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Final report

project

Accelerating the development of finfish mariculture in Cambodia through south-south research cooperation with Indonesia

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Acronyms and abbreviations

ACH50	Alternative Complement pathway Hemolytic activity
ACIAR	Australian Centre for International Agricultural Research
AMFRHR	Agency for Marine and Fisheries Research and Human Resources (Ministry of Marine Affairs and Fisheries, Indonesia)
ASEAN	Association of Southeast Asian Nations
BRIN	Badan Riset dan Inovasi Nasional (National Agency for Research and Innovation, Indonesia)
CapFish	Cambodia Programme for Sustainable and Inclusive Growth in the Fisheries Sector
COVID-19	coronavirus disease
CP	crude protein
DAC	Development Assistance Committee (OECD)
DAD	Department of Aquaculture Development, Fisheries Administration
DAH	days after hatching
EU	European Union
FCR	feed conversion ratio
FiA	Fisheries Administration (Ministry of Agriculture, Forestry and Fisheries, Cambodia)
GoI	Government of Indonesia
IGF-1	insulin-like growth factor 1
IMRAFE	Institute for Mariculture Research and Fisheries Extension (Gondol, Bali, Indonesia)
IPB	Institut Pertanian Bogor (IPB University, Bogor, Indonesia)
JICA	Japan International Cooperation Agency
KKP	Kementrian Kelautan dan Perikanan (Ministry of Marine Affairs and Fisheries, Indonesia)
MARDeC	Marine Aquaculture Research and Development Centre (Sihanoukville, Cambodia)
mRNA	messenger ribonucleic acid
NADS	National Aquaculture Development Strategy
NSW DPI	New South Wales Department of Primary Industries (Australia)
ODA	official development assistance
OECD	Organisation for Economic Co-operation and Development
PCR	polymerase chain reaction
PSFI	Port Stephens Fisheries Institute (NSW DPI)
R&D	research and development
R4D	research for development
RICAFE	Research Institute for Coastal Aquaculture and Fisheries Extension (Maros, South Sulawesi, Indonesia)
SDG	Sustainable Development Goal
SEAFDEC	Southeast Asian Fisheries Development Center
SGR	specific growth rate
SRA	small research activity
SME	small or medium enterprise

SSC	South-South cooperation
SSTC	South-South triangular cooperation
ToC	Theory of Change
USC	University of the Sunshine Coast (Queensland, Australia)
VNN	viral nervous necrosis

Contents

1 Acknowledgments

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2 Executive summary

The overall aim of FIS/2016/130 was to accelerate the development of finfish mariculture in Cambodia through a South-South Triangular Cooperation (SSTC) between Cambodia (beneficiary partner), Indonesia (pivotal partner) and Australia (facilitating partner). The project leveraged previous and ongoing ACIAR R&D investments in finfish mariculture at RICAFE Maros, South Sulawesi, and IMRAFE Gondol, Bali, to train researchers from the Department of Aquaculture Development, Fisheries Administration, Cambodia, in fish nutrition and feed development, larval rearing, and disease diagnosis.

Training of Cohort 1 (2018–19) FiA staff was through work-integrated learning whereby the training was integrated into the ongoing research activities at RICAFE Maros (fish nutrition and feed development) and IMRAFE Gondol (larval rearing and disease diagnosis). However, due to travel restrictions arising from the COVID-19 pandemic, training of Cohort 2 (2020–21) trainees was undertaken using online delivery.

A total of 17 FiA staff (6 female and 11 male) were trained to the equivalent of AQF 8 (Graduate Certificate) level. In addition to improved technical skills provided by this training, the trainees noted that the training provided them with improved non-technical skills: improved communication skills; enhanced teamwork; improved English language capability; increased professional networks.

A gendered value chain analysis of finfish mariculture in Cambodia found that women participate in all nodes of the value chain, except going on fishing boats catching the ‘trash’ fish. The fish farm is perceived as a family business, in which men, women and youths participate equally. Women are dominant in trade-related nodes, both as traders of ‘trash’ fish and of the farmed fish. Men are more present in the fingerling trade and as farmed fish wholesalers. This study identified a range of constraints to the continued development of sustainable mariculture in Cambodia, many of which are being addressed through the training provided under FIS/2016/130.

Research on rabbitfish (*Siganus* spp.) in Indonesia and in Australia demonstrated that *Siganus guttatus* can be produced in moderate quantities using extensive larval rearing methods in brackishwater ponds. Research undertaken in Indonesia on the nutritional requirements of *S. guttatus* has provided information suitable for the development of compounded feed for this species, including the optimal protein requirement (35% crude protein). Due to the ability of rabbitfish to elongate and desaturate short- and medium-chain fatty acids, rabbitfish diets can substitute cheaper lipid sources, such as palm oil, for the more expensive fish oil that is commonly used in fish feeds. The research on *S. guttatus* has generated local interest, including from a commercial hatchery in South Sulawesi, and amongst brackishwater pond farmers.

Linked post-graduate research in Australia on the application of seaweed as a functional ingredient in fish diets showed that the red seaweed *Asparagopsis taxiformis* boosted innate immune responses and growth rates in an herbivorous marine finfish (rabbitfish – *Siganus fuscescens*) and in a carnivorous catadromous finfish (Atlantic salmon – *Salmo salar*). Overall, these results indicate that the inclusion of seaweed as a functional ingredient in fish feeds has the potential to improve the welfare, productivity and environmental sustainability of the aquaculture industry.

An evaluation of the SSTC approach used in FIS/2016/130 concluded that the utilisation of SSTC can contribute to ACIAR’s role of supporting research collaboration to improve livelihoods in the agriculture, fisheries and forestry sectors, while emphasising individual and institutional capacity-building and opportunities for development led by the private sector. Specifically, SSTC approaches are useful for: scaling out R4D outcomes, in cases where ACIAR has a long-term investment in R4D in one country that is in demand by other partner countries; in bridging technological gaps between Australia and developing countries, by utilising the intermediate technologies and capabilities of a third country as a pivotal partner in SSTC; supporting partner countries to shift from beneficiaries to aid

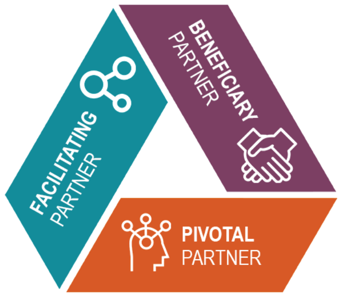
partners; and supporting South-South Cooperation approaches in partner countries. Operationally, SSTC approaches can be incorporated in ACIAR projects with minimal modifications to existing procedures:

The project also undertook a gendered evaluation of progression opportunities at the two Indonesian partner laboratories. At one institute, perceptions were that there is no discrimination of any sort, either in terms of gender or in terms of other personal characteristics such as ethnicity, religion, background or other, nether in the institute nor in the community at large. At the second institute, we found that some aspects scored consistently lower for females than for males, which appeared to reflect that there is less access for females to administrative and management training and thus it is recommended that access of female researchers to administrative and management training be improved.

3 Background

This project was designed to trial and evaluate an emerging modality for development cooperation, namely South-South Triangular (or Trilateral[1]) Cooperation (SSTC), and to develop a framework for incorporating this approach in research-for-development (R4D) projects, specifically ACIAR-funded projects. The terminology around development models is described in detail in the project report *Evaluation of the context favouring successful south-south development cooperation vs. traditional bilateral cooperation*.

Although SSTC models may involve three non-Development Assistance Committee (DAC) states, they typically involve one DAC member as the major funding source, that engages one non-DAC state to provide support to a third (non-DAC) recipient (Sakurai 2015). The terminology of the participants in triangular development cooperation has recently been revised by the OECD to reflect the shift in development thinking from 'aid' and 'assistance' to 'partnership' (OECD 2019), a change that accords with ACIAR's partnership approach to R4D:



- The **beneficiary partner** seeks support to tackle a specific development challenge.
- The **pivotal partner** has proven experience in the issue, and shares its resources, knowledge and expertise.
- The **facilitating partner** helps connect the beneficiary and the pivotal partners, supporting their collaboration financially and technically.

In FIS/2016/130 the R4D model that was used to evaluate SSTC was to leverage Indonesian capability in finfish mariculture research and development (R&D) to accelerate the development of finfish mariculture in Cambodia, supported financially and with some management and technical oversight by Australia.

3.1 The development challenge – finfish mariculture in Cambodia

The overall aim of the project is to ***accelerate the development of finfish mariculture in Cambodia*** *by leveraging previous and ongoing ACIAR R&D investments in Indonesia through south-south cooperation*.

The context of the role of each partner country and the participating agencies in the project is explained in more detail in the following sections.

3.1.1 Beneficiary partner – Cambodia

Finfish mariculture in Cambodia is a relatively new but rapidly growing and changing sector of the industry. Marine finfish bring much higher farm gate prices than freshwater species: USD 5–10 per kg for Asian seabass and grouper compared with USD 1.2–2.1 per kg for freshwater species (Joffre et al. 2016; 2010 data), although there has been a slight decline in the farm-gate price of Asian seabass between 2013–14 and 2015–18 which is ascribed to competition from imported product (Mak et al. 2020). Despite this, finfish mariculture is generally perceived as a lucrative industry that attracts those looking for profitable investments (Larson et al. 2022). Demand for seafood in coastal regions is increasing in response to increasing population, led by emigration from inland regions in

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[1] *OECD uses the terms 'triangular' and 'trilateral' interchangeably.*

search of improved economic opportunities in coastal areas, and an expanding tourism sector (Srean 2018).

Marine finfish aquaculture production is dominated by Asian seabass / barramundi (*Lates calcarifer*) which is farmed in sea cage farms (Fig. 1) and in a few brackishwater pond farms in three coastal provinces (Preah Sihanouk, Kampot and Koh Kong). Finfish mariculture in Cambodia is currently organised as family businesses (small to medium enterprises, SMEs) (Larson et al. 2022). Individual farms range in size from 1 up to 300 cages, with most farms in the range of 50 to 200 cages (Sen et al. 2018; Mak et al. 2020).

Recognising the potential for mariculture to contribute to Cambodian fisheries production, in 2013 FiA, with the support of the Japan International Cooperation Agency (JICA) constructed a new Marine Aquaculture Research and Development Centre (MARDeC) at Sihanoukville in Preah Sihanouk province, to promote mariculture development in Cambodia. A priority species for this centre is Asian seabass.

MARDeC's stated mission is: **To improve the livelihoods of coastal populations and increase marine fisheries production through development of marine aquaculture.**

Many of the constraints being faced by Cambodia are those earlier faced by Indonesia. In particular, hatchery technology needs to be refined to support cost-effective production of seedstock, compounded feeds need to be developed to reduce the reliance on 'trash' fish, and fish health management needs to be improved to reduce production losses and improve farm efficiency and profitability (Sen et al. 2018; Mak et al. 2020).

Figure 1 A typical SME Asian seabass farm in Preah Sihanouk province, Cambodia.

3.1.2 Pivotal partner – Indonesia

Indonesia is recognised within ASEAN, as well as more broadly, for its expertise in marine finfish aquaculture, both in terms of research support and industry development (Rimmer et al. 2013; Fachry et al. 2018). Previous bilateral projects between Australia and Indonesia, funded by ACIAR, as well as bilateral projects with other donors, have built substantial R&D capacity in Indonesia, particularly with the Research Institute for Coastal Aquaculture and Fisheries Extension (RICAFE) at Maros in South Sulawesi (fish nutrition and feeds development) and the Institute for Mariculture Research and Fisheries Extension (IMRAFE) at Gondol in Bali (hatchery technology, fish health) – both of which are long-term partners in ACIAR projects (Hiruy and Eversole 2020). Hiruy and Eversole (2020, p.160) note that 'The [ACIAR] Fisheries Program has been instrumental in developing individual researchers' skills and the organisational capability of [IMRAFE]' and 'also influenced policy to create an enabling environment for the adoption of the technology by entrepreneurs and local farmers'.

The same study notes that this increased R&D capacity in Indonesia has contributed to SDG 1 (No Poverty) by improving the livelihood of local communities by creating employment opportunities; to SDG 2 (Zero Hunger) by improving food security by developing sustainable marine finfish aquaculture and increasing production and productivity of marine finfish aquaculture; and to SDG 3 (Good Health and Wellbeing) by improving the health and wellbeing of local communities as a result of increased access to quality food and income (Hiruy and Eversole 2020).

The approach taken with FIS/2016/130 was to utilise the acknowledged expertise and capability of the Indonesian partner agencies to support the development of marine finfish aquaculture R&D in Cambodia, with an expected contribution to SDGs in Cambodia as has been reported for Indonesia.

3.1.3 Facilitating partner – Australia

Australia has a substantial established marine finfish aquaculture industry, *albeit* mainly producing temperate species such as Atlantic salmon (*Salmo salar*) and Southern bluefin tuna (*Thunnus maccoyii*). Despite limited development of tropical aquaculture, Australia has a relatively large investment in aquaculture R&D. Many state government departments have disbursed their R&D capability in recent decades, leaving the university sector the main R&D provider in most states. One exception is the New South Wales Department of Primary Industries (NSW DPI) which retains a significant R&D capacity at its Port Stephens Fisheries Institute (PSFI). PSFI maintains research projects into marine finfish hatchery technology, grow-out nutrition and feeds development, and mollusc hatchery and culture methods. Researchers from PSFI and from the University of the Sunshine Coast (USC) were involved in the project to provide project management and administration (USC), as well as technical expertise in the knowledge domains in which research and capacity-building was undertaken (PSFI and USC).

3.2 Evaluating project processes and outcomes

Following the development of FIS/2016/130 ACIAR proposed additional activities to support project implementation, monitoring and evaluation, focusing on the capacity-building approaches of the project.

3.2.1 ACIAR SRA FIS/2018/155

Evaluating processes and outcomes in south-south research collaboration – finfish mariculture development in Cambodia through cooperation with Indonesia

Following the commencement of FIS/2016/130, ACIAR commissioned a complementary Small Research Activity (SRA) project to facilitate and document teaching approaches and structures for innovative and effective South-South exchanges applicable to agricultural R&D in the Indo-Pacific region. ACIAR recognised that it is important to evaluate both the processes of training and collaboration, as well as both the individual and workplace outcomes arising from such collaborations, and that enhanced professionalism and behaviours developed during the training are just as important (and often more so) than the technical learnings directly targeted by the research collaboration. Importantly, because enhanced professionalism is core to strengthening institutions in partner countries.

The SRA project had three objectives:

1. To develop pedagogic structure for the delivery of skills training by Indonesian scientists in the context of mariculture development in Cambodia.

2. To evaluate the degree of research and technical skills development arising from focused work-place training within a south-south framework.
3. To evaluate processes which engender increased professionalism in participants involved in south-south collaboration.

SRA FIS/2018/115 was managed by Prof. Janelle Allison (UTAS) and the outcomes of that SRA are reported separately.

4 Objectives

4.1 Overall aim

To accelerate the development of finfish mariculture in Cambodia by leveraging previous and ongoing ACIAR R&D investments in Indonesia through South-South cooperation.

4.2 Objectives

1. To accelerate the development of marine finfish aquaculture in Cambodia by building inclusive research and development capacity at MARDeC:
    - 1.1. Reduce the overall demand for 'trash' fish in marine finfish feeds in Cambodia by partial replacement with local feed ingredients.
    - 1.2. Improve the availability of marine finfish seedstock in Cambodia.
    - 1.3. Improve fish health technical services to farmers in Cambodia.
    - 1.4. Evaluate the roles of men, women and youth in the Cambodian mariculture industry.
    - 1.5. Evaluate the increase in technical capacity at MARDeC developed through project activities.
2. To support the development of rabbitfish aquaculture in Indonesia:
    - 2.1. Develop nutritional approaches to optimise rabbitfish reproduction and spawning success.
    - 2.2. Evaluate low-cost larval rearing techniques for rabbitfish.
    - 2.3. Evaluate the nutritional requirements for rabbitfish grow-out diets.
3. Evaluate the context favouring successful south-south development cooperation vs. traditional bilateral cooperation:
    - 3.1. Evaluate the benefits and constraints of the south-south cooperation approach in this project.
    - 3.2. Develop a framework for application of inclusive south-south cooperation in ACIAR projects.
    - 3.3. Evaluate gender issues for scientists in Cambodia and Indonesia, including an assessment of current barriers to inclusion.

5 Methodology

5.1 Objective 1: To accelerate the development of marine finfish aquaculture in Cambodia by building inclusive research and development capacity at MARDeC

5.1.1 Training of FiA researchers

Work-integrated learning

The training program was originally developed as work-integrated learning, whereby the trainees would undertake a mix of lectures and practical training in Fish Nutrition and Feed Development at the Research Institute for Coastal Aquaculture and Fisheries Extension (RICAFE) Maros, South Sulawesi, and in Larval Rearing and Disease Diagnostics at the Institute for Mariculture Research and Fisheries Extension (IMRAFE) Gondol, Bali.

This approach was used for the first cohort of trainees, during 2018–19 (Fig. 2). However, following the outbreak of the COVID-19 global pandemic in early 2020 and the implementation of travel restrictions, the training program was forced to switch to online delivery for the second cohort of trainees, in 2020–21.

A formal training structure was developed for RICAFE Maros and IMRAFE Gondol by the linked SRA FIS/2018/115 'Evaluating processes and outcomes in south-south research collaboration – Cambodia-Indonesia cooperation for finish mariculture development'. The training comprised modules that integrate Intended Learning Outcomes (ILOs) and assessment tasks. Implementation of the training was undertaken through post-training research activities in Cambodia.

The below tables summarise the training modules, topics, ILOs and take-home tasks.

Fish Nutrition Training

The Fish Nutrition and Feed Development training at RICAFE Maros was arranged as three modules, with each module undertaken at discrete times. The FiA trainees were trained in survey methods to identify and quantify potential aquafeed ingredients, following which they undertook a survey of potential feed ingredients in Cambodia, then returned to Indonesia with samples of feed ingredient materials for proximate analysis. This allowed the FiA trainees to begin compiling a database of the composition of potential aquafeed ingredients available in Cambodia.

Module	ILOs	Take-home tasks
1. Survey on feed ingredient and proximate analysis (2 weeks; 6–19 July 2018)	• Apply samples handling • Conduct sample preparation • Understand basic chemistry • Apply operational standard procedure of proximate analysis • Implement laboratory safety • Implement data collection/ data management	• Undertake a survey on feed ingredients in Cambodia and provide a report • Collect Cambodian local feed ingredients to be analysed for proximate analysis in Maros for Module 2

	• Apply trouble shooting • Reflect on self-discipline	
2. Feed formulation, feed making and feeding experiment (4 weeks; 1 April – 1 May 2019)	• Analyse proximate composition of selected feed ingredients collected in Cambodia • Categorize and select feed ingredients based on the nutrient content, price, and availability of feed ingredients • Identify nutrient requirements of the cultured fish (by species and by sizes) • Generate the feed formulation (Excel spreadsheet) • Make the fish feed • Structure a feeding experiment • Data management (collect and tabulate the relevant data) • Develop team work for preparation of ingredient, making fish feed and undertaking feeding trial	• Design, set up and conduct feeding trials as proposed and manage the data collection (data collected for Module 3).
3. Data analysis and interpretation (2 weeks; 15–28 Sept 2019)	• Apply basic statistics and descriptive analysis • Demonstrate knowledge on experimental design • Demonstrate statistical analysis (ANOVA, t-test, regression) • Interpret results of data analysis • Reflect data integrity	• Report results of data analysis (data from experiment at MARDeC) • Presentation • Evaluation

Figure 2 FiA Cohort 1 trainees undertook work-integrated learning at RICAFE Maros in research methods for fish nutrition, including laboratory analysis methods for proximate composition of feed ingredients.

Larval Rearing training

The Larval Rearing training was undertaken as a single visit to IMRAFE Gondol because a complete production cycle in the hatchery takes 3–6 weeks. The training topics were broken up into modules as per the table below. The Cohort 1 training took place at IMRAFE Gondol on 29 July – 5 September 2019 (Fig. 3) and focused on larval rearing of Asian seabass / barramundi, which is the main target species for the MARDeC hatchery.

Modules	ILOs	Assessment tasks
Broodstock	Discipline • Explain broodstock biology • Explain broodstock management Practical • Operate broodstock facility • Implement artificial spawning Personal • Demonstrate eggs handling	1. Construct / make a poster or flowchart to demonstrate the broodstock management to produce reliable eggs. The poster must include: photos, words, diagrams, graphs. 2. Make practical demonstration in the tanks of egg handling → Test + analyse = reports (graph); write up all in logbook; get feedback from lecturer.

	• Demonstrate capacity to works in team • Building confidence	
Larval rearing	• Familiar with IMRAFE Gondol (practical & personal); • Illustrate on larval rearing managements (practical, discipline & personal); • Explain problems of larval rearing in Cambodia (discipline); • Construct ideas for solving problems by research (discipline, practical & personal); • Analyse and interpret research results (discipline, practical & personal); • Write reports (discipline, practical & personal).	3. Construct and present a diagram of larval rearing managements: feed, water exchange, sampling methods (hatching rate, larval development and grading). Make a comparison between Indonesia and Cambodia and what can be improved in Cambodia. (ILO 2,3,4). 4. Case study: with / without probiotics. This study conducted in triplicate and test analysis
Water quality	Discipline • Identify physical and chemical parameters of good water quality • Understand water treatment Practical • Test water quality, measuring and analysing (input, in tank, effluent) • Manage and maintain water quality • System design Personal • Good communication in team • WHS/ biosecurity	5. Illustrate difference in water quality, explain why this is critical and how to maintain the water quality. Use the 'test' you've learned. This to explain these difference. Illustrate your results in graphic format. Present the results on poster. (ILOs(1, 3, 4, 6). Design facilities that are used in hatchery and explain the function of each. Illustrate your design as a "flow chart" system design. Your diagram may include photos and other graphic formats. It is expected you will present your design. You are encouraged to work as a team (groups). (ILOs 2, 5, 6, 7).
Live feeds	Discipline • To demonstrate basic knowledges of live feed (microalgae, rotifers, copepods, artemia). • Characterize of live feed	6. Conduct a trial of fertilizer and quality improvement of live feed: to compose of fertilizer in order to get optimum density; to improve nutrient quality of live feed (ILO 1); explain the results in their logbook using graphs or table. The trainee will be expected to present their results

	• Role of action: food for rotifers, shading, bioencapsulation. • Food for larvae (rotifers, copepods, artemia. • Monitoring and quantified of live feed. Practice • Culture live feed: laboratory culture, mass culture. • Improve nutrition quality of live feed: explain how to improve, improve the quality by enrichment. • Monitoring and quantified of life feed: quality of cell, density. Personal • To culture live feed. • To improve the ability to do monitoring and counting of live feed.	7. Graph pattern of prey density during the larval rearing. Daily counting of live feed in the culture tank (ILO 2).
Fish diseases	Discipline • Implement biosafety in laboratories • Distinguish parasitic and viral diseases in fish and how to control the diseases Practice • Apply biosafety in hatcheries & laboratories • Analyse fish diseases with different technique • Apply management control of fish diseases using chemicals Personal • Understand biosecurity in aquaculture • Create a good networking	8. Logbooks (photos, reports, checklists); keeping in touch. 9. Posters (research questions).

Figure 3 FiA Cohort 1 trainees undertook work-integrated learning at IMRAFE Gondol in larval rearing of marine finfish, particularly Asian seabass / barramundi.

PCR analysis training (2019)

Training was provided in PCR analysis methods for Mr Tey Toeng at IMRAFE Gondol, 5–16 August 2019.

Topic	Activity	Notes
Collecting fish samples	Preparing of equipment for collecting fish sample Handle fish samples	1 day (Day1)
Extraction of DNA and RNA virus from fish sample	Conventional method Fast method Measure of quantity of DNA and RNA	1-2 day (Day 2-3) Q & A Homework
Q and A Lecture for understanding of PCR and discussion	Related with fish sample collecting and DNA – RNA extraction	Morning (Day 4) Afternoon Homework
PCR amplification	Setting the PCR program for amplification DNA and RNA Preparing enzyme chemical solution	Day 5 ,6, 7 Discussion Homework

	PCR reaction using kits and conventional methods PCR process in the machine Gel running using electrophoresis Observation under UV transilluminator Documentation with gel-doc Understanding the results of virus detection	
Q & A	Related with PCR amplification Visit to private fish hatchery with biosecurity and without	Day 8 Homework
Repeat PCR work	Repeats PCR work for virus (DNA-RNA) detection independently by training participants	Day 9-10 Discussion and draft report

Fish health management for larviculture (2020–21; online)

At the 2019 Training Evaluation Meeting held at MARDeC, senior FiA staff requested that additional training be provided in fish health management and disease diagnostics, noting that (i) MARDeC was experiencing substantial mortality of larval and juvenile Asian seabass in the hatchery, which was ascribed to disease outbreaks and (ii) Asian seabass farmers were reporting losses due to disease outbreaks in the sea cage farms.

<table>
<tr><th>Topics</th><th>ILOs</th><th>Assessment tasks</th></tr>
<tr><td>Treatment of diseased fish – freshwater and chemical bathing</td><td rowspan="3">• Identify the main cause of mortality of fish (discipline)
• Identify bacteria, virus, and parasites in larval rearing by research (discipline)
• Set up an experiment and undertake data collection and surveys (practical)
• Analyse and interpret research results (discipline, practical)
• Write and present a report (practical, discipline and personal)
• Construct ideas for fish health management in terms of preventions and treatments in leaflet/power point (discipline, practical, personal)
• Application of health management in Cambodia (record in videos/pictures)
• Develop confidence in presentations (practical, personal)
• Develop capacity to work as a scientific team (practical, personal)</td><td>Experiment: different densities of larvae or water treatment (chlorination, sand filter filtration) in relation to fish pathology</td></tr>
<tr><td>Larval rearing – feeding, water management and fish health monitoring</td><td>Illustration of fish health management which might be conducted in Cambodia</td></tr>
<tr><td>Causes of fish disease from the perspective of bacteria, viruses and water quality</td><td>A case study (survey) in Cambodia: identify the main cause of the mortality and its pathogen (bacteria, virus, parasite)</td></tr>
</table>

Pivot to online training

As noted above, travel restrictions associated with the COVID-19 global pandemic prevented travel by the Cambodian trainees to Indonesia from early 2020. While the content of the Cohort 2 training was effectively the same as that for Cohort 1, delivery was done online. It should be noted that this substantially increased the workload of the Indonesian trainers, who had to develop additional resources, e.g. videos of laboratory analysis techniques.

The process of online training delivery, review and reporting was summarised by the Larval Rearing and Disease team, as shown below in Figure 4.

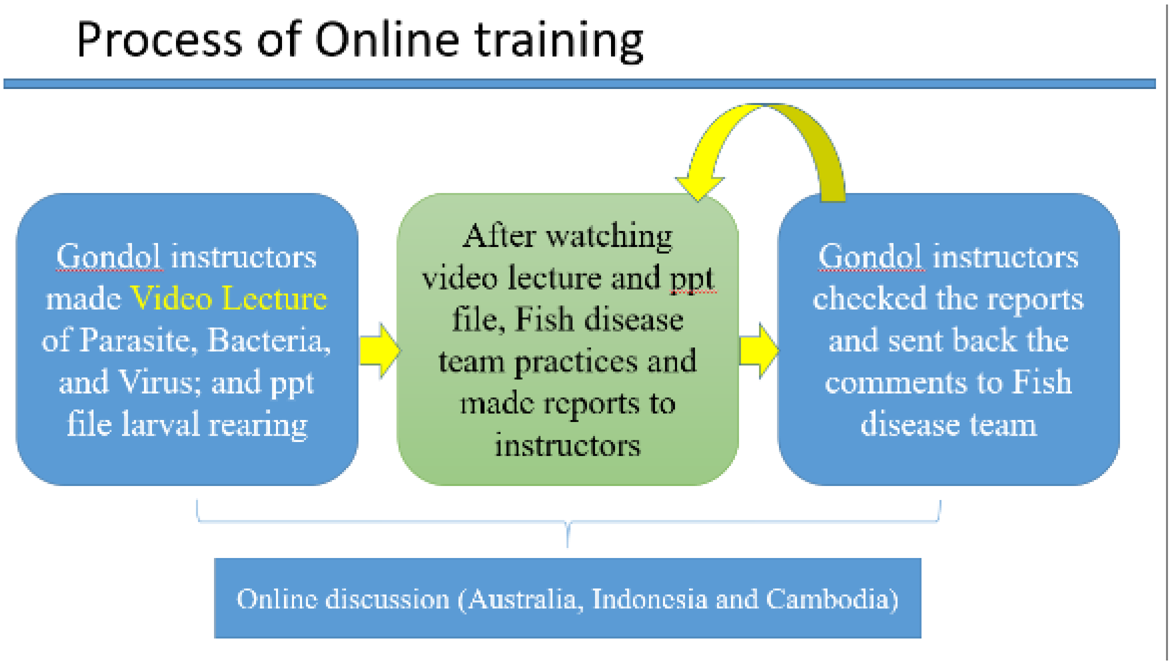

Figure 4 Graphic by the FiA Larval Rearing and Fish Disease Team indicating the processes involved in the provision of online training for Cohort 2 trainees.

The process of delivering training using online methods was challenging, partly due to the limited English language ability of some of the Cohort 2 trainees and partly because of poor internet in Preah Sihanouk which resulted in frequent signal drop-out and delays.

Additional training activities

Wherever possible additional training in scientific approaches and methodology was provided to FiA trainees in association with project meetings or project visits.

Inception meeting

The project Inception Meeting was held at the Mariculture Research and Development Centre, Sihanoukville, Cambodia, on 21–23 August 2018. The meeting was formally opened by His Excellency Eng Cheasan, the Director-General of the Fisheries Administration of Cambodia, and was attended by representatives of all the participating laboratories, including Indonesia (RICAFE Maros and IMRAFE Gondol), Australia (USC and NSW DPI) as well as FiA Aquaculture staff.

The meeting comprised three days: one day for discussing the project structure and its expected outputs, outcomes and impacts. Two days were dedicated to workshops on marine finfish larval rearing research and nutrition research which were compiled and presented by (larval rearing research workshop) Dr Mike Rimmer (USC) and Dr Stewart Fielder (NSW DPI) and (fish nutrition workshop) presented by Mr Steven Gamble (JCU / NSW DPI) based on material compiled by Dr Igor Pirozzi (JCU / NSW DPI).

Full details of the Inception Meeting have been reported separately.

2019 Annual Project Meeting

The 2019 Annual Project Meeting was held at IMRAFE Gondol, Bali, Indonesia, on 19–20 June 2019. The meeting was attended by representatives of all the participating institutions, including Indonesia (IMRAFE Gondol and RICAFE Maros), Cambodia (FiA), Australia (USC and NSW DPI). ACIAR was also represented by the Fisheries Research Program Manager, Prof. Ann Fleming.

The meeting comprised two days. The first day reviewed project progress and outcomes to date, and discussed future activities. The second day comprised presentations from IMRAFE Gondol, RICAFE Maros and NSW DPI on current research activities, with an emphasis on new and innovative research practices. Full details of the meeting, and the scientific presentations, are reported separately.

2019 Training Evaluation Meeting

A 4-day meeting was held at MARDeC on 4–7 November 2019 to evaluate the success of the 2019 training program in Fish Nutrition Research and Larval Rearing Research. The meeting was attended by representatives of the commissioned agency for FIS/2016/130 USC (Project Manager Dr Mike Rimmer), and the participating Indonesian institutes RICAFE Maros (Dr Asda Laining and Dr Usman) and IMRAFE Gondol (Mr Bambang Susanto, Prof. N.A. Giri and Mr Ahmad Muzaki), as well as representatives of the commissioned agency for FIS/2018/115 UTAS (Prof. Janelle Allison and Ms Sandra Knowles).

Overall the 2019 training of Fisheries Administration (FiA) staff was successful, with both the Fish Nutrition and Larval Rearing teams meeting their respective ILOs and consequently ‘graduating’. The first day of the meeting was also attended by the Director-General for Fisheries Administration of Cambodia, H.E. Eng Cheasan, who presented the 2019 graduates with their certificates of achievement.

Project visit training and workshops

Prof. Rachman Syah and Dr Asda Laining (RICAFE Maros) visited Cambodia on 21–26 January 2019, to:

- Provide mentoring of on-going activities by the DAD-MARDeC team relating to the survey of barramundi (*Lates calcarifer*) aquaculture in Cambodia and the potential for using local ingredients in fish feeds. This survey is a follow-up to the training on fish nutrition held in RICAFE Maros in July 2018.
- Discuss follow-up activities, in particular the second phase of fish nutrition training in RICAFE and the proposed feeding trial to be undertaken by the DAD-MARDeC Nutrition Team in Cambodia.

Dr Asda Laining gave a technical presentation on feed making for marine finfish, and Professor Rachman Syah presented the results of his study on the assessment of waste loading and dispersion of organic particle from milkfish cage culture.

Prof. Rachman Syah and Dr Laining also gave presentations to a general audience in Phnom Penh, on aquafeed development and the use of local feed ingredients in feed formulations in Indonesia, waste impacts from milkfish cage culture in Indonesia. This seminar was well attended by representatives of FiA-DAD, and local universities and colleges.

Scientific workshops on Larval Rearing and Grow-out Nutrition research were provided by Dr Stewart Fielder and Dr Igor Pirozzi, 22–24 October 2019, plus informal mentoring of FiA Larval Rearing and Nutrition Teams.

Presentations by Dr Mike Rimmer, 4–5 March 2020: Asian seabass / barramundi (*Lates calcarifer*) biology; Barramundi aquaculture; Barramundi feeds and feeding; Marine finfish larval nutrition.

Online scientific symposium

The project had originally planned for training of both Indonesia and Cambodian researchers in fish nutrition (Activities 1.1.8 and 2.3.3) and in biosecurity and more intensive larval rearing techniques (Activity 1.2.6) at Port Stephens Fisheries Institute in Australia. Because travel to Australia was not possible because of COVID-19 pandemic restrictions, the project team substituted an online symposium to provide project participants with new and innovative approaches to marine finfish aquaculture research. The online symposium had the theme: 'Using Research to Solve Problems to Support Aquaculture Industry Development' to support the broader project objective of developing research approaches and outcomes to promote mariculture development in Cambodia.

The symposium was held over 4 days from 12 to 15 July 2021 and comprised a range of scientific presentations related to marine finfish nutrition and feed development, and larval rearing of marine finfish. There were also presentations on research methods to solve technical problems, and on publishing results in international scientific journals. There were between 34 and 57 symposium participants each day. The structure and content of the symposium, and details of participation, have been reported separately.

5.1.2 Value chain analysis of Cambodian mariculture

To better understand the marine finfish aquaculture value chain in Cambodia, and to target interventions that would improve its overall sustainability, a value chain analysis was undertaken as an activity of this project. Value chain activities are developed in a social and environmental context and thus in addition to functional (flow) analysis, economic, social and environmental analyses should be conducted if the full understanding of the value/supply chain is to be achieved. In this study, we concentrated on the social analysis, however, to do so, we first needed an understanding of the functioning of the chain. Thus, we explored two aspects of the value chain: descriptive functional and social analysis. These are presented in the full report (Larson et al. 2020).

Prior to commencing the field work, training was provided to enumerators at the Cambodian Fisheries Administration (FiA) offices in Phnom Penh. At this time, a capacity building Value Chain Analysis training session was also provided to a wider audience of FiA and Provincial Fisheries staff. Following this training, the study team travelled to Preah Sihanouk and Kampot Provinces to undertake the field work. Field teams comprised representatives of FiA and local (Provincial Fisheries) representatives who facilitated access to local farmers. We collated existing data on finfish mariculture and interviewed key informants, to gain better understanding of the industry. We also conducted value chain mapping exercises with 61 participants and surveyed a total of 118 people – 39 in Stueng Hav; 38 in Prey Nob and 41 in Teuk Chhou district – for their perceptions of the industry and the associated barriers.

A full description of the methodology used for this study is included in the report to ACIAR (Larson et al. 2020). The research activities undertaken through this study were approved by the University of Sunshine Coast Human Research Ethics Committee (approval number A181189).

5.2 Objective 2: To support the development of rabbitfish aquaculture in Indonesia

Research on rabbitfish (*Siganus* spp.) in this project followed on from trials undertaken to evaluate rabbitfish as an alternative aquaculture commodity for brackishwater pond farming, as well as for sea cage culture, in Indonesia. A previous ACIAR-funded project (FIS/2007/124) evaluated rabbitfish and their potential for culture:

5.2.1 Rabbitfish hatchery technology

The larvae of *Siganus* spp. are difficult to rear in the hatchery because of their small mouth size, so that even small-strain *Brachionus* rotifers are generally too large for newly-hatched *Siganus* larvae to ingest. To evaluate the potential use of minute rotifers (Wullur et al. 2009) as live feed for *Siganus* spp., several trials were undertaken at the Brackishwater Aquaculture Development Centre (BADC) Takalar to culture the minute rotifer *Lecane*, which had been isolated and cultured at Sam Ratulangi University, North Sulawesi. Ultimately, this genus of rotifer proved too difficult to culture in the densities required for larval rearing.

Based partly on this outcome, the focus of larval rearing in FIS/2016/130 switched to extensive (marine or brackishwater pond) approaches based on those developed in Australia for fingerling production of Asian seabass / barramundi (*Lates calcarifer*) (Rutledge and Rimmer 1991). *Siganus guttatus* larvae were reared in 0.1 ha brackishwater ponds at the RICAFE Maros facility at Barru, South Sulawesi. The ponds were filled and fertilised with a combination of organic and inorganic fertilisers based on the scheme developed by Rutledge and Rimmer (1991). Further details of the methods used for larval rearing of *S. guttatus* are described in the Proceedings of the Online Symposium for FIS/2016/130.

5.2.2 Rabbitfish grow-out diets and nutrition

As part of FIS/2007/124 RICAFE Maros undertook a series of experiments to evaluate the nutritional requirements of rabbitfish to support development of compounded diets:

- Preliminary study on maturation diets for *Siganus guttatus* (Laining et al. 2019).
- Improvement of nutritive values of copra cake meal through fermentation with *Rhizopus* spp. and its use as protein source for practical diet of rabbitfish (Laining et al. 2017).
- Digestibility assessment of selected feed ingredients for *Siganus* spp. (Usman et al. 2014; Laining et al. 2021).
- The use of aquatic weed *Ceratophyllum* sp. as a protein source in diet for *Siganus guttatus* (Laining et al. 2016).

Nutrition research on rabbitfish, focusing on the inshore euryhaline species *S. guttatus*, was continued under FIS/2016/130. The methodology generally followed that used for earlier studies on nutrition of groupers and rabbitfish. Further details of the methodologies used for the various studies are included in the Proceedings of the Online Symposium for FIS/2016/130.

5.2.3 Value-chain study for rabbitfish in South Sulawesi

An earlier value-chain study for rabbitfish in South Sulawesi, undertaken as an activity under FIS/2007/124, noted that much of the demand for rabbitfish comes from middle and high income families. The preferred size of rabbitfish for household consumption is around 125 g, whereas for restaurant consumption it is 500–700 g. Consequently, for cultured rabbitfish there are several options for smaller (household consumption) or larger (restaurant market) sizes.

5.3 Objective 3: Evaluate the context favouring successful south-south development cooperation vs. traditional bilateral cooperation

A key component of FIS/2016/130 was evaluating the South-South Triangular Cooperation (SSTC) approach used in the project and its potential application in ACIAR-funded projects. Our evaluation methodology draws on recently published frameworks and guidelines for developing, implementing, monitoring and evaluating South-South Triangular Cooperation (SSTC) projects, notably by OECD (OECD 2018; 2019) and by the Global Partnership Initiative (GPI) on Effective Triangular Co-operation (GPI 2019). Where practical we have adopted these approaches for this evaluation, but have modified various aspects to suit SSTC as applied to research-for-development (R4D) projects.

The basis to our conceptual framework is the project cycle, which for SSTC projects (Fig. 5) does not substantially differ in structure from the project cycle for bilateral projects. However, as discussed further in the full report, the details of the project structure components are likely to differ between bilateral and SSTC approaches.

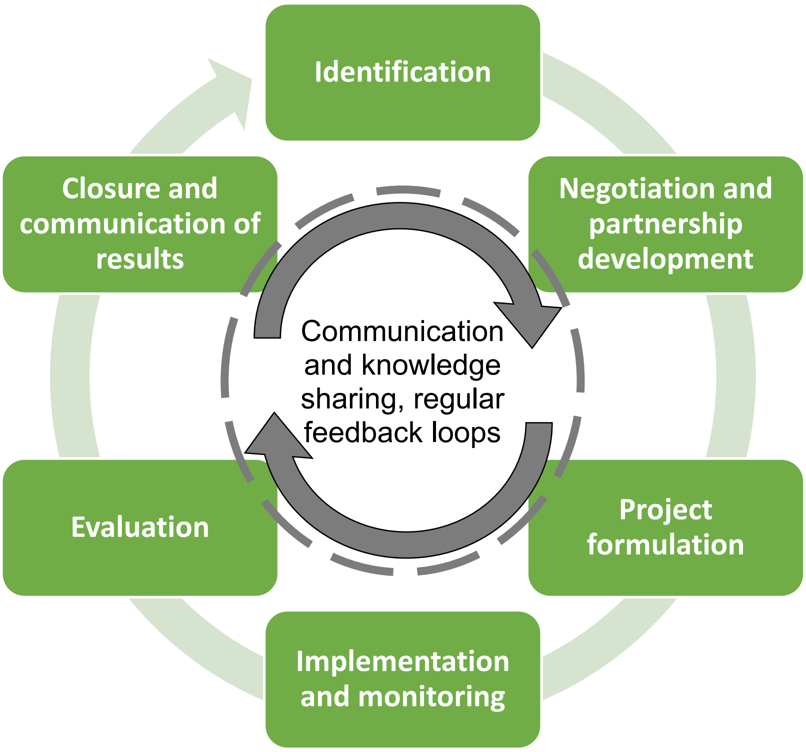

Figure 5 Typical project cycle for an SSTC project, from GPI (2019).

In the full report we firstly synthesise a conceptual framework of SSTC based on recent project development and evaluation approaches (OECD 2018; GPI 2019; OECD 2019) and structured around the project cycle (Fig. 5). Secondly, we test this framework using FIS/2016/130 as a proof of concept case study, and evaluate the outcomes of the project both at the individual level (incorporating the evaluations of FIS/2018/115) and at the agency level (FIS/2016/130 sub-objective 3.1).

In the last step, we adapt the original framework to include our learnings and propose an amended and tested framework for future use by ACIAR (FIS/2016/130 sub-objective 3.2).

5.3.1 Career progression opportunities for research staff of partner institutes in Indonesia

An evaluation of career progression opportunities – taking specific note of gender issues – was undertaken as project sub-objective 3.3. Study participants potentially included all research staff of the project partner institutions in Indonesia, RICAFE Maros and IMRAFE Gondol. Therefore, participants in the study were drawn from staff at each institute, subject to their availability and willingness to participate. The research activities undertaken through this study were approved by the University of Sunshine Coast Human Research Ethics Committee (approval number A181189).

The evaluation consisted of three steps: (1) issue identification, (2) finding solutions, and (3) review and discussion with the partner agencies.

Step 1 – Issue identification

Male and female scientists from both Indonesia partner were requested to fill in a structured questionnaire. All survey related documents were translated to, and administered in, Bahasa Indonesia.

For the purpose of this study, we explored the following three dimensions:

- Human Capital (access to training, grants, scholarships etc);
- Economic Empowerment (career indicators, salary, position, access to training etc);
- Organisational Culture (gender equality, discrimination, etc. at the workplace).

Completed surveys were entered into a spreadsheet and qualitative answers translated to English. Likart-scale data were analysed qualitatively. Based on voluntary recruitment, a total of 31 researchers at RICAFE Maros and 28 at IMRAFE Gondol participated in the survey, representing 69% and 70% of all of the potential participants at RICAFE Maros and IMRAFE Gondol respectively.

Step 2 – Finding solutions

Data collected during Step 1, Issue Identification, were analysed, and the results, trends and findings were summarised and reported back to the research staff in each institute. Following this process, all research staff at each institute were invited to attend FGDs, regardless of whether they completed Step 1 or not (as there was no means of identifying participants of Step 1).

Reporting back and FGD meetings were held on 27–28 February at RICAFE Maros and 4–5 March 2019 at IMRAFE Gondol. In total, 30 research staff at RICAFE Maros and 27 at IMRAFE Gondol, attended the respective FGDs.

During FGDs, the following themes (identified from the questionnaire responses as being of particular concern) were discussed:

(a) patronage.
(b) inequalities due to gender, religion, ethnicity, background or any other personal characteristic; and
(c) career progression issues that are common to all the research staff.

For each theme, barriers were discussed first, followed by potential enablers/solutions and recommendations. For group discussions, participants were asked to self-form the sub-groups, and to take notes. Once this part was completed, each sub-group reported their main discussion points to the plenary and for each of the above three themes, the plenary discussion ensued. The mediator took notes of the main discussion points on the white board, presenting them back to the plenary at the end, for general agreement. This process of participant verification ensured that what was discussed during the FGDs was captured and well understood. Hence, only qualitative data was collected in this step.

Step 3 – Review and discussion

Following the presentation of preliminary results and the FGDs at each participating institute, the outcomes of the study were compiled in a draft report and circulated to the institutes for review and comment. All results were presented in an aggregated form, with no individual identifying information. A presentation summarising the results was provided to the project team at the 2019 Project Meeting at IMRAFE Gondol, Bali. Senior staff of the two Indonesian institutions requested that the results of the study be informed to, and discussed with, senior staff of the AMFRHR in Jakarta.

ACIAR arranged a meeting with AMFRHR in Jakarta on 17 October 2019, participants of which included the Secretary of AMFRHR and International Cooperation Division staff of AMFRHR. An English-language Fact Sheet (Larson et al. 2019a) was provided as material for this meeting.

A full report of the evaluation and its results has been provided to ACIAR (Larson et al. 2019b).

6 Achievements against activities and outputs/milestones

Objective 1: To accelerate the development of marine finfish aquaculture in Cambodia by building inclusive research and development capacity at MARDeC

No.	Activity	Output / milestones	Completion date	Comments
1.1 To reduce the overall demand for 'trash' fish in marine finfish feeds in Cambodia by partial replacement with local feed ingredients				
1.1.1	Provide basic training in fish nutrition to Cambodian and Indonesian participants	Workshop completed Feb. 2018	Aug. 2018	Completed: workshop conducted as part of the Inception Meeting held at MARDeC, 21–23 August 2018. Additional presentations by Dr Igor Pirozzi at the 2019 Annual Project Meeting, Bali, 18–20 June 2019.
1.1.2	Agree on nutrition experiments to be undertaken	Agreed list of nutrition experiments Feb. 2018	Aug. 2018	Completed. Incorporated in Fish Nutrition training curriculum. A series of 3 experiments is planned for comparison of compounded feed with 'trash' fish: (1) in an indoor research system at MARDeC; (2) in an outdoor research system at MARDeC; and (3) on commercial sea cage farms.
1.1.3	Train MARDeC staff in feed ingredient survey and analysis methodologies	Training completed Apr. 2018	Jul. 2018	Completed as part of Fish Nutrition Module 1 training for both Cohort 1 (2018–19) and Cohort 2 (2020–21). Cohort 1 trainees now acting as mentors to Cohort 2 trainees.
1.1.4	Undertake a survey of feed ingredients in Cambodia	Survey completed and reported Oct. 2018	Dec. 2018	Completed and reported for both Cohort 1 (2018–19) and Cohort 2 (2020–21). Magazine article on local (Cambodian) feed ingredients and their proximate composition published in 'Aquaculture Asia-Pacific', September 2020.
1.1.5	Hands-on' training in fish nutrition	Training completed Sep. 2018 Mar. 2019 Sep. 2019 Dec. 2020 Apr. 2021	Cohort 1 (2019): completed November 2019 Cohort 2 (2020–21): completed October 2021.	Cohort 1 (2019): work-integrated-learning completed at RICAFE Maros. Cohort 2 (2020–21):Online training substituted due to COVID-19 travel restrictions. Proximate analysis training undertaken at Royal University of Agriculture, Phnom Penh.
1.1.6	Evaluation of local ingredients in compounded diets for barramundi / Asian seabass at MARDeC	Experiments completed and reported Dec. 2018 Jun. 2019 Dec. 2019 Dec. 2020 Jun. 2021	Experiment 1: Nov. 2019 Experiment 2: Jun. 2020	Facilities for nutrition experiments have been established at MARDeC and are in use. First experiment (in indoor research system) completed and evaluated at the Training Evaluation meeting held in Cambodia in November 2019. Second experiment (outdoor research system) completed and reported. Experiment with revised feed formulation (Cohort 2) .

No.	Activity	Output / milestones	Completion date	Comments
1.1.7	Validation testing of MARDeC formulations	Testing completed, incorporating farmer feedback May 2021	NA	Could not be undertaken due to COVID-19 pandemic (restricted travel within Cambodia, supply chain disruptions).
1.1.8	Provide training in advanced fish nutrition research for Cambodian and Indonesian researchers	Training completed Jun. 2021	Online symposium: July 2021	Additional lectures and workshops provided to FiA staff by Dr Igor Pirozzi (NSW DPI), 22–24 October 2019. Planned training in Australia delayed due to coronavirus pandemic (international travel bans). Substituted with online symposium, 12–15 July 2021.
1.2 To improve the availability of marine finfish seedstock in Cambodia				
1.2.1	Provide basic training in marine finfish larviculture to Cambodian and Indonesian participants	Workshop completed Feb. 2018	Aug. 2018	Completed: workshop conducted as part of the Inception Meeting held at MARDeC, 21–23 August 2018. Additional presentations by Dr Stewart Fielder at the 2019 Annual Project Meeting, Bali, 18–20 June 2019.
1.2.2	Agree on larval rearing experiments to be undertaken under FIS/2016/130	Agreed list of larval rearing experiments Feb. 2018	Aug. 2018	Completed. Incorporated in Larval Rearing training curriculum.
1.2.3	Improve the production and quality of barramundi fingerlings produced at MARDeC through focussed research activities	Experiments completed and reported Jun. 2018 Dec. 2018 Jun. 2019 Jun. 2020 Dec. 2020 Jun. 2021	Experiment 1: Nov. 2019 Experiment 2: Jun. 2020 Experiment 3: Jan. 2021	Facilities for larval rearing experiments have been established at MARDeC and are in use. First experiment (salinity) completed and evaluated at the Training Evaluation meeting held in Cambodia in November 2019. Second experiment (tank colour) completed and reported. Analysis of deformities limited due to restrictions on import of chemicals associated with border closures. Third experiment (use of sterilised sea water) completed and reported. Bacteriology and PCR analyses limited due to COVID-19 disruption of supply chains.
1.2.4	Transfer larval rearing techniques for other species (snappers, groupers) to MARDeC	Production at MARDeC diversified Aug. 2018 Mar. 2019 Aug. 2019 Sep. 2020 Feb. 2021	Dec. 2021	First training of FiA researchers at IMRAFE Gondol (November – December 2018) was in hatchery production of groupers. Subsequently, training and research has focussed on Asian seabass / barramundi. MARDeC has collected broodstock of several grouper species, including tiger grouper (*Epinephelus fuscoguttatus*) and giant grouper (*Epinephelus lanceolatus*) as well as a coral trout species (*Plectropomus* sp.)

No.	Activity	Output / milestones	Completion date	Comments
1.2.5	Stimulate interest amongst private sector investors in developing marine finfish hatcheries in Cambodia	Private sector investment in mariculture Apr. 2021	NA	Could not be undertaken due to coronavirus pandemic (international travel restrictions).
1.2.6	Training in biosecurity and more intensive larval rearing techniques	Training completed Apr. 2021	Online symposium: July 2021	Additional lectures and workshops provided to FiA by Dr Stewart Fielder (NSW DPI), 22–24 October 2019; and Dr Mike Rimmer, 4–5 March 2020. Planned training in Australia delayed due to COVID-19 pandemic (international travel bans). Substituted with online symposium, 12–15 July 2021.
1.3 To improve fish health technical services to farmers in Cambodia				
1.3.1	Training of MARDeC staff in the use of PCR to identify viral diseases	Training completed Dec. 2020	One FiA staff undertook 2 weeks training in PCR in Aug. 2019. Online training for Cohort 2 (2020–21) completed Aug. – Oct. 2020.	Training of one FiA fish disease staff (two weeks duration) was undertaken in August 2019 at IMRAFE Gondol. Subsequent training delayed due to international travel restrictions. Dedicated Fish Health curriculum developed for training of Cohort 2 (2020–21), supported by SRA FIS/2018/115. Follow-up training limited to online delivery. Implementation limited by the difficulty in obtaining reagents due to disruption of supply chains by COVID-19 pandemic.
1.3.2	Survey of viral diseases in cultured finfish in Cambodia	Survey completed and reported Apr. 2021	NA	Could not be undertaken due to delays in provision of training, lack of reagents due to disruption of supply chains, and COVID-19 travel restrictions.
1.4 Evaluate the roles of men, women and youth in the Cambodian mariculture industry				
1.4.1	Inclusive evaluation of Cambodian mariculture value chains	Evaluation completed and reported Dec. 2021	Oct. 2021	Full report provided to ACIAR in October 2020. Summary report provided to FiA for input to policy development, Feb. 2021. One paper published in *Aquaculture*; a second paper drafted for *Marine Policy*.
1.5. Evaluate the increase in technical capacity at MARDeC developed through project activities *Note: this sub-objective is now supported under the linked SRA FIS/2018/115*.				
1.5.1	Evaluation of organisational needs	Evaluation completed and reported: Oct. 2017	Nov. 2017	Evaluation of training and development needs compiled in cooperation with MARDeC staff. Additional evaluation of staff training needs undertaken under FIS/2018/115 in February 2019.
1.5.2	Baseline evaluation of MARDeC technical skills and needs	Evaluation completed and reported: Dec. 2017	Dec. 2018	Baseline evaluation completed as part of FIS/2018/115.

No.	Activity	Output / milestones	Completion date	Comments
1.5.3	Mid-term evaluation of MARDeC technical skills and needs	Evaluation completed and reported: Mar. 2019	Cohort 1 (2018–19): completed Nov. 2019 Cohort 2 (2020–21): interim evaluation completed Jun. 2021. Cohort 2 (2020–21): final evaluation completed Oct. 2021.	The evaluation of the first group of Cambodian trainees was undertaken in conjunction with SRA FIS/2018/115 in Cambodia in November 2019, and involved FiA trainees, senior FiA staff, Indonesian trainers (from both RICAFE Maros and IMRAFE Gondol), and representatives of both FIS/2016/130 (Dr Mike Rimmer) and FIS/2018/115 (Prof. Janelle Allison). A detailed report of this evaluation has been submitted to ACIAR by SRA FIS/2018/115. The evaluation reviewed two aspects of the training: 1. The quality of the training program (developed by Indonesian colleagues), and 2. Professional development of the Cambodian researchers. The Cohort 2 evaluation (Jun. and Oct. 2022) will be separately reported by SRA FIS/2018/115.
1.5.4	Final evaluation of MARDeC technical skills and needs	Evaluation completed and reported: Apr. 2021	Nov. 2021.	Combined evaluation for this activity (in conjunction with SRA FIS/2018/115 and evaluation of SSTC approach (activity 3.1) completed in November 2021.

Objective 2: To support the development of rabbitfish aquaculture in Indonesia

No.	Activity	Outputs / milestones	Completion date	Comments
2.1 Develop nutritional approaches to optimise rabbitfish reproduction and spawning success				
2.1.1	Improve the spawning performance and egg composition of broodstock	Experiments completed and reported Jun. 2019	Dec. 2021	Spawning performance was improved by replacing F0 *Siganus guttatus* broodstock with F1 fish and increasing overall numbers of broodfish. Subsequently, the *S. guttatus* broodstock have spawned reliably every month. Experiments to evaluate different broodstock diet lipid levels (10%, 13% and 16%) on spawning performance in *S. guttatus* broodstock showed substantial temporal variation between sequential spawning events that obscured treatment effects.
2.2 Evaluate low-cost larval rearing techniques for rabbitfish				

No.	Activity	Outputs / milestones	Completion date	Comments
2.2.1	Evaluate extensive larval rearing methods	Larval rearing trials completed and reported Dec. 2020	Dec. 2021	Larval rearing of the rabbitfish *Siganus guttatus* was undertaken using extensive methods in 0.1 ha brackishwater ponds and semi-intensive methods in 70 m^3 concrete tanks at RICAFE Maros Barru facility. Despite low survival, these studies produced a total of 77,800 *S. guttatus* fingerlings which were used for nutrition experiments and for collaborative grow-out trials with the Maros District Fisheries Service and with local brackishwater pond farmers.
2.3 Evaluate the nutritional requirements for rabbitfish grow-out diets				
2.3.1	Evaluate the inclusion of locally-available feed ingredients	Experiments completed and reported Mar. 2020	Dec. 2021	Research outcomes: • Optimal protein level in feed identified as 33% (at 10% lipid). Evaluation of locally-available and/or cheaper feed ingredients in rabbitfish diets: • Palm oil can substitute for (more expensive) fish oil. • Seaweed (*Sargassum*) meal can be included in rabbitfish diets after fermentation to reduce the crude fibre level in the meal.
2.3.2	Provide 'hands-on' training in fish nutrition to MARDeC researchers	Training completed Sep. 2018 Mar. 2019 Sep. 2019 Sep. 2020 Mar. 2021	Cohort 1 (2019): completed November 2019 Cohort 2 (2020–21): completed October 2021.	Cohort 1 (2019): work-integrated-learning completed at RICAFE Maros. Cohort 2 (2020–21):Online training substituted due to COVID-19 travel restrictions. Proximate analysis training undertaken at Royal University of Agriculture, Phnom Penh.
2.3.3	Provide training in advanced fish nutrition research for Cambodian and Indonesian researchers	Training completed Apr. 2021	Online symposium: Jul. 2021	Planned training in Australia delayed due to COVID-19 pandemic (international travel bans). Substituted with online symposium, 12–15 July 2021.
2.3.4	Validation testing of RICA Maros formulations	Testing completed, incorporating farmer feedback May 2021	Dec. 2021	Grow-out trial of rabbitfish provided by RICAFE Maros in 'traditional' brackishwater ponds owned by a local farmer to be undertaken from July 2021.

Note: although not formally part of ACIAR project FIS/2016/130, Valentin Thépot undertook research on the use of seaweed as a functional feed for rabbitfish *Siganus fuscescens* for his PhD study. This research is summarised in Section 7.2.2 of this report.

Objective 3: Evaluate the context favouring successful south-south development cooperation vs. traditional bilateral cooperation

No.	Activity	Outputs / milestones	Completion date	Comments
3.1	Evaluate the benefits and constraints of the SSTC approach in this project	Feb. 2018 Feb. 2019 Feb. 2021	December 2021	Comments and suggestions regarding project activities were compiled during regular visits to participating laboratories, and during annual project meetings.
		Evaluation completed and reported May 2021	Preliminary evaluation: Jun. 2021 Final evaluation: Oct. 2021	Preliminary combined evaluation for activity 1.5.4 (Final evaluation of MARDeC technical skills and needs) undertaken in conjunction with SRA FIS/2018/115 and evaluation of SSTC (activity 3.1) undertaken online in June 2021. Final evaluation completed in October 2021.
3.2	Develop a framework for inclusive application of SSC / SSTC in ACIAR projects	Framework compiled Nov. 2020	Feb. 2022	Methodological Approach documented and provided to ACIAR Nov. 2019. Structure subsequently modified to better fit the new frameworks published by OECD[2] and GPI[3]. Draft report provided to ACIAR for review, Feb. 2022.
3.3	Evaluate gender issues for scientists in Cambodia and Indonesia	Evaluation completed and reported Dec. 2018	May 2020	Draft report and summary document provided to AMFRHR for review and comment. Project team members and Dr Ann Fleming met Dr Maman Hermawan (Secretary of AMFRHR), Mr Andi Soesmono, Mr Agung Purnomo and staff of AMFRHR in Jakarta on 17 October 2019. AMFRHR requested some changes to the format of the recommendations which were adopted for subsequent versions. Revised draft provided to ACIAR on 6 November 2019; ACIAR requested additional details of the staffing complement of both institutes. Final version of report, revised as requested, provided to ACIAR on 28 May 2020. Journal publication under development.

[2] *OECD, 2018. Toolkit for identifying, monitoring and evaluating the value added of triangular cooperation.*

[3] *GPI 2019. Triangular Co-operation in the Era of the 2030 Agenda : Sharing Evidence and Stories from the Field.*

7 Key results and discussion

7.1 Objective 1: To accelerate the development of marine finfish aquaculture in Cambodia by building inclusive research and development capacity at MARDeC

7.1.1 Training of FiA researchers

As noted in section 5.1 of this report, only Cohort 1 trainees were able to undertake work-integrated-learning at RICAFE Maros and IMRAFE Gondol. Cohort 2 undertook the same training program, but using online delivery. A total of 17 FiA staff – 6 female and 11 male (Tables 1 and 2) – were trained to the equivalent of Australian Qualifications Framework (AQF) level 8, i.e. Graduate Certificate level (Tables 2 and 3).

Table 1 FiA DAD staff trained under FIS/2016/130.

Training	Cohort (Years)	Members
Fish Nutrition	Cohort 1 (2018–19)	Khum Sros, Mak Chankakada, Oem Ramana, Hoeun Phearum
	Cohort 2 (2020–21)	Sen Sorphea, Yong Chomnou, Pel Samnang
Larval Rearing	Cohort 1 (2018–19)	Poeurng Sengheang, Virakbot Hou, Mat Nget, Hok Seyha
PCR analysis	(2019)	Tey Toeng
Larval Rearing and Disease Diagnosis	Cohort 2 (2020–21)	Yun Socheat, Keo Samnang, Tey Toeng, Prom Chanmithona, Mey Sothea, (Ao Veasna)

Table 2 FiA DAD trainees trained under FIS/2016/130, by gender.

Training	Female	Male	Total
Fish nutrition and feed development	2	5	7
Larval rearing and disease diagnostics	4	6	10

Formal evaluations of the training program and its outcomes were undertaken in November 2019 (Cohort 1) and in June and October 2021 (Cohorts 1 and 2). Details of these evaluations are reported by the linked SRA FIS/2018/115.

The FiA trainees listed the following technical and non-technical skills that they gained through the training:

Technical skills

- Experimental design for nutrition experiments.
- Ingredient selection.
- Feed formulation.
- Chemical composition analysis.

- Broodstock selection.
- Larval sampling methods.
- Estimating live prey density.
- Counting and measuring fish larvae.
- Sampling for disease diagnosis: wet mount; sample collection, packaging, transport and storage.
- Bacterial culture and counting procedures.
- PCR analysis for viral diseases (VNN and Iridovirus).
- Basic statistical analysis using R and Rstudio.
- Data analysis and interpretation.
- How to write a manuscript / report of experiments.

Non-technical skills

- Improved communication.
- Team work – each team member undertaking specific duties with respectfulness, listening and reliability.
- Improved English language.
- Social network connection.

Integrated research by FiA trainees

To reinforce the technical training, and to ensure that any constraints to implementation in Cambodia were identified, research activities were undertaken at MARDeC. This research focussed on aspects of marine finfish aquaculture that were recognised as constraints during the project development process:

- Nutrition and feed development: identifying and analysing potential ingredients for compounded feeds for Asian seabass; undertaking short-term nutrition trials to evaluate the inclusion of selected feed ingredients in compounded feeds for Asian seabass (Fig. 6).
- Larval rearing: improving survival of Asian seabass (*Lates calcarifer*) in the MARDeC hatchery to produce more fingerlings for local (Cambodia) cultivation (Fig. 7).
- Fish disease: identifying the pathogens commonly found in sea cage culture of Asian seabass in Cambodia.

To this end, the FiA trainees undertook a series of experiments that implemented aspects of the training provided by RICAFE Maros (fish nutrition and feed development) and IMRAFE Gondol (larval rearing and disease diagnosis)

Fish nutrition research

- Survey of feed ingredients available in Cambodia.
- Proximate analysis of selected ingredients.
- Nutrition experiments using locally-available ingredients.

Larval rearing research

- Effect of different salinities on larval growth and survival.
- Effect of different tank colours on larval growth and survival.
- Effect of water sterilisation using chlorine to reduce bacterial loads on larval growth and survival.

Figure 6 Training was implemented at MARDeC with the FiA FIsh Nutrition Team formulating test diets incorporating local ingredients for evaluation with Asian seabass.

Figure 7 Following their training at IMRAFE Gondol, the FiA Larval Rearing Team constructed an experimental larval rearing facility at MARDeC which was used to evaluate a range of parameters to improve survival of Asian seabass larvae.

7.1.2 Value chain analysis of Cambodian mariculture

Results from key informant interviews

Finfish mariculture is regarded as a growing and promising industry for Cambodia, where demand outstrips supply. Information flows between value chain actors are reported as good, and contracting is based on oral agreement. The main challenges for the future of the industry are related to water pollution and the competition for land. There is a recognised need for improved technical training of FiA officers, who in turn would provide improved support services to farmers. There were no perceived differences of treatment of women and men in the industry, and no gender-based cultural or traditional barriers to engagement of women in finish mariculture were reported.

Value chain mapping

Value chain mapping for this study aimed at both providing a descriptive analysis of the value chain and an understanding of the roles of men, women and youths. The 'map' obtained through this exercise (Fig. 8) assists in visualising the roles women and men play at each step of this value chain. We found that women participate in all nodes of the value chain, except going on fishing boats catching the 'trash' fish. The fish farm is perceived as a family business, in which men, women and youths participate equally. Women are dominant in trade-related nodes, both as traders of 'trash' fish and of the farmed fish. Men are more present in the fingerling trade and as farmed fish wholesalers. Wholesalers reported trading with restaurants and supermarkets in Phnom Penh, which is a finding different to previous reports of marine finfish being marketed only locally.

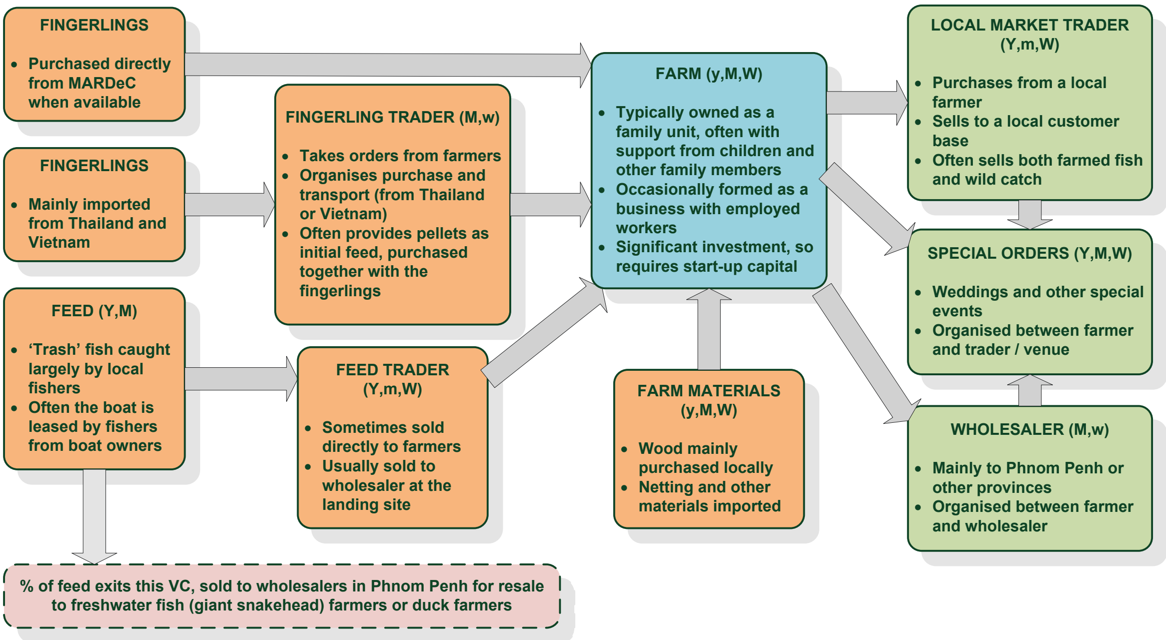

Figure 8 Functional flow of the Cambodian finfish mariculture value chain. Arrows indicate flow of goods and services. Y, y = youths; W, w = women; M, m = men. Capital letter indicates significant presence (i.e. >50% representation) in the value chain node.

In terms of the main areas of work on the farm, such as buying of the feed ('trash' fish), preparing the 'trash' fish, feeding, cleaning cages and selling of the fish (catching and transport of the fish; weighing and pricing) both men and women are involved. Some of the activities, such as cleaning of the cages or catching the fish for sale, are seen as predominantly male work; while others, including negotiations with the buyer, weighing of the fish, and money keeping, are predominantly in the female domain.

Our survey results indicate that women and men are involved in somewhat different activities, both at the farm level and in the value chain overall. The literature suggests that those areas where women are involved are often less visible and may be overlooked, and that women fill in lower-value jobs. In contrast, our evaluation found no indication of systematic discrimination against females in this value chain. They are both visible and not confined to lower-status or lower-paid jobs. The gender roles reported here are in line with other literature for aquaculture in South-east Asia, where women play key roles in processing and marketing.

The bargaining skills of women are openly praised and often viewed by people in the industry and the community as positive and desirable for family production systems. Our case study region exhibits characteristics of ‘weaker patriarchies’ that are common throughout South-east Asia: no or limited cultural prohibitions on women’s mobility, weak distinctions between the public and private domains, the organization of households along corporate lines (around the conjugal unit) with each member contributing to a common purse managed by women, less clear divisions of labour by gender, and generally high labour participation by women who more readily engage in off-farm activities and are traders and entrepreneurs. Men and women work together (that is, providing capital, labour, and expertise) to establish a joint enterprise that will contribute to their diverse livelihoods portfolio.

Perceptions of the industry and the associated barriers

Social analysis of the Cambodian finfish mariculture industry indicated that the general perception of the survey participants was that there are no differences in barriers or opportunities in finfish farming, based on gender, ethnicity, religion etc.; in other words, that the opportunities and constraints are similar to all.

Need for improved technical support services for mariculture

Support services, in particular related to technical training, emerged as the barrier perceived by the highest percentage of respondents, both male and female. The shortcoming related to training was perceived both in terms of lack of training available; and in terms of lack of time to attend training when organised. In relation to productive assets, inputs and resources, difficulties were reported regarding ‘trash’ fish, which was reportedly increasingly difficult to buy, with rising prices; poor water quality (turbidity and water pollution) and poor site/location of the farm; and limited availability of fingerlings, which were mainly imported from Thailand or Vietnam, with a long transport time which sometimes resulted in poor quality and high mortality. These findings are in line with the literature.

Additional services for the future, perceived as of potential benefit, were identified as greater availability of technical information, in particular in relation to handling of fingerlings, disease management and alternative food sources; financial mechanisms and credit; and availability of fingerlings locally from MARDeC at Sihanoukville. We note that activities in this ACIAR project are indeed building the capacity of the MARDeC staff in what are perceived by respondents as highly relevant areas: fingerling production and handling, disease management, and alternative (to ‘trash’ fish) feeds. However, this study also identifies industry demand for expanded extension services, including technical information and training.

Institutional arrangements for mariculture

A large percentage of respondents appeared to have no clear understanding of what the institutional arrangements and ‘rules’ related to access to resources (e.g. land, water) or services (i.e. licenses, certificates) related to finfish mariculture are, indicating that education in this respect might be of benefit to farmers. As reported by government staff interviewed as the key informants, small-scale businesses do not require licences or certificates; and can use common land and water to farm. However, as their businesses grow and the development pressure for land increases, farmers might find themselves in changing conditions resulting in situations where some reportedly exit the value chain.

Understanding consumer requirements

We also explored farmers' perceptions of consumer needs. Harvesting in the 'right season' – including the wedding season; and producing the fish of 'right' characteristics (size, appearance) were reported as ways for increasing returns. However, more than a quarter of respondents (27%) had no understanding of consumer preferences and value adding opportunities. This finding indicates a need and a potential for better integration of the existing mariculture value chain, further moving from a 'supply chain' – where actors supply goods and services to their customers with little knowledge or interest in what goes on in the chain beyond their immediate suppliers and customers – to a true 'value chain', where the focus is not on what can be supplied but rather on what is valued by consumers and how this can be more efficiently delivered. Also, several respondents – mainly females – had ideas for value adding in the finfish mariculture value chain, most frequently through engagement in fish trade/retail.

Barriers to entering mariculture

From interviews with people not currently engaged in mariculture, the lack of money and a lack of a suitable location for the farm emerged as the most common reasons for not becoming a finfish farmer. As reported in the literature, finfish mariculture was also perceived in our study as requiring significant investment and a long time to returns, consequently limiting the ability of resource-poor actors to enter the value chain.

The study also found that decisions about purchases of large assets are most commonly made as a joint husband and wife decision, while purchases of small assets are more likely to be made by the person needing the asset, and household items are typically purchased by women. In terms of household budget overall, 65% of men and 74% of women reported that household budget is controlled by women. This is typically the most senior woman in the household (wife or a mother). In most cases where men reported controlling household budget this was due to lack of a senior female (i.e. widowers). Intra-household dynamics and indeed the broader community dynamics are of significant importance for value chain analysis.

We strongly support such gendered explorations in future studies. We also propose that the relevance of household income control by women and of community perceptions and praise for women's' bargaining skills should not be underestimated and could be used for a positive approach towards improved women's economic outcomes.

Conclusion

Ensuring that gender issues are taken into consideration in value chain -related interventions is vital for facilitating the development of inclusive value chains that benefit both women and men. Our study clearly indicates that both women and youths are present along the finfish mariculture value chain in Cambodia, and in some instances are dominant. A gendered diagnostic analysis, such as one conducted in this study, increases the probability of carrying out successful future gendered value chain interventions.

The full report of this study (Larson et al. 2020) draws upon these findings to table recommendations for potential interventions in the finfish mariculture value chain in Cambodia. A summary document (Larson et al. 2021) has been provided to FiA to inform policy-makers of these recommendations. A component of the study has been published in 'Sustainability and Society' section of the journal *Aquaculture* (Larson et al. 2022), and a second paper is in preparation for submission to the journal *Marine Policy*.

7.2 Objective 2: To support the development of rabbitfish aquaculture in Indonesia

7.2.1 Rabbitfish hatchery technology

Initially, the spawning performance of *Siganus guttatus* at the RICAFE Maros Barru hatchery was unreliable. However, performance was greatly improved once the wild-caught (G1) *S. guttatus* broodstock were replaced with captive-bred (G2) fish and the overall broodstock population increased. Since then, the *S. guttatus* broodstock have spawned reliably each month, allowing more reliable planning of larval rearing research activities.

These *S. guttatus* broodstock were used to evaluate the effect of different dietary lipid levels (10%, 13% and 16%) on spawning performance. There was substantial temporal variation with increasing hatching rates observed for three sequential spawning events. At the third spawning event broodstock fed the diet containing the highest lipid level of 16% had the highest hatching rate of 43% compared to 30% and 27% for the 10% and 13% dietary lipid treatments respectively. A similar response was seen for blood triglycerides, but blood glucose levels were similar for all treatments.

Research at RICAFE Maros found that the domestication process had significant effects on the morphometric and meristic characteristics of the orange-spotted rabbitfish *S. guttatus*. Interestingly, the domestication and selective breeding had little modulatory effect on the genotypic characteristics of the G1 and even G2 fish. The majority of the morphometric and meristic characteristics of domesticated G1 and G2 rabbitfish differed, whereas the genotypic characteristic of domesticated rabbitfish was identical to the GeneBank listing for *S. guttatus*. Further details of this research will be published in the Proceedings of the Online Symposium for FIS/2016/130.

To better understand the dynamics of zooplankton populations in the RICAFE Maros Barru brackishwater ponds, three trials were undertaken to identify the peak of small (<50 micron) zooplankton (assumed to be the size range ingested by newly-hatched *S. guttatus* larvae). These showed that the peak in the <50 mm size class occurred at 6–8 days after filling the ponds. Subsequent larval rearing trials with *S. guttatus* were timed so that the larvae were stocked in the ponds about 1 week after the ponds were filled and fertilised, to coincide with this peak of zooplankton prey.

RICA Maros staff have documented the early larval development of *S. guttatus*.

Research into larval rearing and larval diet by Valentin Thépot at RICA Maros' Barru facility indicated that first-feeding larvae of rabbitfish consume mainly large phytoplankton. This is unusual amongst marine finfish larvae, which are usually zooplanktivorous. Two later trials undertaken to investigate the early larval diet of *S. guttatus* larvae fed zooplankton indicated that the larvae initially (2–3 DAH) consume diatoms but quickly shift to a diet dominated by zooplankton (from 4 DAH).

A number of larval rearing trials were undertaken using 70 m^3 concrete tanks that were filled with seawater, then inoculated with zooplankton prior to stocking *S. guttatus* larvae These tanks were used to sample *S. guttatus* larvae for studies on larval diets, since it proved impossible to sample larvae from the rearing ponds.

S. guttatus fingerling production from the larval rearing ponds and experimental tanks is summarised in Table 2, and monthly larval stocking and production data are appended (Appendix 1).

Table 3 Annual production of *S. guttatus* fingerlings from brackishwater larval rearing ponds (extensive system) and 70 m^3 concrete tanks (semi-intensive system) at the RICAFE Maros Barru hatchery.

Year	Ponds	Tanks
2017	1,200	-
2018	10,331	-
2019	1,850	3,000
2020	10,456	-
2021	47,581	4,600
Total	**70,218**	**7,600**

Observation of the success of extensive larval rearing and climate suggested that survival of larvae in the ponds was higher during the rainy season, when salinity in the ponds was lower. To examine this hypothesis, an experiment was undertaken to evaluate the effect of different salinities on hatching rate and yolk-stage larvae of *S. guttatus*. This experiment showed that the highest hatching rate (73%) for *S. guttatus* eggs was at 20 ppt. Similarly, the best survival rate of *S. guttatus* yolk-sac larvae (32%) was at 20 ppt. Survival for both stages was lowest at 10 ppt and at full seawater salinity of 35 ppt. These results support the observation that survival of early stage *S. guttatus* larvae is higher at moderate salinities.

Further details of the research into larval rearing techniques for *S. guttatus* will be published in the Proceedings of the Online Symposium for FIS/2016/130.

Although overall production is still low, production using these methods was higher than was reported for semi-intensive production of rabbitfish using semi-intensive methods in the RICAFE Maros hatchery (previous GoI-funded research). As described below, the improvements in fingerling production evoked interest amongst private-sector hatchery owners in South Sulawesi, and provided fingerlings that were used in RICAFE Maros experiments (section 7.2.2) and in collaborative grow-out trials (section 7.2.3).

Figure 9 Rabbitfish (*Siganus guttatus*) fingerlings were successfully reared for the first time using extensive larval rearing methods at RICAFE Maros' Barru facility.

7.2.2 Rabbitfish grow-out diets and nutrition

An experiment to evaluate soybean meal as the major protein source, and the seaweed *Gracilaria* as the major binding agent, for rabbitfish diets showed an optimal response of 35% dietary protein (at 11% crude lipid).

Collaborative research between RICAFE Maros and IPB evaluated IGF-1 mRNA expression level in the intestine and liver of *S. guttatus* in this experiment. Rabbitfish fed the 35% protein diet had the highest IGF-1 mRNA expression level, two-fold from the 30% protein diet, 3.6-fold from the 40% protein diet and 5.1-fold from the 25% protein diet. The pattern of the IGF-1 mRNA expression was in line with measured growth responses.

A 20-week feed trial evaluated different dietary lipid sources for rabbitfish diets: soybean oil, palm oil and coconut oil while fish oil was used in the control diet. Fish fed the diets containing fish oil (control) and palm oil had a significantly higher weight gain and SGR and lower FCR than those fed the diets containing soybean oil and coconut oil, suggesting that palm oil can replace fish oil – a more expensive ingredient – as a dietary lipid source in grow-out diets for *S. guttatus*. This finding provides important information for feed producers particularly in Indonesia to develop cost-effective diet by using cheaper and locally available palm oil as dietary lipid source.

Another experiment evaluated the potential for inclusion of the seaweed *Sargassum* in rabbitfish diets, following fermentation of the seaweed to improve its digestibility and available protein levels. *Sargassum* seaweed was fermented using two probiotic products developed by RICAFE Maros: containing *Bacillus subtilis* (designated RICA-4) and *Bacillus licheniformis* (designated RICA-5) and *Sargussum* meal fermented with the two probiotics, plus a combination of both, was compared with unfermented *Sargassum* as the control. Fermentation of *Sargassum* meal reduced the fibre content of the meal from 18% to 13–15% but had no effect on protein or lipid levels of the treated meals. The digestibility of the diet containing *Sargassum* meal fermented using a combination of probiotics (RICA-4 and RICA-5 together), was higher than that of the diet containing unfermented *Sargassum* meal. The different test diets had no significant effect on growth parameters (weight gain, SGR) but the feed efficiency of *S. guttatus* fed the diet with a probiotics was higher than for fish fed by the diet containing unfermented *Sargassum* meal.

Overall this research has demonstrated the potential for compounded diets for rabbitfish to substitute cheaper or more readily available (in Indonesia) ingredients to reduce the cost of the feed, while maintaining performance in line with feeds containing more expensive ingredients.

Seaweed as a functional ingredient in the diet of farmed fish

This section summarises the finding from Valentin Thépot's PhD research, which was jointly supported by ACIAR project FIS/2016/130, a post-graduate scholarship from the University of the Sunshine Coast, with supplementary funding from The Crawford Fund.

Aquaculture provides 50% of the fish we eat today, however the growth and the sustainability of this industry is threatened by disease outbreaks claiming 10% of global aquaculture production and costing more than AU$8.2 billion annually. Current treatments, particularly antibiotics, are of increasing concern regarding both human and environmental health (e.g. increasing antibiotic resistance) and climate change is expected to exacerbate the severity and frequency of disease outbreaks. Alternatives to traditional veterinary drugs are therefore a necessity to support the long-term sustainable development of aquaculture.

Functional ingredients are a promising alternative, because they can boost the immune system of fish and enhance their resistance to disease without posing a threat to human and environmental health. Seaweeds are one type of functional ingredient receiving increasing attention because of their taxonomic diversity (~11,353 species) and the array of bioactive compounds that they produce, representing a unique and largely untapped source of potential functional ingredients. Since no synthesis of the work done on seaweed as a functional ingredient for fish had been done, I first conducted a systematic review of the dietary effects of seaweed on fish immunity, resistance to disease and growth (Thépot et al. 2021c). In this meta-analysis review of 142 studies I found that dietary supplementation with seaweeds or their extracts had substantial positive impacts on the health and growth of fish, particularly when provided in combination with other immunostimulants. This review also highlighted two significant knowledge gaps: 1) only a very small number of seaweed species have been tested (42 species out of 11,353) and 2) there was a clear underrepresentation of marine herbivores (2 studies out of 142) in feeding trials. Following on from these findings, I investigated the effects of 11 different seaweed species (and appropriate controls) on the immune response of a novel aquaculture candidate, the marine opportunistic omnivorous rabbitfish *Siganus fuscescens*. This trial revealed that the red seaweed *Asparagopsis taxiformis* was the best candidate for immunostimulation of *S. fuscescens* with a four-fold increase in haemolytic activity compared to the control fish (Thépot et al. 2021a).

I also demonstrated that the immune response of *S. fuscescens* across dietary treatments did not correlate with their intestinal microbiome, which remained relatively unchanged. To further understand why the intestinal microbiome of the fish did not differ, I compared the microbiome data obtained from that trial to the data from two other studies, which described the intestinal microbiome of wild *S. fuscescens* populations (East and West coasts of Australia). I found that the intestinal microbiome of the fish differed between geographic populations but that regardless of their geographic distribution and dietary treatment, there was evidence of a core microbiome that was shared between all rabbitfish populations, which is a desirable trait for the domestication of fish in aquaculture.

Fish growth and sexual maturation are two key attributes of aquaculture production that need to be considered when introducing functional ingredients into the diet of farmed fish. Therefore, I tested the effects of inclusion of different concentrations and forms of dietary *A. taxiformis* supplements (whole plant, extract and residue at 1.5%, 3% and 6% dietary inclusion) on the growth and sexual maturation of *S. fuscescens* (Thépot et al. 2021b). The fish fed the high *A. taxiformis* extract had the highest growth rate (+49%) and improved feed efficiency (+31%) compared to the control fish. I also found significant reductions in potentially pathogenic bacteria (*Tenacibaculum* spp.) in the intestine of fish fed seaweed diets compared to those fed the control diet. Hilyses, a β-glucan rich functional food used as positive control, resulted in significant increases in gonadosomatic index but no significant effects of seaweed inclusion were detected on sexual maturation. Some positive trends were observed in the fish fed the whole *A. taxiformis* diet: a higher proportion of mature fish (26% above that of the control fish) and, consistent with, a four-fold increase in haemolytic activity in the fish fed that diet compared to the control fish.

The mottled rabbitfish is an exciting candidate for marine aquaculture with substantial potential as a sustainable alternative to carnivorous fish to fulfil fish protein demand and help maintain food security. However, rabbitfish are not currently farmed in significant quantities, thus in order to be an effective and commercially applicable dietary supplement with broad uptake, *A. taxiformis* should also promote the growth and immune response of a prominent carnivorous fish. Therefore, I assessed the effect of *A. taxiformis* on the immune response, growth, immune and stress related gene expression and intestinal microbiome of Atlantic salmon parr, *Salmo salar* (freshwater stage of the carnivorous fish and one of the most valued fish globally) (Thépot et al. 2022). After a four-week trial the fish fed *A. taxiformis* supplemented diets had higher immune responses than the control fish but lower responses than those fed a diet supplemented with a known immunostimulant (LPS). Furthermore, the positive immunostimulatory effects of *A. taxiformis* appeared to peak at two weeks then drop off after four weeks. Importantly, fish that were fed the diets supplemented with seaweed had up to 33% increase in relative growth rate compared to the fish fed the control and LPS-diets. Seaweed supplements also led to higher intestinal microbial diversity compared to the control and LPS diets, which is broadly linked to enhanced health in animals.

Overall, when fed to Atlantic salmon and rabbitfish, the red seaweed *A. taxiformis* boosted innate immune responses and growth rates, which are directly relevant to the aquaculture industry. The mechanisms behind both responses remain unclear but *A. taxiformis* appeared to have a direct immunostimulatory effect on both fish species due to the consistent lack of correlation between immune responses and changes in intestinal microbial composition across three separate trials. In addition, the growth and feeding stimulatory effects of *A. taxiformis* have strong commercial application with no production trade-offs observed in these studies. Overall, this research demonstrated that seaweed has the potential to improve the welfare, productivity and environmental sustainability of the aquaculture industry irrespective of the trophic level (herbivorous vs carnivorous) or the origin (freshwater vs saltwater) of the farmed fish.

Further details of the research into rabbitfish nutrition and diet development will be published in the Proceedings of the Online Symposium for FIS/2016/130.

7.2.3 Rabbitfish grow-out trials

A five month grow-out trial was undertaken in collaboration with Maros District Fisheries Service (Dinas Kelautan dan Perikanan Kabupaten Maros) to evaluate growth and survival of rabbitfish (*S. guttatus*) in net cages in the Maros River. For this trial, Maros District Fisheries Service supplied the grow-out cages and feed; RICAFE Maros provided the fingerlings and technical support, including monthly sampling for growth and survival. Survival of the rabbitfish was high with all cages except one demonstrating >94% survival;

the remaining cage had 57% survival due to fish escapement. At six months there was substantial mortality due to poor water quality and lack of cage cleaning. High survival despite the highly variable water quality at this site (e.g. salinity ranging from 3 ppt during the rainy season to 46 ppt) indicates the robust nature of *S. guttatus* for cage culture.

In April 2019 RICAFE Maros provided 1,000 juvenile rabbitfish (*S. guttatus*) to a farmer group at Barru, South Sulawesi. Although the farmer group did not keep complete records of the trial, they estimate survival to harvest at >90%.

A total of 800 *S. guttatus* fingerlings (mean weight about 80 g) were stocked in a local farmer's 800 m^2 brackishwater pond in July 2021. Feed, water quality monitoring and technical support were provided by RICAFE Maros for the duration of the grow-out trial.

Figure 10 RICAFE Maros undertook collaborative grow-out trials with rabbitfish in sea cages at Maros, South Sulawesi.

7.3 Objective 3: Evaluate the context favouring successful south-south development cooperation vs. traditional bilateral cooperation

As noted in Section 5.3, a key component of FIS/2016/130 was evaluating the South-South Triangular Cooperation (SSTC) approach used in the project and its potential application in ACIAR-funded projects. The approach used was based on published frameworks and guidelines for developing, implementing, monitoring and evaluating SSTC projects (OECD 2018; GPI 2019; OECD 2019), suitably modified to suit SSTC as applied to research-for-development (R4D) projects.

7.3.1 Evaluation of the context favouring successful south-south development cooperation vs. traditional bilateral cooperation

The evaluation study was conducted in three steps:

Step 1 – Conceptual framework

In this step we synthesised a conceptual framework of SSTC based on recent project development and evaluation approaches reported in the literature and structured around the SSTC project cycle:

1. Identification of the development challenge
2. Negotiation and partnership development
3. Project formulation
4. Implementation and monitoring
5. Communication, knowledge sharing and feedback loops
6. Evaluation
7. Closure and communication of results

Step 2 – FIS/2016/130 as a framework case study

Secondly, we then tested this framework using FIS/2016/130 as a proof of concept case study, and evaluated the outcomes of the project both at the individual level (incorporating the evaluations of FIS/2018/115) and at the agency level (FIS/2016/130 sub-objective 3.1). Internal evaluation activities (presentations and structured focus group discussions) were conducted at two time-points during the project: one year into the training (November 2019) and at the end of the project's training activities (June and October 2021). Participants were from each partner country, and included Cambodian trainees (16 people), Indonesian trainers (10 people), Cambodian senior FiA staff members (3 people) and Australian participants (4 people).

Identification of the development challenge

A key element in the development of FIS/2016130 was that it was jointly proposed by representatives of the pivotal partner (Dr Asda Laining, RICAFE Maros, Indonesia) and the beneficiary partner (Mr Somony Thai, DAD FiA, Cambodia). This reflected the strong support of both the pivotal and beneficiary partners for development of a collaborative R4D project.

Negotiation and partnership development

Following the initial identification of the development challenge, this project was conceptualised as a South-South triangular cooperation (SSTC) model, with Cambodia as the beneficiary partner, Indonesia as the pivotal partner, and Australia as the facilitating partner. The partnership between Indonesia (pivotal partner) and Cambodia (beneficiary partner) reflected the difference in finfish mariculture development in both countries. While Indonesia has a well-developed and extensive finfish mariculture sector throughout much of the archipelago, Cambodia's finfish mariculture sector is relatively small and highly reliant on inputs from neighbouring countries.

Project formulation

The foundational approach of the project was to leverage the skills and knowledge that had been developed at RICAFE Maros and at IMRAFE Gondol through their involvement in a series of ACIAR-funded projects implemented from 1999 to 2016. These projects have built capacity at both the Indonesian institutions in fish nutrition and feed development, larval rearing, and disease diagnostics. Supported by pedagogic structures developed under SRA FIS/2018/115, RICAFE Maros and IMAFE Gondol provided training to FiA staff at a level equivalent to AQF 8. The training programs were originally designed as work-integrated learning, with the training integrated into ongoing research activities at the Indonesian institutes. However, from early 2020 travel restrictions arising from the COVID-19 global pandemic forced a change to online delivery.

To further embed the training outcomes and to identify any constraints to implementation, follow-up research activities were undertaken at MARDeC. This research focussed on aspects of marine finfish aquaculture that were recognised as constraints during the project development process:

- Larval rearing: improving survival of Asian seabass (*Lates calcarifer*) in the MARDeC hatchery to produce more fingerlings for local (Cambodia) cultivation.
- Nutrition and feed development: identifying and analysing potential ingredients for compounded feeds for Asian seabass; undertaking short-term nutrition trials to evaluate the inclusion of selected feed ingredients in compounded feeds for Asian seabass.
- Fish disease: identifying pathogens commonly found in Asian seabass sea cage culture in Cambodia.

Implementation and monitoring

In 2018–19 training was implemented as work-integrated learning with the Cambodian (beneficiary partner) trainees undertaking the training at RICAFE Maros (fish nutrition and feed development) or at IMRAFE Gondol (larval rearing and disease diagnosis). However, restrictions on international travel introduced in early 2020 prevented the second cohort of trainees from travelling to Indonesia, and in response both Indonesian institutes developed and provided online training.

Monitoring of the training was undertaken by evaluating the trainees against the ILOs that had been developed for each training module. By the end of the project 17 FiA staff (6 female, 11 male) had been successfully trained to the equivalent of AQF level 8 standard.

Communication, knowledge sharing and feedback loops

A range of communication and knowledge-sharing approaches were used, including:

- Regular reporting by FiA trainees during their training of the training activities, and key learnings from the training.
- Interim and final reporting of research activities undertaken at MARDeC.
- Presentations on training outcomes, and research outcomes, during project meetings.
- Mentoring of FiA trainees by Indonesian (pivotal partner) and Australian (facilitating partner) researchers.
- Regular project team meetings to present project outcomes and plan future activities.
- Technical symposia focused on the main training / research topics.

Following the outbreak of the COVID-19 pandemic, communication was conducted entirely online using various communication tools, including WhatsApp (for less formal communication or asking questions) and email (for more formal communication, including provision of reports).

Evaluation

As noted above, the evaluation was conducted at two time-points during the project: one year into the training (November 2019) and at the end of the project's training activities

(June and October 2021) by interviewing participants from the beneficiary partner (Cambodia), pivotal partner (Indonesia) and facilitating partner (Australia) agencies. Although OECD has developed a Toolkit for Identifying, Monitoring and Evaluating the Value Added of Triangular Cooperation we found that this evaluation framework did not usefully contrast traditional North-South bilateral approaches with SSC / SSTC approaches. Instead we based our comparative evaluation on that proposed by Ashoff (2010). We also evaluated the project against its key objectives, and also evaluated the project outcomes against national SDGs.

Closure and communication of results

Interim project outcomes have been reported regularly through Annual Project Reports to ACIAR.

In line with the expectations for R4D projects, research outcomes have been published in regional and international aquaculture magazines and in scientific journals. To date, FIS/2016/130 has produced 5 peer-reviewed scientific papers, with additional papers planned or under development.

The project has also published two policy briefs. One of these (Report Summary: Career Progression Issues for Research Staff of Partner Institutes in Indonesia) was used to inform a joint meeting of Indonesian and Australian project participants with the Agency for Marine and Fisheries Research and Human Resources in Jakarta in October 2019. The second (Report Summary: Evaluating the roles of men, women and youth in the Cambodian finfish mariculture industry) was provided to FiA to inform policy development for sustainable finfish mariculture in Cambodia.

In all project publications, attempts have been made to improve inclusivity by including authorship by Australian (facilitating partner), Indonesian (pivotal partner) and Cambodian (beneficiary partner) authors; by including both female and male authors; and, in publications by project research teams, revolving level of contribution and hence authorship to facilitate female senior authorship.

Step 3 – Revising the framework for application of SSTC in ACIAR projects

Finally, we adapted the original framework to include our learnings from FIS/2016/130 and proposed an amended and tested framework for future use by ACIAR (FIS/2016/130 sub-objective 3.2):

The utilisation of SSTC can contribute to ACIAR's role of supporting research collaboration to *improve livelihoods in the agriculture, fisheries and forestry sectors, while emphasising individual and institutional capacity building and opportunities for development led by the private sector*. Specifically, SSTC approaches are useful for:

Scaling out R4D outcomes, in cases where ACIAR has a long-term investment in R4D in one country that is in demand by other partner countries.

Bridging technological gaps between Australia and developing countries, by utilising the intermediate technologies and capabilities of a third country as a pivotal partner in SSTC.

Supporting partner countries to shift from beneficiaries to aid partners. Some long-term partner countries for ACIAR (e.g. Indonesia) are in the process of developing their own aid programs, and SSTC supports this approach and helps build skills in regard to developing and implementing R4D programs.

Supporting South-South Cooperation in partner countries. Although there is an increasing focus on SSC internationally, a bilateral SSC approach is not always practical. ACIAR projects can facilitate increased emphasis on SSC as pivotal partner countries develop their own aid programs with SSC elements.

Operationally, SSTC approaches can be incorporated in ACIAR projects with minimal modifications to existing procedures:

Increased investment in project development and formulation, including reciprocal visits between the partners to improve understanding of the capabilities of each partner agency.

For SSTC projects with a strong element of capacity-building, **the involvement of education specialists in project development and design t**o support the development of formal pedagogic structures.

Monitoring of expectations, as well as project activities, throughout the project, recognising that the role of the pivotal partner in SSTC projects will differ from their previous role as a beneficiary partner.

Formal evaluation of capacity-building activities, utilising the pedagogic structures developed during project development and formulation.

In evaluating SSTC R4D projects, we propose three main evaluation approaches:

1. Evaluation of the project's contribution to the beneficiary partner country national development priorities.
2. Evaluation of the project's contribution to national SDGs.
3. Evaluation of the project using donor evaluation criteria.

In regard to 3. above, we proposed some minor changes to ACIAR's established project evaluation structure to incorporate an evaluation of SSTC projects. ACIAR project evaluation criteria, with additional proposed criteria for SSTC projects, are presented in Section 5.2.3 of the report.

Figure 11 The project trained a total of 17 FiA staff (6 female and 11 male) to the equivalent of AQF 8 (Graduate Certificate) level in fish nutrition and feed development, marine finfish larval rearing, and disease diagnosis. This outcome demonstrates the success of an SSTC approach to capacity-building in ACIAR-funded projects.

7.3.2 Career progression opportunities for research staff of partner institutes in Indonesia

The following summarises the findings of the career progression study at RICAFE Maros and IMRAFE Gondol. Additional detail is provided in the full report (Larson et al. 2019b).

RICAFE Maros

Data was collected during Step 1 – Issue identification – from 69% of potential total respondents (31 of 45 researchers participated in the survey), with roughly equal gender distribution. The resulting trends and findings can be summarised as:

- In terms of positions in the organisation, responsibilities on projects, promotions, access to training and grants, males and females are relatively equal.
- Females appear to have comparably more access to scholarships, both national and international, than their male peers.
- Male respondents seem to be distributed at higher career levels (majority at career levels 3-4), whereas females are at lower levels (majority at career levels 1-2); however, more males have a PhD level and more females are at a Bachelor level.
- Males appear to be more published than females, in both national and international journals.
- Levels of motivation to perform well at work were very high, as well as reported satisfaction with life overall. Respondents were also very satisfied with their salaries, career progress and current position. At the other end, lowest satisfaction reported was with the grants received, followed by international publication records and access to international scholarships.
- As a general trend, females demonstrate higher self-satisfaction than their male peers with all factors other than career progression.
- Males reported significantly lower life satisfaction score before starting current work, compared to females.
- Respondents felt their career progression was about the same and slightly better (salary in particular), than the careers of their former university colleagues. No significant differences or prevalent trends were detected in terms of comparison to former university colleagues dependent on respondents' gender.
- The main career goals were reported as advancement in position or education (14 respondents), earning money to support family (13), and service to and development of the country and community (10). The majority (77%) also indicated they entered the career because it is the career that they specifically wanted.
- Most of the questions about equality were answered by all respondents. Overwhelmingly, perceptions were that there is no discrimination of any sort, either in terms of gender or in terms of other personal characteristics such as ethnicity, religion, background or other, nether in the institute nor in the community at large. Overall, 84% of respondents denied that patronage plays any role in the progression of a research career.

A number of recommendations were formulated during focus group discussions conducted as a part of Step 2 – Finding Solutions – and these have been listed in the full report (Larson et al. 2019b) and in the report Summary (Larson et al. 2019a). The recommendations were also presented to the Secretary of AMFRHR and staff of the International Cooperation Division staff of AMFRHR at a meeting with ACIAR and the project team on 17 October 2019. The recommendations are also listed in Section 9.2.4 of this report.

IMRAFE Gondol

Data was collected during Step 1 – Issue identification – from 70% of the potential total survey respondents (28 of 40 researchers participated in the survey). The trends identified during data analysis can be summarised as follows:

- Female to male respondent distribution is relatively equal in terms of education and career levels.
- Males seem to have a higher chance of receiving promotions; permission to delegate to other staff; to be responsible for projects; and to have access to administrative and management training.
- Females appear to have higher access to scholarships and seminars.
- Respondents were very satisfied with their life overall, as well as their career progression; motivation; salary; position; conference publication records and publication credits.
- Female satisfaction with several aspects explored was lower than male, including satisfaction with the job now and with the access to technical training.
- Females are significantly less satisfied (at 5% level) with the amount of responsibility they have at work; the promotions in the last 3 years; and the job when they started the work; and (at the 10% level) with the access to national scholarships and access to administrative training.
- The largest difference in median scores can be noted for access to administrative training, with the female median of 5.00 compared to the male median score of 8.00.
- Both cohorts rated their satisfaction with the International journal publication record, National and International scholarships access, low.
- Female respondents gave higher ratings than males in several categories when comparing their career progression against that of their university colleagues. However, females were less satisfied than males when comparing their access to administrative training to that of their university colleagues.
- Scholarships and access to research opportunities and serving community were the most common career goals for both females and males. Only three respondents indicated money as their career goal.
- All respondents reported positive perceptions of gender equality both inside and outside of the workplace, and no difference in treatment of staff based on other characteristics (ethnic, background, etc.)
- Comments regarding patronage were made by two male respondents, however neither indicated direct perceptions of patronage occurring in their workplace.

When comparing across the objective indicators, to self-referent and other-referent subjective indicators, it can be noted that the following aspects score consistently lower for females than males, i.e. the objective data for females is lower to that for males; as well as is satisfaction with self and ones position compared to others:

- access to administrative and management training;
- responsibilities given at work (in terms of staff supervision/delegation and project leadership);
- likelihood of promotion.

It could be argued that later two aspects (responsibilities and promotions) stem from limited access to administrative and management training and thus it is recommended that access of females scientists to administrative and management training be improved.

8 Impacts

8.1 Scientific impacts – now and in 5 years

8.1.1 Rabbitfish larval rearing

Trials to assess zooplankton dynamics in larval rearing ponds have been completed at the RICAFE research station at Barru, South Sulawesi. These results, together with the data from earlier trials, have provided information on phytoplankton and zooplankton populations and succession patterns in the ponds. This in turn informs the development of extensive larval rearing approaches using these ponds.

Additional observations of the gut contents of rabbitfish (*S. guttatus*) larvae in brackishwater ponds and in large concrete tanks have provided data on the early larval diet. The results indicated that the larvae initially (2–3 DAH) consume diatoms but quickly shift to a diet dominated by zooplankton (from 4 DAH).

A Masters degree student will continue this research on the feed requirements for early stage rabbitfish larvae, in collaboration with RICAFE Maros researchers.

The experimental finding that survival of yolk-sac and newly-hatched *S. guttatus* larvae is highest at around 20 ppt, and lower at both lower (10 ppt) and higher (35 ppt) salinities is valuable in developing larval rearing methodologies for this species. Marine finfish hatcheries generally use salinities around full seawater (35 ppt) for larval rearing, and in the case of *S. guttatus* this may be a contributing factor to low survival of larvae in the hatchery.

8.1.2 Asian seabass larval rearing

An experiment at MARDeC demonstrated that larval rearing tank colour had no significant effect on survival of larval Asian seabass, a small effect on growth rate, and a substantial effect on the proportion of morphological deformities. This knowledge will contribute to optimising larval rearing protocols at MARDeC, and producing better quality fingerlings.

Research at both IMRAFE Gondol and at MARDeC compared the effects of sterilising (using chlorine) larval rearing tank water in an effort to reduce bacterial loads, and the potential disease impacts of *Vibrio* bacteria. Both experiments demonstrated negligible impacts on larval growth and survival associated with the treatments used.

8.1.3 Cambodian aquafeed ingredients

Proximate analysis of a range of feed ingredients available in Cambodia has built a database of ingredient composition that can be used to develop aquafeeds for local use. Local Asian seabass farmers have approached MARDeC to advise on the use of farm-made feeds using local ingredients.

8.1.4 Rabbitfish nutrition

Collaborative research between RICAFE Maros and IPB evaluated the optimal level of protein in compounded feed for rabbitfish *S. guttatus* using levels of expression of IGF-1 mRNA in the intestine and liver. The incorporation of biochemical and molecular techniques is a new and innovative approach to fish nutrition research at RICAFE Maros.

The research being undertaken to define the nutritional requirements of rabbitfish is contributing to our knowledge of the dietary requirements of rabbitfish for aquaculture, and thus to the development of compounded feeds for omnivorous species. At RICAFE Maros a 20-week feed trial evaluated different dietary lipid sources for rabbitfish diets. Fish fed the diets containing fish oil (control) and palm oil had a significantly higher weight gain and

SGR than those fed the diets containing soybean oil and coconut oil, indicating that palm oil may be a substitute for fish oil in rabbitfish feeds.

Because there are no herbivorous fish diets available in Australia, experiments with *Siganus fuscescens* in Australia of necessity used a commercial fish feed designed for use with native Australian (carnivorous) species. Rabbitfish fed this feed developed lateral line disease which was ascribed to deficiencies in vitamins C and E in the diet. Soon after (days to a week) additional vitamin C and E were added into the diet, the affected fish recovered. This result suggests a higher requirement for vitamins C and E in rabbitfish than is seen in other fish species.

Grow-out trials with rabbitfish *S. guttatus* in sea cages in Maros District, South Sulawesi, showed poorer growth when fed a low-protein (21–23% CP) commercial feed, compared with higher protein (26–28% CP) feed. This result informs the optimal nutritional requirements for *S. guttatus*.

8.1.5 Inclusion of seaweed in finfish diets

The linked postgraduate research in Australia was the first to investigate multiple seaweed species in the diet of fish and what effect these could have on the productivity and immune responses of the fed fish.

The whole-life-cycle approach to testing the effects of seaweed, and more specifically, of the red seaweed *Asparagopsis taxiformis*, on the opportunistic omnivorous rabbitfish *S. fuscescens* was also a first and produced key results in regard to the use of seaweeds as functional ingredients for this fish species.

Additionally, testing the *A. taxiformis* diet in the carnivorous Atlantic salmon *Salmo salar* was also novel and revealed that the positive effects of this seaweed species were consistent across the two fish species investigated in this postgraduate work.

8.1.6 Analysis methodology improvements

Improved method to concentrate seaweed bioactive compounds

Initially whole seaweed (dried and powdered) was used as functional feed supplement in the diet of the mottled rabbitfish *S. fuscescens*, To further increase the immunostimulatory effect of the seaweed while reducing the dietary inclusion rate a concentrated extract had to be produced. Initially this was done using exhaustive methanol extraction of freeze dried seaweed biomass followed by an evaporative step to rid the seaweed extract of the methanol which is lethal to fish. However, because of the extended amount of time required to evaporate even a small volume of methanol containing seaweed extract (~2h for 50ml) this method did not prove feasible to produce larger quantities of seaweed extract. For this reason the evaporative step was changed to include a rotary vacuum in which the extract-rich methanol was evaporated under vacuum in a *bain-marie* at 30°C in a round bottom flask rotating at 30 rpm. The use of the rotary vacuum allowed for the processing of 2L of methanol-rich extract to be processed in less than 2h.

Adapted methodology for immunoassays

The lysozyme and the ACH50 assays are two serum based immunoassays using respectively gram positive bacteria and red blood cells as substrate of lysis. In order to find the serum activity for both of these innate immune indexes one requires to know a range of volume where that activity would be measurable. Since this work has not previously been done on rabbitfish S*. fuscescens*, a working range of dilutions had to be established for both immunoassays with 10μl of serum for 140μl of bacteria substrate for lysozyme. For ACH50 the serum concentration (serial dilution) was 10% to 0.15% for the fish with normal/low ACH50 which it was lower, 5% to 0.019% for fish with higher ACH50 activity.

8.1.7 Academic manuscript for official 'release' of rabbitfish *Siganus guttatus*

Supported by FIS/2016/130, RICAFE Maros is preparing an academic manuscript for the official 'release' of *S. guttatus* as an aquaculture commodity in Indonesia. This study covers a wide range of topics of relevance to the larval rearing, nursery and grow-out of this species. A summary of the studies and a complete list of topics are appended (Appendix 2). *S. guttatus* will be the first commodity to undergo this official process by RICAFE Maros.

8.1.8 Cambodian mariculture value chain analysis

A study of Asian seabass sea cage farming in Cambodia showed that women and men were represented equally in several value chain nodes, namely: farmers, farm materials suppliers, and traders with special orders. Middle-aged men predominated as wholesalers and fingerlings traders, while women were predominant as 'trash' fish traders and local market traders of farmed fish. Only men, of all ages, were reported as fishers for the 'trash' fish supply. Youths of both sexes were present in feed (fishing or trading) nodes, and several of the local market traders were young females. This was the first scientific study of women and youth participation in Cambodian finfish mariculture value chain.

The study found that most farms were effectively family-owned, in contrast to literature reports that mariculture farmers are predominantly male. Although an earlier study found that all marine finfish production was marketed locally (in the southern coastal provinces) we found that some farms sold fish to wholesalers in Phnom Penh and other districts, suggesting that the marine finfish value chain is maturing and integrating into a national-level value chain.

Results of this study have been summarised and provided to FiA to inform aquaculture policy development in Cambodia. Part of the results have already been published in the scientific journal *Aquaculture* (Larson et al. 2022) and another paper is in preparation for submission to *Marine Policy* journal.

8.1.9 South-south triangular cooperation

The evaluation of SSTC undertaken for this project is the first such study focusing on the application of SSTC in R4D projects.

The SSTC approach is enthusiastically endorsed by FiA and, at the request of FiA, is being employed by the EU-funded CapFish (Cambodia Programme for Sustainable and Inclusive Growth in the Fisheries Sector) project to seek technical input from Indonesia on specific R&D topics where Indonesia has recognised expertise, e.g. freshwater fish hatchery technology and culture methods.

8.2 Capacity impacts – now and in 5 years

Note that a more detailed evaluation of capacity impacts has been provided by the linked SRA FIS/2018/115 *Evaluating processes and outcomes in south-south research collaboration – finfish mariculture development in Cambodia through cooperation with Indonesia*.

Training of FiA researchers in Indonesia has necessitated using English as a common language, giving both trainers and trainees enhanced opportunities to use and practise English.

8.2.1 Cambodia – training

Cohort 1 (2018–19)

A formal evaluation of the training undertaken in 2018–2019 was undertaken at MARDeC, Sihanoukville, in November 2019 through the linked SRA FIS/2018/115. Summaries of the Intended Learning Outcomes for both the Larval Rearing and Fish Nutrition training are included in Section 5.1 of this report.

Overall the 2019 training was successful, with both Fish Nutrition and Larval Rearing teams meeting their respective ILOs and consequently ‘graduating’. A detailed evaluation of the training and its impacts has been provided separately to ACIAR by SRA FIS/2018/115.

Exposure to laboratory protocols and procedures has improved the FiA researchers’ knowledge of laboratory practices.

Regular (usually daily) reporting of training activities, and feedback from Indonesian and Australian project staff on these reports, has strengthened the FiA researchers’ reporting abilities. Similarly, involvement of the FiA researchers in developing publications has strengthened their analytical and writing abilities.

Cohort 2 (2020–21)

A second formal evaluation of the Cohort 1 (2018–19) and of Cohort 2 (2020–21) training was undertaken in June 2021, and a follow-up evaluation undertaken in October 2021. This has been reported separately by the linked SRA FIS/2018/115.

Notably, for the 2020–21 (Cohort 2) training, laboratory facilities at the Royal University of Agriculture (RUA) were used for training in proximate analysis because the trainees could not travel to Indonesia. This benefitted the project by increasing the self-sufficiency of the trainees and benefitted FiA by developing collegiate linkages between RUA and FiA.

Cohort 1 trainees have been utilised as mentors for Cohort 2, a role that they reportedly enjoy and which is appreciated by Cohort 2 trainees.

Regular reporting of training activities, and feedback from Indonesian and Australian project staff on these reports, has strengthened the FiA researchers’ reporting abilities.

Reporting of experimental results has strengthened the FiA researchers’ knowledge of scientific writing, including graphing data and undertaking statistical analyses of data.

Involvement of the FiA researchers in developing publications has strengthened their analytical and writing abilities.

FiA Value Chain Analysis training

Nine FiA DAD and two FiA Cantonment staff were trained in Value Chain Analysis Methods in Phnom Penh on 19–20 October 2019. Both FiA Cantonment and several FiA DAD staff participated in the subsequent field work to gather data for the value chain analysis of Asian seabass aquaculture in Cambodia.

Sreynov Hoy has been contracted by FAO to undertake a value chain analysis of freshwater aquaculture, utilising her expertise developed through the ACIAR project.

8.2.2 Cambodia – implementation

Further evidence of the success of the training program is the effective implementation of the training in Cambodia. The FiA Nutrition Team has carried out several experiments on different feeds (‘trash’ fish, commercial pellets, locally-made pellets) for Asian seabass culture.

The FiA Larval Rearing team has completed three experiments to test methods to improve the growth and survival of Asian seabass larvae in the MARDeC hatchery.

Senior FiA staff have noted that the Cambodian trainees are demonstrating greater teamwork, which they attribute to exposure to working amongst Indonesian research teams.

8.2.3 Research facilities at MARDeC

A small experimental facility has been established to run replicated trials to evaluate various management regimes for larval rearing of marine finfish. The facility comprises 12 tanks on a recirculation system to ensure similar water quality in all replicate tanks. At the Larval Rearing Research workshop held by Dr Stewart Fielder (NSW DPI) in October 2019, this facility was reviewed and Dr Fielder proposed some improvements, notably in regard to biosecurity. The larval rearing facility has been used to run three experiments to improve the growth and survival of hatchery-reared Asian seabass / barramundi (*Lates calcarifer*) at MARDeC:

- Effect of different salinities on growth and survival of larval Asian seabass;
- Effect of different tank colours on growth, survival and morphological deformities of Asian seabass.
- Effect of sterilisation (with chlorine) of seawater used for larval rearing.

A small (research-scale) feed laboratory has been established at MARDeC to produce small quantities of feeds to customised formulations. This facility was utilised for a feed workshop run by Dr Igor Pirozzi (NSW DPI) in October 2019. The facility is also being used to develop feeds utilising local ingredients for trials with Asian seabass.

Some additional equipment (e.g. an autoclave) has been purchased to facilitate the experimental work at MARDeC.

8.2.4 Indonesia – rabbitfish

The research into identification of nutrient requirements of rabbitfish provides a knowledge base to formulate appropriate diets for this species, potentially improving grow-out performance and FCRs.

The project provided a new microscope to RICAFE Maros, which was handed over by Dr Ann Fleming in October 2019. The microscope will be used to support project research, including the assessment of rabbitfish larvae sampled from larval rearing trials.

At RICAFE Maros, a number of staff and students undertaking undergraduate or post-graduate study have been directly involved in research activities (Table 4). This has contributed to capacity-building within RICAFE Maros.

Table 4 RICAFE Maros staff undertaking undergraduate or post-graduate studies who have been involved in FIS/2016/130 research activities.

Name	University	Program – Aspect	Year
Sri Redjeki HM (RICAFE staff)	Hasanuddin University, Makassar	Doctor – Bioprocessing of *Gracilaria* as a feed ingredient for rabbitfish (Nutrition)	2020–2023 Preparing seminar; waiting for accepted publication

Name	University	Program – Aspect	Year
Kamaruddin (RICAFE staff)	Hasanuddin University, Makassar	Doctor – Bioprocessing of *Sargassum* as a feed ingredient for rabbitfish (Nutrition)	2020–2023 Writing dissertation
Bunga Rante Tampangallo (RICAFE staff)	Hasanuddin University, Makassar	Doctor – Sinbiotic microcapsules as an additive in feed for rabbitfish juvenile – Pathology	2020–2023 Writing dissertation
Darsiani	IPB University, Bogor	Doctor – Enriched live feed for indoor larval rearing	2020–2023 Preparing the seminar; waiting for accepted publication
Haira Ainun Sulaeman	Hasanuddin University, Makassar	Masters – Evaluation of sea lettuce *Ulva lactuca* as fresh feed at different combination with pellet diet for juvenile of golden rabbitfish	2021-2022 Graduated
Unggul Adhi Utama	Hasanuddin University, Makassar	Masters – Kinds of live feed for indoor larval rearing	2020–2021 Graduated
Putri Meira Shyiang Sri	Hasanuddin University, Makassar	Masters – Morphological and molecular identification of parasites infected cultured rabbitfish at different culture system	2021–2022 Graduated
Alief	IPB University, Bogor	Undergraduate – histopathology	2020 – Graduated
St Mulkia	University of West Sulawesi, Majene	Undergraduate - salinity tolerance	2021 – Graduated
Hasra	University of West Sulawesi, Majene	Undergraduate – nutrition	2021 – Graduated
Guyanti	University of West Sulawesi, Majene	Undergraduate – nutrition	2021–2022 Graduated

In addition, a number of school and university students have participated in project research activities at RICAFE Maros – see Appendix 3 for details.

8.3 Community impacts – now and in 5 years

Cambodia

The gendered value chain study of Asian seabass mariculture in Cambodia found that support services, in particular related to technical training, emerged as the barrier perceived by the highest percentage of respondents, both male and female. The shortcoming related to training was perceived both in terms of lack of training available; and in terms of lack of time to attend training when organised. In relation to productive assets, inputs and resources, difficulties were reported regarding 'trash' fish, which was reportedly increasingly difficult to buy, with rising prices; poor water quality (turbidity and water pollution) and poor site/location of the farm; and limited availability of fingerlings, which were mainly imported from Thailand or Vietnam, with a long transport time which sometimes resulted in poor quality and high mortality.

We note that activities in this ACIAR project are increasing the capacity of the MARDeC staff in what are perceived by value chain respondents as highly relevant areas, such as fingerling production and handling, disease management, and alternative feed sources. However, this study also identifies industry demand for expanded extension services, including technical information and training, that would need to be provided by MARDeC.

Indonesia

RICAFE Maros has entered into a collaboration with a local commercial hatchery in Barru district. RICAFE Maros is providing newly-hatched rabbitfish larvae as well as technical advice for commercialisation trials.

A rabbitfish grow-out trial undertaken in collaboration with Maros District Fisheries Service (Dinas Kelautan dan Perikanan Kabupaten Maros) to evaluate growth and survival of rabbitfish (*S. guttatus*) in net cages in the Maros River evoked interest in rabbitfish aquaculture by the local government. Consequently, RICAFE Maros was visited by the Bupati (Regent) of Maros District and his staff who expressed support for the development of rabbitfish aquaculture in Maros. This was followed by a visit by the Head of the Maros District Fisheries Service and staff to discuss technical aspects of promoting rabbitfish aquaculture.

The provision of juvenile rabbitfish (*S. guttatus*) to a farmer group at Barru, South Sulawesi stimulated interest in culturing that species. The farmer group feel that rabbitfish is more profitable than milkfish (*Chanos chanos*) which is their main commodity, and are keen to obtain more rabbitfish fingerlings.

8.3.1 Economic impacts

Development of improved larval rearing protocols for Asian seabass at MARDeC will contribute higher survival and better fingerling quality, which will improve the cost-efficiency of hatchery operations. The value chain analysis of Asian seabass mariculture in Cambodia identified that the supply of fingerlings is a significant constraint to the efficiency of this industry. Cambodian farmers would much prefer to buy locally-produced fingerlings rather than fingerlings imported from neighbouring countries, due to the lower survival rates of imported fingerlings. It is expected that production of better quality fingerlings from MARDeC will improve the economic basis of Asian seabass farming in Cambodia.

Knowledge of the price, availability and composition of aquafeed ingredients in Cambodia can provide flexibility in diet formulation. This can then have a flow-on effect to economic impacts if a 'least cost' approach to formulation is adopted.

Evaluation of the rabbitfish grow-out trials currently underway in South Sulawesi will provide baseline information on the profitability of farming rabbitfish, and the economic viability of using compounded pellet diets configured for this species.

Development of seaweed dietary supplements for farmed fish to increase their productivity and reduce their FCRs and susceptibility to disease could contribute to substantial economic benefits. Faster-growing fish provide farmers with the opportunity to have shorter production cycles to minimise risks of issues (e.g. disease) during this growth period or to have larger animals to harvest at the end of a standard production cycle, which could translate to an increase in revenue for farmers.

8.3.2 Social impacts

Exposure to training in another country has increased the cultural awareness of the Cohort 1 trainees.

The ability of FiA staff to undertake research to improve larval rearing methodologies is expected to increase the availability of Asian seabass fingerlings which will support more efficient production by Cambodian Asian seabass farmers, and allow expansion of finfish mariculture. This will contribute to improved social and economic outcomes for coastal communities in Cambodia.

The project's gendered value chain study of Asian seabass mariculture in Cambodia found that women and men are involved in somewhat different activities, both at the farm level and in the value chain overall. In terms of the main areas of work on the farm, such as buying of the feed ('trash' fish), preparing the ' trash' fish, feeding, cleaning cages and selling of the fish (catching and transport of the fish; weighing and pricing) both men and women are involved. Some of the activities, such as cleaning of the cages or catching the fish for sale, are seen as predominantly male work; while others, including negotiations with the buyer, weighing of the fish, and money keeping, are predominantly in the female domain. The study found no indication of systematic discrimination against females in this value chain: they are both visible and not confined to lower status or lower-paid jobs.

Rabbitfish is a high-value marine species in demand in South Sulawesi. Development of cost-effective fingerling production methods, and commercial grow-out of rabbitfish, will provide income to sea cage and pond farmers in South Sulawesi.

Project team members from USC, RICAFE Maros and IMRAFE Gondol, Dr Ann Fleming (ACIAR Fisheries RPM) and Mrs Mirah Nuryati (ACIAR Country Manager, Indonesia) met with Dr Maman Hermawan (Secretary of AMFRHR), Mr Andi Soesmono, Mr Agung Purnomo and staff of AMFRHR in Jakarta on 17 October 2019 to formally present the results of the 'Career progression opportunities for research staff of partner institutes in Indonesia' study. Draft copies of the full report and the summary document were provided prior to the meeting. AMFRHR accepted the results, and noted the various recommendations arising from the study. AMFRHR requested some changes to the format of the recommendations to identify those that should be implemented by AMFRHR and those that should be implemented by the MMAF Secretariat.

8.3.3 Environmental impacts

The breeding of the rabbitfish S. *fuscescens* using adapted standard marine fish larval rearing protocols could further help the development of this novel aquaculture candidate. This low-trophic-level fish can be expected to have lower environmental impact than its carnivorous counterparts due to its ability to more effectively digest plant (including seaweed) -based diets.

The improved productivity and lower FCRs observed in farmed fish fed diets containing seaweed functional ingredients could further reduce the demand for wild-sourced ingredients or ingredients that could be directly used for human consumption.

The immune improvements observed in both rabbitfish (*S. fuscescens*) and Atlantic salmon (*S. salar*) fed diets containing the seaweed *A. taxiformis* (Thépot et al. 2021a; Thépot et al. 2022) may translate to improved pathogen resistance which would lead to a reduction in the need for chemotherapeutic treatments in aquaculture.

8.4 Communication and dissemination activities

A range of communication strategies were employed to share knowledge and provide feedback between the Cambodian (beneficiary partner) trainees, the Indonesian (pivotal partner) trainers, and the Australian (facilitating partner) mentors. During 2018–19 these were largely in-person activities undertaken during project visits to the participating institutions. During 2020–21 most communication activities were undertaken online because of COVID-19 pandemic travel restrictions.

8.4.1 Training activities

During their work-integrated learning training, the Cohort 1 trainees provided short daily reports of their activities and learnings. This provided the rest of the project team with an overview of the training activities being undertaken in Indonesia. It also provided material that could subsequently be reviewed by the trainees for reinforcement of learnings.

8.4.2 Research activities

Research activities undertaken at MARDeC were reported regularly. In general, the research teams provided a research plan which was critiqued by the Indonesia (pivotal partner) trainers and by the Australian (facilitating partner) staff. Once the research plan was agreed, and the research activity begun, the research teams reported intermediate results usually weekly. This enabled additional teaching to be done, such as graphing data to identify outliers or data entry errors.

Once the research activity had been completed, the FiA research teams provided a full report on the research objectives, methodology, results, and interpretation. Again, this report was critiqued by the Indonesia (pivotal partner) trainers and by the Australian (facilitating partner) staff.

The FiA research team also presented their results using PowerPoint, either at the 2019 Training Evaluation Meeting (Cohort 1) or during online meetings (Cohort 2) for formal evaluation of the outcome of their training.

8.4.3 Project meetings and symposia

Wherever possible additional training in scientific approaches and methodology was provided to FiA trainees in association with project meetings or project visits.

Project Inception Meeting, MARDeC, Sihanoukville, Cambodia, 21–23 August 2018. Attended by representatives of all the participating laboratories, including Indonesia (RICAFE Maros and IMRAFE Gondol), Australia (USC and NSW DPI) as well as FiA Aquaculture staff. The meeting comprised three days: one day for discussing the project structure and its expected outputs, outcomes and impacts. Two days were dedicated to workshops on mariculture larval rearing research and nutrition research which were compiled and presented by (larval rearing research workshop) Dr Mike Rimmer (USC) and Dr Stewart Fielder (NSW DPI) and (fish nutrition workshop) presented by Mr Steven Gamble (JCU / NSW DPI) based on material compiled by Dr Igor Pirozzi (JCU / NSW DPI).

2019 Annual Project Meeting, IMRAFE Gondol, Bali, Indonesia, 19–20 June 2019. Attended by representatives of all the participating institutions, including Indonesia (IMRAFE Gondol and RICAFE Maros), Cambodia (FiA), Australia (USC and NSW DPI) and ACIAR (Prof. Ann Fleming, Fisheries Research Program Manager). The first day reviewed project progress and outcomes to date, and discussed future activities. The second day comprised presentations from IMRAFE Gondol, RICAFE Maros and NSW DPI on current research, with an emphasis on new and innovative research practices.

2019 Training Evaluation Meeting, MARDeC, 4–7 November 2019. Attended by representatives of the commissioned agency for FIS/2016/130 USC, and the participating

Indonesian institutes RICAFE Maros and IMRAFE Gondol, as well as representatives of the commissioned agency for FIS/2018/115 UTAS. This meeting comprised a formal evaluation of the 2019 training program in Fish Nutrition Research and Larval Rearing Research, to provide a formal 'graduation' of the Cohort 1 trainees.

Final Project Meeting, online, 27 January 2022. A final project meeting was held online to report project outcomes, in particular the learnings by the FiA Nutrition and Larval Rearing Teams, and their planned application of the new skills and knowledge. The results of the evaluation of SSTC, based on a case-study evaluation of FIS/2016/130, were also presented at this meeting.

Mentoring by Pivotal and Facilitating Partner participants

RICAFE Maros staff (Prof. Rachman Syah and Dr Asda Laining) visited Cambodia on 21–26 January 2019, to:

- Provide mentoring of on-going activities by the DAD-MARDeC team relating to the survey of Asian seabass / barramundi aquaculture in Cambodia and the potential for using local ingredients in fish feeds – a follow-up to the training on fish nutrition held in RICAFE Maros in July 2018.
- Discuss follow-up research activities, in particular the second phase of fish nutrition training in RICAFE and the proposed feeding trial to be undertaken by the DAD-MARDeC Nutrition Team in Cambodia.

Prof. Rachman Syah and Dr Laining also gave presentations to a general audience in Phnom Penh, on aquafeed development and the use of local feed ingredients in feed formulations in Indonesia, and on waste impacts from milkfish cage culture in Indonesia at MARDeC and at FiA DAD offices in Phnom Penh.

Scientific workshops on Larval Rearing and Grow-out Nutrition research were provided by Dr Stewart Fielder and Dr Igor Pirozzi, 22–24 October 2019, plus informal mentoring of FiA Larval Rearing and Nutrition Teams.

Technical presentations by Dr Mike Rimmer, 4–5 March 2020: Barramundi biology; Barramundi aquaculture; Barramundi feeds and feeding; Marine finfish larval nutrition.

Online scientific symposium

The project had originally planned for training of both Indonesia and Cambodian researchers in fish nutrition and in biosecurity and more intensive larval rearing techniques at Port Stephens Fisheries Institute in Australia. Because travel to Australia was not possible during the latter part of the project, the project team substituted an online symposium to provide project participants with new and innovative approaches to marine finfish aquaculture research. The online symposium had the theme: 'Using Research to Solve Problems to Support Aquaculture Industry Development' to support the broader project objective of developing research approaches and outcomes to promote mariculture development in Cambodia.

The symposium was held over 4 days from 12 to 15 July 2021 and comprised a range of scientific presentations related to marine finfish nutrition and feed development, and larval rearing of marine finfish. There were also presentations on research methods to solve technical problems, and on publishing results in international scientific journals. There were between 34 and 57 symposium participants each day. The structure and content of the symposium, and details of participation, have been reported separately.

Online communication

Following the outbreak of the COVID-19 pandemic, communication was entirely online. Both Cambodian (beneficiary partner) trainees and Indonesian (pivotal partner) trainers differentiated between different communication tools. While both WhatsApp and email were used, email was perceived as more official and formal, and required a more considered – and hence often delayed – response. In contrast, responses to questions sent using WhatsApp were rapid and frequently immediate.

9 Conclusions and recommendations

The following section is based on the outcomes of both FIS/2016/130 and the linked SRA FIS/2018/115. For background on the latter, please refer to the FIS/2018/115 Final Report.

9.1 Conclusions

The training program is viewed by all participating agencies as having had positive outcomes:

- It has provided increased technical knowledge in the relevant domains (larval rearing, fish nutrition, disease diagnostics).
- The South-South element of the project has created strong personal and professional linkages between Indonesian and Cambodian researchers.
- There is evidence of increased teamwork and coordination, both within MARDeC and between MARDeC and FiA DAD in Phnom Penh.
- There is evidence of increased leadership skills, particularly amongst those FiA staff nominated as mentors.
- MARDeC is increasingly seen (by FiA, external funding bodies and industry) as a valuable resource supporting aquaculture industry development in Cambodia.
- Enhanced capacity is contributing to broader aquaculture development in Cambodia.
- There is ongoing transfer of knowledge and skills from trainees to other MARDeC and FiA DAD staff.

There is evidence of increasing industry engagement:

- Asian seabass farmers are increasingly seeking technical support from MARDeC staff.
- Farmers have requested support from MARDeC staff in making on-farm feeds to partially replace 'trash' fish feed for Asian seabass farming.
- The project is addressing some key industry development issues, but these need to be expanded.

The pedagogic structure developed through SRA FIS/2018/115 has been valuable:

- Demonstrated the value of pedagogically structured training to build scientific research skills and capabilities.
- Demonstrated the value of inclusive collaboration to define the training focus, training approach and desired outcomes.
- Informed by MARDeC needs curricula developed in collaboration with the two best aligned Indonesian institutes provided clear intended learning outcomes (ILOs), allowing for objective evaluation of training successes.
- The incorporation of practical and personal skills development with technical and discipline-based skills in the pedagogic design (particularly ILOs) has strengthened teamwork, confidence, and self as a scientist.
- The pedagogic structure used by the trainers transferred readily to online delivery and kept all participants focussed and on task.
- Capacity building for Indonesian researchers in design and delivery of training has equipped them to meet similar demands at their research institutes.

- Online training materials such as PowerPoint presentations and video demonstrations have provided a repository of training resources for both Cambodian and Indonesian participants.
- Online delivery is less effective than work-integrated learning (WIL), but provides useful complementary and follow-up learning resources after WIL (or placements) have been undertaken and or completed.
- Learnings from the adoption of pedagogic structure and WIL provide a platform for future capacity building initiatives in ACIAR, Indonesia and Cambodia.

The gains made are fragile:

- FIS/2016/130 was designed primarily to test the SSTC model as a modality for R4D capacity-building. As outlined above, it has ably demonstrated that SSTC works effectively and provides positive outcomes to all participating countries.
- Given that FIS/2016/130 was fundamentally a 'proof-of-concept' project, the increased capacity built within FiA requires additional support if it is to become embedded in that agency. Specifically, additional training and development is required in:
    - Leadership skills development – focusing on emerging leaders and younger early career researchers and technicians.
    - Continued technical training (fish nutrition, larval rearing, fish disease) to improve the operations of MARDeC and strengthen its role as the primary provider of mariculture technical support services in Cambodia.
    - Development of effective extension and technical support services to provide support along the Cambodian mariculture value chain.
    - Continued capacity building for Indonesian researchers in design & delivery of research training.

9.2 Recommendations

9.2.1 Short-term recommendations to ACIAR

As noted above, the project has demonstrated successful outcomes both in the area of original research to support aquaculture development in Cambodia, Indonesia and Australia, and particularly in strengthening the capability of FiA to support sustainable marine finfish aquaculture in Cambodia. However, the limited nature of the project, and the severe disruptions caused by the COVID-19 pandemic have limited the project outcomes, and there is a need to continue to support the project's activities into the future. Specifically:

1. Facilitate continued remote support by the Indonesian trainers for follow-up research activities in Cambodia while international travel is still restricted. As noted in the 2021 Annual Report for FIS/2016/130, these research activities have commenced, but have been delayed and some aspects restricted by COVID-19 pandemic impacts.
2. Ensure continued curricula and scientific support for Indonesian trainers for the follow up research activities in Cambodia. In the short term this would be provided by the current project team, but with a succession plan in place to transition this support.
3. Develop succession plans to replace the current project leaders / managers for FIS/2016/130 and FIS/2018/115 and integrate potential new project leaders from Australia by involving them (remotely) in research activities. In line with this, offer an online SSTC Emerging Leaders Workshop to build relationships across potential new leaders from Indonesia, Cambodia and Australia.

4. At a later date, review institutional arrangements for a follow-on project, including:
    4.1. Explore opportunities to more closely link a follow-on project with the broader ACIAR initiative to develop more effective fish feeds in Southeast Asia.
    4.2. Identify potential partner agencies to provide training and mentoring in extension and technical support services in Cambodia.
5. Develop a follow-on project through the ACIAR project development pathway, linking closely to the proposed SSTC Emerging Leaders Workshop.

9.2.2 Medium- and long-term R4D recommendations

Continue to build research capacity amongst FiA DAD staff

FIS/2016/130 successfully increased capacity of FiA DAD staff. However, impacts of the project were limited by two factors: (i) that the project was a 'proof-of-concept' project focussing on the potential for applying SSTC approaches in R4D projects, and (ii) training activities were disrupted by the COVID-19 pandemic which resulted in travel restrictions and supply chain disruptions. Additional capacity-building is essential to support FiA's vision of a sustainable mariculture industry that contributes social and economic benefits to coastal communities.

Provide improved technical support services for mariculture

The value chain analysis of marine finfish aquaculture in Cambodia identified the availability of technical support services (extension and training, and fish health management) as significant barriers to the development of this sub-sector. Training in provision of these services was not covered in FIS/2016/130 but there is a clear need for such services, and appropriate training and follow-up activities should be included in future projects.

Educate value chain participants about the institutional arrangements for mariculture

The value chain analysis noted that a large proportion of people involved in finfish mariculture in Cambodia appeared to have no clear understanding of what the institutional requirements related to access to resources (e.g. land, water) or services (i.e. licenses, certificates). Provision of extension material and training of value chain participants is required to improve the understanding of institutional requirements for mariculture.

Improve farmer understanding of consumer requirements

The Cambodian finfish mariculture value chain analysis found that about a quarter (27%) of farmers had no understanding of consumer preferences and value adding opportunities. This finding indicates a need and a potential for better integration of the existing mariculture value chain, further moving from a 'supply chain' – where actors supply goods and services to their customers with little knowledge or interest in what goes on in the chain beyond their immediate suppliers and customers – to a true 'value chain', where the focus is not on what can be supplied but rather on what is valued by consumers and how this can be more efficiently delivered.

Support further engagement of females and youths in the value chain

The project's value chain study indicated that both women and youth are present along the finfish mariculture value chain in Cambodia, and in some instances are dominant. Any proposed interventions in the Cambodian marine finfish value chain should take into consideration our findings and include specific responses to support, or improve, inclusiveness. For example, several female respondents in this study had ideas for value adding in the finfish mariculture value chain, most frequently through engagement in fish trade/retail.

9.2.3 Recommendations for finfish mariculture value chain development in Cambodia

1. Emerging priorities for FiA:
    1.1. Improved availability of fingerlings locally from MARDeC, of good quality and exhibiting low post-stocking mortality; and information in relation to handling of fingerlings.
    1.2. Improved availability of compounded feeds, because 'trash' fish is seen as increasingly expensive and difficult to source.
    1.3. Improved access by farmers to technical information, including:
        - transport, handling and stocking of fingerlings in sea cages;
        - farm siting and water quality;
        - fish health management and disease diagnosis;
        - use of compounded (commercial pellet or farm-made) feed.
    1.4. Provision of training to farmers in the topics listed above, particularly training that is organized in ways that would facilitate farmer participation and training that encourages female participation.
    1.5. Better integration of the existing mariculture value chain, including improved understanding of consumer preferences and value-adding opportunities.
2. Emerging priorities for wider government, private sector and donor institutions:
    2.1. Availability of financial mechanisms and credit for mariculture.
    2.2. Awareness of value chain participants in relation to relevant institutional arrangements and regulations related to access to resources (e.g. land, water) or services (i.e. licenses, certificates) of relevance to finfish mariculture.
    2.3. Education and assistance for those who are already in the value chain but would like to extend their activities to other value chain nodes (e.g. farmers wishing to engage in processing or fish trade, and who are predominantly female).
    2.4. Ensuring that the institutional environment at all levels remains supportive of both aquaculture and gender equality.
    2.5. Using 'positive approaches' (promoting what is good and doable rather than concentrating on vulnerabilities and barriers), in particular women's strong position in control of household budgets and the community perceptions and praise for women's bargaining skills, to improve women's economic outcomes.
    2.6. Accepting gender analysis as an integral part of value chain analysis, as a tool that increases the probability of carrying out successful future value chain interventions. Mistaken assumptions about roles and power of actors along the value chain might have implications not only for gender equity but may also have potential to damage the operation of the entire value chain and reduce the economic growth of this important and profitable industry.

9.2.4 Recommendations for improving career progression opportunities for women in KKP

The following recommendations arose from the study into career progression opportunities in KKP research institutes. Following discussion with AMFRHR, they were grouped to indicate the agencies primarily responsible for implementation. However, from January 2022 many staff of the KKP research institutes will move to the newly-formed Badan Riset dan Inovasi Nasional (BRIN – National Agency for Research and Innovation) and it is likely that some of these responsibilities will subsequently fall to BRIN.

Agency (Secretary General KKP) level

- Revise employment regulations to be more open and transparent, including online system. Provide clear job descriptions when recruiting a candidate to ensure he/she is willing as well as capable to undertake all duties required of the position.
- Revise and simplify study permit regulations.
- Change regulations related to access to MSc and PhD scholarships – eliminate waiting times and make applications open for all.

Agency (AMFRHR) level

- Foster collaborations and networks (national and international), including budgetary support.
- Improve financial support for research and increase in budget.
- Initiate self-development programs / HR career progression.
- Provide improved access to scientific journals for research staff.
- Support the provision of childcare facilities at all institutes.
- Change policy to improve access to training and further education for remote locations.
- Develop an internal (institute) Policy and Standard Operating Procedures or similar, on how to conduct selection of candidates for a range of opportunities, including scholarships and attendance at international conferences (overlapping with the Research Institute level).

Research Institute level

- Institute to subscribe to some international scientific journals.
- Initiate monthly scientific discussions for research staff. For example, on a paper presenter is writing or one s/he has recently read. This promotes effective presentation skills and allows for scientific feedback.
- Arrange for workshops to improve scientific writing skills: for some staff at Bahasa level (for national journals) and for other staff in English (for international journals).
- It was noted by staff that the opportunity provided by this project to get together and discuss their career goals, aspirations and obstacles, was very valuable. It is therefore further recommended that such meetings with participation of all scientific and research staff, be regularly conducted at each institute, once or twice a year.
- Make decisions more transparent, using an open system and open discussions.
- Support timely and transparent planning of future activities.
- Invite trainers to come to the institute and deliver training for all (rather than send one or two individuals away for training).
- Develop a depository of research ideas / proposals: Concept notes to be developed as people get research ideas, and to be deposited in a folder from which they can be accessed and used as and when needed (proposed at RICAFE Maros only).
- Further promote ethnically mixed teams (proposed at IMRAFE Gondol only).
- Clarify distinctions between groups of roles and responsibilities (proposed at IMRAFE Gondol only).
- Access of female scientists to administrative and management training should be improved (data finding for IMRAFE Gondol).

Individual level

- Individuals to take more initiative themselves in all aspects, including better awareness of and use of online materials and depository sites.
- Continue to develop mixed research teams.
- Undertake self-improvement / self-study.
- Proactively seek research grants.
- Proactively initiate collaborations with institutes and universities.
- Use existing networks to invite collaborations, grants, etc.
- Senior staff should provide mentoring of junior staff.
- Regular monthly meetings to discuss publications and build presentation skills.
- Outside of the direct influence of the workplace, improve household workload distribution, rising awareness of time demands placed on women by the family.

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2019 Training Evaluation Meeting for ACIAR Project FIS/2016/130, held at the Marine Aquaculture Research and Development Centre, Sihanoukville, Cambodia, 4–7 November 2019; 29 pp.

Online Symposium for ACIAR Projects FIS/2016/130 and FIS/2018/115 *Using Research to Solve Problems to Support Aquaculture Industry Development*, 12–15 June 2021; 13 pp.

Domestication documentation

In line with MMAF procedures, RICAFE Maros documented various aspects of the biology of *Siganus guttatus* to support the official recognition of this species as an aquaculture commodity in Indonesia. Much of the research underpinning this documentation was supported by FIS/2016/130. Details of the supporting documentation are listed in Appendix 2 (Section 11.2) of this report.

11 Appendixes

11.1 Appendix 1: Rabbitfish (*Siganus guttatus*) fingerling production at RICAFE Maros Barru facility

Month	Ponds		Tanks	
	No. of larvae stocked	No. of juveniles harvested	No. of larvae stocked	No. juveniles harvested
Jul-17	–	–	–	–
Aug-17	715,481	1,200	–	–
Sep-17	2,414,547	0	–	–
Oct-17	–	–	–	–
Nov-17	85,000 (pond 9) 5,000 (pond 10)	0	–	–
Dec-17	–	–	–	–
Jan-18	–	–	–	–
Feb-18	–	–	–	–
Feb-18	504,000	1,293	–	–
Mar-18	1,725,667	0	–	–
Apr-18	2,476,600	0	–	–
May-18	1,455,000	1,338	–	–
Jun-18	413,2000	0	–	–
Jul-18	–	0	–	–
Aug-18	(Larvae not counted)	2,500	–	–
Sep-18	1,168,000	0	–	–
Oct-18	1,726,000	1,200	–	–
Nov-18	8,993,000	0	–	–
Dec-18	4,310,000	4,000	–	–
Jan-19	11,281,000	0	–	–
Feb-19	8,990,000	0	–	–
Mar-19	3,100,000	1,200	–	–
Apr-19	5,859,000	270	–	–
May-19	9,073,000	230	–	–
Jun-19	2,835,000	–	–	–
Jul-19	–	–	2,800,000	–
Aug-19	9,745,168	0	–	–
Sep-19	8,017,000	0	1,048,000	–

Month	Ponds		Tanks	
	No. of larvae stocked	**No. of juveniles harvested**	**No. of larvae stocked**	**No. juveniles harvested**
Oct-19	7,127,000	0	1,614,000	3,000
Nov-19	8,641,000	0	982,000	–
Dec-19	7,288,000	150	–	–
Jan-20	5,008,000	1,500	–	–
Feb-20	2,276,300	240	–	–
Mar-20	5,171,000	400	–	–
Apr-20	–	–	–	–
May-20	7,410,000	0	–	–
Jun-20	4,567,000	–	–	–
Jul-20	–	–	–	–
Aug-20	4,177,000	–	–	–
Sep-20	6,852,000	–	–	–
Oct-20	3,281,000	5,316	–	–
Nov-20	1,991,000	3,000	–	–
Dec-20	7,687,000	–	–	–
Jan-21	2,616,000	–	551,000	
Feb-21	3,747,000	–	516,000	
Mar-21	1,271,000	–	190,000	3,000
Apr-21	3,212,000	–	–	–
May-21	–	–	120,000	1,000
Jun-21	921,000	1,365	–	–
Jul-21	1,556,000	1,500	–	–
Aug-21	1,327,000	11,976	–	–
Sep-21	1,404,000	32,000	–	–
Oct-21	2,536,000	500	–	–
Nov-21	2,899,000	120	103,000	–
Dec-21	940,000	120	103,000	600

11.2 Appendix 2: Domestication of golden rabbitfish *Siganus guttatus* for aquaculture in Indonesia

11.2.1 Summary of domestication documentation

Rabbitfish is a herbivore (or opportunistic omnivores) that grows rapidly and has great potential to be cultivated because of expected low production compared with other marine finfish. *Siganus guttatus* is a euryhaline species of rabbitfish which has high tolerance to changes in salinity and other environmental variables including temperature.

The purpose of the domestication of *S. guttatus* is to obtain a type of rabbitfish that is adaptive to the culture environment with known phenotypic and genotypic characteristics as well as known variations in growth, survival and resistance to the culture environment.

The series of domestication activities *S. guttatus* include: 1) Testing the morphometric and meristic characteristics of G1 and G2 phenotypes; 2) Testing the characteristics of G0 and G2 genotypes using the PCR method with BLAST analysis (Basic Local Alignment Sequencing Tools) and matched with the *S. guttatus* gene database on the NCBI geneBank (www.ncbi.nlm.nih.gov); 3) Testing of reproductive and production characters including growth, survival and utilization of feed as well as testing of environmental resistance for G2 fish; 4) Inventory of parasitic infections found during the domestication process, techniques for preventing and treating these parasites and testing for resistance to bacterial infections.

Rabbitfish can be cultured using an extensive larval rearing system in earthen or concrete brackishwater ponds by utilizing natural feed that is cultured through fertilization and can also be cultured in tanks with a controlled system. The estimated spawning time is known, namely the 9-11th of each month based on the Qomariah calendar. Larval rearing was carried out using an extensive system in brackishwater ponds and in tanks with a capacity of 70 m^3 with a maximum survival rate of 22% and 7% respectively. Larval rearing was also carried out using semi-intensive larval rearing methods for marine finfish, with a maximum survival rate of 4%. The domesticated *S. guttatus* very responsive to artificial feeds and require a relatively low protein of about 33% compared to other marine fish species (40–50% crude protein). The survival rate of *S. guttatus* is very high ranging from 80–100% for the nursery stage and grow-out stage with a rapid growth rate ranging from 1.4–1.6%/day. The feed conversion ratio at nursery and rearing stages ranged from 1.47 to 1.70. Data on the quality of *S. guttatus* flesh as a food source also complements this academic paper including the proximate and amino acid composition of the flesh.

S. guttatus is a euryhaline species and has a high resistance to changes in salinity. Juveniles can survive in the salinity range of 5–40 ppt, temperature in the range of 26–36oC, pH 5.5–9.5 and dissolved oxygen 3–5 mg/L. The types of parasites that infect *S. guttatus* during the domestication process included *Caligus* sp., *Lepeophtheirus* sp., *Haliotrema* sp., *Benedia* sp., *Gyrodactylus* sp., *Lernaea* sp., and *Pseudohaliotrema*.

Based on the genotype test, the heterozygosity of the G2 *S. guttatus* was 1%. The results of the domestication of *S. guttatus* are expected to be a reference in the development of aquaculture for this species, especially the hatchery technology so that the seed production can be carried reliably. Domestication of *S. guttatus* is also expected to support the diversification of brackishwater aquaculture in Indonesia.

11.2.2 Contents of research documentation for 'release' of *S. guttatus*

1. Sources of wild fish/G0 (time, location)
2. Classification: name of fish (scientific, global, local)
3. Phenotype
    3.1. Morphometric
    3.2. Meristic
    3.3. Colour
    3.4. Growth and survival
        3.4.1. Embryonic and larvae stages
        3.4.2. Nursery in earthen pond
        3.4.3. Nursery in floating cage in pond
        3.4.4. Nursery in fibreglass tank

        3.4.5. Grow-out in sea cage
        3.4.6. Grow-out in earthen pond
    3.5. Tolerance level to environment (temperature, salinity, pH, DO)
    3.6. Quality of carcass and fillet
    3.7. Kind of feed and feeding behaviour
    3.8. Reproduction (sex differentiation, fecundity, etc)
    3.9. Diseases identification
4. Productivity
5. Genotype
6. Fish collection (prioritized Generation 2)
7. Positive impact of the domesticated fish (socio-economic and environment)

11.3 Appendix 3: Students involved in project activities at RICAFE Maros

The following students were involved in various project research activities undertaken by RICAFE Maros.

No.	Name	School / university	Training location	Year
1	Ayu Puspita Sari	SMKN 1 Maros	Sea cages	2019
2	Narti	SMKN 3 Majene	Hatchery	2019
3	Linda Sari	SMKN 3 Majene	Sea cages	2019
4	Wulandari	SMKN 3 Barru	Hatchery	2019
5	Sultan	SMKN 3 Barru	Sea cages	2019
6	Haura Ainun Sulaeman	Hasanuddin University, Makassar	Sea cages	2019
7	Nursun Marhumatul	Hasanuddin University, Makassar	Hatchery	2019
8	Klemensiu Leonard	University of Nusa Cendana, Kupang	Sea cages	2019
9	Yoseph Palkalis	University of Nusa Cendana, Kupang	Hatchery	2019
10	St Mulkia Nasira Basri	UNSULBAR, University of West Sulawesi	Hatchery	2019
11	Hasrawati	UNSULBAR, University of West Sulawesi	Larval rearing	2019
12	Masna	UNSULBAR, University of West Sulawesi	Hatchery	2019
13	Sartika	Polytechnique KP Bone	Hatchery	2019
14	Andriati	Polytechnique KP Bone	Hatchery	2019
15	Nurul Hikmah	Polytechnique KP Bone	Hatchery	2019
16	Mulkani	Polytechnique KP Bone	Hatchery	2019
17	Kristomy Rama	Polytechnique KP Bone	Hatchery	2019
18	Hasniar Sulfiqhi	Polytechnique KP Bone	Hatchery	2019

No.	Name	School / university	Training location	Year
19	Irfan	Polytechnique KP Bone	Sea cages	2019
20	Nursalim	Polytechnique KP Bone	Sea cages	2019
21	Ahmad Alif Zulkifli	Polytechnique KP Bone	Sea cages	2019
22	Fikri Aidil Nur	Polytechnique KP Bone	Sea cages	2019
23	Dewi Indrawati	Polytechnique KP Bone	Sea cages	2019
24	Nur Hikma Nasir	Polytechnique KP Bone	Sea cages	2019
25	Nurul Fauziah	Polytechnique KP Bone	Sea cages	2019
26	Nur Sakinah	Polytechnique KP Bone	Sea cages	2019
27	ABD Muttalib	Polytechnique KP Bone	Sea cages	2019
28	Indar Alam M	Hasanuddin University, Makassar	Hatchery	2019
29	Monalisa A. Musa	SUPM Bone	Hatchery	2020
30	Sukmasari	SUPM Bone	Sea cages	2020
31	Yustika Diro Damis	Hasanuddin University, Makassar	Sea cages	2020
32	Emilia Defista	Hasanuddin University, Makassar	Sea cages	2020
33	Lisna	SMKN 8 Wajo	Hatchery	2020
34	Aswan	SMKN 8 Wajo	Sea cages	2020