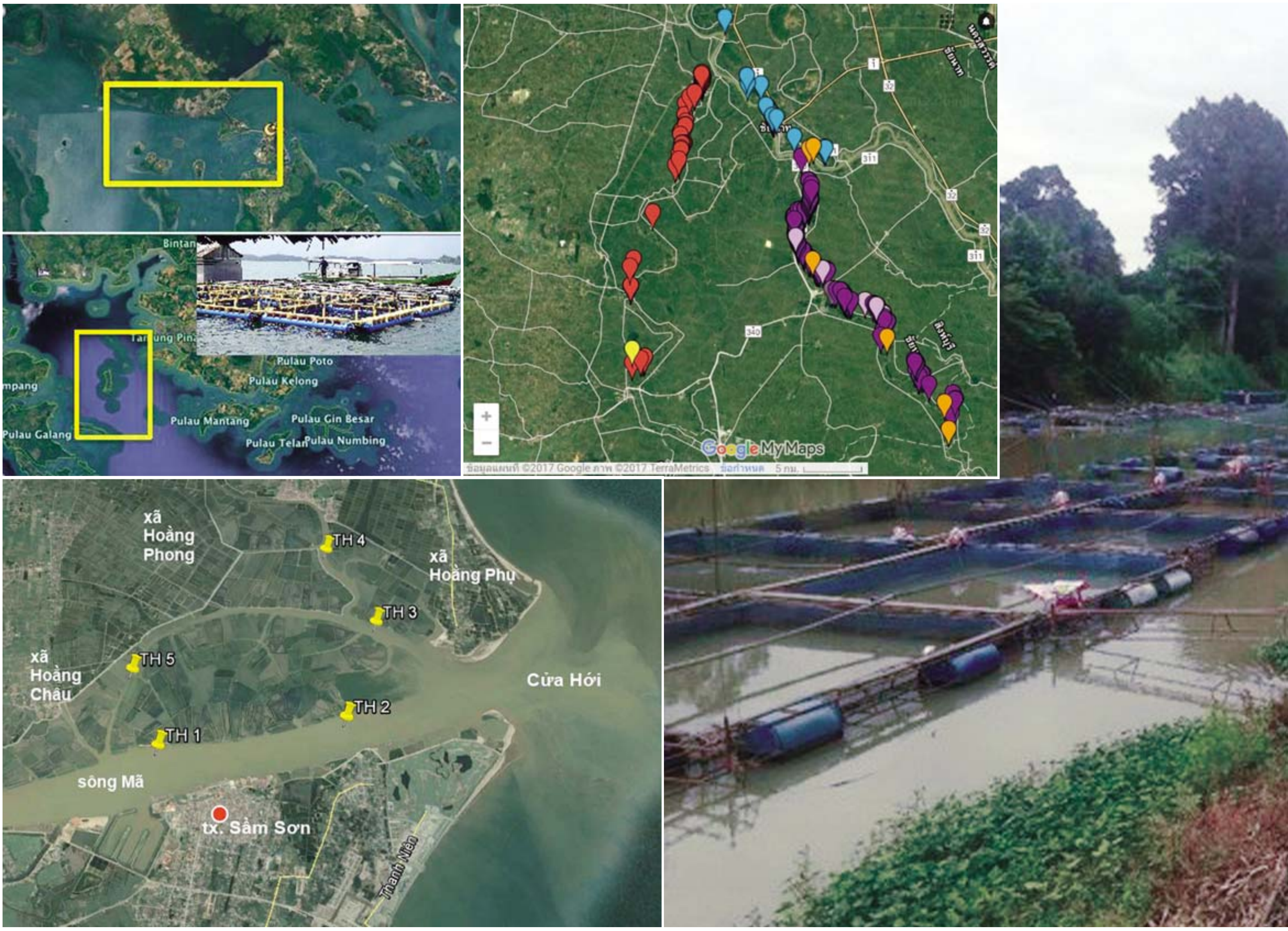
Food and Agriculture Organization of the United Nations

Pilot application of selected aquaculture planning and management tools in Indonesia, Thailand and Viet Nam



Pilot application of selected aquaculture planning and management tools in Indonesia, Thailand and Viet Nam

Edited by Miao Weimin

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Contents

Preparation of this document

This publication is a compilation of documents prepared in the implementation of an FAO regional Technical Cooperation Programme project "Pilot application of aquaculture planning and management tools for sustainable growth in selected Southeast Asian countries" (TCP/RAS/3511). Three international consultants contributed four aquaculture planning and management tool manuals as the most important outputs of their technical services to the project. Three national project coordinators contributed the summary reports on the implementation of the project in Indonesia, Thailand and Viet Nam. The FAO lead technical officer for the project prepared the summary report on the overall implementation of the regional project and merged different technical components into the compiled publication.

Acknowledgements

This publication is the result of the collective effort of the international consultants, national project teams led by the national project coordinators in Indonesia, Thailand and Viet Nam and FAO staff.

First, great thanks are due to Mr Patrick White, Mr Ramesh P Perera and Mr Vincent Andre, who prepared and finalized the four aquaculture planning and management tools, which are the core technical components of the document, and guided the pilot application of the tools in Indonesia, Thailand and Viet Nam.

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Deep appreciation is extended to the Directorate of Aquaculture, Ministry of Marine Affairs and Fisheries of Indonesia, Department of Fisheries, Ministry of Agriculture and Cooperatives of Thailand and Directorate of Fisheries, Ministry of Agriculture and Rural Development of Viet Nam and FAO representative offices in Indonesia, Thailand and Viet Nam for their strong support and excellent facilitation, which ensured the successful implementation of the TCP.

Many thanks are due also to Ms Chanphen Bhawangkananth, who handled the FAO internal publication work flow and coordinated the complete editing and printing process.

Abstract

Asia has experienced rapid growth of aquaculture in the past four decades and this has significantly contributed to an increased supply of fish products for improved nutrition of the Asian people. It has also strongly benefitted the global seafood trade, local livelihoods and overall economic development. Being a relatively new food production sector of industrial scale, aquaculture has been developed in the region, in many cases, without good planning and management. This has caused immediate threat and emerging risks to its sustainability in the long term. With population growth and changes in people's dietary habits as the result of improving living standards, it is anticipated that the global demand for food fish will increase significantly in the coming decades. Sustainable growth of aquaculture is considered as the most feasible approach to meet this increasing demand. But, it is very difficult to imagine Asian aquaculture achieving sustained growth without significantly improved planning and management.

In order to support the member countries in the region to achieve sustainable growth of aquaculture through improved planning and management, FAO Regional Office for Asia and the Pacific implemented a regional TCP project "Pilot application of aquaculture planning and management tools for sustainable growth in selected Southeast Asian countries" (TCP/RAS/3511) from May 2016 to December 2017. The regional TCP project was implemented in three selected ASEAN member countries, namely Indonesia, Thailand and Viet Nam, which covered a range of project activities at regional and country level. The project focused on the development of technical manuals for the aquaculture planning and management tools prioritized by the participating countries, awareness raising and technical capacity building for application of the aquaculture planning and management tools, pilot application of four selected aquaculture planning and management tools in the project participating countries and sharing of the project results for scaling up.

This document is an important product of the project implementation and consists of three components: a summary report on the overall implementation of the project at regional and country level; the individual summary report on implementation of project activities in the three participating countries; and technical manuals of four prioritized aquaculture planning and management tools. The overall project implementation report introduces the major regional and country level project activities implemented under the project and the major outputs delivered. It also summarizes the major achievements of the project and the important lessons learned in the general implementation of the project. The individual country implementation reports summarize the implementation of major project activities in Indonesia, Thailand and Viet Nam. The country reports focus more on the piloting of selected tools in each individual country, particularly the process, major results and the lessons learned. The country reports also include recommendations for scaling up the application of aquaculture planning and management tools at country and regional levels. The technical manuals for the four aquaculture planning and management tools, namely environmental carrying capacity assessment, feasibility study, farm biosecurity planning and aquaculture traceability, cover the tool concept, methodology and practical guidance for their field application.

The hope is that the production of this document will help to scale up the results of the project for wide application of the aquaculture planning and management tools in the region. The document is expected to serve as a knowledge product and to provide practice guidance to a wide range of readers, including but not limited to aquaculture planners and managers, researchers and extension workers and farmers, who are engaged in aquaculture planning and management at different levels.

Project regional evaluation and dissemination workshop

National training on tools in Viet Nam

National training on tools in Thailand

National training on tools in Indonesia

Regional training on tools

Presentation of Thai country implementation report

Collecting water samples for ECCA in Thailand

Measuring water parameters for applying ECCA tool in Viet Nam

Field data collection for tool application in Indonesia

Monitoring water parameters for tool application in Indonesia

PART I

Report on overall implementation of the FAO regional TCP project

Pilot application of aquaculture planning and management tools in Indonesia, Thailand and Viet Nam

1. Background

The Asian region dominates global aquaculture production, contributing about 90 percent of the global production in the past two decades. The global and regional demand for fish is expected to increase significantly because of the population increase and the potential change in people’s eating habits in the coming decades. Further growth of aquaculture in Asia is crucial to meet such an increasing demand for fish globally and regionally. It is estimated that Asian aquaculture production will need to increase by 60 percent by 2030 from the current level.

Many countries in the region have sought to develop the aquaculture industry to contribute to national food security and nutrition as well as to increase livelihood opportunities and overall economic development. However, the rapid development of the aquaculture sector has caused significant adverse environmental and socio-economic impacts because of lack of proper planning and effective management and this has raised wide concern over the sustainability of the industry. Many countries in the region have identified sustainable development as a priority for the aquaculture industry and this will require significant improvements in the planning and management of the sector.

In order to support the member countries’ efforts to improve the planning and management of the aquaculture sector, FAO in collaboration with the Network of Aquaculture Centres in Asia-Pacific (NACA), conducted a regional study and workshop on the application of aquaculture assessment (planning and management) tools in the region. The study indicated that most aquaculture countries in the region could not adequately plan and manage the aquaculture industry largely because of a lack of appropriate aquaculture planning and management tools that are adapted to the regional context. Moreover, they have a weak capacity for effective application of the tools that are available. To address these major constraints, FAO supported the development of an aquaculture planning and management toolkit that comprises 16 tools addressing specific planning and management objectives for the aquaculture industry. The toolkit was introduced to the member countries through a regional technical consultation. The regional consultation strongly recommended the pilot application of the tools in those countries with a strong interest in using the tools before they are widely applied in the region.

Based on the recommendation of the Asia-Pacific Fishery Commission (APFIC) and strong interest expressed by the governments of Indonesia, Thailand and Viet Nam, an FAO regional Technical Cooperation Programme (TCP) project – “Pilot application of aquaculture planning and management tools for sustainable growth in selected Southeast Asian countries” was developed to support the implementation of the FAO Regional Initiative on Sustainable Intensification of Aquaculture for Blue Growth in the Asia-Pacific region. The regional TCP was to support the translation of aquaculture planning and management tools that were developed with FAO support in 2013 into operational manuals and to develop related training materials for selected participating countries. The project also aimed to support the pilot application of selected tools in Indonesia, Thailand and Viet Nam and related national and local capacity development through regional and national training activities.

2. Project framework

The regional TCP was developed to contribute to the sustainable growth of aquaculture for food security, nutrition and livelihood development in the region through improved planning and management of the sector at different levels. To achieve the objective, the project was designed to produce four major outputs:

Output 1

Operational manuals of four aquaculture planning and management tools. These were developed and finalized by the project's international consultants with country inputs. The four tools are: (1) aquaculture environmental carrying capacity assessment (ECCA); (2) aquaculture feasibility study; (3) farm level biosecurity planning; and (4) aquaculture traceability systems. Relevant training materials were developed for regional and country level training courses. The four operational tool manuals will be made available to interested parties throughout the region.

Output 2

National and local capacity development for applying the four selected aquaculture planning and management tools. This was achieved through regional training courses (40 persons in total) and national training courses (more than 200 persons). One regional project inception workshop and three national project inception workshops were conducted, which significantly increased people's awareness of the importance of applying tools for improved planning and management of aquaculture and how the project will contribute to this.

Output 3

The piloting of three of the four selected aquaculture planning and management tools in each participating country based on the country's priorities with the support of international and national project consultants. The process and results of the tools piloted in each participating country were well documented.

Output 4

A review of the project implementation at country level, particularly the tool piloting process, the dissemination of the tools and the piloting results. This was achieved through national project evaluation and dissemination workshops conducted in each project participating country.

3. Implementation of the project

The project was implemented from May 2016 to December 2017 and included activities at regional level and in three participating countries for achieving different project outputs.

3.1 Implementation at regional level

As part of the regional TCP project implementation, a number of important activities were successfully carried out at regional level and this provided a solid foundation for the country level activities.

3.1.1 Regional project inception workshop

A two-day project inception workshop was organized in May 2016 with the participants comprising the national project coordinators and experts from the three participating countries and NACA.

In the inception workshop, the participating countries shared their status with respect to aquaculture planning and management. The project background and framework was introduced to the participants. The draft project implementation was reviewed and discussed with particular consideration given to its implementation in the three respective countries. Prior to the inception workshop, the participating countries identified four tools for implementation: aquaculture environmental carrying capacity assessment (ECCA), aquaculture feasibility study, farm biosecurity planning and aquaculture traceability systems.

3.1.2 Development of project tool manuals

Three international project consultants developed draft manuals for the four selected tools based on the toolkit developed with FAO support earlier and prepared relevant material for training national experts at regional level.

3.1.3 Regional training workshops

Regional training workshops on each tool were organized for national project experts. During the regional training workshops, the national experts provided feedback and suggestions for the improvement of the draft tools. During the training workshops, each country team prepared a detailed work plan for implementing all the country level activities.

3.1.4 Regional project evaluation and dissemination workshop

A regional project evaluation and dissemination workshop was held at the end of the project implementation. The workshop participants were the three national project teams, representatives from 13 non-project participating countries in Asia, NACA and international and national project consultants. The workshop comprehensively reviewed the implementation of the programmme at regional and country levels with presentations by the national project coordinators and consultants and the project technical lead officer from FAO.

While sharing the successes, experiences and lessons learned from the project implementation, the workshop participants also recommended further refinement of the tool manuals and the actions necessary to promote wide adoption of the tools in the region (including new tools to be developed and piloted for strengthening aquaculture planning and management, such as tool for impact assessment).

3.2 Implementation of the project at country level

Numerous major project activities were implemented at country level. These were led by the national experts responsible for each tool and supported by relevant national institutions and international consultants.

3.2.1 National project inception workshop

A national project inception workshop was organized in each project participating country. The workshop participants comprised important stakeholders in aquaculture planning and management at different levels and the direct beneficiaries of the project. The national project inception workshops introduced the project framework to the stakeholders and enhanced their awareness of its components. The country implementation work plans were prepared in the national inceptions workshops.

3.2.2 Translation of the tool manuals

Supported by the international consultants, the national consultants translated aquaculture planning and management tools selected for piloting in respective project participating countries and prepared materials for national training courses.

3.2.3 National training workshop

National training workshops on all selected planning and management tools were organized for the ultimate users (including farmers involved in the piloting) in each country participating in the project. The participants were introduced to the tools and trained on how to apply the tools by the national experts with the support of the international consultants responsible for each respective tool. The international consultants visited the pilot sites and provided technical guidance on the piloting of the specific tools during their country support visit.

3.2.4 Piloting of selected tools

The piloting of three selected tools was carried out in each project participating country with some slight differences: (Indonesia: aquaculture environment carrying capacity assessment; aquaculture feasibility study; and aquaculture traceability systems. Thailand and Viet Nam: aquaculture environment carrying capacity assessment, aquaculture feasibility study and aquaculture farm biosecurity planning). The piloting of the tools in each country was technically implemented by the national experts responsible for each tool and supported by national and local institutions. The national experts took the main responsibility for data collection and analysis of the results of the project with the technical support of the international consultants.

3.2.5 Review of national regulatory framework

In order to better understand the need to strengthen the regulatory support to improve aquaculture planning and management through the application of relevant tools, the national experts for the respective tools reviewed the relevant existing national laws and regulations and recommended some revisions and amendment to them.

3.2.6 National project evaluation and dissemination workshop

A national workshop was organized in each participating country to review and evaluate the project implementation, disseminate the results of the project implementation and identify the gaps and strategies to scale up the adoption of the tools for improved aquaculture planning and management in the country. The national project coordinator and experts for specific tools prepared a national report on the implementation of country level project activities and technical reports on piloting of each tool in the country.

4. Major outputs of the project implementation

The regional TCP project was successfully implemented and effectively delivered the expected outputs, which include:

- Operational tool manuals were developed for aquaculture environment carrying capacity assessment, aquaculture feasibility study, aquaculture traceability systems and aquaculture farm biosecurity planning. These were verified and finalized using the inputs from the piloting process in the project participating countries.

- National and local human capacity for application of the four aquaculture planning and management tools was established and relevant knowledge products in local languages were produced, which will support the scaling up of the tool application in each participating country.
- Four aquaculture planning and management tools were successfully piloted in the three participating countries, the successful experiences and lessons from the piloting are very important assets to benefit the scaling up of the tool application in the three countries and the entire region.
- The implementation of the project has significantly increased the awareness of the importance of applying relevant tools for strengthened aquaculture planning and management in the entire region. The knowledge products and experiences and lessons from the project implementation will contribute to increasing application of planning and management tools for the sustainable development of the aquaculture industry in the region.

5. Key lessons learned from the project implementation

- The countries that participated in the project were all key aquaculture producers in the region. Their governments attach high importance to sustainable development of aquaculture. Therefore, the national aquaculture authorities in all the three countries were strongly committed to the implementation of the project activities and provided strong support to the implementation of the project activities. This is the key factor contributing to the success of the project.
- As a regional project, the project kept a good balance between project activities at regional and country level. Over 50 percent of the total project budget was allocated for supporting project activities at country level and this ensured country ownership of the project and the achievement of substantial results at country level.
- The project implementation at country level was technically led by the national project consultants and supported by the relevant national and local government institutions. Implementation was more successful in the countries where there was more support from the government institutions to the national consultants in implementing the country level activities, particularly the piloting of the tools.
- Although the implementation of the project was successful in general, it is observed that using relevant tools for aquaculture planning and management is not yet a common practice in the region. The related regulatory framework cannot provide adequate support to the wide application of specific tools in planning and management of the aquaculture sector and the related human and institutional capacity is generally weak in the region. Great effort is needed to mainstream the application of specific tools into aquaculture planning and management.

PART II

Country reports on project implementation

Piloting of aquaculture planning and management tools in Indonesia

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1. Summary

Aquaculture in Indonesia is a growing sector with 60 percent of the total area (land and water) of the country having mariculture potential. Until now, only 2.3 percent of the area with mariculture potential is utilized. The area utilized for aquaculture will continue to be expanded in line with the country's aquaculture development vision, which is to create a self-sufficient, competitive and sustainable aquaculture sector. It is also supported by the three pillars of national development: (i) sovereignty; (ii) prosperity; and (iii) sustainability.

In order to realize sustainability, aquaculture development in Indonesia should be based on the environmental carrying capacity of any area to support fish production. Realizing economic benefits and promoting rural development by providing employment and business opportunities should also be goals for the sector. Sustainability must not only be seen from the environment side, but also from the business side. Therefore, aquaculture products should meet consumer demand standards, especially in terms of quality, food safety and traceability.

This report addresses the government's efforts to realize sustainable aquaculture through the implementation of three management tools from FAO, namely *environmental carrying capacity assessment* (ECCA), *feasibility study* (FS), and design of a *traceability analysis* system. The piloting of these tools was done in Batam City and Bintan Regency, Riau Islands Province.

From the results of the piloting activities of these three tools, it can be concluded that the existing feasibility study tool is quite easy to use, but the actual application results revealed difficulties when the modelling was done for a polyculture system. As for the ECCA tool, the use of the Legović model for estimating environmental carrying capacity (ECC) of waterbodies on the basis of nutrient inputs from aquaculture, other sources and flushing rate method was simple (in the pilot application only N and P levels are considered as these are the limiting nutrients for phytoplankton growth that can cause algal bloom development). Nevertheless, its accuracy is still in doubt for measuring ECC in rivers and brackish waters as many parameters affect the waters. Therefore the method still needs further testing before being adopted nationally. The application of the traceability analysis tool was not problem free either. There is a need to improve the understanding of the farmers that traceability is not only concerned with increasing the selling price of aquaculture products but in fact gives greater emphasis to ensuring the food safety of aquaculture fishery products.

2. Introduction, background and summary of the country level implementation

Indonesia has a large potential to develop the aquaculture sector, considering that it is an archipelagic country with 16 056 islands, with a long coastline of 99 093 km. The potential waters that can be developed for aquaculture activities include freshwater (rivers, lakes, ponds), brackish waters (ponds) and marine waters (coastal and offshore).

Indonesian aquaculture has an important role in supplying fish protein because the growth of capture fisheries has been more or less static since 1980, whereas the production of aquaculture has increased significantly.

Indonesia is the second larger aquaculture producer in the world after China with a total fisheries production in 2014 of 14.3 million tonnes (Figure 1).

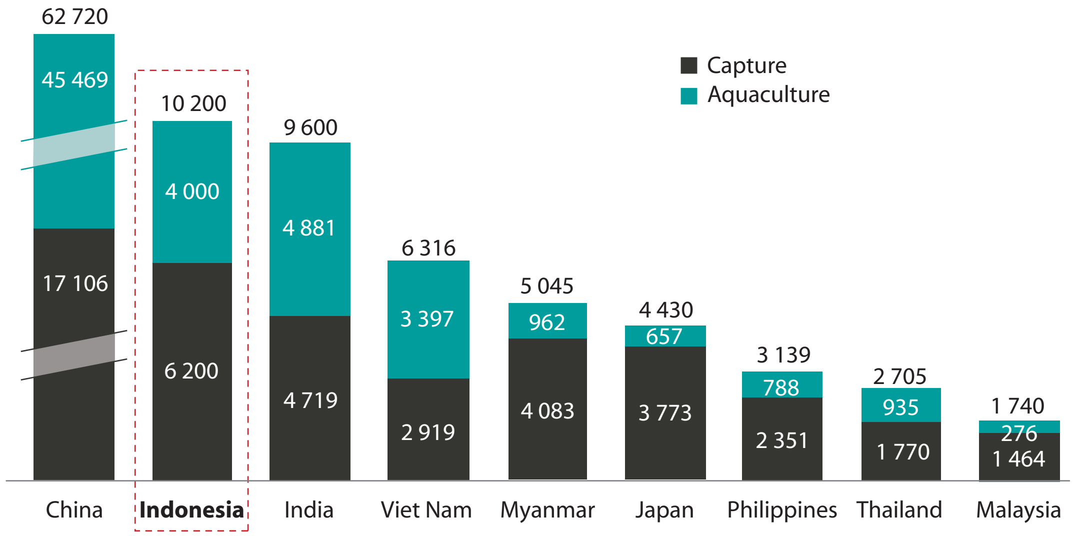


Figure 1. Top Asian Nations in 2014 Fisheries Production ('000 tonnes)

Remarks: Products consist of: Fish, Crustaceans, Molluscs. Aquatic plants such as seaweed not included
Source: OECD-FAO Agricultural Outlook, 2015

Aquaculture has a very important role in various national economic activities and also in rural development. Thus, with the transfer of technology and science and on the basis of Good Aquaculture Practices, Indonesia has the opportunity to become one of the largest aquaculture producers in the world. However, there are concerns about the impact of aquaculture activities on environmental sustainability, and about the quality and food safety for consumers. In the Asia-Pacific region demand for high quality, environment-friendly and safe aquaculture products is also increasing. Therefore, planning aquaculture activities based on environmental carrying capacity, business feasibility and application of traceability are important for the Indonesian aquaculture sector.

In order to develop sustainable aquaculture, Indonesia has cooperated with FAO to implement three tools, namely *environmental carrying capacity* assessment (ECCA), *feasibility study* (FS), and design of a *traceability system* as stated in project document TCP/RAS/3511.

The three management tools were piloted in Tiang Wangkang Waters – Batam, and in Pulau Pangkil – Bintan, both of which are located in Riau Islands Province. This province was selected as it has a mariculture potential area of 1 168 221 ha, and at present only 0.33 percent is utilized (Review of Masterplan of Aquaculture, 2014). Moreover, there is a high commitment among local governments to promote aquaculture as a productive activity in the community that is integrated from upstream to downstream, especially mariculture. Riau Islands Province is a centre of aquaculture activities for pompano (*Trachinotus blochii*), grouper (*Epinephelus fuscoguttatus*) and barramundi (*Lates calcarifer*), and geographically close to international markets (Singapore and Thailand). Implementation of these tools was done simultaneously with various stakeholders in the region.

3. Country level project activities and results achieved

Implementation of the piloting aquaculture management tools TCP/RAS/3511 in Indonesia is presented in Figure 2, where the activities are divided into several stages: preparation stage, regional training, piloting preparation, national training, implementation and results.

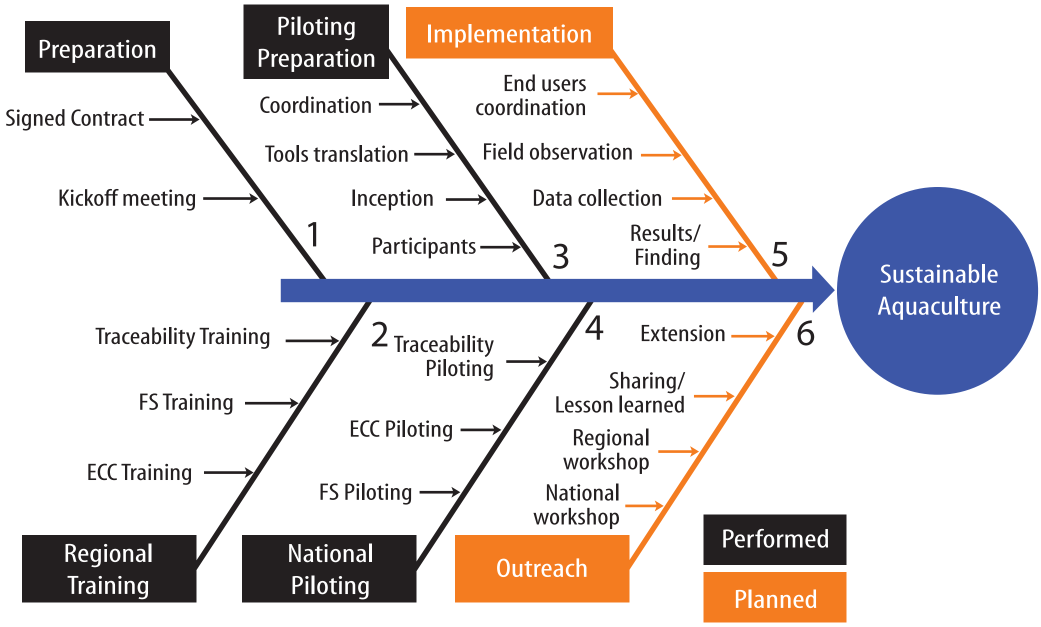


Figure 2. Fishbone diagram for TCP/RAS/3511 activities

3.1 Preparation

This phase begins, under the direction of the national project coordinator, with the signing of a national consultant contract with FAO. Then a kickoff meeting was held by the Directorate General of Aquaculture (DGA), Ministry of Marine Affairs and Fisheries (MMAF) and the national consultant and FAO representatives. This meeting focused on the project background, description and timelines. The results of the meeting were:

1) formulation of a field visit plan for piloting and project implementation in Batam, Kepulauan Riau Province; and
2) submission of information on regional training related to ECCA, FS and design of traceability systems in Bangkok.

3.2 Regional training in environmental carrying capacity assessment (ECCA), feasibility study (FS) and traceability systems

Regional training is intended to train national consultants and persons in charge (PIC) of aquaculture development of the DGA-MMAF in understanding the tools provided by international consultants, so that they can play an active role in adapting and training stakeholders in the use of the tools at the national level.

- Training on ECCA tools was implemented from 6 to 9 November 2016 at the Sukosol Hotel, Bangkok. Participants involved in this meeting were from Indonesia, Thailand and Viet Nam. Indonesia was represented by the National Consultant (Mr M Mukhlis Kamal), the PIC from DGA-MMAF (Mr Iman I Barizi) and the PIC from Riau Islands Province (Mr Aang Abubakar).

Training was held for three days under the direction of Mr Patrick White, the international consultant, and comprised background theory and implementation of the tools through practice and simulation of tool usage.

- Training on FS tools was conducted from 10 to 12 November 2016 with guidance from the same international consultant, Mr Patrick White. The countries participating were the same as those in the ECCA training, but there was a change in personnel composition. For Indonesia, the participants were the national consultant (Mr M Mukhlis Kamal), the PIC from DGA-MMAF (Mr Ikhsan Kamil) and the local PIC from Kepulauan Riau Province (Dikrurahman, MT). Implementation of the training was similar to the ECCA training.
- Traceability systems training was held from 20 to 24 November 2016 led by Mr Vincent Andre, another international consultant. Participants from Indonesia consisted of the national consultant (Mr M Mukhlis Kamal), the PIC of DGA-MMAF (Mr Tajuddin Idris and Ms Diana Rakhmawati) and the local PIC (Mr Ipong Adiguna).

International consultants have developed guidelines for each tool and teaching materials for the participants. All teaching materials were translated into Bahasa Indonesia by the national consultant.

3.3 Piloting preparation

a. National inception workshop

A national inception workshop was held on 27 February 2017. The meeting was a half-day workshop followed by a visit to net floating cages owned by fish farmers in Batam. The meeting was attended by representatives of fish farmers, the Office of Marine Affairs, the environment agency and the regional planning board both at the provincial and district levels. The workshop aimed to familiarize the participants with the project and encourage the involvement of stakeholders in its implementation. The workshop also discussed the national level training plan, the nomination of the participants and the delivery of information about the tools.

Some of the outcomes of this meeting were:

a. Dates were confirmed for national training courses on ECCA and FS.
b. It was confirmed that the manuals for each tool will be prepared and translated by the national consultant.
c. The relevant provincial and district/city offices agreed to provide full support in the application of the tool (especially in the case of official permission being required for on-site project implementation, staff participation in the training and staff support for any facilities used).
d. It was agreed that all trainers who had attended the training of the trainers (TOT) workshop in Bangkok during the national level training would be involved.

3.4 National piloting

a. National level training for environmental carrying capacity (ECC) assessment and feasibility study (FS)

A national training course on ECC assessment and FS was carried out at the Allium Batam Hotel between 22 and 25 March 2017, with the following objectives:

i. to introduce ECC assessment to fish farmers and policymakers so that they can assess the ecological aspects and carrying capacity of a watershed; and

ii. to transfer knowledge of feasibility study (FS) (cost-benefit analysis) to farmers so that the farmers can consider whether an aquaculture business can be run or not and would be profitable or not on a business scale.

The FS tool will assist fish farmers and other stakeholders in identifying inputs, processes and outputs as well as the cost consequences of implementing an aquaculture business. In addition, the FS management tool can be used to prevent losses in an aquaculture business.

The participants of the national level training comprised international consultant (Mr Patrick White), national consultant (Mr M Mukhlis Kamal), the national PIC of DGA for the ECC assessment tool (Mr Iman I Barizi), the national PIC of DGA for the FS tool (Mr Ikhsan Kamil), staff of DGA, representatives of the environment agency and the regional planning board both at the provincial and district levels, representatives of fish farmers, representatives of the fisheries agency both at the provincial and district level, representatives of Maritim Raja Ali Haji University (UMRAH) and also representatives of Batam Marine Center.

During the national level training, the participants were introduced to the simplest and quickest way of selecting and assessing a suitable location for aquaculture activities. The piloting of both tools was conducted during June – October 2017 in Tiang Wangkang and Pangkil Island.

b. National training for traceability

The training course for designing traceability systems was carried out in Allium Batam Hotel on 10 and 11 April 2017 and was attended by 30 participants. These comprised representatives of related stakeholders within the supply chain of aquaculture involving barramundi (*Lates calcarifer*), tiger grouper (*Epinephelus fuscoguttatus*), and star pomfrets (*Trachinotus blochii*) that exist in Bintan District and Batam City. The participants included the international consultant (Mr Vincent Andre), the national consultant (Mr M Mukhlis Kamal), the national PIC of DGA for the traceability tool (Mr Tajuddin Idris, MT), staff of the DGA, fish farmers, collectors, seed producers, fish feed suppliers, fish feed distributors, exporters, representatives of Balai Perikanan Budidaya Laut (BPBL) Batam, which is a marine unit of the DGA, and respresentatives of universities.

The objectives of this national level training were:

i. to transfer knowledge on the importance of traceability with respect to aquaculture activity – this is done by documenting every stage of producing, processing and distributing aquaculture products (that is, along the complete supply chain) so that if an incident occurs the product can be rapidly recalled and the cause of the incident investigated;
ii. to provide simple tracking techiques to participants that are easy to understand and can be applied to daily aquaculture activities; and
iii. to apply the tool in the field between June and October 2017 in Tiang Wangkang and Pulau Pangkil.

3.5 Project activities implementation

a. Field data collection for tools application in Pulau Pangkil and Tiang Wangkang

Field data collection activity was done in two stages, the first was from 31 July to 6 August 2017 and the second was during the second week of October 2017 in two locations, Batam City and Bintan Island. Data collection was done through:

i. primary data collection such as water quality, current, nutrient content on waters;

ii. secondary data was collected from the department of fisheries of city/district and BPBL Batam;
iii. direct interviews with fish farmers; and
iv. coordination with the department of fisheries at city/district level, universities and related institutions.

Environmental carrying capacity assessment

The type of data taken for the application of ECC assessment tools included pH, temperature, DO, weather conditions, substrate and number of benthos and plankton in the water. Fish production data and the nutrient input to the waters were obtained through interviews with various respondents in two locations:

i. 10 to 12 members of the fish farmers group;
ii. the head of Bintan fisheries agency;
iii. the head and staff of Batam Marine Fisheries Center;
iv. representatives from UMRAH; and
v. fisheries extension workers.

Figure 3. Area for aquaculture development in Riau Archipelago Province

There are several issues related to the implementation of the ECC assessment tool:

- for simplicity, area and depth determination could be done in a more straightforward manner;
- in the area where water exchange is good, cage number and space available may be overestimated; and
- ECC assessment must address the fact that aquaculture practice in marine areas uses a high proportion of so-called "trash fish".

Feasibility study

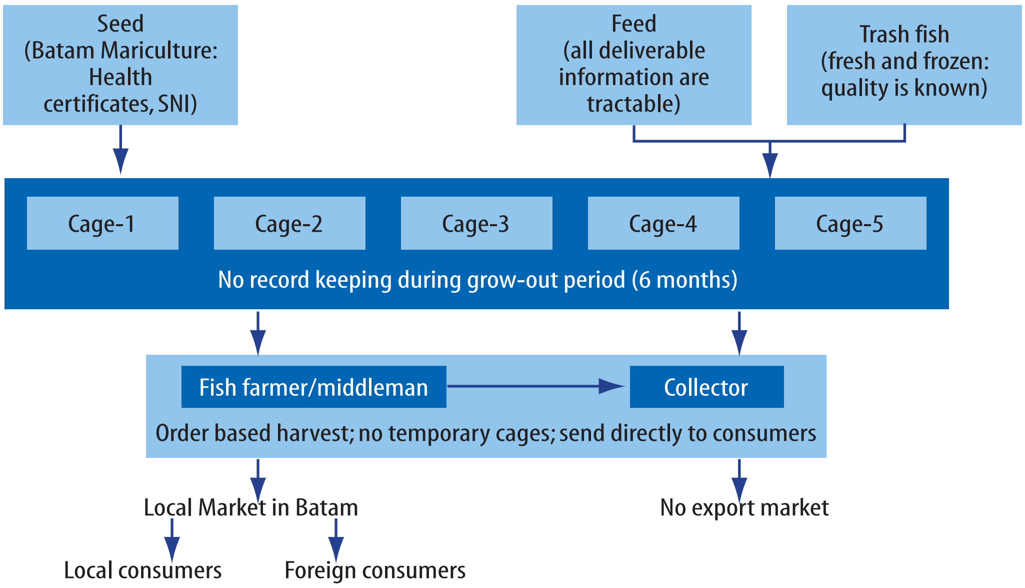
The data collection by interviews for the feasibility study tool was conducted in the same area as the ECC assessment with the main respondents being from the Kudus Jaya fish farmers group (Bintan) consisting of 12 members and the Kerapu Jaya fish farmers group (Batam) consisting of ten members. Both of the groups had at least five years experience in the aquaculture business. The main commodities usually cultured in the Riau Islands area are grouper, pompano and barramundi.

There are some issues related to the implementation of the FS tool in the field:

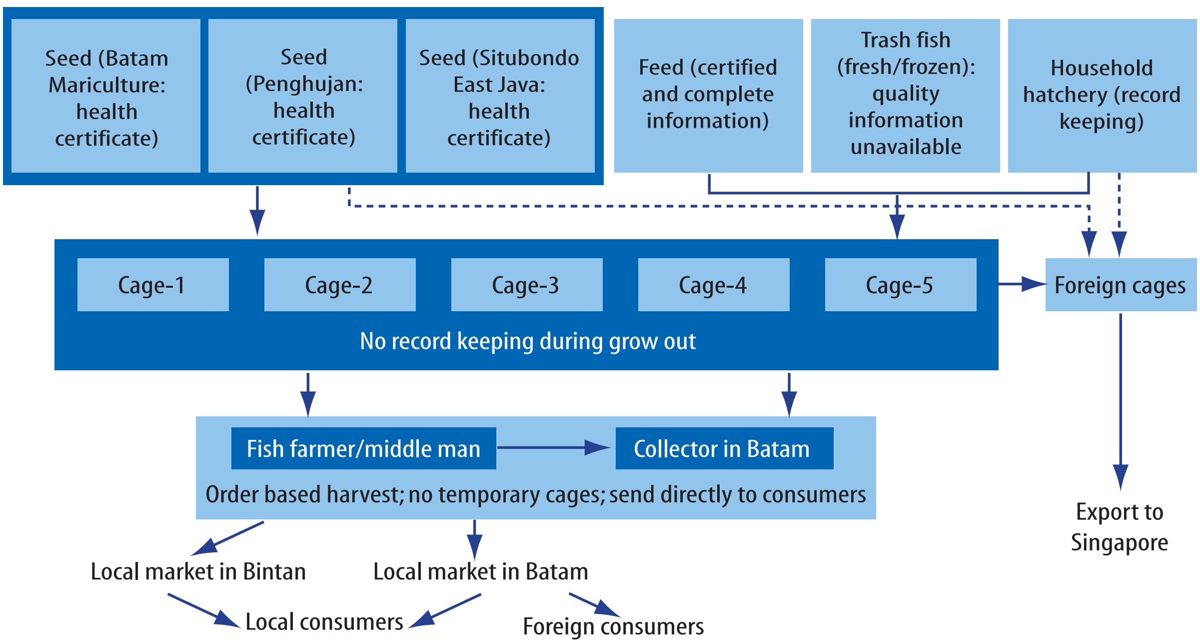
- prices are relatively stable for all fishes, however, **the fear of lower prices because of mass production of similar products on an industrial scale** (e.g. in Republic of Korea, Singapore, Taiwan Province of China). The present price may be seen as the minimum price that enables some profit; and
- prices in Bintan are influenced by the price fluctuation in Batam (all products go to Batam market first).

Traceability

The data collection for traceability tools was conducted through interviewing the fish farmers groups in Bintan Island and Batam City. Based on the interviews, the supply chain that exists in Batam City is as follows:



The supply chain that exists in Bintan island is as follows:



Thus every stage of producing, processing and distributing aquaculture products in Batam City and Bintan Island is identified so that if a problem occurs the product can be rapidly recalled and the cause of the incident investigated.

3.6 National evaluation workshop

A national level workshop to evaluate the implementation of the management tools was held on the 23 and 24 November 2017 in the Allium Batam Hotel. The objective of this meeting was to evaluate the implementation of the whole series of management tools in Batam City waters and Bintan District waters. The meeting was opened by the Secretary of the Directorate General of Aquaculture and attended by representatives of fish farmers and related stakeholders involved in the implementation of TCP/RAS/3511.

The results of the workshop were:

a. ECC assessment tool: (i) the tool could be applied properly in both locations, but it needs to be simplified; (ii) on the basis of the ECC assessment tool, the environment carrying capacity in Tiang Wangkang is 200 tonnes per year whereas in Pulau Pangkil it is 500 tonnes per year; and (iii) the regional utilization in both waters is still under 10 percent, hence there are plenty of opportunities to invest in aquaculture.
b. FS: (i) the feasibility of a business is strongly influenced by seed price, feed price, aquaculture facility and business scale; (ii) the commodities that should be developed are those with high economic value; and (iii) most aquaculture business units in the two locations have not yet met the optimum business scale because most fish farmers have additional jobs (e.g. collector, restaurant owner or farmer) and do not focus all their energy on farming fish.
c. Traceability: (i) there are still constraints found in terms of data recording during the production process; and (ii) considering that Kepulauan Riau is a border area where most likely its aquaculture production will be marketed to the international market, a food security guarantee through traceability is necessary.

4. Success and lessons learned from the country implementation of the project

Based on the implementation of TCP/RAS/3511 project in Riau Island, there are several lessons that can be learned:

Feasibility study

- The existing tool is quite easy to use, but from the piloting results there are still difficulties when the modelling is done for a polyculture system.
- From the results of the piloting of the tool it appears that most of the grouper fishers using floating cages in Indonesian waters do not meet the business scale necessary to obtain optimum results. The existing business scale is only half of the optimum business scale. However, farmers feel fortunate because they have additional jobs as collectors, restaurant owners, and others. Therefore, it is suggested to the farmers that they should do business in groups so it will be easier for them to get capital to increase their business scale.
- Implementation of a cluster system is also important to support group farmers' business management that will improve business efficiency.
- In addition, the price and the input component of production also greatly determine the size of farmer profits, therefore using high quality seeds will increase the survival rate of the fish which will increase the productivity and hence the profits from the business.

- It is recommended to improve this management tool by considering the effect of natural disasters, the maintenance cost of aquaculture equipment and the use of a polyculture system.

Environmental carrying capacity assessment

- The use of the ECC assessment tool is relatively simple (it is based only on N and P levels), but its accuracy is still doubtful for assessing ECC in rivers and brackishwaters because there are so many parameters that affect the waters. Therefore the method still needs to be tested further before being adopted nationwide.

Traceability

- The implementation of a traceability system in the field is very difficult and fish farmers are still reluctant to keep records continuously for each stage of their activities or for the materials used. This condition might be influenced by the inadequate knowledge of farmers about the importance of food security and also the absence of incentives received by farmers when implementing a traceability system.
- There needs to be law enforcement to implement GAP (Good Aquaculture Practices) including traceability.

Beside that, it is also necessary to develop the understanding of the farmers that traceability is not only focused on increasing the price of aquaculture products but in fact gives greater emphasis to food safety guarantees for the aquaculture products. Such guarantees will enable the farmers' products to access and succeed in domestic and international markets.

5. Strategy to support wide application of aquaculture planning and management tools

At this time, Indonesia has several regulations that support the development of sustainable aquaculture and these regulations indirectly support the further application of aquaculture planning and management tools. The regulations are as follows:

1. Law nr 45 year 2009 regarding Fisheries.
2. Law nr 32 year 2014 regarding Marine Affairs.
3. Law nr 7 year 2016 regarding the Protection and Empowerment of Fishermen, Fish Farmers and Salt Farmers.
4. Government Regulation nr 28 year 2017 regarding Aquaculture.
5. Presidential Decree nr 7 year 2016 regarding Acceleration of National Fisheries Industry Development.
6. Minister of MMAF Decree nr 2 year 2007 regarding Good Aquaculture Practices.

The acceleration of the implementation of aquaculture planning and management tools (APMT) is prioritized in the aquaculture areas that have been established by territorial utilization regulations, namely Rencana Tata Ruang dan Wilayah (RTRW)/spatial planning for territories) and Rencana Zonasi Wilayah Pesisir dan Pulau-Pulau Kecil (RZWP3K)/spatial zoning for coastal areas and small islands.

The implementation of APMT in public areas would require coordination and harmonization with other stakeholders. Since the majority of aquaculture activities is already appropriate with respect to the RTRW, the implementation of APMT in special areas should be faster.

The strategy adopted to accelerate APMT implementation is to issue a policy to implement APMT in the form of a ministerial decree or technical guidelines so that the local policy will harmonize with the central policy.

As a follow up from the implementation of TCP/RAS/3511 in Indonesia, there are a few tasks that need to be done by the Government of Indonesia:

i. DGA should prepare the planning of ECC assessment and FS implementation methods as FAO recommended so that they can be implemented in fisheries management policy in the country.
ii. The implementation should start with the preparation of technical guidelines.
iii. Tool implementation should be demonstrated in others areas through aquaculture cluster piloting.
iv. The involvement of the DGA technical implementing units (TIUs) and the local fisheries agencies should accelerate the acceptance and spread of the implementation of these methods in the country.
v. Implementation by every business stakeholder of FAO's recommended traceability methods should be further encouraged by the government through fish farmer groups.
vi. To achieve the acceptance and spread of these methods in the country the focus should be on fish farmers.

6. Recommendations on continued FAO support

The piloting of the three aquaculture planning and management tools was successful. But the piloting was carried out for marine cage fish culture in a few selected sites only. The Government of Indonesia expects the continued efforts from FAO to support Indonesia and other countries in the region to improve aquaculture planning and management through wider application of appropriate tools.

From the result of TCP/RAS/3511 activity, Indonesia requests the FAO to support the trials of the three chosen tools for other aquaculture activity, that is in freshwater and brackishwater aquaculture as well as the implementation of the tools in other aquaculture areas. Moreover, Indonesia also requests support from FAO for piloting different tools, such as: (a) environmental impact assessment and monitoring, which is needed to support the environmental management of areas affected by aquaculture activities. This is very important considering that many aquaculture activities still have not paid much attention to ecological and environmental aspects; (b) monitoring and evaluation, which is needed to know how to assess or evaluate government activities that have been conducted. It will help the government and stakeholders to know which activities that have been conducted already as part of TCP/RAS/3511 have achieved their stated objectives and also have provided good outcomes for the community.

Piloting of aquaculture planning and management tools in Thailand

Prepared by

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1. Introduction

With the financial and technical support of the Food and Agriculture Organization of the United Nations (FAO), the Department of Fisheries of Thailand (DOF) implemented country level activities related to “Piloting of selected aquaculture planning and management tools in Thailand” under a Letter of Agreement (LOA) signed by the DOF and FAO on 13 March 2017 for implementation of the FAO regional Technical Cooperation Programme (TCP) – TCP/RAS/3511 “Pilot application of aquaculture planning and management tools for sustainable growth in selected Southeast Asian countries”.

According to the LOA, Thailand was expected to deliver the following outputs:

1. national and local capacity for applying selected aquaculture planning and management tools is well established;
2. three selected aquaculture planning and management tools (environmental carrying capacity assessment, aquaculture feasibility study and the design of farm level biosecurity systems) are successfully piloted in selected sites; and
3. experiences and lessons from the piloting of the selected aquaculture planning and management tools are documented and shared at national and regional level for scaling up.

This summary final report presents the overall project implementation findings, including lessons learned and recommendations with respect to project activities implemented in Thailand.

2. Activities implemented under the signed Letter of Agreement (LOA)

The activities implemented were as follows:

i. coordination of the implementation of the country level project activities of TCP/RAS/3511 in Thailand following the country work plan agreed between the national project team and the FAO project lead technical officer;
ii. organization of one national project inception workshop, three national training events on selected aquaculture planning and management tools and one national project evaluation workshop;
iii. translation and preparation of training materials and other documents for national capacity building and tool piloting;
iv. selection of specific site (s) and farming system(s) for piloting the three selected aquaculture planning and management tools and development of detailed implementation plan for piloting the three tools in selected site(s);

v. implementation of the piloting of the three aquaculture planning and management tools in the selected site(s) following the work plan agreed by FAO;
vi. provision of technical and organizational support to the target farmers and local institutions engaged in the piloting of the tools;
vii. collection of relevant data, monitoring and reporting on the piloting of the selected tools in Thailand;
viii. preparation of the comprehensive reports on the piloting of the selected tools in Thailand; and
ix. other related activities required for the successful implementation of the country project activities as necessary.

3. Piloting of aquaculture planning and management tools implementation in Thailand

Three aquaculture planning and management tools were selected for implementation in Thailand as follows:

1) Aquaculture feasibility study (FS) tool: using the tool a feasibility study on striped snakehead fish (*Channa striatus*) culture development in Kamphaeng Phet Province was carried out.
2) Aquaculture environment carrying capacity assessment (ECCA) tool: using this tool an environmental carrying capacity assessment of tilapia cage culture in the Noi River, Chainat Province was carried out.
3) Farm level biosecurity plans tool: using this tool a farm level biosecurity plan for cage culture in the Noi River, Chainat Province was designed.

4. Project implementation findings

4.1 Feasibility study on striped snakehead fish (*Channa striatus*) culture

4.1.1 Introduction

The striped snakehead fish is one of a number of potential species suitable for aquaculture in Thailand. This species has been developed for aquaculture by the Department of Fisheries and successfully transferred to farmers in many provinces such as Ayutthaya, Singburi, and Roi-Et.

The technical developments required for this species are broodstock management, breeding, nursing, feeding by using pellet feeds to replace the use of live feed and marketing and trade. Currently, the DOF has the capacity to produce a sufficient quantity of fingerlings of striped snakehead fish to distribute to the farmers interested in raising them. Moreover, DOF has developed a good striped snakehead fish aquaculture system and provides good technical support to the farmers adopting striped snakehead fish culture in earthen ponds.

The DOF plans to promote striped snakehead fish culture in earthen ponds in one district of Kamphaeng Phet Province. A feasibility study using the FS tool selected by FAO was conducted to evaluate the potential of such a project and analyse the feasibility of promoting this species for aquaculture development.

4.1.2 Objectives

The objective of the feasibility study on striped snakehead fish (*Channa striatus*) culture was to apply the feasibility study tool developed by the FAO's international consultant for planning an aquaculture development project that seeks to establish the requirements for the project's biological feasibility, technical feasibility, economic viability and social acceptability. The immediate objectives of this study were:

- to study the feasibility of striped snakehead fish culture in earthen ponds in the area of Khanu Woralux Buri District, and Klong Klung District, Kamphaeng Phet Province, Thailand by using the FAO tool; and
- to communicate knowledge about aquaculture feasibility to government officials and other stakeholders involved in the promotion and development of aquaculture.

4.1.3 Project site and methodology

The project is located in Salokbat District, Kamphaeng Phet Province. About 30 farmers were targeted, selected on the basis of the existing number of striped snakehead fish culture farms.

The scope for the evaluation of the feasibility of a proposed striped snakehead fish culture development project covered: (1) technical feasibility; (2) economic feasibility (cost-benefit analysis to assess profitability; (3) biological feasibility; and (4) social acceptability including environmental safety. The field data for model simulation were obtained mainly from a household survey using a questionnaire.

4.1.4 Results

The analysis of the results found that aquaculture farmers who had three or more ponds had a higher return on investment (internal rate of return). Farmers have to invest about 699 000 baht and have a payback period of three years. Farmers started to culture snakehead fish at a stocking size of four grams at a density of five fish per square metre, using feed pellets with a food conversion rate (FCR) of 1.326. The average survival rate was 55.6 percent. Culture lasted about six months or until the fish weighed up to 330 grams before being harvested. The average yield was 16.5 tonnes/year. More than 100 000 tonnes/year can be produced in this area and supplied to the markets without affecting the market price significantly.

The farmers indicated that they require government support including infrastructure support, technical support, operation support and organization support such as:

- farmers want the government to build a dry processing factory and market place;
- farmers want to have knowledge about producing and nursing fish fingerlings and processing technology;
- farmers want to have a production plan, processing technique and market channel; and
- only one organization in the village produces fish fingerlings for use by its members and for sale to other farmers. Therefore, the organization needs to be stronger and requires funding to expand its business.

The major competitors include: the cheap wild fish imported from other countries such as Cambodia, snakehead fish brought in from other provinces and other fish species such as tilapia that can be eaten instead of snakehead fish.

The main problem associated with snakehead fish culture was high investment cost especially for the pellet feed which is expensive and the price of fish is sluggish because of the overproduction of fish. Another problem or risk is climate change.

4.2 Environmental carrying capacity assessment of tilapia cage culture

4.2.1 Introduction

Nile tilapia (Oreochromis niloticus) has become the main farmed species in inland aquaculture. Over the past decade, tilapia cage culture has been practised in many natural waterbodies (river, canal, reservoirs etc.) in all parts of the country and supported by the efforts of public and private research and extension agencies. This has lead to a rapid increase in the number of tilapia cage culture operations and has created numerous problems for this sector including: (1) high investment cost especially for feed; (2) high risk of declining profitability because of increased fish mortality and low growth rate of fish; (3) climate change (air and water temperature) which makes fish more susceptible to disease; (4) change in water level and quality (especially during the dry season; (5) increased water pollution; (6) limited number of waterbodies for operating tilapia cage culture; and (7) carrying capacity of tilapia cage culture in natural waterbodies being exceeded.

Therefore, the environmental carrying capacity assessment tool for aquaculture planning in Thailand is urgently needed by the Department of Fisheries. The results of the assessment will help to establish the number of cages that should be allowed for culture in freshwater bodies.

4.2.2 Project site and methodology

The pilot application of the environmental carrying capacity assessment tool for aquaculture planning was conducted for the assessment of carrying capacity of tilapia cage culture in the Noi River, Chainat Province, located in the central part of Thailand. The Noi River, a tributary of the Chao Phraya River, flows through three provinces, namely Chainat, Ang Thong and Ayutthaya and is 155 km long.

Both primary and secondary data were used to assess the results of the pilot application. The secondary data included the boundaries of the river catchment area (Google Earth map), water flow into the river from the dam gates, annual rainfall for the province, population within the catchment area, agriculture production and land use within the catchment area. These secondary data were collected from different offices such as statistics office, land use office, irrigation office, agriculture extension office and meteorological office. The primary data were collected from three sampling stations and included water quality and feed data analysis. A questionnaire was used to collect data about fish culture such as cultured species, sizes of fish, size of cage, stocking density, culture period, feeding, production, number of crop, survival rate, and mortality, etc.

The data were used for model simulation. The main results of the carrying capacity assessment for tilapia cage culture in the Noi River are presented in Table 1.

4.2.3 Success and lessons learned

- DOF staff have learned about a new ECC assessment tool;
- this model seems to be an appropriate tool for cage culture carrying capacity assessment and should be very useful because it is quite easy to use/apply to other rivers;
- to use the results of this assessment for regulation enforcement, a consultation process with the stakeholders/farmers is required because the cages are operated mostly in one or two parts of the river that are close to the water gate;

Table 1 Results of the environmental carrying capacity assessment

Parameters	
Production unit area (cage/pond) m^2	27.5
Production unit depth (m)	2
Average rearing density (ready for harvest) (kg/m^3)	18.02
Fish production per unit (kg)	991.10
Number of production units per farm (ponds/cages)	12
Production per farm per cycle (kg)	11 893
Production per farm per year (kg/yr)	30 366
Maximum environmental capacity (farms)	1 498
Farms per km of river	39.96
Production per km of river (tonnes/year/km)	1 213.30
Assessment results of physical carrying capacity	
Waterbody area/land culture area (m^2)	1 671 750
Allowed square metres of cages	33 435
Allowed number of cages	1 216
Maximum physical carrying capacity (farms)	101

- fisheries biologist/management specialists of DOF are interested in applying this ECCA tool as it is very useful and is an advanced tool that is suitable for monitoring the carrying capacity for cage culture; however, it may need to be adjusted to be more more easily applied with aquaculture practices in Thailand before dissemination; and
- a lot of data are required for this ECCA tool, therefore planning for field data collection, available data compilation and data management should be conducted with many organizations and data sources.

4.2.4 Major concerns about the ECCA tool manual

- regarding the manual and tool, it would be useful to know more on the theory or the principles of how the guidelines of each parameter were developed;
- it is necessary to have a deeper understanding of the following issues: how to use/manage the data that were collected from the field and analysed in the laboratory before inputting into the model because a lot of data were collected, but only a few parameters were used in the model simulation. This would make the assessment more comprehensive;
- about five species are cultured in the Noi River, it is therefore necessary to know how this model can be used for assessment of these five species that are used in the same waterbodies in which tilapia are cultured;
- this is a linear model so there is some doubt (expressed in the national workshop) about whether it is good enough for assessing very complex situations; and
- ECC assessment should be carried out in two different seasons – November to April and from May to October.

4.2.5 Recommendations for wide applications of the ECCA tool

1) Implementers should continue with the following:
   a. data cleaning, data management, data analysis; and
   b. model simulation in different seasons.
2) A technical paper should be written and published so that it can act as a reference for further application by DOF.
3) Support for farmers on the use of the results of assessment should continue – this was requested by the provincial office during the national evaluation workshop as they are the DOF agency for regulating aquaculture (cage culture) implementation.

4.3 Farm level biosecurity plan for tilapia cage culture in the Noi River, Chainat Province

4.3.1 Introduction

The Noi River is one of the three tributaries of the Chao Phraya River. The Noi River branches off from the Chao Phraya River about 5 km south of Chainat Province, running to Ang Thong Province and rejoins the Chao Phraya River at Bangsai, Ayutthaya Province after a run of 170 km through the central flood plains.

Recently, many irrigation projects have been developed in Chainat Province for promotion of agriculture development as well as aquaculture, especially cage culture in the Noi River. Consequently, the freshwater aquaculture has been rapidly developed in Chainat Province because of the water availability and aquaculture technology provided by the Department of Fisheries (DOF) and the number of cages used for fish culture has rapidly increased in recent years. This has led to the occurrence of fish disease because of changes in the environment, high fish density, inappropriate farm management, and the lack of control of fish disease/pathogens.

A farm biosecurity plan is the tool that describes the measures to be put in place to protect farms from diseases. These measures can reduce the risk of damaging diseases entering a farm, they can prevent health issues emerging within a farm, and they can reduce impacts of disease when it does occur. Therefore, the farm level biosecurity planning tool should be piloted and then transferred to farmers – those operating hatcheries and those engaged in the culture of fish – for prevention of fish deaths/disease in this project location.

4.3.2 Objectives

The purposes of the piloted aquaculture biosecurity plan were to:

- develop a biosecurity plan for cage culture farming;
- transfer knowledge to farmers/local fisheries officers by using the biosecurity planning tool developed by FAO; and
- involve cage culture farmers in the project implementation.

The objectives of a farm biosecurity plan are to:

- protect farms from diseases;
- reduce the risk of diseases entering a farm;
- prevent health issues emerging within a farm;
- reduce impacts of disease when it does occur;

- manage emergency disease outbreaks; and
- prevent fish from dying.

4.3.3 Project site and methodology

There are 168 cage culture farms and 2 468 cages in the Noi River located in Chainat Province, and 25 farmers whose tilapia farm size included small-scale, medium-scale, and large-scale farms were targeted. All existing tilapia fish cage culture practices/systems were targeted for project implementation. The project applied the biosecurity planning tools provided by the international experts and translated into the Thai language by national experts. The Thai manual for this study was developed as follows:

1) the FAO manual for developing a farm level biosecurity plan was prepared by an international consultant;
2) it was then translated into Thai by a national consultant;
3) the consultants and project teams explored the cage culture in the Noi River, Chainat Province and information was gathered;
4) a risk analysis for disease was conducted; and
5) a meeting with the local officers was organized to improve the guidelines for use in the area and an implementation plan for the pilot project was developed.

Field implementation of the farm level biosecurity plan tool was as follows:

1) training for the 25 selected farmers was carried out;
2) the biosecurity plan for each farm was adopted;
3) the biosecurity plans were applied to 25 cage culture farms;
4) the implementation of the farm biosecurity plan was monitored for three months with strict record keeping;
5) data processing and analysis were conducted;
6) a national evaluation was conducted;
7) the existing government aquaculture related laws and regulations were reviewed; and
8) the farm biosecurity control tool for tilapia river cage culture in Thailand was reviewed.

4.3.4 Results

The results showed that the farmers had a better understanding about fish diseases and their prevention. Farmers are now checking cages and collecting dead fish from cages daily and no longer throw the dead fish into the river. They have recorded important information such as date, size and number of fish released in each cage, the amount of feed provided and the number of dead fish. However, some farmers are still overfeeding since they believe that more feeding will make the fish grow faster. This causes the accumulation of waste and losses.

In addition, the cage culture in the river is a semi-open farm type. Thus, a biosecurity plan should be developed jointly between cage culture farms in the same river to manage the risk of disease in the area, as a disease in any farm could easily spread and affect the yield of other farms. It aims to reduce the risk of diseases being introduced into a farm and spreading within and outside the farm. Procedures for dealing with disease outbreaks need to be implemented correctly and effectively.

4.4 Review of the existing government aquaculture related laws/regulations

There are new regulations for cage culture in the river. The provincial fisheries commission will declare the province's aquaculture area and determine the conditions for registration. The farms must be registered with the Department of Fisheries. Farm biosecurity planning and the results of this pilot project will be used to determine the conditions for fish farming in the cages and farmers will have to conform to these.

5. Overall lessons learned from the project implementation

1) the piloting of three selected tools (FS, ECCA, biosecurity planning) is a useful approach for aquaculture development and management in Thailand;
2) the piloting of the selected aquaculture planning and management tools in Thailand was successful and can be widely adopted;
3) the three tools can be used to provide technical support to get the necessary data/ information for implementing the new fisheries regulations, especially those related to the aquaculture sector; and
4) the pilot project can help to improve the technical capacity of the fisheries biologists working in the Department of Fisheries. The knowledge and lessons learned from this project implementation can be used for sustainable aquaculture planning and management in Thailand.

6. Recommendations

Recommendations for wide application of the tool

- manual updates based on implementation feedback;
- culture farms should not take fry to nurse;
- a biosecurity plan should be developed jointly between cage culture farms in the same river;
- continue to follow up in the dry season;
- apply the tool to other types of aquaculture; and
- make having a biosafety plan a requirement or condition for acquiring a licence for engaging in cage culture in the rivers that are public waterbodies.

Recomendations on continued FAO support

As this piloting of selected tools for aquaculture planning and management is very useful for aquaculture development and planning in Thailand and other ASEAN member countries, the FAO should continue funding to support further/wider use of the results for implementation at the country level. In addition, there needs to be funding support to organize consultation meetings with farmers (stakeholder meetings) on the use of the results of assessment, etc.

Piloting of aquaculture planning and management tools in Viet Nam

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1. Summary

Viet Nam is one of the world's largest producers, processors and exporters of seafood with a total seafood export turnover in 2017 of USD 8.3 billion. Of the main aquaculture species in Viet Nam, brackish water shrimp is the most important species, contributing about 43 percent of total export value. Brackish water shrimp in Viet Nam has been cultured in 29 coastal provinces with a total farming area of 720 000 hectares and a production of 689 000 tonnes in 2017. The area of black tiger shrimp farming accounts for 80 to 86 percent of the total production and is cultured mainly in the country's mangrove forests. Productivity is very low. Black tiger shrimp farmers are from small households with few opportunities for investment and their farms are highly vulnerable to disease and climate change and other environmental disruptions. These shrimp farmers were therefore targeted to participate in TCP/RAS/3511.

The project has been implemented by FAO since 2016 with many different activities at the regional level. At the national level, Viet Nam officially started project activities from March 2017 and the last activity was completed in November 2017.

This report covers only country level project activities undertaken by the Directorate of Fisheries in Viet Nam under the Letter of Agreement between the Directorate of Fisheries of the Ministry of Agriculture and Rural Development (MARD) of Viet Nam and FAO.

2. Introduction, background and summary of the country level implementation of the project activities

In 2016, Viet Nam nominated four representatives to participate in the FAO inception workshop in Bangkok, Thailand.These were policymakers and researchers with more than ten years of experience working with farmers and developing legal documents. The workshop provided stakeholders with the necessary information to enable them to start national level project activities after the workshop. Based on the FAO fisheries planning and management toolkit, Viet Nam selected three tools which are needed for the improved management of the fisheries sector in Viet Nam: the ECCA tool, feasibility study and biosecurity planning. All three tools were implemented in Hoang Phong, Hoang Chau, and Hoang Phu communes in Hoang Hoa District, Thanh Hoa Province. These three communes are adjacent, encircled by the Ma River and the tributaries of the Ma River, forming a separate area (see Figure 1). Moreover, aquaculture ponds in these areas are concentrated mainly along the river's branches and estuaries in order to take water into the ponds through a gate. Farmers have adopted improved farming and integrated farming methods mostly. The major species cultured here are tiger shrimp, tilapia, mullet, crab, seaweed, etc. Households have set up a cooperative and strictly abide by the regulations of the cooperative. This has facilitated the implementation of the above three tools in Hoang Hoa District.

Figure 1. Site where the three tools were applied

After identifying the planning tools and the location of the project, 11 Vietnamese personnel with knowledge and experience of aquaculture were invited to attend four regional training courses, one on each of the four tools to be implemented in the three countries participating in TCP/RAS/3511. These personnel consisted of three national experts, six technicians who would assist in the implementation of the three tools selected for Viet Nam and the two technicians who attended the regional training workshop on the traceability tool. This is the source staff for effective implementation of the project in Viet Nam.

3. Country level project activities and results achieved

3.1 Activity 1. National inception workshop

The workshop aimed to: (a) introduce the project: objectives, contents, implementation schedule, responsibilities of stakeholders; and (b) introduce the three tools to be implemented in Viet Nam.

It was held in Thanh Hoa Province on 17 March 2017.

There was a total of 30 participants (including organizers) from the Directorate of Fisheries (D-Fish), Thanh Hoa Provincial Department of Agriculture and Rural Development, the People's Committee of Hoang Hoa District, the cooperatives of Hoang Chau Commune and Hoang Phong Commune, the Vietnam Institute of Fisheries Economics and Planning, the Department of Aquaculture, the Department of Science Technology and International Cooperation, and stakeholders from Hoang Chau Commune, Hoang Phong Commune and Hoang Phu Commune.

In this workshop, there were four presentations followed by discussions and in the afternoon the participants and the project team discussed how to implement project activities in the field. Key discussion results are as follows:

- For ECCA tool and aquaculture project feasibility tool: national consultants and technical staff will be in charge of collecting and analysing data, compiling a report, collecting data with the support of farmers and correcting data as well.

- The international consultant and national consultants should concentrate on developing a guideline document that helps farmers understand and apply biosecurity planning at farm level easily to ensure food safety, prevent disease and maintain environmental integrity. In addition, in order to prepare an efficient training document, all Vietnamese biosecurity material should be reviewed to make a proper document for farmers.
- Cooperatives also play an important role not only to organize input services for its members such as provision of seed, chemical supply, sign contracts and arrange the sale of raw products with middlemen or companies but also require all members to apply the same Good Aquaculture Practices. Farmers invest proper resources (budget, labour etc.) but get excellent benefits. The big challenges are how to introduce farmers to biosecurity planning to help them to understand it and adapt their farming practices, especially, the detailed recording of data, which is not generally practiced.
- National consultants on the three tools should compile a list of the required data to make it easier and more convenient for farmers to obtain them.

Workshop results:

- a consensus between farmers, local authority and project activities personnel was achieved on responsibility, obligation, and benefit for relevant parties during implementation of project activities;
- the head of the cooperative agreed to select suitable farmers to join in the activities;
- basic general information was gathered for making an implementation plan; and
- local farmers and the local authority agreed on the expected timetable and implementation plan.

3.2 Activity 2. Training farmers in Hoang Hoa District on biosecurity

The training course aimed to: (a) provide knowledge to help farmers understand biosecurity; (b) identify hazards that threaten biosecurity in the field; and (c) exchange basic information about farming areas and farms. It was held on 2-3 April 2017 in Thanh Hoa Province.

Thirty participants comprising shrimp farmers in three communes (Hoang Chau, Hoang Phong, Hoang Phu) including cooperative members attended the training course.

The training course documents were prepared by the international consultant (Mr Ramesh P Perera) and the national consultant (Mr Le Quang Hung).

Based on the biosecurity knowledge that was disseminated by various lecturers, the participants practiced identifying risks and hazards that could threaten biosecurity in the farm of Mr Truong Van Mien (Hoang Chau Commune) and Mr Luong Huu Binh (Hoang Phong Commune).

Results of the training course:

- participants developed an understanding of biosecurity hazards and how to control these (e.g. with respect to fingerlings, water);
- participants promised to apply biosecurity planning on their farms; and
- participants promised to record all data relevant to biosecurity planning on their farms.

3.3 Activities 3 and 4. Managers at central and provincial level trained on ECCA and aquaculture project feasibility tool

Two training courses were aimed to: (a) provide an overview of the ECCA and project feasibility tool; (b) instruct the participants in data collection and data entry; and (c) instruct the participants in data analysis. The first training course was held on 24-25 March 2017 for ECCA and the second on 26-27 March 2017 for the feasibility study tool. Both were held in the city of Ha Noi by the international consultant Mr Patrick White and two national consultants Mrs Cao Le Quyen and Mrs Tran Thi Tuyet Lan.

A total of 26 participants from Aquaculture Research Institute No. 1, No. 2 and No. 3, the Research Institute on Marine Fisheries, Vietnam Agriculture University, various departments of MARD, and the Fisheries College attended the ECCA training course and 18 participants from the same institutions attended the feasibility study training course.

The international consultant (Mr Patrick White) and the national consultants (Mrs Cao Le Quyen for ECCA and Mrs Tran Thi Tuyet Lan) prepared the training documents and worksheets for the project feasibility tool.

Results of the training course:

- Participants developed an understanding of ECCA and the feasibility study tool, and learned how to collect data, decide what data should be analysed and how to analyse the data.
- Participants were able to simulate some different models and practice them.

3.4 Activity 5. Survey and analyse data for ECCA

From May to August 2017, the project team including the national consultant and technical staff collected information in the field for piloting the ECCA tool. They collected background data on water quality, waterbody and river catchment area, population, livestock and land use, nutrient extraction, estimated areas cultivating mangrove and seaweed and calculated water exchange.

Results:

- 45 farmers were interviewed for the ECCA tool;
- 34 samples were taken and tested (total N, total P, water flow velocity etc.).
- Aquaculture in the study site is characterized by extensive integrated aquaculture farming: tiger shrimp with mullet fish, tilapia, crab and seaweed with an average productivity of 0.5 to 0.7 tonnes of shrimp, fish and crab per hectare. With total island aquaculture farming areas of 364 hectares and 1.5 crops produced per year (one main crop and one extra crop), the current average annual aquaculture production of the island is from 273 tonnes to 382 tonnes per year.
- The water for aquaculture farming in the study site (Con Truong Island) is supplied from the small Cung River and the large Ma River. Therefore, for easy ECC calculation, the Con Truong Island (studied site) is divided into two parts (the north zone with water supply from the small Cung River and the south zone with water supply from the large Ma River). The ecological carrying capacity of Con Truong Island considered both sustainable environmental carrying capacity and physical carrying capacity of the north zone and the south zone. With the calculated environmental carrying capacity and physical carrying capacity of each zone, the smaller value among the environmental and physical carrying capacities of each zone is taken as the ecological carrying capacity for the zone following the precautionary principle.

The results of the study show that the total sustainable environmental carrying capacity of the study site is 1 520 tonnes/year (including: 248 tonnes/year for the north zone + 1 272 tonnes/year for the south zone). The physical carrying capacity of the study site is 945 tonnes/year (including: 695 tonnes/year for the north zone + 250 tonnes/year for the south zone). Applying the precautionary principle, the ecological carrying capacity of the north zone of the study site is limited by the environmental carrying capacity (248 tonnes/year) and the environmental carrying capacity of the south zone of the study site is limited by the physical carrying capacity (250 tonnes/year). Thus, the ecological carrying capacity of the entire study site is about 500 tonnes per year (248 + 250 = 498 tonnes per year).

Implications:

(1) With the estimated ecological carrying capacity of about 500 tonnes per year from the study, the present aquaculture production can still increase significantly and be sustainable in the study area.

However, the aquaculture development in the study island of Con Truong is currently impacted by infrequent waste water discharge from the nearby sluice of Quang Chau. This sluice discharge waste water is from the upper catchment areas of Thanh Hoa City and nearby agriculture and residential areas. The sudden discharge of the sluice will make the river water quality polluted and adversely impact the aquaculture activities on the island. Therefore, better coordination between the sluice management board and the local aquaculture association should be strengthened to reduce negative impacts from waste water discharge from the sluice. Furthermore, as the seaweed farming density and mangrove areas in and around the island are still scattered, the expansion of seaweed farming in aquaculture ponds in the island and better management of mangrove forests around the island are also good and necessary measures to improve water quality on the island. Mangrove forests are also good for protecting pond dykes and farmed species on the island from storm and strong sea surges from the sea.

(2) From the ECC calculated above, the ecological sustainable aquaculture production that could be undertaken in the waterbody on the island is about 500 tonnes per year and about 270 ponds with an average size of 1 hectare per pond could be developed in the area.

In order to limit or control aquaculture development on the island, farm registration, farm production monitoring and water quality monitoring measures should be performed by the Management Board of Hoang Chau Aquaculture Association. With their representatives elected by all association members, they can implement those measures to control sustainable aquaculture development. Local commune authorities should also support them to fulfill these tasks.

3.5 Activity 6. Survey and data analysis for feasibility study

From May to August 2017, the project team including the national consultant and technical staff implemented the feasibility study tool in the field. A total of 40 farmers were interviewed, including 30 semi-extensive polyculture households in Hoang Phong Commune (monodon shrimp + mud crap; monodon + mud crap + tilapia; monodon shrimp + mud crap + tilapia + greasy back shrimp) and ten intensive shrimp culture households in Hoang Phu Commune, Hoang Hoa District, Thanh Hoa Province.

Data collected:

- production related: species cultured, culture system area, stocking size, initial stocking density, survival during culture, FCR, production, harvesting size, market price, length of culture period (in months), feed type, price per bag;

- capital cost: start-up cost, production facility costs, production equipment costs, depreciation costs; and
- operating costs.

Results:

- For the model of monodon shrimp + mud crap: NPV is USD 60 235 in the tenth year and IRR is 76 percent, capital return after the third year.
- For the model of monodon shrimp + mud crap + tilapia: NPV is USD 17 500 in the tenth year and IRR is 45.7 percent, capital return after the first crop in the fourth year.
- For the model of monodon shrimp + mud crap + tilapia + greasy back shrimp: NPV is USD 17 500 in the tenth year and IRR is 41 percent, capital return after the first crop in the fourth year.
- For the intensive model of vanamei shrimp: NPV is USD 190 325 in the tenth year and IRR is 83.5 percent, capital return after the first crop in the third year.

3.6 Activity 7. Farm level biosecurity plan for semi-extensive farming of tiger shrimp in Hoang Hoa District

3.6.1 Introduction

Although farmers understand the need for and the benefits of improving aquaculture productivity, economic development and increasing the income from aquaculture, they do not really know enough about the source of water on their farms and about the quality of the shrimp they are farming – knowledge of specific pathogen free (SPF) shrimp and shrimp seed quarantine is not high enough, and polluted water sources and pollution in the waterbodies where shrimp are cultured have affected productivity and product quality. Therefore, there is a need for assistance regarding suitable farming practices that can help local farmers reduce production risks, while sustainably increasing their incomes. Semi-extensive small-scale tiger shrimp farming was introduced in Hoang Chau Commune and Hoang Phong Commune, Hoang Hoa District, Thanh Hoa Province and these areas were selected as the location for aquaculture farm level biosecurity (AFLB) planning.

Aquaculture farm level biosecurity plans involve farm design and operational procedures aimed at minimizing the risk of an outbreak of disease and its spread.

3.6.2 Objectives

The objectives were as follows:

- to implement and monitor the pilot application of AFLB tool in Viet Nam;
- to introduce management with the participation of local farmers by using the biosecurity planning tool developed by FAO through the participatory approach and management of the biosecurity shrimp culture;
- to minimize the outbreak and spread of tiger shrimp diseases;
- to reduce the hazard of shrimp disease culture; and
- to control risks.

3.6.3 Project site and methodology

Small-scale, semi-extensive and integrated farming of tiger shrimp in Hoang Chau Commune and Hoang Phong Commune were selected as the location for aquaculture farm level biosecurity. The farmers of the aquaculture cooperative in Hoang Phong Commune and the aquaculture association

in Hoang Chau Commune, Hoang Hoa District, Thanh Hoa Province were invited to participate and were trained in the use of the tool. Prior to the training, the working group translated the tool manual and training material on aquaculture farm level biosecurity developed by the international consultants into Vietnamese, prepared training workshops, including technical presentations.

A training course and workshop on the farm biosecurity tool was provided for the 25 aquaculture farmers in Hoang Phong Commune and Hoang Chau Commune who agreed to participate in the project. The training course introduced the aquaculture farm level biosecurity tool and explained its significance and benefits. It also dealt with hazard identification and risk assessment, including identifying current risk and risk management. The training course also provided a checklist of all the steps to assess the effectiveness of the biosecurity plan.

Field trips to the ponds of farmers in Hoang Phong Commune and Hoang Chau Commune were organized to implement and monitor the pilot application of the aquaculture farm level biosecurity tool.

The status of aquaculture in the research areas was surveyed by means of a questionnaire and this included: shrimp species cultured, the shrimp culture cycle, farming areas, type of culture, feed quality and regime. Observations of each farm were also made.

3.6.4 Results and recomendations

The farmers are now aware of the importance of farm level biosecurity in aquaculture facilities through the guidance of experts and they have an understanding of the need to identify, analyse and assess hazards and have solutions to implement a biosecurity plan in their aquaculture establishments. The most important requirements to achieve biosecurity are:

- purchasing shrimp/post larvae from a producer selling specific pathogen free (SPF) seed;
- recording data in the shrimp diary book;
- knowing the pathway-transmission way of disease; and
- following standard operating procedures for responding to disease events.

A technical centre should be established where farmers can come and learn from each other and exchange experiences.

Shrimp farming areas that are vulnerable to disease outbreaks should be identified and targeted for the implementation of safe aquaculture zones.

A national activity of great benefit could be the identification, mapping and characterization of shrimp diseases the farmers are likely to face in Viet Nam.

An inventory of shrimp diseases in Viet Nam should be made in the short and long term.

3.7 Activity 8. Country evaluation workshop

A project evaluation workshop was organized in Ha Noi with 38 participants and chaired by the Deputy Director of the Directorate of Fisheries. Participants were representatives of policymakers at central level and local level, researchers, FAO Ha Noi and 22 farmers who took part in the piloting of the tool. In this workshop, four presentations on the results of the piloting were presented by the national coordinator and the national consultants. The participants discussed the results and made recommendations for further activities.

Recommendations:

- The tools should be piloted/implemented simultaneously in order to have a stronger and clearer final decision regarding investment in aquaculture projects.
- The ECCA and feasibility tools are quite difficult to use but very important in planning, so worksheets should be simplified to make them more efficient and feasible for a variety of farming types.
- The tools should be applied in at least three areas that are representative of a region, technology, species and farming types (pond, cage, open sea).

3.8 Conclusions

- All project activities have been completed in accordance with the approved proposal or signed TOR.
- The three selected tools play an important role in improving planning in Viet Nam, so FAO's support has been very valuable to the country.
- It has been confirmed that shrimp farmers in Thanh Hoa Province are going to continue to practise the biosecurity design tool in their farms after the project activities are completed.

4. Success and lesson learned from the country implementation of the project

4.1 Lesson learned: apply three tools in same place

The project has selected and successfully piloted three tools at the same site and at the same time. The implementation at the same site helped the project team to share information and cross-check the accuracy of the information. In order to be able to assess the ECC, the team collected and analysed information, including socio-economic information, for three consecutive years. In order to obtain valuable and accurate information, the involvement of local authorities at the beginning such as the District Department of Agriculture and the People's Committees at District and Commune level was very important. As the participants were invited to the relevant project meetings, the project activities team and local authorities easily agreed and shared the information needed for the assessment of the ECC and feasibility study.

The three tools selected by the Vietnamese side complement each other as the primary and secondary data were collected in the same location (Hoang Chau, Hoang Phong, Hoang Cat Communes of Hoang Hoa District, Thanh Hoa Province) and were mutually beneficial. The results showed that with respect to piloting the implementation of the biosecurity system design tool the farming of black tiger shrimp with fish and seaweed had limited disease outbreak. This was attributed to the cleaning of the watershed area and the fact that farmers shared information with respect to the discharge of water from culture ponds. Regarding the feasibility tool, if they continuously maintain the farming method, and ensure biosafety, they will get profit after three to five years depending on the level of investment. The assessment of the ECC suggests that farmers can double the stocking density to increase productivity without exceeding the environmental carrying capacity.

4.2 Application of the biosecurity planning tool over a large area

Biosecurity planning is an effective tool for controlling pathogens that are harmful for farmed fisheries commodities. Given the extensive nature of tiger shrimp farming in Viet Nam, the

application of the biosecurity design tool is only effective when applied on a large scale and fish ponds' banks are adjacent and use the same water supply and water discharge channels. The tool is not practical if applied only to a single household.

However, in the case of *Penaeus vannamei* shrimp culture in closed and separate farming, the biosafety design tool will be ineffective.

5. Strategy to support wide application of aquaculture planning and management tools

- In the workplan of the Directorate of Fisheries 2017, it is expected that six training courses will be organized with five days for each and the training contents will include three selected tools.
- The Vietnamese manual on biosecurity planning will be translated, refined and disseminated to shrimp farmers in other provinces.
- Vietnam Institute of Fisheries and Economic Planning (VIFEP) will apply ECCA and the feasibility study tools in their work with the support from the Department of Science Technology and the Department of International Cooperation.

6. Recommendations on the continuing effort of FAO to support the member countries to improve planning and management for sustainable growth of aquaculture

- Consider further refining the ECCA tool because the worksheet lacks some input data related to risk.
- Consider further refining the aquaculture project feasibility tool by adding some parameters in the worksheet in the case of polyculture.
- We expect that FAO will have a plan to implement other relevant tools not covered here, and suggest a focus on site selection and zoning for marine (cage), inland aquaculture, and an emergency disease response tool.
- Ecological footprint is quite a new concept in Viet Nam so we hope FAO will consider developing a project on this issue.

PART III

Aquaculture planning and management tool manuals

Tool manual 1:
Aquaculture environment carrying capacity assessment

Guidelines for undertaking environmental carrying capacity studies for aquaculture projects

By

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1. Background

Carrying capacity is an important concept for ecosystem-based management. It helps set the upper limits of aquaculture production given the environmental limits and social acceptability of aquaculture, thus avoiding "unacceptable change" to both the natural ecosystem and a community's social functions and structures.

Four types of carrying capacity have been identified (Inglis, Hayden and Ross, 2000):

- ***Physical carrying capacity*** is based on the physical factors of the environment and the farming system.
- ***Production carrying capacity*** estimates the maximum aquaculture production and is typically considered at the farm scale.
- ***Ecological carrying capacity*** estimates the level of aquaculture production that can be supported without leading to significant changes to ecological processes, services, species, populations or communities in the environment. This is covered in this tool.
- ***Social carrying capacity*** evaluates the amount of aquaculture that can be developed without adverse social impacts. This is covered by this tool and the socio-economic impact assessment tool.

Carrying capacity estimation

Before aquaculture is established in a certain area, the carrying capacity should be estimated using appropriate models together with representative observational data from the area and water quality standards or criteria as well as other environmental quality standards in force. To estimate the carrying capacity it is necessary to develop reliable, objective methods or predictive models for estimating the response of both the environment and the farmed stock to farming. Using such models together with field observations from a specified locality and the quality standards in force, the carrying capacity for the locality can be estimated.

Carrying capacity estimation should be undertaken at the planning stage before aquaculture is established in a certain area or location. It is normally undertaken to set the maximum sustainable production that has no unacceptable impacts on the environment and no significant conflicts with other stakeholders. The tool can be used by the regulator to set maximum production limits as part of the licencing procedure or by the developer to be able to plan the maximum production at a farm.

The assessment of ecological carrying capacity uses the assimilative capacity approach that considers the maintenance of a healthy environment in relation to its ability to deal with inputs of waste wherever they arise. The important fish farming waste components are nutrients, particulates and associated potential biochemical oxygen demand (BOD) resulting from the metabolism of fish food, and residues of chemicals used to treat diseases or parasites. It is also important to consider waste such as sewage discharges and diffuse inputs from agriculture and forestry.

Ecological carrying capacity of an area depends on tidal flushing and the current and assimilative capacity of the waterbody with regards to pollutants. Overall and specific assessment of the environmental capacity for the ecosystem (upland, estuary, near-shore), and for individual aquaculture systems (pond, cage, raft, pen) respectively with different rates of intensification is necessary for estimating carrying capacity to ensure sustainable and environment-friendly aquaculture.

With the rapid unplanned expansion of coastal aquaculture in the tropics, especially with a high level of intensification based on a high level of inputs, especially feed, the industry has faced several crashes in recent years in different countries of Asia and South America. These crashes have occurred mainly as a result of the overexpansion of aquaculture which has exceeded the carrying capacity. This overexploitation of natural resources in combination with the problem of industrial pollutants has resulted in severely polluted environments and the devastation of the aquaculture industry.

Environmental impacts of aquaculture

The environmental and social impacts of aquaculture are primarily:

Biological impacts

- dissolved nutrients – excretion of dissolved nutrients that can lead to localized eutrophication of waterbodies;
- particulate nutrients – faeces and waste food settling on the seabed or pond floor causing changes in the water column because of dissolution and in the sediment (oxygen depletion and extinction of benthic living species);
- chemical impact – antifoulants on boats and fish cage nets and medications and treatments;
- escapes – causing changes in the genetypes of wild fish populations and biodiversity;
- sensitive habitats – smothering of corals, seagrasses, conversion of mangrove areas into shrimp ponds, etc.;
- sensitive species – impacts to turtle breeding beaches, etc.;
- the use of "trash fish" to feed fish specially in Asia, increasing pressure on coastal fisheries for aquaculture feed; and
- increasing use of wild larvae for shrimp culture, which is booming again in some countries in the region.

Social impacts

- social impacts: conflicts with local community, fishermen, other users of the coastal or aquatic resource;
- visual/scenic impact that may pose a problem for tourism; and
- positive impact from providing livelihoods, quality protein and increased fisheries.

Physical impacts

- physical structures such as cages, pens, ponds, jetties constructed along the coast pose a threat to maritime traffic; and
- changes in water flow and volume (e.g. arising from net friction to water exchange).

Impacts from nutrients

Environmental impacts can cover a range of factors such as nutrients, genetics, chemicals, diseases, invasive species, etc. The following aquaculture polluting outputs are considered including release of nutrients, diseases, medications, chemicals and escapees.

The metabolic activity involved in converting fish feed to fish flesh produces nutrient waste products such as suspended solids and dissolved nutrients.

In a fish farm, suspended solids and dissolved nutrients originate from:

- uneaten feed;
- fish metabolism producing faeces and pseudofaeces in the case of filter feeders; and
- solids carried into the farm with the flow from the external water source; and
- growth of micro-algae and bacteria.

Nutrients are added in the form of fertilizers and feed to culture systems as well as juveniles that are stocked, but not all the nutrients are absorbed by the growing fish or shrimp. Soluble nutrients coming from the digestion processes will dissolve in the water column, and their initial dilution and transport is a function of water current dynamics. Solid waste made up of uneaten feed pellets, feed fines (fine particulates caused by pellet damage during transport or by automatic feeding systems) and faecal material can also accumulate below culture cages and in the outflows of aquaculture facilities. The material also dissolves in the water column directly affecting water quality. The accumulation on the bottom will also depend on the local currents and depth. There is some benthic flux where organic material is decomposed and nutrients are released back into the water column from the sediments. A typical nutrient balance for fish cage farm is given in Figure 1.

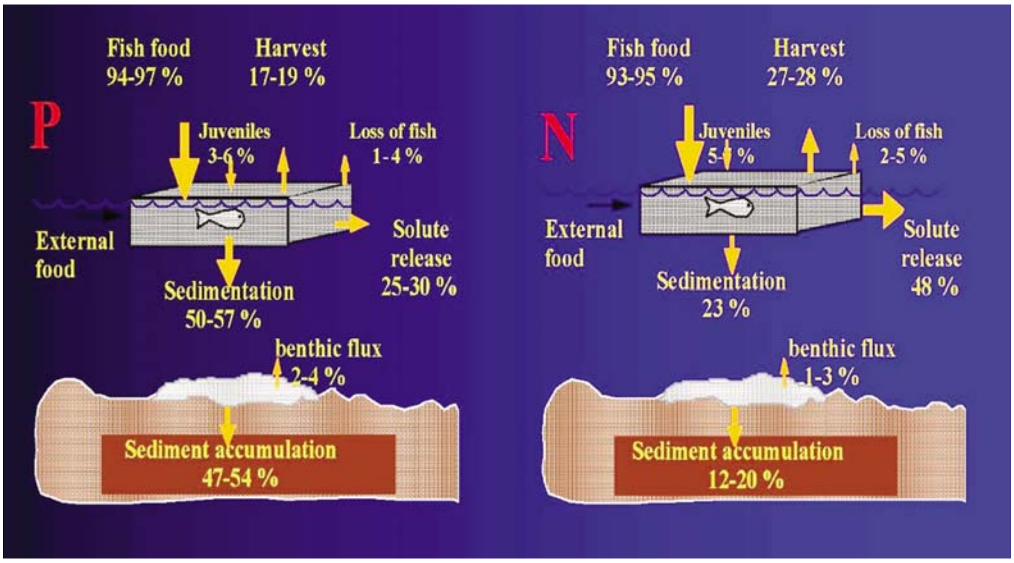

Figure 1. Nutrient balance from cage farming

Source: Holby and Hall, 1991

Whether a nutrient becomes a pollutant in an aquatic system is a function of whether it is a limiting nutrient in each environment, its concentration and the carrying capacity of that ecosystem. In fresh waters, phosphorus (P) is typically the limiting nutrient, so its addition will dictate the amount of primary production (algal growth). In open water marine environments, nitrogen (N) is typically the limiting nutrient, so its addition will do likewise. However, in coastal seas phosphorus is the limiting nutrient most of the time, followed by nitrogen and finally silica.

Nutrient impacts (N, P and C outputs) can lead to:

- **impacts on the water column** leading to eutrophication or algal blooms that reduce water clarity (and consequently sunlight availability in the water column to other organisms), and can strip oxygen from the water column when the organisms die, sink and decompose; and

- **impacts on the sediment** leading to changes in the benthic community or even anoxic sediments. Nutrients can also impact by smothering benthic (e.g. seagrasses) and other sensitive habitats (e.g. corals) close to the farm.

2. Carrying capacity

Each ecosystem has a different capacity to absorb and assimilate excess loading of organic compounds and nutrients from a farm or capacity to absorb social changes, habitat modifications, etc. that come with the farm. Therefore, aquaculture production facilities should adjust their production to the carrying capacity of the relevant waterbody and socio-economic system. Carrying capacity estimation is undertaken as part of the aquaculture zoning and/or licencing of farms.

Carrying capacity is typically undertaken using depositional models (particle tracking) that predict the particulate outputs from fish cage aquaculture. These can be used in local scale assessment of the effects of fish cages on the organic footprint and thus the impact on the sediment and sensitive demersal flora and fauna. Particle tracking models use either the output from a spatially explicit hydrodynamic model or direct current measurements to predict (organic) flux from culture sites to the bottom. At the local scale, screening models may be used to look at aquaculture yields, local impacts of fish farming, and water quality. Government planning departments need to have the capacity to undertake carrying capacity estimations or have access to specialists who can make the calculations. In this way informed decisions can be made of the sustainable production in aquaculture areas.

Carrying capacity estimation sets the upper limits of aquaculture production given the environmental limits and social acceptability of aquaculture, thus avoiding "unacceptable change" to both the natural ecosystem and the social functions and structures of a community.

The tool is intended for the regulators to ensure sustainable planning of aquaculture development. The tool is also useful for other users as follows:

- **aquaculture regulators** – to set the maximum limits to aquaculture production within a certain zone or site;
- **farm developers** – to determine the maximum sustainable size of a farm;
- **farm managers** – to know the limits of acceptable environmental impact at the farm level; and
- **coastal zone managers** – to be able to estimate the cumulative aquaculture production along the coast.

3. Estimate of effects/consequences at local and broader scale (e.g. watershed)

Calculating the nutrient input to waterbodies from aquaculture is part of the calculation for sustainable aquaculture carrying capacity within the waterbody. Carrying capacity can be estimated at the farm level and is sometimes used to limit the size of a production licence granted for example in Scotland and Norway or on a broader scale such as a lake, bay or watershed. Nutrient impact in marine waters tends to be localized and is quickly diluted by tidal flushing compared with fresh water culture systems, where impacts can be on the waterbody as a whole and where there is a relatively long water residence time, e.g. dams and lakes.

The table below summarizes the key pollutants, the level of the nutrient impact and the scales at which the impacts occur.

Table 1. Estimated scale of impact from P and N

Culture system/species	Key pollutant	Nutrient impact	Local scale	Medium scale	Wide scale
Seaweed culture		+++	+++	++	+
Bivalve culture		+++	+++	++	+
Small-scale freshwater fish cage culture	P	- -	- -	-	
Multiple small-scale freshwater farms	P	- - -	- - -	--	-
Small-scale marine fish cage culture	N	-			
Multiple small-scale marine fish cage farms	N	- - -	- - -	-	
Industrial marine fish cage culture	N	- - -	- - -	-	
Freshwater fish pond culture	P	- -	- -	-	
Shrimp pond culture	N	- -	-		

Note: + positive impact; - negative impact

Factors influencing level of ecological impact

There are a number of factors affecting the level of impact from aquaculture mainly as a result of the intensity of production, the species being cultured, the culture system, and the planning and management of the farms.

Fed or fertilized aquaculture

This refers to aquaculture that involves the addition of feed or fertilizer, for example fish farmed in cages and shrimp farmed in ponds. With this type of aquaculture nutrients are added to the culture system in the form of feed or fertilizer. These nutrients are not fully utilized by the production and the remaining nutrients are added into the water system. Because of the continued intensification of aquaculture (higher productivity per unit area) where feeds are given, the share of fed species in total farmed food fish production increased further from 66.5 percent in 2010 to 69.2 percent in 2012. This trend is expected to continue resulting in increased nutrient release to the environment. However, with improved management of the feeding, increased production is possible without significantly increasing waste and while minimizing environmental impacts.

Extractive aquaculture

This refers to aquaculture of species that are not fed but extract nutrients from the environment such as extensive culture of finfish, seaweed and mollusc culture. In 2012, global production of non-fed species from aquaculture was 20.5 million tonnes, including 7.1 million tonnes of filter-feeding carps and 13.4 million tonnes of bivalves and the harvesting of 23.8 million tonnes (wet weight) of aquatic plants. China and Indonesia dominate seaweed production accounting for 81.4 percent of the total. World production of farmed seaweeds more than doubled from 2000 to 2012 however, non-fed aquaculture remains lower than fed aquaculture.

Open aquaculture

This refers to aquaculture systems that are open systems such as pen or cage culture of fish where water passes freely through the cage nets and unused nutrients are released directly into the waterbody with the distribution of the nutrients highly influenced by the hydrodynamics of the site location.

Semi-closed aquaculture

This refers to aquaculture systems that are semi-closed such as fish and shrimp pond culture. In pond culture much of the excess nutrients is either utilized by primary production and is subsequently eaten by the fish or accumulates on the pond bottom as sediments. However, nutrients are only released into the environment during water exchange and at harvest time when pond water effluent is released to the environment as a point source release into the river, estuary or sea.

As the trend in aquaculture development is to produce more intensively and produce in open culture systems such as fish cage culture, there is a move from low waste nutrient output systems to higher waste nutrient output systems that the environment needs to assimilate.

At the farm level, the production rate of dissolved and suspended solids within a fish farm is affected by a range of factors, including feed quality, feeding rate, feeding method, water exchange rate, pond and tank hydrology, fish stocking density, dissolved oxygen level, efficiency of farm management and the skills of personnel. Climatic factors can also influence appetite and feeding rate through changes in temperature (especially extreme temperatures), heavy rainfall affecting water pH and salinity, etc. Climate change therefore could affect the efficiency of nutrient uptake in the future.

Different culture systems will need to use different carrying capacity prediction models. This primarily depends on whether there are significant nutrient inputs (feed or fertilizer) as part of the culture process and whether the water supply is open (cages) or partially closed (ponds).

Pond culture

A large amount of nutrients and chemicals is contributed to the environment from pond aquaculture, which varies according to culture intensity, level of feed and fertilizer use and species cultured. Dissolved material from farm effluents are mixed with the water column whereas the largest proportion of solid wastes is accumulated on the pond bottom or in the immediate vicinity of the farm. When compared with phosphorus, a greater amount and proportion of discharged nitrogen remains in the water, most of which is accumulated in the sediment.

Typically ponds have a pulsed waste discharge if exchange is tidal or pumped and reaches its peak during harvesting and cleaning.

Cage culture

Conventional cage design does not permit treatment of wastes before their discharge to the sea. Cage fish farming thus relies on natural dilution and degradation to assimilate its wastes. The capacity of the environment to assimilate waste is limited by the hydrodynamic characteristics of the recipient waterbodies. A precautionary approach is normally advocated using a predictive model to highlight areas where the natural capacity to assimilate additional nutrient load and particulate organic matter adequately may be most at risk. The modelling assumes that increases in natural concentrations of nutrients and the impact of organic matter may be estimated by comparison of such inputs to available residual and tidally-driven dilution in the recipient waters.

Major changes occur in the community structure of benthic fauna beneath the cages. With the increase of pollutants, faunal dominance changes from molluscs to polychaetes.

4. Mass balance model

The mass balance model provides users with an aggregated view of the processes in the pond from feed application, shrimp production and water quality effects. These vary according to the inputs provided, allowing users to stress test different conditions.

The main drivers are

- feed application and food eaten;
- feed conversion ratio (FCR);
- fish/shrimp production;
- faeces, waste food and organic deposits; and
- nitrogen availability (for marine waters) and phosphorus availability (for freshwaters) and algal growth.

These guidelines contain instructions on using a programme to calculate carrying capacity of fish in defined waterbodies. Nutrients in waterbodies limit phytoplankton growth. Depending on the amount of nutrients present in the waterbody, phytoplankton species will grow to a maximum possible density reducing the concentration of nutrients to the minimum. Initially, there is a small number of phytoplankton cells, but when a large quantity of nutrients enters the water column, phytoplankton cells rapidly accumulate existing nutrients and divide into more cells. These new cells continue to take up existing nutrients in the water column and divide. Finally, when phytoplankton density reaches a maximum, there are many more phytoplankton cells that cannot reproduce anymore because the water column has been depleted of nutrients. This is the time of maximum phytoplankton "bloom".

The massive quantity of phytoplankton cells exists in the water column for at least two more weeks. After that, they release a huge quantity of organic matter that sinks as phytodetritus ready for decomposition. The decomposition of organic matter causes hypoxia in the waterbody. The intensity of hypoxia may be related to the density of phytoplankton during a bloom. Hence, by limiting nutrient inflow, one limits fish culture since fish emit nutrients into the water column. Consequently, the carrying capacity for fish culture can be computed.

5. Legović carrying capacity model

Legović and colleagues developed a model to estimate the ecological carrying capacity of waterbodies based on nutrient inputs from aquaculture, other sources and flushing rate (Legović *et al*., 2008). The model calculates the risk of algal blooms and hypoxia. It was applied to three different areas of the Philippines – Bolinao (a marine site), Dagupan (a brackish water site) and Taal Lake (a freshwater site). The ecological carrying capacity for fish aquaculture is estimated based on arriving at the critical phytoplankton concentration.

Calculations were made for the discharge of nutrients from aquaculture and estimates are made for the discharge of nutrients from other sources. The quantity of biomass is theoretically increased (or decreased) until critical phytoplankton concentration is reached. This quantity of fish stock will define the carrying capacity of the waterbody for a given species of fish.

The model calculates carrying capacity in three steps.

1. Identifying the characteristics of a waterbody. How quickly is water being exchanged with neighbouring water where fish is not grown? What are the intensities and locations of other nutrient sources that enter the waterbody under consideration? Since fish is usually

grown close to the coast, the impact of other nutrient sources may be considerable and may cause smaller carrying capacity for fish grown in aquaculture systems.

2. Considering how phytoplankton is grown and what concentration it is able to reach with given nutrient sources. This gives the remaining concentration of phytoplankton that may be reached by increasing aquaculture size.
3. Increasing fish stock until critical phytoplankton concentration is reached. So the obtained fish stock will define the carrying capacity of the waterbody for a given species of fish (Figure 2).

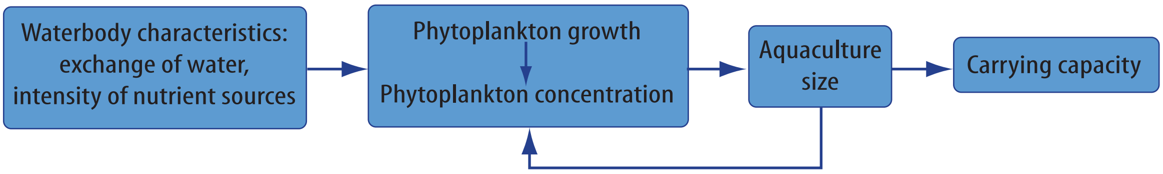

Figure 2. The minimum scheme of determining carrying capacity for fish aquaculture

Note: This is based on arriving at the critical phytoplankton concentration that, upon decomposition, induces detrimental hypoxia.

6. Estimating nutrient inputs

The carrying capacity tool is based on estimating nutrient inputs to a fish aquaculture system and the mass balance box model.

Ambient water nutrient exchange

Ambient water nutrient exchange provides inputs and outputs of nutrients.

- **Water exchange**. These are the nutrients that enter and exit the waterbody through tidal and residual exchange in the case of marine waters or rainfall in the catchment area in the case of fresh waterbodies.
- **Terrestrial environment**. These are the nutrients entering the waterbody from fresh water runoff such as agriculture, livestock production or domestic waste.

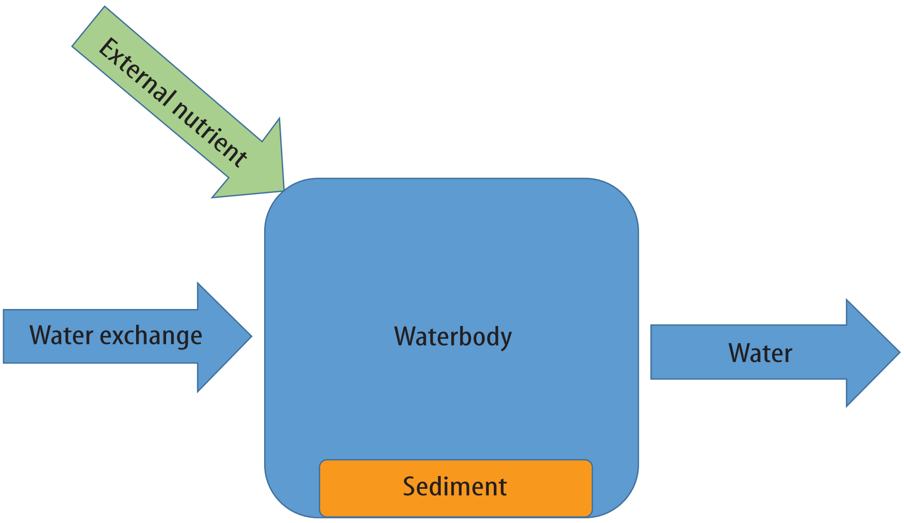

Figure 3. Pathways of nutrients exchange in a waterbody without aquaculture

In a waterbody without aquaculture a natural nutrient concentration will be present with changes during the year depending on the season (rainy or dry).

In a waterbody with aquaculture, there is an additional nutrient source that will increase nutrient loading in the form of dissolved nutrients and suspended solids.

- **Aquaculture production**. These are the nutrients that enter the aquaculture system as feed. Whereas some nutrients are utilized by the fish for growth, the remaining nutrients enter the aquatic environment as dissolved nutrients (from fish excretion) and suspended solids (faeces and uneaten food).

The result of the interaction of all the nutrient inputs and outputs leads to the development of a nutrient concentration that can be measured in the waterbody.

If the dissolved nutrient concentration is over a threshold level, then there is an increased risk of an algal bloom and so the carrying capacity is deemed to have passed the ecological carrying capacity.

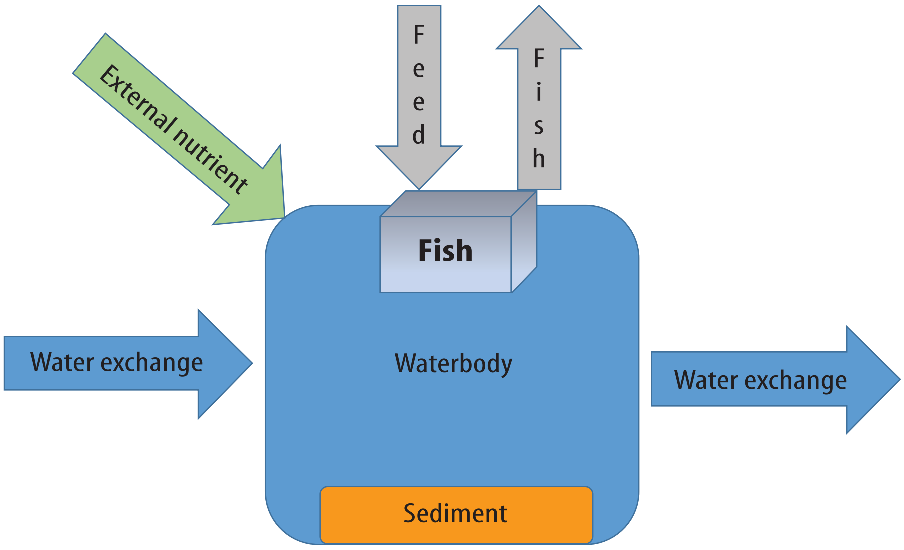

Figure 4. Pathways of inflows and outflows of nutrients into a waterbody with fish aquaculture

The carrying capacity model therefore has five components that try to estimate and present the level of aquaculture production that can be sustainable in the long term and is within the carrying capacity.

Water exchange

- The estimation of water exchange in the straits and calculation of residual current and residence time.

Background nutrient inflow

- If known, the dissolved N and or P inflow into the waterbody from all sources including the open boundary.
- If unknown, the baseline fresh water and marine nutrient concentration plus an estimate of the nutrient inputs from terrestrial sources.

Nutrient input from aquaculture

- The estimation of the nutrient source from aquaculture based on the quality and quantity of feed given, survival rate and percentage of uneaten food.

Threshold nutrient concentration

- The threshold level of the dissolved concentration of P in fresh water and P or N in marine water that would trigger an algal bloom.

Aquaculture carrying capacity

- The sustainable level of aquaculture standing stock in terms of tonnes (carrying capacity).

7. Estimating water exchange

The estimation of water exchange in a lake or dam (residence time)

This is estimated by calculating the catchment area upstream of the waterbody and the annual rainfall to give the quantity of fresh water entering the waterbody. This figure is divided by the volume of the waterbody. The resulting figure is the residence time of the waterbody in years (the number of years required for a complete exchange of the waterbody).

The estimation of water exchange in a semi-enclosed or enclosed bay resulting from tidal exchange

The volume (m^3) of the enclosed bay is calculated by estimating the area of the bay (m^2) and multiplying by the average depth (m) using Google Earth or a bathymetric chart. Then the average tide is calculated over a 14-day period (half tidal cycle) and this fluctuation in metres is multiplied by the area of the bay (m^3) to give the volume of water exchanged per tide. As there are 2.07 tides per day, the volume is multiplied by 2.07 to give the volume exchanged per day. The total volume of the bay is divided by the daily water exchanged to give the number of days it takes to exchange the water in the bay.

There is a complication if the bay is enclosed and the water in the bay is not flushed in a plug flow manner but has restricted mixing. In this case, the number of days is increased by a factor relating to the level of enclosure.

8. Background nutrient concentration

If the dissolved P (for coastal marine waters or freshwater) or N (for open marine waters) concentrations in the waterbody are known before aquaculture started, then this is the background nutrient concentration.

If the natural background nutrient concentration before aquaculture starts is unknown, then an estimate is made of the nutrient inputs from terrestrial sources and/or open water marine source.

The additional nutrient contribution is estimated by calculating the catchment area upstream of the waterbody (m^2) multiplied by the annual rainfall (m) to give the quantity of fresh water (m^3/year) entering the waterbody. This value can then be multiplied by average concentration in the entering fresh water (kg/ m^3) or, alternatively, it can be multiplied by a factor that is related to the dominant land-use to give an estimate of the nutrient runoff into the waterbody.

Threshold nutrient concentration

According to Dufour and Berland (1999) and Dufour *et al*., (1999), South Pacific waters are nitrogen limited. However, these results are derived from the very oligotrophic subtropical Tuamotu archipelago and are probably not valid for waters in Southeast Asia.

Based on short-term responses of coral reef micro-phytobenthic communities to inorganic nutrient loading, Dizon and Yap (1999) found that N and P are limiting when added together whereas neither N nor P seems to be limiting when added alone.

In areas where aquaculture is the dominant nutrient source, the limiting nutrient will be determined by the ratio in which aquaculture systems discharge nutrients. The distribution of N and P in fish feed is 73 kg N/tonne and 14 kg P/tonne respectively, giving a N/P ratio of 5.21. If the nutrient source for phytoplankton was only provided with fish feed, P would be given in excess of N, since the ideal ratio in phytoplankton is N/P = 7 (by weight), and hence N would be limiting. However, fish farms discharge 68 percent of N and 28 percent of P into the water column through excretion and soluble faeces (Lupatsch and Kissil, 1998). This makes the ratio in emission: N/P = 13.13 by weight and hence, a fish farm induces P limitation of phytoplankton.

However, there may be phosphorus limitation at one point in time and nitrogen limitation at another point of time, even when the same ratio of nutrients has been discharged to the water column. The phytoplankton species composition is dynamic in time because of the existing seasonal succession of phytoplankton species and hence for the same nutrient ratio in emission one species is limited by nitrogen whereas another may be limited by phosphorus or even silica. This latter is because of the fact that different phytoplankton species require different optimum N/P ratios. Hence, nutrient impacts are a function of phytoplankton composition and dominance for a given time instant.

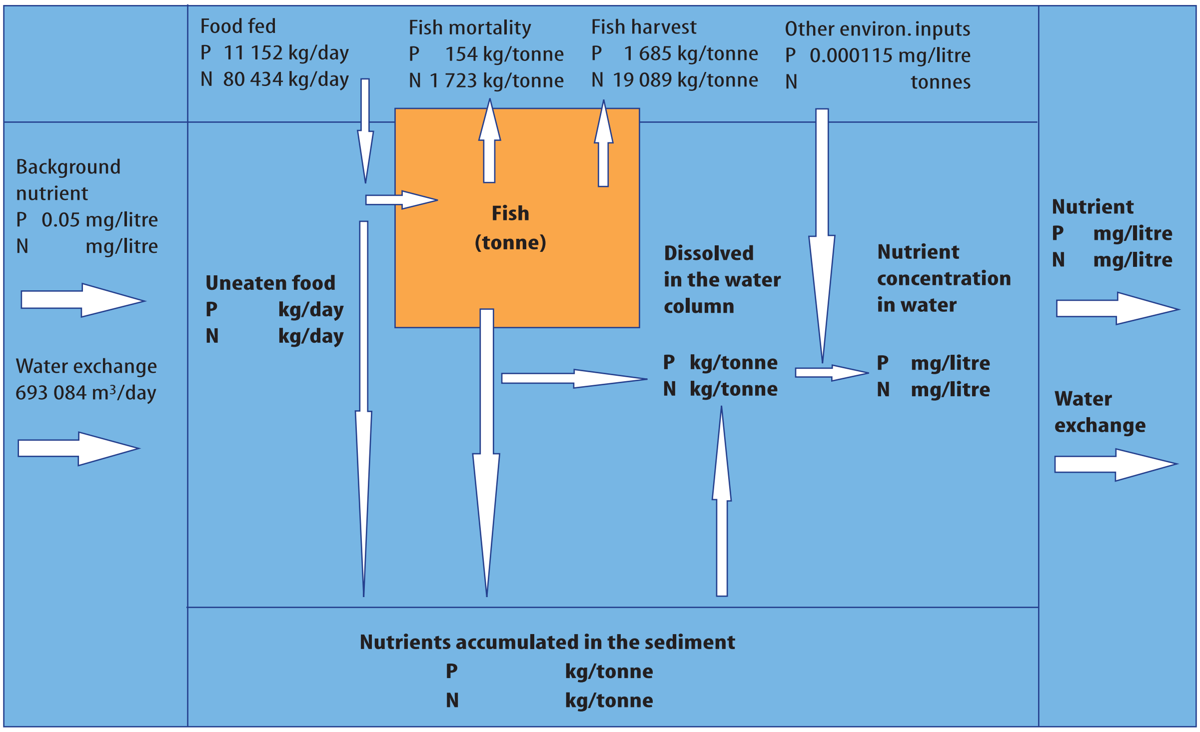

Figure 5. Pathways of phosphorus and nitrogen inputs and outputs at a fish culture site

Fresh waterbody

The threshold level of the dissolved concentration of phosphorus in freshwater that would trigger an algal bloom.

Marine waterbody

The threshold level of the dissolved concentration of phosphorus and nitrogen in marine water that would trigger an algal bloom.

9. Estimation of aquaculture nutrient outputs

To estimate the nutrient output from aquaculture, the spreadsheet requires information on the feed quality and production criteria.

Data inputs required on feed quality (taken from feed manufacturers information):

Feed information	Level	Unit	Example
Feed protein level	X	%	45
Feed nitrogen level	X	%	24
Feed phosphorus level	X	%	1

Data inputs required on production performance (taken from expected productivity information):

Production information	Level	Unit	Example
FCR	X	:1	1.8:1
Mortality	X	%	18
Uneaten food	X	%	5

Based on this input data and using the mass balance model and the fate of nutrients (Bermudes and Olsen) in the table below (assuming an FCR of 1.8:1):

Fate of phosphorus*	**%**
Total in food	100.0
Harvest	17.0
Mortality (18%)	1.7
Uneaten food (5%)	5.0
Release	76.3
Solute release	25.9
Sediment accumulation	47.6
Benthic flux	2.8
Total	100.0

Phosphorus	**%**
Sediment accumulation	52.6
Solute accumulation	28.7
Total P released	81.3

* 60% digestible

Nitrogen	**%**
Total food	100.0
Harvest	26.7
Mortality (18%)	2.7
Uneaten food (5%)	5.0
Released	65.6
Solute release	46.6
Sediment accumulation	17.1
Benthic flux	1.9
Total	100.0
Sediment accumulation	17.1
Solute accumulation	48.5
Total N Released	65.6
* 90% digestible	

The spreadsheet will then automatically calculate the nutrient output in terms of the concentration of:

- the dissolved phosphorus and nitrogen in the water column; and
- the phosphorus and nitrogen accumulated in the sediment.

This is calculated for one tonne of fish produced. This figure is used by the model to calculate the carrying capacity of the waterbody.

10. Estimating nutrient input to the waterbody from other sources

To estimate the nutrient inputs from other sources, the following information is required:

a. the catchment area for each river entering the waterbody;
b. the average annual rainfall for the region;
c. the land-use in the catchment area;
d. the population census in the region;
e. the agricultural census for livestock; and
f. the estimate of the area of extractive species.

Using this data, the discharge of phosphorus and nitrogen is estimated using the discharge coefficients in the table below. The additional nutrient contribution is estimated by calculating the catchment area upstream of the waterbody (m^2) multiplied by the annual rainfall (m) to give the quantity of fresh water (m^3) entering the waterbody. This figure can then be multiplied by a factor that is related to the dominant land-use to give an estimate of the nutrient runoff into the waterbody.

Examples of the discharge coefficients for the different nutrient sources are given in Table 2.

Table 2. Discharge coefficients for the different nutrient sources

Activity	Discharge coefficient (unit)		Reference
Household			
a. Solid waste	1.86	kgN/prn/yr	SOGREAH, 1974
	0.37	kgP/prn/yr	Padilla *et al.*, 1997
b. Domestic sewage – good treatment	1	kgN/prn/yr	World Bank, 1993
	0.25	kgP/prn/yr	World Bank, 1993
c. Domestic sewage – normal treatment	2	kgN/prn/yr	World Bank, 1993
	5	kgP/prn/yr	World Bank, 1993
d. Domestic sewage – poor treatment	4	kgN/prn/yr	World Bank, 1993
	10	kgP/prn/yr	World Bank, 1993
Urban runoff	**Discharge coefficient**		**Reference**
(unsewered areas)	3 000	kgN/km²/yr	Howarth *et al.*, 1996
	750	kgP/km²/yr	Howarth *et al.*, 1996
Livestock	**Discharge coefficient**		**Reference**
a. Cattle	43.8	kgN/cow/yr	WHO, 1993
	11.3	kgP/cow/yr	WHO, 1993
b. Horses	95.3	kgN/hor/yr	WHO,1993
	16.4	kgP/hor/yr	WHO, 1993
c. Sheep	4	kgN/shp/yr	WHO, 1993
	21.5	kgP/shp/yr	WHO, 1993
d. Piggery	7.3	kgN/pig/yr	WHO, 1993
	2.3	kgP/pig/yr	WHO, 1993.
e. Poultry	0.3	kgN/bird/yr	Valiela *et al.*, 1997
	0.7	kgP/bird/yr	Valiela *et al.*, 1997
Non-point runoff	**Discharge coefficient**		**Reference**
a. Agriculture	1 266	kgN/km²/yr	Howarth *et al.*, 1996
	405	kgP/km²/yr	Howarth *et al.*, 1996
b. Paddy field	3 410	kgN/km²/yr	Yetunde, 2006
	175	kgP/km²/yr	Yetunde, 2006
c. Forest	250	kgN/km²/yr	Yetunde, 2006
	20	kgP/km²/yr	Yetunde, 2006
d. Grassland	150	kgN/km²/yr	Yetunde, 2006
	20	kgP/km²/yr	Yetunde, 2006
Non-point absorption	**Absorption coefficient**		**Reference**
a. Mangrove	580	kgN/km²/yr	Nirmal Kumar *et al.*, 2011
	134	kgP/km²/yr	
b. Seaweed	110 000	kgN/km²/yr	Blaas, 2017
	355	kgP/km²/yr	
c. Water hyacinth	491 655	kgN/km²/yr	Reddy & Tucker, 1983
	109 682	kgP/km²/yr	

However, not all the nutrients will reach the waterbody. Some nutrients will be absorbed before they reach the waterbody. The percentage entering the aquatic resource is estimated as follows:

- 10 percent if land very flat;
- 25 percent if land gently sloping;
- 50 percent if land sloping; and
- 75 percent to 100 percent if land is strongly sloping.

When these tables are completed and the spreadsheet will automatically calculate the quantities of phosphorus and nitrogen entering the waterbody.

The concentration of phosphorus or nitrogen in the water will depend on the level of input and the water exchange (dilution). For the same emission, if the exchange of water is higher (assuming small background concentration), the concentration of phosphorus in the water column will be smaller.

This is calculated as the emission of phosphorus or nitrogen by aquaculture standing stock/water exchange = concentration of phosphorus or nitrogen in water.

The maximum carrying capacity therefore is the maximum amount of aquaculture standing stock that will not emit more than the critical concentration of phosphorus or nitrogen in the water column.

The above assumes that there are no other sources of phosphorus and nitrogen entering the waterbody, which is clearly not the case. The estimation of the other sources of phosphorus and nitrogen is undertaken either by knowing the baseline nutrient levels before aquaculture took place or by calculating the upstream catchment area and using land-use to estimate the nutrient output into the annual rainfall.

The estimated total phosphorus or nitrogen concentration is therefore calculated by adding the other sources of phosphorus/nitrogen, i.e. from streams and runoff plus the maximum emission of phosphorus or nitrogen by aquacultures divided by water exchange = maximum concentration of phosphorus in the water column.

The carrying capacity in terms of aquaculture standing stock (biomass of fish in the water at any time) should now be converted into annual fish production. This is calculated using fish market size and culture period (number of years to reach market size).

In marine waters, the threshold concentration of nitrogen and phosphorus that could trigger an algal bloom is calculated to be 4.624 gN/m^3 and 0.178 gP/m^3 respectively.

11. Carrying capacity based on a nutrient balance

In order to construct a model to help in computing carrying capacity of fish in the coastal sea where both fish and shellfish are reared, one should consider nutrient balance in the water column and consequently the maximum phytoplankton density.

Let us consider a balance of a nutrient in the water column, denoted by N, in a well-mixed box of a unit volume. The nutrient balance depends on the inflow of nutrients by rivers and fish culture, sedimentation to the bottom, extraction by shellfish and export by currents to the open sea. Although shellfish do not consume nutrients directly, they consume organic particles and phytoplankton that contains nutrients. Hence they are considered as a sink for nutrients in a particulate form.

Using the above processes, one can write an equation that expresses a change in nutrient concentration:

$$dN/dt = (N_{in} - N)*D - k_s*A*N/V - k_{shell}*S + k_f*F$$

where:

N is the concentration of nutrient in the waterbody (gN/m^3 = mgN/litre)

N_{in} is the concentration of nutrient at the inflow (gN/m^3)

D is called dilution or exchange rate and it is equal to:

Q/V where Q is the inflow of water (m^3/s) and V (m^3) is the volume of the considered body of water. Hence, the unit of D is (1/s)

k_s is the sedimentation rate of the nutrient (m/s)

A is the area of the waterbody (m^2)

k_{shell} is the specific consumption by one kg of shellfish gN/(kg*s)

S is the density of shellfish (kg/m^3)

k_f is the specific rate of nutrient emission by fish (gN/(kg_of_fish*s)

F is the density of fish biomass (kg/m^3)

A verification of units:

$$gN/(m^3*s) = gN/(m^3*s) - (m/s)*(m^2)*(gN/m^3)/(m^3) - (gN/(kg*s))*(kg/m^3)$$

$$-(gN/(kg*s))*(kg/m^3)$$

$$= gN/(m^3*s) - gN/(m^3*s) - gN/(m^3*s) - gN/(m^3*s)$$

Now, if we impose a steady-state, then dN/dt = 0, we have:

$$(N_{in} - N^s)*D - k_s*A*N^s/V - k_{shell}*S + k_f*F = 0$$

Where N^s is the value of nutrient concentration at a steady-state.

Furthermore, a very high concentration of a nutrient in a coastal sea will induce a phytoplankton bloom, since there exists a relationship between nutrient concentration and phytoplankton bloom. Let us denote the critical concentration of nutrient that will not yet induce a detrimental phytoplankton bloom by N_{crit}.

By increasing the concentration of fish, F, we are increasing the steady-state value of N^s. If we increase the fish density to F_{cc} then N_{crit} is reached. Hence, we call F_{cc} the carrying capacity for fish.

From the above equation we have the carrying capacity for fish:

$$F_{cc} = (k_s*A*N_{crit}/V + k_{shell}*S - (N_{in} - N_{crit})*D)/k_f.$$

In units:

$$(kg/m^3) = ((m/s)*(m^2)*(gN/m^3)/(m^3) + (gN/(kg*s))*(kg/m^3) - gN/(m^3*s))/$$

$$(gN/(kg\_of\_fish*s)$$

$$= (gN/(m^3*s) + gN/(m^3*s) + gN/(m^3*s))/gN/(kg\_of\_fish*s)$$

$$= (kg/m^3)$$

Obviously, in order for F_{cc} to be greater than zero, the condition:

$k_s*A*N_{crit}/V + k_{shell}*S > (N_{in} - N_{crit})*D$ must be satisfied.

Otherwise, we cannot rear fish in such a waterbody because fish would be in constant danger of death from phytoplankton blooms.

The above expression also tells us that even if the average concentration of nutrients from rivers (N_{in}) is greater than N_{crit}, it may be that F_{cc} is greater than zero.

If N_{in} is smaller than N_{crit}, then F_{cc} is always greater than zero, and this may serve as a simple criterion to check whether we can rear the fish in a specific waterbody.

12. Calculation of carrying capacity

Adequate data is required to calculate F_{cc}.

Nutrient inflow

If there are several rivers entering the waterbody, they must be entered in the model as follows:

Inflow of water from the river no. 1 (m^3/s)

Nutrient concentration in a river no. 1 (gN/m^3 = mgN/litre)

Inflow of water from the river no. 2 (m^3/s)

Nutrient concentration in a river no. 2 (gN/m^3 = mgN/litre)

Inflow of water from the river no. *n* (m^3/s)

Nutrient concentration in a river no. *n* (gN/m^3 = mgN/litre).

If one knows the inflows of all the *n* rivers (Q1...Qn) and if their concentration of nutrient is approximately the same, C, then the inflow of nutrient is:

$(Q1 + Q2 +...+ Qn)* C$ = inflow of nutrient ($m^3/s *gN/m^3 = gN/s$).

If one knows only the representative concentration in one of the rivers, then one is forced to assume that the concentration of the nutrient is the same in all the rivers.

If one does not know the representative concentration in one or several rivers, then one is forced to assume that the concentration of the nutrient is the same as a known concentration in another river.

Volume

The volume of the waterbody or any of their sub-areas is entered in m^3.

Surface area

The surface area of the waterbody or any of their sub-areas is entered in m^2.

Sedimentation rate

The average sedimentation rate is very difficult to estimate precisely. First, dissolved nutrients do not sediment at all, so this seems easy. However, nutrients are adsorbed to particles which then sediment

to the bottom. But particles come in many sizes where each size sediments at its own speed. Moreover, there are particles with the same size, but different density and hence have different sinking rates. Finally, there are particles with a density smaller than the surrounding water, and they do not sink at all but rise to the surface of the water column.

The problem is even more difficult because a dynamic aspect exists in the coastal sea too. Namely, during a phytoplankton bloom in freshwater, as freshwater phytoplankton is transported to the sea, on contact with a seawater many phytoplankton cells "explode" releasing organic matter whereas only their frustules sink. In addition, a part of the released organic matter settles to the bottom, and a part rises to the surface.

From the experiments, during phytoplankton blooms, it has been determined that some phytoplankton cells sink at a rate as high as 0.01 (m/s) but this is an exception and far from the average. In addition, phosphorus gets resuspended into the water column. The average value is close to 0.0005 (m/s).

Critical concentration of nutrients

In coastal seas under strong anthropogenic influences, one may argue that both phosphorus and nitrogen are added in great quantity, and hence a natural supply of silica is likely to be limiting for diatoms. Although diatoms are the first to make a bloom after a sudden inflow of nutrients, it is some species of dinoflagellates that are toxic to fish and shellfish, and they should be of primary concern. Dinoflagellates do not require silica for the building of their cells. From the above consideration, it follows that one should take phosphorus as the limiting nutrient.

Now, to set correctly the critical concentration of phosphorus, we need a relationship between total phosphorus and phytoplankton density. The assumption here is that practically all the limiting nutrient concentration will be used by phytoplankton for growth and reproduction. The assumption is valid because phytoplankton can deplete nutrients from the water column down to undetectable values.

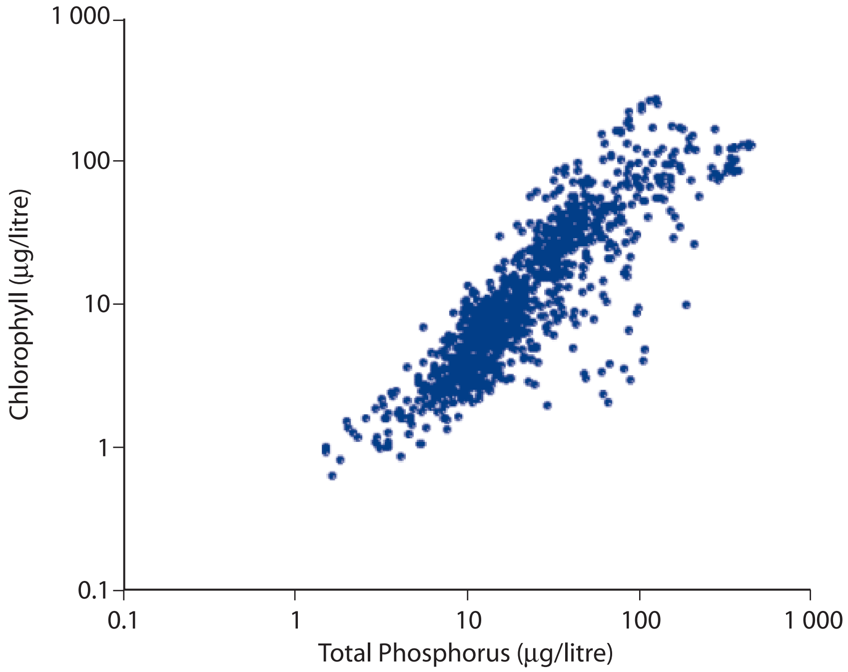

Figure 6. Total phosphorus versus total chlorophyll from 543 Florida lakes

Source: Florida LAKEWATCH, 2000)

The relationship between total phosphorus and total chlorophyll originating from 534 lakes in Florida (Figure 1) is:

$$Log(Chl) = -0.369 + 1.053*log(TP)$$

where

Chl is the total chlorophyll content, and TP is the total phosphorus concentration.

The classification originating from the total phosphorus concentration in the water column is shown in Table 3.

Table 3. Trophic state according to total phosphorus concentration in the water column

TP (µg/litre)	Trophic state
< 15	oligotrophic
>15-25	mesotrophic
>25-100	eutrophic
>100	hypereutrophic

Source: Florida LAKEWATCH, 2000

Let us consider the following statements in order to set correctly the critical TP concentration.

Box 1. Critical TP concentrations

"When chlorophyll concentrations reach a level *over* 40 µg/litre, some scientists will call it an algal bloom".

When algal biomass exceeds 100 µg/litre (measured as chlorophyll concentration), there is an increased probability of a fish kill.... This can lead to oxygen depletion.

Chlorophyll concentrations below 100 µg/litre generally do not adversely affect fish and wildlife, but dead fish and wildlife can occasionally be found."

Source: Florida LAKEWATCH, 2000

If we take 100 µg Chl/litre as a limit, then using the relationship between total phosphorus and chlorophyll, we get the limit on total phosphorus:

$$N_{crit} = 177.73\ \mu gTP/litre = 177.73\ mgTP/m^3 = 0.17773\ gTP/m^3 = 0.17773\ mgTP/litre.$$

Shellfish quantity

Shellfish mass in the waterbody must be given in kg.

By "shellfish mass" we do not mean only reared shellfish but all shellfish.

Since the model is computing quantity of fish in m^3, shellfish mass will be divided with volume V.

Specific extraction rate by shellfish

White, 2017 writes:

"For every tonne of oysters or mussels harvested, approximately 0.25 kg/day of phosphorus is harvested and 1.45 kg/day of phosphorus is deposited to the sediment as faeces and pseudofaeces".

It follows that shellfish extract 1.7 kgP/(tonne of shellfish*day) from the water column:

k_s = 1.7 kgP/(tonne*day) = 1.7 gP/(kg*day) = 0.00002 gP/(kg*s)

Estimation of error in the value of k_s

In the above consideration, we have assumed that phosphorus in particles being deposited to the bottom stays out of the water column. This is not entirely true. While sinking to the bottom, pseudofaeces dissolve in the water column. But if the dissolution is slow, and the waterbody is relatively shallow, this contribution is not significant. In addition, bottom-dwelling organisms and tidal currents move the surface sediment, and some particles get an additional opportunity to dissolve in the water close to the bottom and in the interstitial water.

13. Conclusions

The importance of each factor in the computation of carrying capacity of fish is given below.

13.1 Critical phosphorus concentration

The average value of 100 µgChl/litre means that all of the areas under consideration will reach this value. This event will never occur. Although this value may not be dangerous for fish, the phytoplankton blooms are patchy. This means that at the same time one sub-area may reach higher than 100 µgChl/litre and another area may reach 10 µgChl/litre and the two areas will not have the same surface value. So, the total phosphorus concentration corresponding to the average value of 100 µgChl/litre may induce a fish kill of limited proportions, as it did in Florida.

Going beyond the value of total phosphorus set in the programme (0.18 mgTP/litre) is considered dangerous, so it is not recommended.

13.2 Sedimentation of total phosphorus

Sedimentation induces by far the most dominant effect on the carrying capacity. Unfortunately, this factor is least known. At the same time, it is out of reach by any management measure.

Doubling sedimentation rate induces almost doubling of carrying capacity.

13.3 Specific extraction rate of shellfish

As has been mentioned above, this factor is an order of magnitute higher than the emission by fish, so installing more shellfish is beneficial to the carrying capacity of fish. However, the benefit is masked by the dominant impact of the sedimentation rate. Nevertheless, keeping in mind that shellfish consume phytoplankton, the benefit is even higher. Strategically dispersing shellfish culture means that phytoplankton blooms will reach smaller density and this is particularly important with regard to harmful algal blooms.

13.4 Total mass of shellfish

This value is difficult to estimate acurately because what matters is not only cultured shellfish but all existing shellfish. Of course, strategically dispersed shellfish culture operations/cages have a much greater impact on phytoplankton bloom than shellfish attached to or in the general vicinity of the coast.

13.5 Specific emission by fish

This factor does not include phosphorus in the food given to fish and not consumed. If one expects that this value is considerable, one should increase the value.

13.6 Area available for fish farming

The area available for fish farming (m^2) should be known. Since this area is certainly smaller than the total surface area of the straits, or any of their sub-areas where the computation will be applied, implementing fish culture in such an area means that the critical concentration of total phosphorus will not be reached. This represents an additional safety factor in expanding fish culture to other areas not yet developed for aquaculture.

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Tool manual 2:
Aquaculture feasibility study

Guidelines for undertaking aquaculture farm development feasibility studies

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1. Introduction

The purpose of these guidelines is to provide a practical tool for government planners to assess the financial and economic feasibility of the development of new aquaculture developments. Projects will need to undertake a feasibility study to provide the information necessary to decide whether to proceed or not with a project. A full feasibility study requires substantial time and money as it involves design studies as well as on-site investigations and surveys. A pre-feasibility study is the precursor to a feasibility study and its main purpose is to ensure there is a solid basis for undertaking a full analysis.

The development of a project through several stages also facilitates investment promotion and provides a better basis for project decisions and implementation by making the process more transparent.

The pre-investment phase (Table 1) comprises several stages:

- **Preliminary evaluation.** Identification of investment opportunities (opportunity studies), analysis of project alternatives and preliminary project selection.
- **Pre-feasibility studies.** Project preparation requires both pre-feasibility and feasibility studies.
- **Feasibility studies.** A project feasibility study can apply to a business idea or a proposed development investment, to a private initiative or a public development project.

Table 1. Phases in development project planning

Phases	Necessary information and tools	Purpose of the appraisal
Preliminary evaluation	Information still preliminary and thus uncertain – first estimation of costs and profit.	Eliminating those proposals that are clearly too expensive when compared to the potential benefits.
Pre-feasibility	Approximate investment and management costs, better estimation of operational costs, etc.	Identifying the most promising solutions. Verifying the available technological alternatives.
Full feasibility	Detailed investment, operational and management costs, final market prices, etc. Detailed economic analysis.	Verifying the profitability of the project.

Pre-feasibility studies

The division of the pre-investment phase into stages avoids proceeding directly from the project idea to the final feasibility study without examining the project idea step by step or being able to present alternative solutions. This also cuts out many superfluous feasibility studies that would have little chance of reaching the investment phase. Finally, it ensures that the project appraisal to be made by national or international financing institutions becomes an easier task when based on well-prepared studies.

The project idea must be elaborated in a more detailed study. However, formulation of a feasibility study that enables a definite decision to be made on the project is a costly and time-consuming task. Therefore, before assigning larger funds for such a study, an assessment of the project idea might be made in a pre-feasibility study, the principal objectives of which are to determine whether:

- all possible project alternatives have been examined;
- the project concept justifies a detailed analysis by a feasibility study;
- aspects of the project are critical to its feasibility and necessitate in-depth investigation through functional or support studies such as market surveys, laboratory tests or pilot-plants tests;
- the project idea, on the basis of the available information, should be considered either non-viable or attractive enough for a particular investor or investor group; and
- the environmental situation at the planned site and the potential impact of the projected production process are in line with national standards.

A pre-feasibility study should be viewed as an intermediate stage between a project opportunity study and a detailed feasibility study, the difference being in the degree of detail of the information obtained and the intensity with which project alternatives are discussed. The structure of a pre-feasibility study should be the same as that of a detailed feasibility study.

A detailed review of available alternatives must take place at the stage of the pre-feasibility study since it would be too costly and time-consuming to have this done at the feasibility study stage. It is an exercise that involves documenting each of the potential solutions to an aquaculture development opportunity.

In particular, the pre-feasibility review should cover the following main fields (components) of the study:

- project or development strategies and scope of project;
- location, site details and available infrastructure and services; and
- climate and water supplies.

For each alternative option, the following the costs and requirements should be analysed:

- culture species and system;
- pre-investment and capital costs;
- operating and marketing costs;
- raw materials and feed and seed supplies;
- market and marketing concept;
- organization and overhead costs; and
- project implementation schedule and budgeting.

The financial and economic impact of the factors should be assessed. A detailed justification of the selection of the preferred alternative should be given, together with a description of the methods and formulas used in the selection process.

The methodology to carry out pre-feasibility studies does not differ substantially from the one applied for a full feasibility study, the main difference being the degree of detail of the analysis. Therefore, a pre-feasibility study makes extensive use of existing information, minimizing as far as possible site surveys and field investigations.

Feasibility studies

A project feasibility study can apply to a business idea or a proposed development investment, to a private initiative or a public development project. The application of a series of feasibility screens

that establishes the requirements for the project's biological feasibility, technical feasibility, economic viability and social acceptability, including environmental safety.

It is not difficult to find examples of private business or public development projects that have failed because the decision to proceed with the project was based on the belief that it was feasible because there was money and technical resources to implement it. (An exaggerated example is you can grow salmon in the tropics if you have the money and technical resources; the question is whether it is worth doing so). Another possibility is that the decision to proceed was driven by reasons other than viability, such as political, to implement the project regardless of technical resource costs. Ideally, the reasons for conducting a feasibility study range from making a decision to proceed or abort, to increasing the probability of success, to helping secure funding.

Specifically, these include the following:

- enhance the probability of success by addressing risk factors early on that could affect the project;
- provide quality information for decision-making;
- provide documented proof that the project idea was thoroughly investigated;
- help secure funding from donor agencies and development banks; and
- help to attract equity investment.

Aquaculture development feasibility study tool

This tool is tailored for a feasibility study for an aquaculture development project that proposes to promote particular species and a particular production system for adoption by farmers in a project area.

Some examples are:

- a mariculture park to grow marine finfish;
- a shrimp development project that requires building ponds and other infrastructure such as hatchery, nursery and processing facilities and bringing in utilities and setting up the technical support services;
- a freshwater finfish development project on land or a waterbody such as cage culture on a lake, a reservoir, or a stretch of a river;
- a coastal finfish cage culture or mollusc (oyster, mussel, abalone) development project; and
- a seaweed development project or an aquaculture industrial zone.

The feasibility study would seek to establish the requirements for the project's biological feasibility, technical feasibility, economic viability and social acceptability. The study can enhance the probability of project success if the result signals a decision to proceed. It does so by addressing and mitigating early the internal and external risk factors that could affect the success of the project.

The assessment methodologies and tools would similarly apply to a private business enterprise and a development investment project. The tool can be used by a private investor in an aquaculture business and a manager of a government agency that has to decide or recommend a decision on whether to proceed with a proposed aquaculture development project. This tool focuses on the latter.

The feasibility study should be undertaken by an interdisciplinary team consisting of the following expertise:

- aquaculture biology and technology (breeding and grow-out);
- aquaculture design and engineering;
- business management and economics (resource and marketing);
- rural socio-economics;
- policy and regulation; and
- environment

The tool can be used for an area development project (watershed scale, a waterbody or part of it) and an aquaculture business enterprise or development project.

It is applicable to:

- all systems whether large scale, medium scale or small scale in the context of an area or local development project (in other words small-scale enterprises that are going to be established under the development project, such as cage farms in a mariculture park project);
- industrial scale aquaculture business investment;
- medium-scale to large-scale commercial aquaculture enterprise establishment or expansion;
- projects along the supply chain such as an input production project (feed processing plant), market infrastructure, processing plant;
- an aquaculture estate; and
- a mariculture park.

There are five sets of indicators of feasibility: biological, technical, economic/financial, and social. The latter includes environmental safety on the assumption that any environmental risk invariably translates into a social risk. A broad description of these indicators can be expressed by casting them into feasibility screens, in other words by turning them into questions as shown in the proceeding sections.

Biological feasibility

The perspective on biological feasibility is whether the selected species can be commercially produced in the project area (local environment and climatic conditions) at acceptable productivity levels (growth, survival, FCR, etc.).

- Can the selected species be produced in the hatchery or caught sustainably from the wild?
- Can the species grow to its genetic potential in the project environment?
- Will it grow to market size and can it be farmed to an acceptable yield level?

Technical and operational feasibility

The perspective on technical feasibility is what the farmers can achieve at the commercial scale with their resource structure and environment, not what can be achieved in a pilot or research project.

- Can the species perform well (growth, survival, FCR) to market size in the proposed culture system (as in a cage, tank or pond)?
- Will the technical inputs be available when needed? The technical inputs include seed, feed, fertilizer, funds, skilled labour, post-harvest facilities and services (transport, ice supply or refrigeration, processing), market (domestic and export), and technological services (research, extension, information)?

- Does the farmer have the technical and management ability and the means to farm the species to an acceptable yield level with the financial resources available?
- Is there a sustained market demand for the product and is there a marketing and distribution system that can bring the product to the consumer?

Economic/financial viability

The perspective on economic feasibility is whether there is sufficient profitability for farmers given the investment that they have to make.

- If the selected species is biologically feasible to culture and the selected culture system technically feasible, will it be worth investing money and allocating resources into its farming?
- As economic viability is determined by the costs of the resources (capital and operational costs) and the market prices of the products, is it possible for the farmers to have an acceptable level of economic returns from producing a given species under a certain production system?
- Although the main influences on profitability are the productivity of the farm, the market price, the cost of inputs (feed, seed, energy, etc.) and the cost of capital, it is also related to farmers being able to have economy of scale. Thus, will the farmers be able to achieve economy of scale, for instance by being part of an organized group?

Social, cultural acceptability and environmental safety

The perspective on socio-economic feasibility is whether the project will cause social conflicts, cause unacceptable environmental impacts or clash with cultural norms.

- Will the production system create conflicts with other resource users?
- Will the development fit into the social and cultural norms of the community? A project can be technically sound, but the new project may conflict with the social norms of the end users or even cause societal disequilibrium resulting in a shift in power relationships within the society.
- Are the production and management practices acceptable as well as beneficial to the community?
- Are the production and management practices environment friendly and designed so as not to weaken ecological resilience? It may result in adverse impact on the environment in terms of water quality and biodiversity.

The feasibility report is divided into five main sections

- **Executive summary.** The feasibility study should begin with a brief executive summary outlining the project scope, species, culture system, markets and the conclusions of the economic and financial analysis.
- **Introduction and background.** This should state the aims and objectives, scope of the development project.
- **Body of the study.** The body of the study should present and cover the various feasibility aspects of the study (biological, technical, economic and financial, social) as well as the project input and output, risk in price fluctuations (sensitivity analysis) as well as the infrastructure and support required by a cluster of small farmers.
- **Conclusions.** Whether the proposed development will be sufficiently profitable or have sufficient benefits to go ahead.

- **Separate annex.** The annex should include any supporting material (statistics, results of market surveys, detailed technical descriptions and equipment lists, farm layouts etc.).

Executive summary

The executive summary is needed to provide the reader with a general overview of the project in a clear and concise manner. It will include a brief narrative text for each section of the feasibility study.

The executive summary should be drafted once the whole feasibility study is completed in order to correctly summarize each section of the document.

Complete Form. 1. This is a summary of the project and completed at the end when all the data and calculations have been made.

Text length suggested: 2 pages

Executive summary	
The project	*Country and area of the project* *Type of farmer (household/business)*
Location and suitability	*The selected location* *Suitability of the location*
Biological feasibility	*Selected fish species* *Species productivity*
Technical feasibility	*Technology used, production size and intensity*
Operational feasibility	*A summary of the timing of key activities*
Economic feasibility	*Capital costs* *Operational costs* *Overhead costs*
Financial feasibility	*Investment required* *Internal rate of return* *Sensitivity analysis* *Break even point*
Market at the cluster scale	*Target market and market demand* *Competitor analysis* *Marketing strategy*
Cluster management and support	*Infrastructure (hatcheries, nurseries, jetties, ice machine, market area, feed store, etc.)* *Demonstration farm, training, extension service* *Farmer organization* *Technical support (carrying capacity estimation, water quality analysis, disease monitoring, etc.)*
Social feasibility at the cluster scale	*Benefits to the farmers and their households* *Benefits to surrounding communities* *Benefits to the country*

Risks and mitigation of risks at the cluster scale	*Disease risks and biosecurity* *Water quality and environmental impact* *Theft and security* *Potential conflicts with local community or other users of the water resource* *Other risks (e.g. climate change)*

2. The project

This section defines the project in detail. The purpose of this section is to provide detailed descriptions about the type of farmer and the technical aspects of the proposed aquaculture project. It is important to detail the reasons why the selected site is suitable for aquaculture purposes and what kind of technology will be used to achieve the production targets.

Aims and objectives

The feasibility study should start with the aims, objectives and scope of the study. Establish the scope of the feasibility study – state exactly what the project is and what it is intended to achieve – its objectives. State the aims, goals and objectives of pursuing the development opportunity.

Some aims and objectives for a feasibility study could be:

The aims and objectives of this feasibility study are to investigate the feasibility of cage culture of grouper for the Hong Kong market, as well as investigate the costs involved and the potential profits and return on investment.

Project background

To ensure the success of the feasibility study, it must be clearly understood how the project idea fits into the framework of general economic conditions and aquaculture development of the country concerned. The project should be described in detail and the sponsors identified, together with a presentation of the reasons for their interest in the project.

The project

In this section give the location of the proposed project and the type of farmer that is targeted (family, small business, etc.).

Text length suggested: Ownership 1/4 page

Name and ownership
1. Country and location of the proposed project
2. Type of ownership (household/business)

Selected location and suitability

This section describes the selected location for the farms and the suitability of the selected area for aquaculture.

Initially the geographical area should be selected using agreed site selection criteria and then actual farm sites identified. Location and site are often used synonymously but must be distinguished. The

choice of location should be made from a fairly wide geographical area, within which farm sites can be considered. The types of data required are:

1) primary data for site selection;
2) secondary data from literature, studies or reports; and
3) historical data from the community or the people who have familiarity with the area.

The influence of natural conditions and biotic factors on the production performance of the proposed aquaculture species and systems should be assessed. Natural conditions of the site that impact on the performance of the proposed species would include water, soil, water temperature, water availability, vulnerability to floods and others climatic risks. Biotic factors that could impact on performance of proposed species include pathogens, natural food, predators and competitors.

Topography, altitude and climate may be important for a project, as well as access to water, electric power, roads and railways or water transport. This analysis is related to materials and inputs as well as technical infrastructure discussed below. The distance to urban centres and the social and economic infrastructure may be important for the availability of labour. The study should also cover existing rights of way (regarding, for example, access roads and water supply) and indicate potential problems.

The cost of land is an obvious element of a site as well as the costs of site preparation, and development considerations should be detailed for the selected site. Existing buildings, infrastructure, services and facilities of different kinds may reduce the construction cost and consequently the investment costs as well as financing required. The feasibility study should therefore identify and describe the infrastructure and service requirements and demands during the construction and installation phase.

The analysis should cover not just the quantities required but also other characteristics (such as electricity reliability, water quality and quantity). The study must distinguish between desirable and critical requirements and demands.

Water. The water supply should be identified. The water required for a farm can be calculated from the farm capacity and technology. First, the availability of water and the costs entailed should be determined, including the quantities that could be obtained and their estimated cost to supply the farm from surface (for example a river) or sub-surface sources. Secondly, the quality of the water at different locations should be assessed.

Electricity. The inadequate supply of electricity or its high unit cost in a particular area can constitute a major constraint for a project or for a particular technological process such as recirculating aquaculture systems. Where the location of a resource-based project cannot be changed, the project may have to provide its own power source.

Fuel. For fuel oil or gas, such data should cover, for each item, the quantities normally required, the source, distance to different locations, transport facilities and costs.

Transport. Transport facilities (by rail, road, air or water) may be available for the supply of various inputs and for the marketing of products. Availability and cost need to be detailed for the total volume of inputs into the proposed farm and the total outputs leaving the farm, with comparisons for various alternative input supplies and market locations.

Human resources. The availability of human resources, including skilled and semi-skilled workers, and the type of skills, should be taken into account. Labour requirements should be estimated together with any allowances for on-site housing costs.

Effluent and waste disposal. Farm effluent disposal may be another critical factor. Effluent from farms produces waste products, in some cases highly toxic substances or emissions that may have significant impacts on the environment.

Text length suggested: Site Selected 3 to 5 pages

The selected site
1. The selected location
2. The suitability of the location

Studies and licences required

List any studies that need to be undertaken. List any registration or licences required to start and operate the farms.

Text length suggested: Studies and licences 1/2 page

Studies, licences and permissions
1. Studies required • feasibility study, business plan • environmental impact statement
2. Aquaculture registration and licences • aquaculture registration • aquaculture operational licences

Biological feasibility

This section should include in reasonable detail (according to the farm size), the Latin name, common name and local name of the proposed species to be cultured. It should include the proposed source of fry/fingerlings, the proposed market size, the expected time to reach market size, the proposed stocking density and expected food conversion rate and survival rate. If more than one species will be cultured, then give data for each species.

Gather secondary data such as studies on species growth and performance that might have been conducted in the area or other areas with similar climate and ecological conditions.

Assess the data and decide whether the natural and biological factors of the site are favourable to the biological performance of the species and production systems being proposed.

Text length suggested: Proposed species 2 pages

The proposed species
1. Selected species to be cultured
2. Species productivity

Technical feasibility

An integral part the feasibility stage is the selection of an appropriate technology, as well as planning of the acquisition and absorption of this technology and of the corresponding know-how. The required machinery and equipment must be determined in relation to the technology and processes to be used and the local conditions.

This section should describe the proposed technology to be used for the nursery and production facilities (such as: ponds/pens/cages) and the level of production intensity in pieces per m^2 or kg per m^3 (intensive, semi-intensive, extensive).

Text length suggested: Technology to be used 3 to 4 pages

The technology to be used
1. Description of the production technology to be used (such as ponds/pens/cages)
2. Intensity of production (intensive, semi-intensive, extensive)

Operational feasibility

Whereas the choice of technology defines the production processes to be utilized, the effective management and operation of technology transfer requires that the technology and know-how are acquired on suitable terms and conditions, and that the necessary skills are available or developed. Skill development needs to be planned through training programmes at various levels.

A feasibility study should define the detailed production programme indicating the levels of output to be achieved during specified periods and consider the various production stages, in terms of both production activities and timing.

Provide a summary of any key activities that need to be undertaken before the farms can start to operate, such as building of water supply channels, wells, water intake systems, effluent water discharge channels, digging ponds, etc. Provide a summary of the operational timing from initial stocking to first harvests.

Text length suggested: Timing 1 page

Time scheduling
1. Preparation works • building of water supply channels, effluent water discharge channels • digging ponds
2. Operational timing • stocking • first production • first harvesting and marketing

3. Economic analysis

This section summarizes the economic analysis of production. It details the start-up costs, capital costs, operational costs and overheads. The economic assessment provides an analysis of the project's capacity to be profitable and generate enough revenues to recover the investment and operating costs.

Variable costs

Variable costs are those expenses related directly to the quantity of fish produced for market. These include feed, fingerlings, chemicals, fuel, labour, etc.

Fixed costs

Fixed costs are those costs that a farmer will have whether or not any fish are produced. Fixed costs include depreciation, taxes and general overhead costs. Fixed costs are important in determining if the business will be viable over a long period of time.

Table of assumptions

The economic analysis is based on a number of production and cost assumptions.

Data must be collected pertaining to:

- the biological performance of the species (stocking size, growth rate, survival, harvest size, etc.);
- the production system (surface area, depth, number of systems, etc.); and
- the productivity of the culture system (stocking density, food conversion rate, etc.).

Example of grow-out assumptions

Table 1. Grow-out assumptions

Grow-out facility	Shrimp	Crab	Tilapia
Culture system area (m^2)	10 000	10 000	10 000
Culture system depth (m)	1.5	1.5	1.5
Culture system volume (m^3)	15 000	15 000	15 000
Number of systems	1	1	1
Total system volume (m^3)	15 000	15 000	15 000
Stocking size (g)	0.15	0.20	10
Harvesting size (g)	28	325	750
Initial stocking density (pieces/m^3)	13	0.35	0.15
Initial stocking number (total)	125 000	3 500	1 500
Survival during culture (%)	11.5	31.5	32.0
Final stocking number (total)	14 400	1 103	480
Final stocking density (kg/m^3)	0.026	0.238	0.024
Production (kg/system)	400	358	360
Food conversion rate X:1	0.34	0.34	0.34
Biomass Increase (kg/system)	397	358	355
Production per system (# fish)	14 400	1 103	480
Production cycles/year	1.0	1.0	1.0
Total production/year (kg)	400	358	360

A new farm may take some time to reach full productivity. For example, it may not be able to produce 100 percent productivity in the first year of operation so the rate of production is given in another table.

Example of grow farm productivity

Table 2. Expected annual production (tonnes)

Efficiency (%)	Production (tonnes)	Shrimp	Crab	Tilapia
50	Year 0	0.20	0.18	0.18
100	Year 1	0.40	0.36	0.36
100	Year 2	0.40	0.36	0.36
100	Year 3	0.40	0.36	0.36
100	Year 4	0.40	0.36	0.36
100	Year 5	0.40	0.36	0.36

The cost of feed needs to be given. This may be different for different species.

Table 3. Feed cost assumptions

Feed cost assumptions	Shrimp	Crab	Tilapia
Ongrowing feed cost (cost/tonne)	500.50	557.40	555.50

The cost of fry/seed needs to be given. This may be different for different species.

Table 4. Fry/Seed cost assumptions

Fry cost assumptions	Shrimp	Crab	Tilapia
Fry cost (cost/piece)	0.001	0.10	0.07

Start-up cost estimate

Estimates should be made for any start-up costs (costs before the construction and operation of the farm).

Required studies

- feasibility studies
- bathymetry and/or topography study
- soil and/or water quality study
- design studies
- environmental licences

Table 5. Start-up costs

Assumptions	Cost
Studies	
Water quality analysis	
Environmental studies	
Other costs	
Sub-total start-up costs	

Sub-total costs will go to summary tables

Capital cost estimates (production facilities)

Once the type and size of a farm are defined, a preliminary order-of-magnitude estimate can made for the engineering works to build the production facilities.

Civil works

- site preparation
- excavation/infill
- drainage
- flood control
- internal roads

Structural works – building slab and drains, walls, ceiling, roof, doors and windows.

- stores
- workshops

Building fit out

- electrical
- plumbing
- equipment

Culture facilities

- tanks and ponds construction
- assembly and installation of pens, cages, moorings

Table 6. Production facility costs

Production facility costs	Cost
Cost of land	
Digging ponds	
Making drains	
Well construction	
Internal roads	
Staff accommodation	
Other costs	
Sub-total land and building costs	

Sub-total costs will go to summary tables.

Capital cost estimates (production equipment)

Once the type and size of farm are defined, a preliminary order-of-magnitude estimate can be made for the equipment required for the production facilities.

Production equipment costs

- feeders
- harvesting nets
- pumps
- etc.

Table 7. Production equipment costs

Production equipment costs	Cost
Harvest net	
Trailer	
Raft	
Pond pump	
Other costs	
Sub-total equipment costs	

Sub-total costs will go to summary tables.

Depreciation cost

Depreciation is an accounting method used to distribute the initial cost of investment over the lifetime of the cost. Depreciation costs should be calculated on the basis of the original value of fixed investments, according to the straight-line method and rates approved by the tax authorities.

These are typically:

- concrete works and buildings: 20 years;
- dry equipment (not in contact with water): 10 years; and
- wet equipment (in contact with water): 3 to 5 years.

Table 8. Depreciation cost

Depreciation cost	Cost	Depreciation years	Annual cost
Digging pond		20	
Make drains, well construction, internal roads, staff accommodation		10	
Harvest net, trailer, raft, pond pump		3	
Sub-total depreciation costs			

Sub-total costs will go to summary tables.

Operating or production cost

Regarding the **operating costs**, these are the expenses for the purchase of materials and the supply of services to produce the fish/shrimp/bivalves on an annual basis for ten years.

The majority of the operating costs include:

- direct production costs (consumption of materials and services, personnel, maintenance and general production costs);

- administrative and general expenditures; and
- sales and distribution expenditures.

The production variable costs include:

- feed
- fingerlings
- fuel
- electricity
- communications
- hired labour
- chemicals and medication
- fertilizer
- repairs and maintenance
- travel
- etc.

The harvest and post-harvest variable costs include:

- harvesting
- packing
- processing
- marketing
- distribution costs

Table 9. Estimated operational costs

Operational costs (VND)	Full production	Year 1	Year 2	Etc.
Feed grow-out	21 071 574	10 535 787		
Fry/seed	20 923 265	10 461 633		
Rent pond annually	4 380 000	2 190 000		
Disease control	2 000 000	1 000 000		
Fuel	500 000	250 000		
Communications	600 000	300 000		
Hired labour	15 810 000	7 905 000		
Drug, medical	2 650 000	1 325 000		
Repairs and maintenance	9 050 000	4 525 000		
Ice and boxes				
Interest on loan	2 000 000	1 000 000		
Contingency (10%)	7 698 484	3 849 241.96		
Depreciation	18 517 333	9 258 667		
Sub-total operating costs	105 200 656	52 600 328		

Data for shaded cells comes from previous tables.

Market price

The market price at farm gate needs to be given. This may be different for different species.

Table 10. Market price (USD)/kg

Assumptions	Shrimp	Crab	Tilapia
Sales price (USD)/kg	6.5	7.25	1.25

Table 11. Estimated sales income

Sales income	Year 1	Year 2	Etc.
Shrimp			
Crab			
Tilapia			
Total sales income			

4. Financial analysis

This section evaluates the financial profitability of an investment in a project and its sustainability.

The purpose of the financial analysis is to evaluate the financial profitability of an investment in a project and its sustainability. The profitability assessment provides an analysis of the project's capacity to generate monetary cash flows: a project is profitable if it generates enough revenues to recover the investment and operating costs. In particular, in the profitability analysis the focus is on the capacity of a project to generate adequate cash flows.

Net cash flow table

The project cash flow is defined as the difference between the money inflows and the outflows produced by a project. It is calculated on the basis of the differences in the costs and revenues. The net cash flow example contains a list of expenses that a farm has to produce the fish and the income from sales of fish. These should be taken into consideration by the investor when preparing a cash flow statement.

Definition of terms

- **Cost escalation factor.** Cost escalation is defined as changes in the cost or price of specific goods or services in a given economy over a period. This is similar to the concepts of inflation and deflation except that escalation is specific to an item or class of items (not general in nature).
- **Benefit escalation factor.** Benefit escalation factor is the percentage at which an annual change in the market price levels of the product is expected to occur.
- **Income tax rate.** The income tax rate is the ratio (usually expressed as a percentage) at which a business or person is taxed.
- **Discount rate.** The discount rate is the minimum interest rate set by the national banks for lending to other banks.

Assumptions:	Percentage rate
Cost escalation factor	2.00
Benefit escalation factor	2.20
Income tax rate	0.00
Discount rate	7.00

Net cash flow table	Year 1	Year 2	Year 3
Net capital costs			
Land and building costs			
Production equipment costs			
Total capital costs			
Operating and maintenance costs			
Feed			
Fry			
Other costs			
Total production costs			
Sales revenue income			
Revenue from sales			
Total sales revenue			
Cash flow before taxes			
Income tax calculation			
Depreciation expense			
Operating cost			
Operating benefits			
Net income taxes			
Cash flow after taxes			
Discounted cash flow (after tax)			

Simple payback analysis

The payback period is determined by counting the number of years it takes to pay back the money invested (disregarding the time value of money). For example, if it takes five years to recover the cost of the investment, the payback period is five years.

The discounted payback period (DPP) is the amount of time that it takes (in years) to pay back the initial money invested based on the discounted value of expected cash flows (taking into account the time value of money).

Break even results:
Simple payback
Discounted payback

Financial analysis

Break even

Break even analysis offers additional insights into the overall feasibility of the operation. It refers to the volume of sales at which the net sales of the business just equals its costs.

Internal rate of return (IRR)

The IRR is the rate of return on the investment that is made over the life of the project. It is calculated by the initial investment and the cash flow return each year during the project. The IRR should be greater than the interest rate that could be achieved by keeping the investment in the bank.

Net present value (NPV)

The net present value is the present value of an investment's future net cash flows minus the initial investment. NPV of the project should be positive.

Sensitivity analysis

Farm economic analyses are based on average expected prices, costs, quantities and yields. However, in some cases, certain prices and costs may be highly variable or change over time. Sensitivity analysis highlights the key costs that can affect profitability.

(%)	Sensitivity analysis	37.1%
120	Capital costs	31.3%
120	Equipment costs	36.8%
120	Fry costs	35.0%
120	Feed costs	35.0%
120	Other costs	32.6%
120	Sales price	52.6%
120	Survival	47.7%

The above sensitivity analysis table shows that sale price is the most sensitive factor to economic feasibility of the project. If sale price increases 20 percent, the IRR of project could reach 52.6 percent. If the survival increases 20 percent, the IRR of project could be 47.7 percent.

5. Support services at the cluster level

Support services at the cluster scale

Describe the support infrastructure required to support the cluster of farms (hatcheries, nurseries, jetties, ice machine, market area, feed store, etc.). Describe the technical support required (demonstration farm, training, extension services, etc.). Describe the farmer producer organization/association/club that needs to be established. Describe the operational support requirement (biosecurity guidelines, water quality monitoring, disease monitoring, etc.)

Text length suggested: Service overview 3 to 4 pages

Services Overview
1. Support infrastructure required
2. Technical support required
3. Farmer organization
4. Operational support

6. Market analysis at the cluster level

This market overview provides a better understanding of the market and marketing plans and strategies. It provides an overview of the planned market for the products, in terms of geographic area, market dynamics, who the customers are and what are their needs, how these needs will be met and the strengths of the product that will be offered.

Effective marketing is about identifying market demand and supplying this demand better than competitors. The selection of a target market and the understanding of the needs is the core of good and effective marketing.

Target market and market demand

The target market should be identified (local, provincial, country, export). Estimate how much production can be supplied to these markets without affecting market price significantly. The market demand should also be analysed to ensure that adequate demand exists for the outputs of the project.

Text length suggested: Market demand 2 to 3 pages

The target market and market demand
Target market and market demand
• potential markets
• market demand
• market price (different fish size)
• seasonal price variation

Competitive analysis

Competitive analysis of other suppliers of the same product is necessary to ensure profitability. Can producers of the same product in other locations produce it cheaper, are closer to the main markets, can supply fresher fish, etc. By knowing this, the producers can develop a marketing strategy based on their strengths and beat their competitors.

Text length suggested: Competitors 1 to 2 pages

Competitive analysis
Competitive analysis
• identify competing producers
• identify competitor strengths and weaknesses
• analyse cluster producer strengths and weaknesses

Marketing strategy

Based on the previous market analysis, this section identifies strategies to beat competitors. Decide if the products will be sold at wholesale or retail outlets. Will the products be sold for cash or will they be sold with some credit terms? Will the products be collected at the farm by traders or will the farmers deliver to the market?

Text length suggested: Strategies 1 to 2 pages

Marketing strategies
Marketing strategy • identify strategies to beat competitors • market channel – trader, wholesale or retail • payment terms • distribution logistics – collection or delivery

7. Social benefits at all scales

Social benefits

This section describes social benefits of the project to the local inhabitants, other stakeholders and users of the resource as well as to the county as a whole.

- Describe the benefits to the farmers and their households (higher quality diet, additional income, diversified income).
- Describe the benefits to the surrounding community (direct employment of local people, part-time employment of local people, employment of females, providing other support services and other indirect benefits to the local community).
- Describe any benefits to other stakeholders and users of the aquatic resource (e.g. increased wild fisheries for fishermen).
- Describe the benefits to the country (rural development, potential food security, potential export earnings).

Text length suggested: Social benefits 1 to 2 pages

Social benefits
Benefits to the farmers and their households • higher quality diet • additional income • diversified income **Benefits to the surrounding community** • direct employment of local people • part-time employment of local people • employment of females • indirect benefits to the local community **Benefits to other stakeholders and users of the aquatic resource** • benefits to local fishermen **Benefits to the country** • potential food security • potential export earnings

8. Risks and mitigation of risks

A description of key risks to productivity and economic viability and any mitigation measures that can be taken is required. Information should be provided regarding:

Disease risks and biosecurity

Disease outbreak is one of the highest risks to farmers. This risk can be reduced by pro-active disease prevention such as vaccination or by implementing biosecurity measures.

Biosecurity in aquaculture consists of practices that minimize the risk of introducing an infectious disease and spreading it to the fish at the farm and the risk that diseased fish or infectious agents will spread to other farms.

Water quality and environmental impacts

It is essential that there are sufficient water resources available and of good quality throughout the year. The effluent water quality should not significantly cause significant environmental impact.

Theft and security measures

Theft from production systems can be problematic in some areas and so there may be measures that need to be taken at the cluster level such as night guards or guard dogs.

Potential conflict with surrounding communities or other users of the water resource

The development of new aquaculture activities can cause conflict with surrounding communities or other users of the water resource.

Other risks (e.g. climate change)

Climate change is affecting rainfall patterns and so there may be increased risk of heavy rain leading to floods, change in dry and wet seasons, long hot spells, etc.

Text length suggested: Risks 1 to 2 pages

Risks and mitigation of risks
• biosecurity to reduce disease risks • water quality and environmental impact • security measures • conflict with neighbours or other users of the aquatic resource • climate change risks

Tool Manual 3:
Aquaculture farm biosecurity plan

Guidelines for developing a farm level biosecurity plan

By

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1. Introduction

Issue to be addressed by the tool

Communicable diseases are a major obstacle to the profitability of aquaculture enterprises. Managing disease risks is therefore an essential part of managing commercial aquaculture operations.

Many disease agents or pathogens capable of causing disease in aquatic animals are typically ubiquitous in farm water and animals, but are only problematic when the host-environment-pathogen equilibrium is disturbed. For example, clinical disease can manifest if environmental conditions (such as pH or temperature) change sufficiently to compromise the host's ability to resist infection. A range of best practice husbandry measures can be applied to minimize stock losses. However, there are some pathogens that can cause significant losses even under best practice or that can limit international market access even if they don't affect production. Farm biosecurity plans are farm design and operational procedures aimed at minimizing the risk of an outbreak of such diseases.

Biosecurity can be defined more broadly to capture pest risks as well as disease risks, but in the context of this document, only disease risks are considered (NZMPI, 2016). So, 'biosecurity' as considered here is the exclusion, eradication or containment of disease agents from aquaculture systems that would otherwise pose an unacceptable risk to farm profitability.

A farm level biosecurity plan is made up of the procedures that have been put in place to manage biosecurity risks, specifically to reduce the risk of diseases being introduced into a farm, spreading within a farm, or escaping from a farm, including by responding effectively to contain or eradicate diseases when outbreaks do occur.

Purpose of the tool

The purpose of this tool is to guide farmers in developing a farm biosecurity manual – it is a set of instructions on how a farm biosecurity plan can be set up and maintained, and documented into a farm biosecurity manual. This tool can be applied to checking if farms (both existing or design-stage) have the range of biosecurity measures needed to manage the risk of serious diseases entering the farm or spreading within or from the farm. Each farm's biosecurity manual, once written, can be used for training purposes, as a quick reference during normal farm operation or during a disease outbreak, or as a means of demonstrating the farms biosecurity arrangements for regulatory, certification or other purposes.

Who will use the tool?

The tool is intended primarily for use by farmers in managing biosecurity risks. The establishment of a farm biosecurity plan may also assist farms in meeting any regulatory obligations or market access requirements. Equally, this tool may help government agencies in designing regulatory conditions or extension or awareness-building programmes as they relate to farm biosecurity.

Principles of the tool

This manual takes, in the main, the form of a checklist. That is, a list of biosecurity measures that can be used as an audit table to check if an existing or design stage farm has the range of biosecurity measures needed for effective biosecurity. At the heart of these biosecurity measures is a focus on prevention and readiness to respond if preventive measures fail.

Optimal application of the tool requires some technical knowledge (aquatic animal health management) and as such, it is envisaged that the tool would be applied with some external technical guidance, especially in the case of small to medium-scale farms (which are typically less well resourced). This technical guidance could for example take the form of government extension services and/or private sector aquatic animal health experts.

Farming systems for tool application

The checklist can be applied in any farm circumstance, ranging from semi-open systems such as marine cage culture to fully closed recirculating systems and to small, medium and large-scale farms, as well as farm clusters. Of course, not all possible biosecurity measures would suit all farm circumstances, so the tool has been designed in a way that those measures applicable in a particular farm circumstance can be readily identified.

Tool limitations

It is important to recognize the limitation that even the most well-resourced biosecurity plan is not fool proof – biosecurity plans are not a means of eliminating risks, but rather managing risks. It is impossible to completely prevent the entry of serious pathogens into any farm. So, the objective of biosecurity is to reduce risk to a level where the biosecurity measures are affordable and the biosecurity risks (and the associated business risk) to the farm are acceptable.

This tool presents a comprehensive range of possible biosecurity measures to cover the range of possible farm scenarios. These measures vary in cost and several may be out of the reach of small-scale household-level farmers in particular. It should be acknowledged that unless legally mandated (e.g. in licence requirements), the implementation of a biosecurity plan, or any single measure within a plan, is a business decision, based intuitively or otherwise, on cost-benefit analysis.

Planning, management and resource implications

From a government level aquaculture resource management perspective, competent authorities should consider developing awareness building and training programmes in farm level biosecurity for farmers and extension officers. Such programmes could be tailored to the types of aquaculture operations relevant to the locality.

Good farm level biosecurity is not only important from the perspective of a single farming operation, but is also important in maintaining favourable health status at a range of jurisdictional (such as provincial and national) levels. Government support of this kind has financial resource implications, but given this common good that farm biosecurity contributes to in maintaining the quality of aquatic resources, there is a compelling case for public sector support in ensuring that farmers implement effective farm biosecurity plans.

Acknowledgements

This tool has been developed primarily on the basis of the work of Australia's Sub-Committee on Aquatic Animal Health (SCAAH, 2016). It also drew on the New Zealand Government's Aquaculture Biosecurity Handbook (NZMPI, 2016) and the United Kingdom's Cefas Shellfish Biosecurity Measures Plan (Cefas, 2009).

The tool was trialled in Thailand and Viet Nam by the Department of Fisheries and the Department of Aquaculture (Directorate of Fisheries), respectively. The Thai pilot was conducted on mostly family-owned, small-scale to medium-scale tilapia cage culture operations in the Noi River, Chainat Province. The Vietnamese trial was conducted on integrated small-scale semi-extensive tiger shrimp

(polyculture) farming operations in Hoang Hoa District, Thanh Hoa Province. Feedback provided from these trials was taken into consideration in finalizing this tool. The efforts of the Thai and Vietnamese government agencies and farmers involved in the two trials are gratefully acknowledged.

How to use this tool

This manual provides stepwise directions on how to develop a farm level biosecurity plan.

Not all elements of biosecurity recommended in this document would apply to all aquaculture scenarios; the recommendations herein should be tailored to what is applicable, practical and affordable to each individual farm.

The steps in developing a farm biosecurity plan are:

- information gathering;
- risk analysis;
- auditing against best practice guidelines;
- developing an implementation plan for identified biosecurity measures;
- documenting the biosecurity plan in a farm biosecurity manual; and
- periodically reviewing the farm's biosecurity effectiveness.

Each is detailed in Sections 2-5.

The process of developing farm biosecurity needs to be a cyclical one, where biosecurity plans once implemented and documented, are periodically reviewed (ideally annually or bi-annually) to ensure their ongoing effectiveness, beginning with the gathering of any new information such as on emerging diseases or new biosecurity technologies that may be available to farmers. Ideally, biosecurity plans should be developed in consultation with an aquatic animal health specialist.

Pathways for the spread of disease

Farm level biosecurity needs to recognize the pathways (routes) by which diseases of concern could spread to, within and from a farm. The main pathways for disease entering a farm are via infected animals or via contaminated water, vehicles, equipment, feed, people and farm waste.

These same pathways also spread disease within a farm and from a farm to other farmed or wild aquatic animal populations. Within a farm, different stock populations will differ in health status. For example, broodstock and hatcheries may have the highest health status, nursery areas may have a slightly lower health status, and grow out populations may have the lowest health status on the farm. Within a class of stock (e.g. grow out stock), there would typically be subpopulations such as a pond or a cluster of ponds that form epidemiologically isolated units. These units present an opportunity to manage the spread of disease risk within a farm.

Disease spread out of a farm to neighbouring farms or wild aquatic animal populations represents a disease risk to the local area, province or country. The risk can also be to the farm itself if the disease is a new one that becomes established in local farmed and wild aquatic animal populations and continues to be reintroduced into the farm, even after the disease has been eradicated. Preventing the spread of disease to surrounding farms and waterways is therefore an important component of farm biosecurity.

Animals

The movement of aquatic animals such as broodstock, seed, genetic material (e.g. eggs), and animal products into, within or out of a farm can present a significant disease risk, particularly if they are of unknown health status. Escapees and wild aquatic animals entering via the water supply, wild animals such as birds, and pest animals such as rodents and other scavengers can also be a means of disease spreading, carrying the agent via infection or mechanically in fomites.

People

People (staff, contractors, visitors or unauthorized persons) can spread aquatic animal diseases via contaminated skin, clothing and footwear, particularly where they move from one farm to another or if they have visited high-risk areas such as the site of "fish kills".

Equipment, vehicles and vessels

Equipment that has been in contact with aquatic animals can cause disease to spread. Equipment can include for example harvest, grading, diving, and feeding equipment. The level of risk will depend on the history of use, for example, equipment used by other farmers or processors will have a much higher risk compared to new equipment. Vehicles such as cars, trucks and tractors can spread diseases and again, the level of risk will depend on the history of use. Vessels can also be a means of disease spreading, particularly when they have been used at other farms or have been in close contact with animals, for example, well boats or fishing vessels.

Water

A farm's water supply has a major influence on animal health. In open systems such as sea cages there can be little control of water as a route of disease transmission; however, the nature of water currents and positioning of farms can be considered in managing biosecurity risks. For land-based facilities, the risk of disease spreading via water will depend on the nature of the water source into and within the farm, the presence of host animals in that water and the proximity of other farms that may discharge into and receive from the same water source.

Feed

Manufactured feeds such as extruded pellets generally present a low risk of disease transmission because of deactivation of pathogens during the manufacturing process, which often includes temperatures above which most pathogens cannot survive. However, live, fresh or frozen feeds can present significant risks. The level of risk will depend on the pathogens of concern, the origin of the feeds and the degree of processing; for example, freezing may kill parasites but may not kill viruses. Aerosols may also be important in disease spread – although the role of aerosols is not well studied, they may be an important means of disease spreading across short distances.

Waste

Waste products such as cultivation water, dead animals and cleaning effluent can be vectors for transmission of disease onto, within and from a farm. Appropriate infrastructure and disposal procedures are required to manage the disease risks associated with potentially contaminated waste products.

2. Information gathering

The more armed you are with information, the better will be the biosecurity plan. Importantly, information is needed to support risk analysis (see Section 3), audit existing biosecurity arrangements in farms, as well as to document the biosecurity plan in the form of a farm biosecurity manual.

The following checklist is provided to assist in the information gathering process. Because of the technical nature of much of the information needed to undertake a farm biosecurity plan (including risk analysis) and implement a biosecurity plan, it is recommended that this information is gathered in consultation with an aquatic animal health specialist.

General

- Description/map of the area where the farm is sited in terms of other aquaculture operations, especially those that farm the same species.
- Diagram of the farm layout, including
  - site access points;
  - vehicle parking;
  - visitor reception;
  - water supply, treatment and discharge routes;
  - water pumps and valves;
  - water intake and discharge points;
  - water flow patters;
  - equipment/vehicle wash-down points;
  - marinas and boat ramps;
  - production units – hatchery, nursery, grow out;
  - quarantine facilities;
  - footbaths or disinfection areas;
  - escape prevention measures (e.g. screens);
  - routes of typical stock movement through the facility; and
  - waste disposal areas.
- Farm husbandry practices related to aquatic animal health/biosecurity, including
  - overall farming process – breeding, nursery, grow out, harvest;
  - animal movement rerecord keeping;
  - health status/treatment monitoring and record keeping;
  - water quality monitoring; and
  - standard operating procedures.
- Regulatory requirements with a view to aligning the biosecurity plan.
- Useful contacts: aquatic animal health/biosecurity expertise; government experts.

Host factors

- farmed species;
- optimal feeding rates;
- normal growth rates;
- availability of SPF stock – where are the source suppliers?
- gross signs/mortality/morbidity;
- host range/life stage infected; and
- life cycle.

Agent factors

- diseases of concern for the farmed species;
- disease symptoms;
- host range, including carrier species;
- routes of infection (e.g. oral, cohabitation etc.);
- agent stability and pathways for disease spreading;
- disinfection methods;
- geographical range of the disease;
- history of any local outbreaks;
- environmental/water conditions more likely to result in an outbreak; and
- chemotherapeutants effective against agents of concern/vaccines – regulations governing use.

Environmental factors

- normal water quality parameters;
- weather and seasonality (including temperature and rainfall); and
- frequency of extreme weather events (such as floods and storms).

3. Risk analysis

Risk analysis is an accepted approach for evaluating biosecurity risks. In the context of this document, risk analysis will identify specific diseases of concern to a farming operation, determine the level of risk posed by each of these diseases and determining the biosecurity measures that will reduce the risk to an acceptable level.

These measures can then be compared against those measures listed in Appendix 1 to ensure that the farm's biosecurity plan addresses the risks posed by the specific diseases identified in the risk analysis. Importantly, going through the risk analysis process also gives the farmer an appreciation of the relative risk posed by the range of pathogens to which the farmed species is susceptible and an appreciation of the benefits of the biosecurity plan.

The following provides a methodology for risk analysis. It is a nine-step method adapted from SCAAH (2016). The analysis should ideally be conducted in consultation with an aquatic animal health specialist to ensure it is thorough and accurate. The analysis must also be periodically reviewed as part of reviewing the farm's biosecurity plan.

The nine risk analysis steps are grouped into four stages:

- hazard identification;
- risk assessment;
- risk management; and
- documentation.

Hazard identification

Hazard identification involves identifying the diseases that could potentially produce adverse consequences to aquatic animal health and farm productivity. The hazards include not only damaging pathogens that are best excluded from the farm, but also other pathogens that are known

to occur within the facility and that must be managed to mitigate production impacts (production diseases).

1. Collect information about the potentially serious pathogens that could affect the farmed species – both scientific and industry literature/sources should be examined, keeping in mind that new diseases emerge regularly in aquaculture and a precautionary approach must be taken to include in the hazard analysis any little known emerging disease.

2. For each pathogen, describe:

    a. the nature of the organism (e.g. tilapia lake virus (TiLV), an enveloped single-stranded riboneucleic acid (RNA) virus);
    b. the geographic distribution (i.e. is the pathogen endemic or exotic to the country, region or locality?);
    c. The likely consequences (what morbidity/mortality or marketability impacts an outbreak in the farm?);
    d. The means of transmission (how can the pathogen be introduced into the farm and spread within the farm – via infected brood stock, via the water, by cohabitation with infected animals, in the feed etc.?); and
    e. Any additional information (e.g. are there intermediate hosts involved – what is the method and ease with which the disease can be contained or eradicated?).

3. Based on the information collected, determine which pathogens should be the subject to risk assessment. Some pathogens might not be classified as a hazard because they are expected to cause little or no impact on farm productivity or product market access.

The outcome of hazard identification will be a list of diseases expected to have adverse consequences, and for which risk assessment must be conducted as per below.

Assess risks

In the risk assessment part of the risk analysis, a level of risk is assigned to each hazard that is expected to have adverse consequences. Risk is made up of a combination of two factors: the likelihood of the disease entering a farm and the consequences (impacts) of the disease if it did enter the farm.

4. For each pathogen identified as requiring risk assessment, assign a likelihood of occurrence on the farm using the range of likelihood described below. Likelihood can be estimated by considering the pathways necessary for entry of a disease, and for exposure of your animals to the disease. For example, the likelihood of entry and exposure might be "certain" for a pathogen that occurs in untreated intake water. Similarly, pathways involving infected live animals have a high likelihood of entry and exposure because they may carry large quantities of viable pathogens. The likelihood rating will vary depending on the properties of the disease, the occurrence of the disease outside the farm, and the possible pathways into the farm. Likelihood ratings and descriptors are shown in the Table 1.

Table 1. Likelihood ratings and descriptors

Likelihood level	Descriptor
Remote (1)	Never heard of, but not impossible here (occurs less than once in 20 years).
Unlikely (2)	May occur here, but only in exceptional circumstances – occurs more than once in 20 years.
Possible (3)	Clear evidence to suggest this is possible in this situation – occurs more than once in 3 years.
Likely (4)	It is likely, but not certain, to occur here – occurs more than once in 2 years (>50%).
Certain (5)	It is almost certain to occur – occurs nearly every year.

5. For each pathogen, determine the impact if the disease entered the farm using the list of consequence levels described in Table 2. Consequence can be estimated by considering the impacts of a disease on the productivity of your farm. The consequences could include multiple aspects, e.g. mortality, reduced growth or food conversion, product quality, market access or treatment costs.

Table 2. Consequence levels and descriptors

Consequence level	Descriptor
Insignificant (1)	Impact not detectable or minimal.
Minor (2)	Impact on farm productivity limited to some production units or short term only.
Moderate (3)	Widespread impact on farm productivity as a result of increased mortality or decreased performance.
Major (4)	Considerable impact on farm production resulting in serious supply constraints and financial impact.
Catastrophic (5)	Complete depopulation of the farm and possibly barriers to resumption of production.

6. For each pathogen, combine the likelihood and consequence level estimations using the risk matrix (Figure 1) to get a risk rating. Risks are highest when both likelihood and consequences are high. However, risks may be low even if the consequence is "catastrophic" but the likelihood is "remote"; or even if likelihood is "certain" but the consequence is "insignificant".

Consequence rating

Likelihood rating	insignificant	minor	moderate	major	catastrophic
remote	1	2	3	4	5
unlikely	2	4	6	8	10
possible	3	6	9	12	15
likely	4	8	12	16	20
certain	5	10	15	20	25

Figure 1. Risk matrix

7. For each pathogen, determine if risk management is necessary using Table 3.

Table 3. Risk level and management response

Risk level	Risk management response
Negligible (1-2)	Acceptable level of risk. No action required.
Low (3-5)	Acceptable level of risk. Ongoing monitoring may be required.
Medium (6-10)	Unacceptable level of risk. Active management is required to reduce the level of risk.
High (12-15)	Unacceptable level of risk. Intervention is required to mitigate the level of risk.
Extreme (16-25)	Unacceptable level of risk. Urgent intervention is required to mitigate the level of risk.

Risk management

8. For each pathogen, identify measures to reduce the identified risks to an acceptable level.

   a. For medium, high and extreme risk pathogens, risk management measures to reduce biosecurity risks to acceptable levels must form part of the farm biosecurity plan. There may be many options for managing the risk, such as using specific pathogen free seed or targeted surveillance of farm stock for the disease. The preferred option should be chosen based on practicality, effectiveness and affordability, keeping in mind that often a range of measures can be applied in combination if deemed necessary. Risk management options may reduce likelihood, consequence or both. For example, vaccination would have no influence on likelihood of entry of a pathogen but may reduce consequences significantly. For management options that reduce likelihood, the measure must correspond to the pathway(s) that represent the unacceptable risk.

   b. For low risks pathogens, specific mitigation measures may not be required, but may warrant ongoing monitoring of the latest information (including scientific and industry sources) to identify if the risk profile changes over time.

Documentation

9. Document the risk analysis so that risks and risk management measures can be easily reviewed as a part of the routine review of the biosecurity plan. This will also record the rationale for specific measures in the biosecurity plan. Table 4 provides an example of how the risk analysis can be recorded concisely.

Table 4. An example of how to record a risk analysis

Hazard	Likelihood	Consequence	Unmodified risk rating	Management response & control measures	Modified risk rating
Entry and spread of "*disease X*" into and within the farm.	Possible The disease is endemic and has occurred in source hatcheries previously.	Major Destruction of affected stock would be required as a result of impacts on performance.	12 (High)	Mitigation measures are required to reduce risk. Likelihood reduced by sourcing stock only from hatcheries with a health accreditation scheme. Active targeted surveillance of the farm stock for the disease agent.	Control measures reduce likelihood to "Remote". Measures reduce risk rating to 4 (Low). Modified risk is acceptable.

4. Biosecurity audit and implementation

In developing a farm biosecurity plan, it is important to consider the biosecurity measures that are already in place in the farm. A checklist (or audit table) should be developed for this purpose. A generic checklist is provided in Appendix 1.

The generic list comprises a range of biosecurity measures grouped into:

- administration
- farm design/structure
- managing the routes of disease introduction and spread
  - people
  - animals
  - equipment/vehicles/vessels
  - water
  - waste
  - feed
- health monitoring and emergency response, and
- review/audit

Each of the biosecurity measures should be considered for inclusion in a farm's biosecurity plan, where appropriate to the farming system. Any biosecurity risk management measures identified through risk analysis (see Section 3) that are not in the recommended list in Appendix 1 should be incorporated into the audit table.

As the audit is being conducted, for each biosecurity measure on the checklist a note should be made in the "findings" column as to whether the measure is relevant to the type of farming operation. If so, further note should be made as to whether the measure is already in place at the farm. If the measure is an existing one, note should be made of any improvements needed.

If the recommended measure is not an existing one (or one that needs improvement), a decision must be made whether to include the measure into the farm's biosecurity plan. This information is documented in the third column of the audit table, under *Action plan: Implementation timeline and confirmation of resourcing*. As indicated, it is also useful to document the recommended timeline for completion and confirmation of resources being available to implement the measure. If any of the measures are in the table as a result of the risk analysis, then those measures identified to address the higher risks should be given priority in terms of getting done before other measures.

All actions resulting from the audit should then be consolidated to create a biosecurity action plan. This consolidated list (the action plan) can be used to progress and monitor the implementation of the farm's biosecurity plan.

5. Farm biosecurity plan

The farm biosecurity plan should document farm design and operational procedures, including individual responsibilities (*who does what, when and why)* that go to make up the biosecurity plan. It must be concise, easy to read and regularly reviewed. It can be used for training purposes, as a quick reference during normal farm operation or during a disease outbreak, or as a means of demonstrating the farm's biosecurity arrangements for regulatory certification or other purposes. Having all the information relevant to biosecurity in a single, easy to access document is particularly useful in responding rapidly to disease emergencies. As a guide, the manual should be sufficiently

detailed, yet sufficiently easy to read and digest, for managers/decision makers or an aquatic animal health professional to get a ready understanding of the farms biosecurity arrangements.

Importantly, the plan could be the basis of discussion with neighbouring farms, to achieve a consistent approach to managing disease risks in a locality – poor biosecurity practices can undermine the productivity and profitability of all farms that share same water sources, staff or equipment, or that are otherwise in the same locality.

The biosecurity plan should include as appendices all the biosecurity related standard operating procedures (SOPs) and refer to general husbandry SOPs that include biosecurity elements. As minimum, this should include SOPs on:

- health monitoring and disease surveillance;
- disinfection (including vehicles, equipment, people and ponds);
- waste disposal (including animals from routine mortalities and mortalities from serious disease incidents); and
- responding to disease incidents (including reporting, sampling, disinfection, safe disposal of dead animals and quarantine isolation).

As a guide, the following template table of contents is provided to assist in compiling a farm biosecurity plan.

Table of contents

1. Introduction: structure of document and how to use
2. Responsibilities and contact details
3. Farm layout and general description of farm biosecurity plan
4. Diseases of concern
   – Host range
   – Disease signs
   – Life cycle
   – Routes of transmission
   – Emergency response measures
5. Appendices
   – Risk analysis
   – Audit sheet
   – SOP Health monitoring and disease surveillance
   – SOP Response to disease incidents
   – SOP Disinfection
   – SOP Waste disposal

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NZMPI. 2016. Aquaculture biosecurity handbook – assisting New Zealand's commercial and non-commercial aquaculture to minimise on-farm biosecurity risk. [online]. Wellington. [Cited 12 December 2016]. http://mpigovtnz.cwp.govt.nz/dmsdocument/13293/loggedIn

Sub-Committee on Aquatic Animal Health (SCAAH). 2016. Aquaculture Farm Biosecurity Plan: generic guidelines and template. Version 1.0. Department of Agriculture and Water Resources, Canberra. [online]. Canberra. [Cited 14 December 2016]. http://www.agriculture.gov.au/SiteCollection Documents/fisheries/aquaculture/aquaculture-farm-biosecurity-plan.pdf

Annex 1

Biosecurity audit table and implementation plan

The following presents a seven-step process of auditing the biosecurity arrangements of a fish or shellfish farm to identify potential shortcomings and develop an action plant to set up and maintain a farm level biosecurity plan.

1. Add to the list of biosecurity measures in the table below any extra measures that may have arisen from *risk analysis*.

2. Then starting from the first measure listed in the audit table, decide if the measure (or similar measure) is *already in place* at the farm. If yes, then go to step 3. If no, then go to step 7.

3. Decide if the measure as currently implemented *needs improvement*. If "no", then in the findings column describe the measure that is in place and write "measure is in place". In the actions column write "no action". Then move to the next measure. If "yes", then describe in the findings column the required improvements and go to step 4.

4. Decide whether the recommended change is *practical and affordable*, including checking with farm management that resources are available to implement the change. If "yes", then go to step 5, if "no", then go to step 6.

5. Write in the actions column the name of the individual who will take *lead responsibility* for the recommended action, the *timeline* for implementation and confirmation from the farm owner/manager that *resources* are available to implement this change. Then move to the next measure.

6. Write in the findings column that the improvements are "NOT practical/affordable" and a brief explanation, and in the actions column, write "NO action". Then move to the next measure.

7. Write in the findings column that the "measure is NOT in place" and describe in detail the measure that is recommended. Then go to step 4.

Table A1. Biosecurity audit

BIOSECURITY MEASURE	FINDINGS	ACTIONS
ADMINISTRATION		
1. A staff member (with nominated backup) is responsible for overseeing farm biosecurity.		
2. All farm staff understand basic disease risks to the farm, the role of the farm biosecurity plan in managing disease risks and their responsibilities for its implementation, including reporting and responding appropriately to emergency disease incidents.		
3. Staff members receive periodic training on aspects of the farm biosecurity plan relevant to their work and have ready access to the farm biosecurity plan and standard operating procedures (SOPs). Biosecurity is a core element of new staff induction and training.		

4. SOPs are regularly reviewed to ensure all routine husbandry practices relating to biosecurity are documented, with associated staff training provided.		
FARM DESIGN/STRUCTURE		
5. The farm has a secure perimeter fence or an otherwise well-defined boundary, establishing a clearly defined biosecurity zone. Entrances to the site restrict vehicle and foot traffic and are locked during all non-visitor hours.		
6. Where practical, types (hatchery, grow out, nursery) and clusters of holding systems are epidemiologically separated.		
7. All production units (e.g. sheds, ponds, tanks, raceways) have a unique and permanent identifier.		
MANAGING THE ROUTES OF DISEASE INTRODUCTION AND SPREAD		
PEOPLE		
8. Staff and visitor access is managed (through access controls and signage) and the risk they present is assessed.		
9. The farm has biosecurity rules that are explained to all visitors.		
10. Measures to prevent disease entry are applied to all persons entering and exiting the farm (e.g. dedicated changing areas, farm footwear and hand washing facilities), and for persons moving between productions areas of different disease status within the farm.		
11. Access to sensitive areas (e.g. broodstock holding facilities) is restricted.		
12. Production units (or epidemiologically compartmentalized clusters of units) are managed separately to reduce the risk of disease spreading within the farm. Staff are assigned to production units based on risk or disinfection procedures (e.g. hand washing and foot baths) are in place for moving between production units.		
13. If staff must work in multiple production units, higher health animals are visited first and lower health or diseased animals last, with appropriate cleaning and disinfection protocols followed between visits.		
ANIMALS		
14. Movement records are maintained for all animals moved onto the farm, between areas of potentially different biosecurity status within the farm and off the farm.		
15. Animals should only be introduced to the farm if they are of known health status and that status is of equal or better status than animals on the farm. Translocation approvals or permits are obtained if required by the receiving national and/or sub-national authority per relevant jurisdictional requirements.		
16. If the health status of introduced animals is unknown (e.g. wild broodstock; seed stock of unknown health status) the animals are isolated from other farm populations in separate production units or dedicated quarantine facilities.		
17. If risks are found to be high, quarantine of broodstock is lifelong with a view to producing high-health or specific-pathogen-free progeny that would become broodstock.		

18. Where feasible, treatment of quarantined animals is considered to mitigate disease risks (e.g. for external parasites). Treatments are conducted in accordance with regulatory requirements.		
19. Movement of animals between different farm populations only occur following consideration of the disease risks and with a view to maintaining high health status.		
20. Measures are in place to prevent escape of aquatic animals.		
21. Predatory or scavenging animal populations are controlled or excluded from production facilities.		
22. All production units have features that prevent entry of wild animals and escape of farmed animals.		
23. In closed/semi-closed systems, there are measures to prevent entry of aquatic animals in the water supply.		
24. In semi-open systems there are measures to limit entry of animals to, or aggregation near production units.		
25. Sick or dead animals are removed promptly from production units and safely disposed of.		
EQUIPMENT/VEHICLES/VESSELS		
26. Equipment, vehicles or vessels brought onto the farm are assessed for biosecurity risk.		
27. Procedures and infrastructure is in place to clean and disinfect equipment, vehicles or vessels, as per identified risk.		
28. The farm has designated delivery and loading areas.		
29. Separate equipment is assigned for use in production units of different health status. Where equipment must be used in multiple production units it is cleaned and disinfected prior to movement between units.		
WATER		
30. The biosecurity risk of a farm's water source is considered and appropriate actions are taken to manage any identified risks.		
31. Infrastructure for decontamination of water is adequately monitored and maintained to ensure it remains effective.		
32. For land-based farms, water intake and outflows is located to avoid cross-contamination.		
33. The flow of water within the farm is managed to minimize the potential for diseases to spread between different production units or populations with different health status.		
34. For sea-based farms, lease sites should be located to maintain epidemiological separation of populations with different health status (e.g. different year classes).		
WASTE		
35. Waste products (e.g. dead animals, water and effluent) are assessed to determine potential biosecurity risk to the farm, neighbouring farms and the environment.		
36. Containment, handling and disposal of waste products minimize identified disease transmission risks.		

FEED		
37. The biosecurity risk of feeds is considered and appropriate actions taken to manage any identified risks.		
38. Manufactured feeds are used wherever possible in preference to live or unprocessed feeds.		
HEALTH MONITORING AND EMERGENCY RESPONSE		
39. There is a health monitoring schedule and SOP, and health monitoring records are kept for different animal populations within the farm and include details of any sickness, mortality, treatments, disease testing and relevant environmental information. Also feeding/growth rates/behaviour/coloration etc. are also monitored.		
40. If animal populations become sick, precautions should be taken to avoid contact with other farm populations until the cause is known and it is safe to do so.		
41. There are farm procedures for responding to a suspected emergency biosecurity incident that include reporting, containment, sampling, diagnostic testing, stock destruction/ emergency harvest, safe disposal of dead animals, record keeping and trace back, decontamination of holding facilities, water and equipment.		
42. All farm staff members understand the farm's emergency procedures and their own role in an emergency.		
REVIEW/AUDIT		
43. There is a schedule and resources for routine review of the biosecurity plan and extraordinary reviews in the event of a potential or actual biosecurity failure.		
44. All inputs to the farm (e.g. animals, people, water, equipment and vehicles) and between zones within the farm are assessed (and periodically re-assessed) for potential biosecurity risks.		
45. There is periodic audit of the farm biosecurity plan (and effective record keeping of formal audits) to ensure the plan is being implemented effectively.		

Tool manual 4:
Aquaculture traceability planning

Guidelines for implementing a traceability system for aquaculture

By

Vincent Andre

FAO International Consultant

1. Introduction

Issue to be addressed by the tool

Traceability is both a regulatory and a non-regulatory requirement. It is required by law mainly to protect consumers against food safety hazards. The lack of traceability and inefficient product recall can threaten food safety, biosecurity, the environment and eventually lead to economic loss.

Traceability is also required to demonstrate that fishery products are produced according to particular requirements, most often as a part of certification schemes (e.g. ecolabelling, organic, fair trade schemes). Complying with these schemes is often a condition of accessing some markets and can thus represent a competitive advantage.

Some countries in the ASEAN region that are major exporters of seafood have begun to implement traceability systems for their aquaculture products, such as Thailand (shrimps) and Viet Nam (catfish). However, with increasing requirements for traceability in international seafood markets, the implementation of traceability systems by exporters in the aquaculture industry is a necessity to comply with the regulations of the importing countries. In addition, domestic consumers in the region who are becoming more affluent and educated are also demanding a higher level of food safety and quality in their seafood. In view of these developments, various organizations including FAO have implemented a project on traceability for aquaculture products in the ASEAN region. This will provide a platform for the sharing of information and experiences among the ASEAN member countries on traceability systems tools. It will also enable their aquaculture industries to implement appropriate traceability systems in aquaculture products and to meet international traceability requirements in the network of aquaculture production, marketing, and trade.

Purpose of the tool

The purpose of this tool is to guide aquaculture stakeholders on how to build traceability systems necessary to demonstrate the production of safe and high quality fishery products. Traceability will demonstrate:

- that products are free of natural contaminants;
- the use of uncontaminated land and water sources for farming operations;
- the responsible use of drugs and chemicals, including the monitoring of residues in farmed products;
- proper microbial sanitation during the handling and transport;
- the application of materials and processes in compliance with prevailing regulations;
- the ability to recall the product to avoid any harm to the consumers and prevent any threats to consumer health in the future;
- the ability to follow the fishery products throughout the supply chain (with the purpose of food security and/or environment protection);
- that fishery products are free from fraud, and truthfully reflect the labelling claim; and
- the compliance with particular requirements, which are often part of certification schemes (e.g. organic, fair trade). Complying with these schemes is indispensables for accessing some markets and can thus represent a competitive advantage.

Principle of the tool

Where traceability is required by law for food it is mainly for the purpose of protecting the consumers against food safety hazards that may have contaminated the product because of mistakes or fraud in the production and distribution processes. If a product with a hazard that can endanger human health is identified by anybody, anywhere in the supply chain, it should be possible to warn the consumers specifically about the product by referring to a specific code and in the worst case scenario to call back from the market the products linked with the hazard.

For food, traceability requirements are also incorporated into the law because the producer should be able to demonstrate to the buyers as well as the food safety authorities that all materials and processes have been applied in compliance with prevailing regulations. If a product with a hazard as mentioned above is found on the market, it should be possible to trace back to all inputs and operators to find out where the problem may have occurred so measures can be taken to avoid it happening again.

Acknowledgements

The tool was trialled in Indonesia by the Ministry of Marine Affairs and Fisheries. The pilot was conducted on mostly family-owned, small-scale to medium-scale marine fish cage culture operations in Batam and Bintan islands. The efforts of the Indonesian government agencies and farmers involved in the trials are gratefully acknowledged.

2. Application of the tool

This manual provides a stepwise approach on how to develop a traceability system in an aquaculture supply chain.

Not all elements of traceability recommended in this document would apply to all aquaculture scenarios; the recommendations herein should be tailored to what is applicable, practical and affordable for each individual farm.

The steps in developing a farm biosecurity plan are:

- identify the **supply chain operators** who will be involved in the traceability system;
- define a **unique identification** system for operators and products in the supply chain;
- define the **minimum information to be recorded** in the traceability system; and
- define the means of data transfer between operators in the supply chain.

Who will use the tool?

Both producers in the supply chain and competent authorities in the management of their control function are going to benefit from such a system. The traceability system tools can be used by technical staff of regulatory agencies, middle management in private enterprises and any others with relevant facilities and expertise.

Farming systems for tool application

The traceability system tools are to be used in all aquaculture production systems. Aquaculture refers to the farming of aquatic organisms such as fish, molluscs, crustaceans, echinoderms and aquatic plants. This involves some form of intervention, such as regular stocking, feeding and protection from predators, in the rearing process to enhance production. Farming also implies individual or corporate

ownership of or rights, resulting from contractual arrangements, to the stock being cultivated primarily for livelihood and business activities. Also, aquatic organisms harvested by an individual or corporation that has owned them throughout their rearing period as a common property resource, with or without appropriate licenses, are considered the harvest of fisheries.

The production of aquatic organisms for final consumption, for use as raw materials in the production of other products, or for trade, from cultured aquatic organisms, is referred to as aquaculture production. Aquaculture production also includes the production of aquatic organisms, such as ornamental fishes and hatchery output, which are quantified by numbers instead of weight.

Tool limitations

Traceability system can effectively trace food quality and reduce safety scares. However, a traceability system cannot be seen as a stand-alone product that will substitute quality or food safety systems. Once properly traced, the source of a safety scare will be better analyzed and therefore better managed.

This tool was designed to assist small and medium business on how to design and manage a traceability system. It is acceptable to operate a traceability system manually, recording data on hard copy and still comply with regulatory requirements. Computerized traceability systems are only an option.

Planning, management and resource implications

From a government level aquaculture resource management perspective, competent authorities should consider developing awareness building and training programmes in traceability for farmers and extension officers. Such programmes could be tailored to the types of aquaculture operations relevant to the locality.

The design and implementation of whole chain traceability from farm to end-user has become an important part of the overall food quality assurance system. "Internal systems" are designed by each operator in the supply chain to ensure that a record is kept that links management and data communication of every unit of raw materials and ingredients during the processing at each step, until the appearance of the final products. "External systems" ensure that there are links between management and the data communication of operators of the supply chain. This is the minimum traceability the industry must maintain.

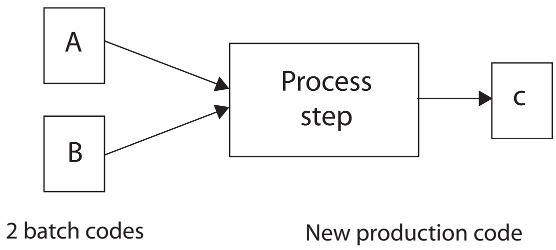
3. Element/parameters to be considered in the design of a traceability system

Why implement a traceability system?

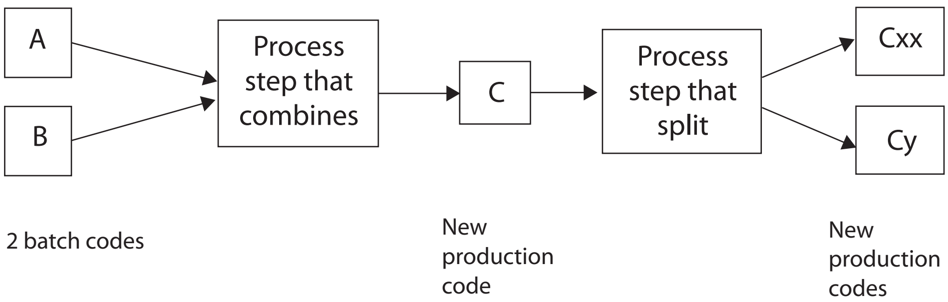
Regulations and international standards typically require that all operators shall be able to trace "one step backward" and "one step forward" of their own operation. This means that operators should keep documentation on all inputs used for the formulation of their products and on the distribution of the final products from their operations. If everybody in the supply chain can identify one step backward and one step forward, then it is possible to trace a product in the full supply chain if it is necessary.

Unique identification

Most operators receive daily raw materials from several suppliers or they receive from the same supplier *different batches of raw materials that they may want to mix in the final products.* In such cases it is important to keep records on what is mixed at what step, and that a new unique lot number is given to the mix.



Most operators also split batches of raw materials during the processing for example because of size grading or because the process steps being carried out require smaller batches.



Such cases make the unique identification important as follows:

- Any actor in a value chain should be uniquely identified. This identification may be a production license or any kind of authorization given by the national competent authorities. The unique identification of the farms is usually needed for the official controls system and constitutes a good starting point for traceability.
- Any lot/batch of fishery products has to be traceable and must therefore be uniquely identified. The unique identifier should provide data about each batch's history, application or location. Most products are traced by their lot or production batch, and by their transport/storage/distribution. The identifier should bear some meaning and be verifiable (e.g. on a 10 digits number the first 2 digits are the coded origin, the next 6 digits are the date of reception/production (ddmmyy) and the last 2 digits are a running number) and should reflect the lot definition (e.g. 1 lot = raw material received in 1 delivery or 1 lot = quantity produced in 1 day).

  These principles are needed to establish codes for each operator and product at every operational step so the "sub-batches" can be linked with the "mother batch".

Data capture and management

This is the data capture and record keeping at the operator level. This is called "internal traceability system". The quality of the documentation will affect the potential precision of a traceability system and therefore will define its efficiency and robustness.

The links management system between the documents and between steps within the value chain is called the "external traceability system". This is the minimum traceability that the industry must maintain and it is the one required by the regulations of the main fishery products markets. External traceability is also what is needed in case of product recall in a food safety crisis or discovery of regulation non-compliance.

Figure 1 shows the value chain operators to be included in a traceability system:

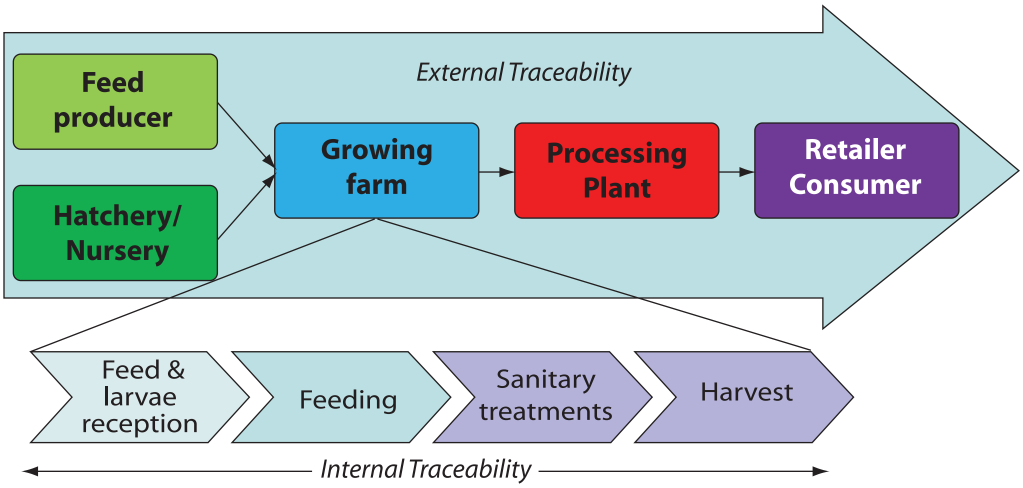


Figure 1. External and Internal traceability

Usually a traceability system is organized in such a way that it can be verified and tested with a mock product recall. The verifiability of the internal and external system is part of the data management.

Data communication

The information exchanged between various actors in the value chain has to be in a standardized format. The data captured is transferred along with the physical flow of products. To ensure the continuity of the information flow, each value chain actor must communicate the captured traceability data to the next actor, enabling traceability. The complexity of the value chain in a globalized industry requires a high level of efficiency. The information required may be standardized by the regulation, e.g. labelling requirements, certificate of origin, catch certificate, certificate of analyses.

If traceability is established by simple paper records kept by the individual operators, the system may be solid and safe enough, but it may take quite a long time to go through the documents if a certain case needs to be investigated by reviewing the related documents. Robustness of the system refers to the reliability of the information that will be received when tracing back – how likely is it that the correct and most valuable information will be received or how big is the risk that something will go wrong somewhere in the chain so the information received does not relate to the problem under investigation. The relative importance of the two situations should be considered when designing the system.

The actors in the value chain may use other means for data exchange such as telephone, fax and email. Modern technologies tend to replace such practices that are inefficient with some data being non-reusable and with a high risk of errors. It is worth noting that the food businesses are concerned about data security because of the sensitive nature of information and do not want to share it unless this information is stored in protected repositories.

The choice of the traceability solution is therefore going to vary depending on the level of requirements (from paper to computerized system). The better and more precise the tracing system is, the faster a producer can identify and resolve food safety or quality problems. The breadth, depth, and precision of the traceability systems vary depending on the attributes of interest and each operator's traceability costs and benefits:

- Depth ("how far forward or backward"): it is recommended to adopt a stepwise approach with a focus on the farm-collector-processor/exporter levels first, and later the system could be upgraded to the feed producers, hatcheries levels.
- Breadth ("amount" of information required to be collected by the system to be effective): it is recommended to consult numerous stakeholders dealing with purchasing countries to check whether the data are useful and relevant for them and design the system accordingly.
- Precision ("degree of assurance") with which the tracing system can "pin-point" the shrimp/prawn movement or products' characteristics.

4. Methodology

Value chain operators identification

The identification of various stakeholders involved in the aquaculture production, distribution, trade and retail is a mandatory step in the establishment of an efficient and robust traceability system. A generic value chain of the aquaculture products is proposed below. These are the stakeholders who should generate and hold the information necessary for traceability.

All operators involved in the production/farming of fishery products operations should be authorized by the competent authority.

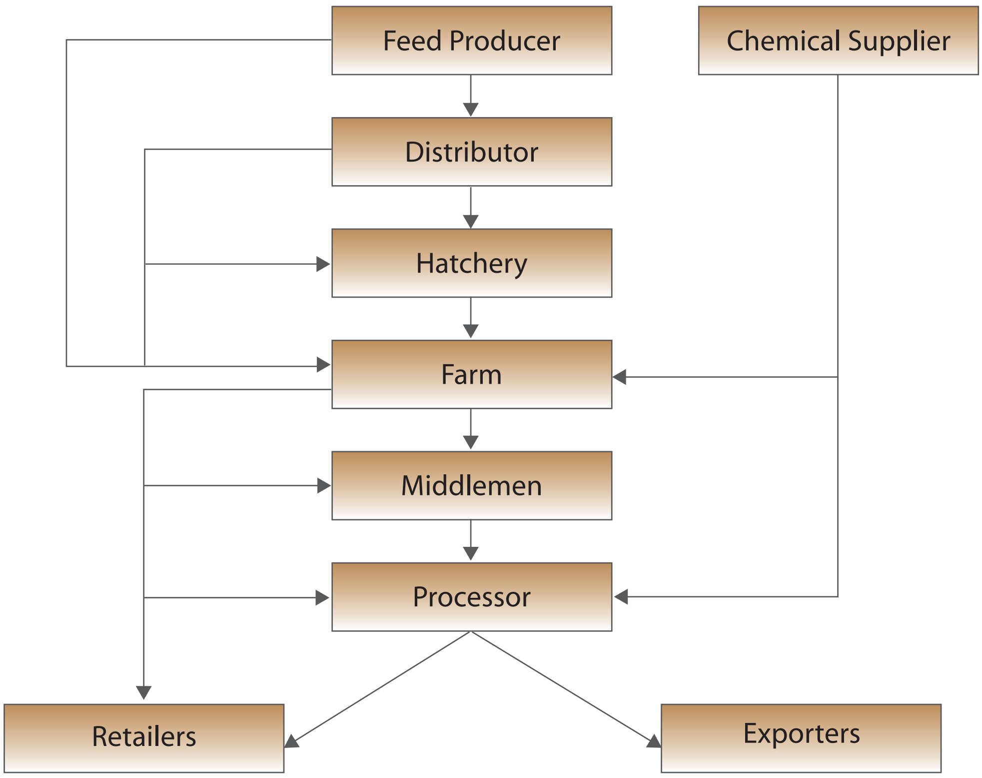


Figure 2. Generic supply chain for aquaculture products (fish and shrimps) in the ASEAN region

The identification of the operators in the system should be unique and meaningful. Possible integration of the existing GIS mapping system into the registration or licensing procedure may be envisaged.

The location of the farm should be documented and has to be in accordance with the national requirements. The tool on site selection and zoning shall address this issue.

The record keeping shall be organized in a way that it is practical and realistic for the farms to carry out without risk of mistakes. The records should not be destroyed by water, weather or other harsh physical conditions.

The record keeping shall also be established in such a way that the documents can be retrieved in a short time. It is therefore advised to maintain to two sets of documents:

- *documents related to the operator* e.g. production license, quality standard certificates, certificates of analysis of the water source, soil and common elements to every pond/cage at the farm; and
- *documents related to the operations* e.g. feed manufacturing, larvae production, feeding and sanitary treatment, animal movement.

Unique identification

The lot/batch size or definition of the trade unit depends on the practical situation and may vary from one product to the other. Some criteria regarding the definition of the lot may be linked to risks analysis related to this product:

- food safety: a "lot" may identify a group of products that are often from the same origin and that experienced the same treatments; and
- economical: the smaller a lot, the more economical is the destruction of a non-conforming product in case of withdrawal.

The lot identification format should be clearly defined and accompany the product at all times, e.g. on the label in the case of pre-packaged food or on the packaging, on the container, or the accompanying documents in other cases.

Record keeping

Feed manufacturer/producer

Feed manufacturing operations should be recorded in order to be able to trace back to the origin of the raw materials and the potential non-conformities. The following data are the minimum data required:

- Feed producer authorization number
- Production date
- Feed commercial name
- Feed registration number
- Production lot number
- Quantity/unit
- Feed batch quantity

- Feed analysis result
- Expiration date
- List of ingredients, lot number, origin and analysis results
- Delivery date
- Invoice number and/or delivery bill number
- Client name.

Larvae production (hatchery/nursery)

The following data on larvae production should be recorded in order to be able to trace back the origin of the brood stock:

- Brood stock origin
- Brood stock reception date and/or lot number
- Tank number
- Brood stock quantity received.

Farm operations

It is advised to maintain a set of documents per pond/cage with the following elements:

o Larvae origin:

The basic information should allow the tracking back to the hatchery and the potential controls/inspections done during the hatching process and transportation.

The basic information to record is proposed in the following template:

Seed/larvae/fry origin		
Reception date (dd/mm/yy):		
Farm Pond/cage number:	Species:	Pond/cage size:
Larvae origin (name/contact details of the hatchery):		
Harvest date (dd/mm/yy):		
Farm name:		
Farm address:		
Hatchery quality standard (if any):		
Certificate number (if any):		
Seed/Larvae Stage:		
Quantity purchased (ind.):	Lot/Batch number:	
Details/Comments:		

More documents could be stapled to the record such as the invoice and/or delivery bill of the seed/larvae with the name of the supplier, results of analysis.

- o Feeding:

The basic information should allow the tracking back to the feed manufacturers and the potential controls/inspections done during the production of the feed. The farm should make sure that all feed purchased has been authorized by the national competent authority and that the feed packaging has an identification number (lot or batch). Some support documents, e.g. delivery bill, invoice may be kept to ease the tracking back especially if the feed was purchased through feed distributors.

The labels and/or bags of the feed used at the farm may be kept during the production period in a proper way, e.g away from rain, to ease the verification of the traceability system at the farm.

The basic information to record is proposed in the following template:

Feeding					
Farm Pond/cage number:		Species:		Pond/cage size	
Date	Feed producer name	Feed commercial name	Feed registration number	Feed lot number	Quantity fed (kg)

More documents could be stapled to the record such as the invoice and/or delivery bill of the feed with the name of the supplier, results of analysis.

- o Sanitary treatments:

The basic information should allow the tracking back to the manufacturers of the *chemicals*. The term "*chemical*" is used here for *any treatments applied during production other than feed.* The farm should make sure that all *chemicals* purchased have been authorized by the national competent authority and that the *chemicals* packaging has an identification number (lot or batch). Some support documents, e.g. delivery bill, invoice may be kept to ease the tracking, especially if the chemicals were purchased through distributors.

The labels and/or bags and/or containers of the *chemicals* may be kept during the production period in a proper way, e.g. away from rain, to ease the verification of the traceability system at the farm.

The basic information to record is proposed in the following template:

Sanitaty treatment		
Farm Pond/cage number:	Species:	Pond/cage size:
Date	Treatment	Information about the chemical used, supplier

More documents could be stapled to the record such as the invoice and/or delivery bill of the chemical with the name of the supplier, results of analysis.

o Harvest and distribution:

The basic information should allow the identification of the clients that purchased the fishery products from the farms. The details on the harvest, e.g. date, quantity, pond of origin should be recorded. A batch/lot should be constituted of the quantity harvested from one single pond/cage on a given date to better follow the various input (larvae, feed and *chemicals)* used. In the case of partial harvest, the quantity harvested from the same pond/cage at different dates should be considered as different batches/lots. The movement of this batch/lot should be recorded and the information about the harvest should accompany the delivery to the next step of the supply chain.

The basic information to record is proposed in the following template:

Harvest		
Pond number:	Species:	Pond/cage size:
Harvest date (dd/mm/yy):		
Farm name:		
Farm address:		
Farm quality standard (if any):		
Certificate number (if any):		
Harvested quantity (kg):	Results of the veterinary drugs residues:	
Shrimp/fish average size (animal/kg):		
Details/Comments:		

More documents could be stapled to the record such as the invoice and/or delivery bill of the fishery products with the name of the client, results of analysis.

Fishery products processing

The following data on fish product processing should be recorded in order to be able to trace back to the clients:

- Order number from client
- Production date
- Fish product reception lot number and/or batch number
- Produced quantity
- Reference of the animal movement (when available)
- Intermediate/broker name

Data transfer

Traceability can be established by the individual operators or by groups of uniform operators or by operators in a whole supply chain. It may be established by simple paper records or by more sophisticated systems involving electronic records, identification by international barcodes, etc.

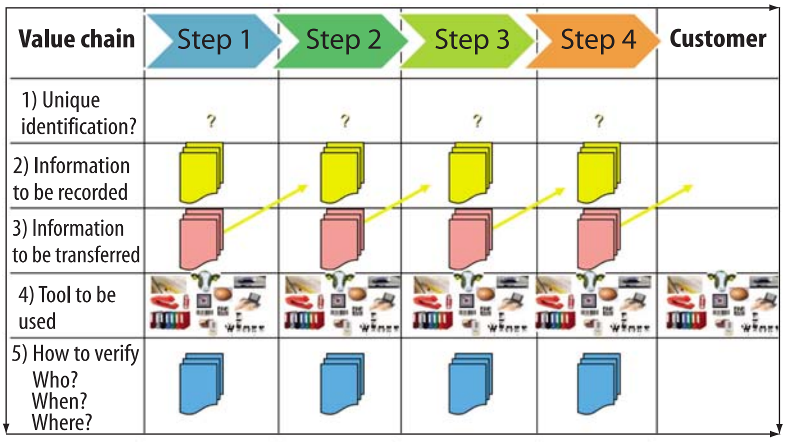


Figure 3. Establishing a traceability system

	Feed Producer	Hatchery/ Nursery	Farm	Collector	Processor	Exporter	Consumer
Information to have	Business license Registration number **Processing information** Production date, feed registration number, ingredients, brand, type, pellet size, batch volume, batch number, selling unit, expiry date Feed certificate of analysis Factory quality standards (GMP, HACCP)	Business license Registration number **Broodstock information** Reception date, origin, size/age/species, health certificate **Feed information** Feed registration number, brand, type, pellet size, batch number, selling unit, expiry date **Treatments information** Date of treatment, chemicals used **Harvest information** Harvesting date, quantity, tank number Seed health certificate Hatchery/nursery quality standards certificate	Business license Registration number **Seed information** Reception date, origin, size/age/species, seed health certificate **Feed information** Feed registration number, brand, type, pellet size, batch number, selling unit, expiry date **Treatments information** Date of treatment, chemicals used **Harvest information** Harvesting date, quantity, tank/pond/ cage number Product health certificate Farm quality standards certificate	Business license Registration number **Harvest information** Harvesting date, quantity, tank/pond/ cage number Farm quality standards certificate Product health certificate	Business license Registration/approval number (FDA, EU etc.) **Reception/production information** Harvesting date, quantity, tank/pond/ cage number Production date, brand, batch volume, batch number, selling unit **Delivery information** Date of delivery, expiry date, brand, batch volume, batch number, selling unit, product registration number, name of client Product health certificate Factory quality standards certificate	Business license Registration/approval number (FDA, EU etc.) **Reception information** Date of reception, expiry date, brand, batch volume, batch number, selling unit, product registration number, name of supplier **Delivery information** Date of delivery, expiry date, brand, batch volume, batch number, selling unit, product registration number, name of client Product health certificate Factory quality standards certificate	Production date, brand, batch number, selling unit, product registration number

Information to transfer	Business license Registration number Feed registration number, brand, type, pellet size, batch number, selling unit, expiry date Factory quality standards (GMP, HACCP)	Business license Registration number Harvesting date, quantity, tank number Seed Health certificate Hatchery/Nursery quality standards certificate	Business license Registration number Harvesting date, quantity, tank/pond/cage number Product health certificate Farm quality standards certificate	Business license Registration number Harvesting date, quantity, tank/pond/cage number Product health certificate Farm quality standards certificate	Business license Registration/approval number (FDA, EU etc.) Production date, brand, batch number, selling unit **Delivery information** Date of delivery, expiry date, brand, batch volume, batch number, selling unit, product registration number Factory quality standards certificate	Business license Registration/approval number (FDA, EU etc.) Production date, brand, batch number, selling unit **Delivery information** Date of delivery, expiry date, brand, batch volume, batch number, selling unit, product registration number Factory quality standards certificate	
Tool to use	Feed bag label Copy of factory quality standards (GMP, HACCP)	Commercial documents Farm book Copy of seed health certificate	Commercial documents Farm book Copy of product health certificate	Logbook Approved vendor list Commercial documents Copy of product health certificate	Product label/packaging Copy of farm quality standards certificate Delivery documents	Product label/packaging Copy of farm quality standards certificate Delivery documents	
How to verify?	Internal traceability	Internal traceability Farm book	Internal traceability Farm book	Internal traceability	Internal traceability Quality certificates	Internal traceability Quality certificates	
Archive	3 years	3 years	3 years	3 years	>3 years	>3 years	

5. Consideration for the competent authorities

Competent authorities should facilitate the implementation of traceability systems to ease record keeping, ideally through an integrated approach the systems should be sufficient to identify the immediate previous sources and immediate subsequent recipients of the aquaculture products. The documented information should be archived for at least three years.

The following guidelines on traceability system for aquaculture are for the consideration of the competent authorities.

Supply chain	Guidelines
Feed producer	
Competent authorities should establish and maintain effective record-keeping practices as early as from the fish feed used. Regardless of the source of aquaculture products, be they locally reared in fish farms or imported from foreign sources by means of air transportation, relevant feed mill related information should be identifiable upon tracing. The feeds product traded should be identified as the trade unit (TU).	1) Competent authorities should compile and update all information pertaining to source of feed mill, inclusive of name, address, contact number and regulatory certificate of the feed miller. 2) Competent authorities should establish and maintain the national statistical system covering relevant feed mill related information, including manufacturing date and expiry date, list of feed ingredients, batch and lot number of products, quantity of supply, feed types and registration of processing facility. Relevant certifications from competent authority or regulatory body should be kept in place as well.
Distributor	
Competent authorities should adopt an integrated approach to the development, maintenance and update of record keeping pertaining to the distribution and movement of aquaculture products. Distributors are known to be responsible for the distribution of the sales bulk or auction bulk, particularly with feeds involved as the TU from feed miller down the supply chain.	1) Competent authorities should ensure all distributors possess records of suppliers and buyers through invoices or receipts or equivalent, as well as the information regarding the names of the transporter's immediate previous source and immediate subsequent recipient, origin and destination points, date shipment received and date released, number of packages, description of freight, route of movement and transfer point(s) of shipment. 2) Competent authorities should ensure that apart from the relevant information obtained during the distribution processes, any incoming source related information such as the batch or registration number of the source, records for transportation of auction bulk and the seed/larvae/fry Movement Document up till the middlemen should be established and maintained as well.
Hatchery	
Competent authorities should recognize the importance of hatcheries, where it involves the receiving of the seeds of an aquaculture product that are subsequently cultivated into fish seedlings or fish fry as a new TU that could range from a few thousand to several hundred thousand fishes passed down the supply chain.	1) Competent authorities should ensure that sources of origin for the aquaculture fry should be properly documented for traceability purpose, inclusive of the registration number, invoice number, batch number and health certificate for the source from hatchery in particular. 2) Competent authorities should ensure that as far as is practicable for the import of aquaculture fry, accredited or licensed suppliers should be preferred over those

	unaccredited or unlicensed suppliers by competent authorities. This would include proper record keeping of the suppliers' information for traceability purposes.
Chemical supplier	
Competent authorities should establish and maintain records on the information associated with materials used that are from outside the main domain of the supply chain. The identified TU could be the supply of any form of chemical substance or supplement that varies accordingly at the receiving ends of different stakeholders such as fish farms and fish processing plants.	1) Competent authorities should establish appropriate mechanisms for regulation and monitoring of any drugs and chemicals used in aquaculture, based on the list of banned drugs and chemicals, as well as the list of authorized drugs and expiration dates of such drugs. 2) Competent authorities should ensure that there is accurate record keeping on chemical supplies. Pharmaceutical supply related information should be established and maintained, inclusive of the following: contact details and information such as name and address of supplier, certification for authorized supplier by Food and Drug Administration (FDA), certification for drug or chemical from Good Manufacturing Practices (GMP) or Hazards Analysis and Critical Control Points (HACCP) certified factory, invoice and license number of the lot of product.
Farm	
Aquaculture products within the region could be raised from fingerlings or a seeds breed-on hatchery or through imports from a hatchery for better quality control. States and the region should establish a legal framework, laws and regulations to ensure farms or hatcheries comply with regional guidelines or global standards in farming activities. Locally reared aquaculture products with commercially acceptable or marketable size are the common TU identified.	1) Competent authorities should ensure the information for on-site breeding is accurately recorded. This includes the origins of breed in terms of type, duration, location and quantity, quality assurance records for breeding environment, source and quantity of feed (kg), date of production of feed and use-by date, as well as quality assurance record on feed concerning any addition of any chemical inputs. 2) Competent authorities should ensure that the necessary records and information with regards to any of the farm activities should be kept in place such as the date and quantity of harvest, farm and (or) pond registration number. 3) Competent authorities should ensure efficient record keeping and traceability by utilizing movement documents should be in place for the fish farmers in order to facilitate information sharing and traceability beyond the fish.
Middlemen	
Competent authorities should be aware of the existence of the number of tiers of "middlemen" within the aquaculture supply chain. Reared aquaculture products with commercially acceptable or marketable size from the fishermen or farms are the common TU identified.	1) Competent authorities should ensure that there is proper record keeping in place to keep track of all the middlemen related information which would include the details of the middlemen or tiers of middlemen, dates and volume of each fish species purchased until being sold, batch registration number and invoice number. 2) Competent authorities are recommended to maintain proper documentation and record keeping of the aquaculture products from various stakeholders during the distribution process as many middlemen could be involved in the distribution activities, hence movement documents should be in place.

Processors	
Competent authorities should establish and maintain legal framework and regulations for the processors to follow as the processing of aquaculture products are performed differently throughout the Southeast Asia region – either through processing plants and establishments or direct processing in fish farms. Processed aquaculture products are the common TU identified.	1) Competent authorities should ensure that processors should adhere to the GMP and processing plants or establishments should be encouraged or recommended to have HACCP in place, all these standards should be coupled or enhanced with good hygiene practices, International Organization for Standardization (ISO) and health certifications to increase product quality in the mid-stream of the aquaculture product supply chain. 2) Competent authorities should ensure that the processors obtain relevant information of the list of suppliers and buyers, as well as the information on batch and registration numbers, prior to receiving the product from previous source. These records should be kept in place through all sales transactions such as invoices and receipts, alongside all transportation or delivery records. 3) Competent authorities should ensure the processing plants establish and maintain record keeping internally for all laboratory results or quality and safety monitoring records of the necessary raw materials, intermediate and end products along the processing line(s). This record keeping should be done concurrently with the records of batch or container number, date of processing and other critical parameters.

6. How to use the guidelines in the planning and management decision process

Traceability cannot be seen as a "stand-alone" requirement, but it has to be based on quality or safety or legal sourcing compliance conformity. The chain of traceability has to be complete in order to trace the history of a product by means of unique identification procedures and at every level of the supply chain.

In order to be efficient, a traceability system has to provide:

- the identification of the operators, storage and preparation units and identification of the product and its registration along the whole chain;
- an efficient traceability system inside and between the organizations that can be controlled to ensure the proper functioning of the traceability system among all the organizations; and
- a periodical verification of the traceability system to make sure that the data communicated are correct. Annex 1 is a checklist to check the traceability system.

Withdrawal/recall procedures should be tested at the farm to ensure the correctness of the traceability system. Mock recalls are used to check if the information available allows the "one step backward/one step forward" rule.

Farms should be able to identify any person from whom they have been supplied with larvae, feed, or any substance intended or expected to be used in the pond/cage.

Farms should have in place systems and procedures to identify the other businesses to which their fishery products have been supplied.

This information should be made available to the competent authorities on demand.

7. Resources for running the tool (data requirement, ease of use, cost, human capacity/resources)

Within the context of small-scale farms, the most effective system can be chosen from some of the following:

- documents based system;
- enhanced document system (with support of database); and
- fully computerized system for the operations.

Once the system is designed, the implementing in practice is all about being able to work in a systematic way. All staff members should be trained to understand that the data they record is a part of the traceability system of the products, and that this is linked with both legal and commercial requirements.

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9. Annex 1: Checklist on traceability basic compliance

Date:		Name:	
	Yes	**No**	**Comments**
1. Farm identification			
1.1 Farming operations are registered by the national competent authority.			
1.2 Authorization/license has to be valid for farming operations.			
1.3 The standard certificate(s) for the farm have to be made available upon request.			
1.4 The tank/ponds/cage are identified systematically and a farm layout is available and up to date.			
2. Larvae origin			
2.1 The list of hatcheries supplying the farm is kept up to date.			
2.2 The seed delivery at the farm is recorded.			
2.3 Documents accompanying the larvae delivery are recorded and archived.			
3. Feeding			
3.1 Feed manufacturers used are registered and a list is kept up to date at the farm.			
3.2 Commercial name of the feed used at the farm is recorded on a day-to-day basis.			

3.3 All feed formulae are authorized by the national authority.			
3.4 Lot numbers of the feed given to each pond are recorded on a daily basis.			
4. Sanitary treatment			
4.1 List of *chemical* manufacturers used at the farm is kept up to date.			
4.2 Commercial names of the *chemicals* used at the farm are recorded on a day-to-day basis.			
4.3 *Chemicals* used at the farm are authorized by the national competent authority.			
5. Harvest and distribution			
5.1 A list of clients of the farm is kept up to date and available upon request.			
5.2 Details of every delivery are recorded.			

Date of the next assessment: ____________________

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