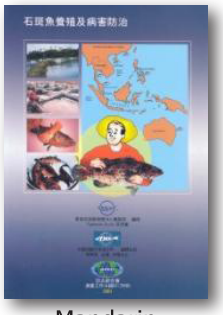
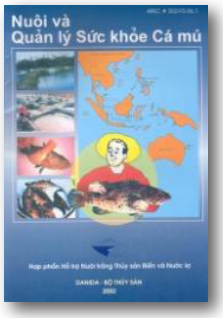

Mandarin



Vietnamese

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    - Research Institute for Coastal Aquaculture, Maros, South Sulawesi
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