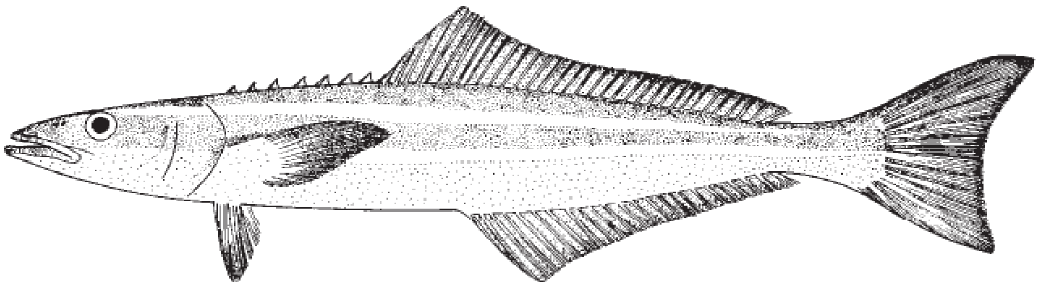
Pathogen and Ecological Risk Analysis for the introduction of Cobia (*Rachycentron canadum)* from the Philippines into Papua New Guinea



by

Ruth Garcia-Gomez[1] and **Jeff Kinch**[2]

NATIONAL FISHERIES AUTHORITY
Papua New Guinea

SPC
Secretariat of the Pacific Community

[1] Aquaculture and Quarantine Advisor; Fisheries, Aquaculture and Ecosystem Division, Secretariat of the Pacific Community, Noumea, New Caledonia
[2] Principal, National Fisheries College, Kavieng, New Ireland Province, Papua New Guinea

Contents **Page**

Figures

Tables

Acronyms

ALOP	Appropriate level of protection
EIA	Environmental Impact Assessment
EIR	Environmental Inception Report
FAO	Food and Agriculture Origination
FCR	Food Conversion Ratio
GMO	Genetically-modified Organisms
IRA	Introduction Risk Analysis
NAQIA	National Agriculture and Quarantine Inspection Authority
NFA	National Fisheries Authority
NFC	National Fisheries College
NIMRF	Nago Island Mariculture and Research Facility
OIE	World Animal Health Organization
PNG	Papua New Guinea
RSVID	Red sea-bream iridovirus
SPC	Secretariat of the Pacific Community
SPS	Sanitary and Phyto-sanitary
UN	United Nations
USA	United States of America
UV	Ultra-violet
VER/VNN	Encephalopathy and Retinopathy inodavirus
WTO	World Trade Organization

Executive Summary

The objective of this document is to undertake an Introduction Risk Analysis (IRA) of the potential pathogen-related, ecological, and socio-economic risks associated with the proposed introduction of an improved strain of cobia (*Rachycentron canadum*) from the Philippines into Papua New Guinea (PNG) for aquaculture development.

The proposed location for grow out of cobia is the Kavieng Lagoon in the New Ireland Province (Figure 1) and will be undertaken by a private company which is based in Kavieng, with technical and quarantine support from the National Fisheries Authority (NFA) and their Nago Island Mariculture and Research Facility which is located in the Kavieng Lagoon; and the National Agriculture and Quarantine Inspection Authority (NAQIA).

In total, 18 cages of 300 m³ (six sets of three cages with each one set, involving one coastal community in its management) will be established during the first year of the project, with a final stocking density of 10-15 kg/m³ with final total production is expected to be around 60-100 tonnes, and between 210-250 local people employed in cage farming, fish processing and aqua-feed production.

PNG has little experience with IRAs for aquatic animals, and as there has been recent requests for the importation of exotic aquatic species for aquaculture development (e.g. the introduction of seaweed in the Milne Bay Province from Malaysia), it is hoped, that this IRA will serve as an example to both the NFA and the NAQIA which can be used for evaluating pathogen and ecological risks associated with future proposals to introduce other exotic aquatic species.

The IRA presented here uses both a qualitative and/or semi-qualitative approach, depending on the availability of specific information, which has been determined during the scoping exercise.

The pathogen risk analysis examines the potential risks due to pathogen introduction along with the movement of the species and considers ways to reduce these risks. The ecological risk analysis focuses on the invasiveness and 'pest potential' of the species to be translocated and will consider the likelihood of its escape and/or release into the natural environment of the receiving country and the nature and extent of any potential ecological impacts such escape or release may entail.

The pathogen risk analysis was conducted using a qualitative approach with six risk categories (i.e., high, moderate, low, very low, extremely low, negligible); and recognized two viruses as potentially serious hazards associated with the importation of cobia.

In determining the significance of an impact for the ecological risk analysis, 'magnitude' was assessed against 'importance' to provide a range of significance from 'negligible' to 'major':

The IRA also gives an estimate of the certainty or uncertainty for the parameter being assessed. Both the pathogen and ecological sections of the risk analysis are characterized by a moderate level of uncertainty. For the Philippines, there is sufficient accurate information regarding the general health status of the stock to be introduced, the sanitary status of the facility of origin and the country. Regarding PNG, the country to receive cobia from the Philippines, there is a general lack of information on aquatic animal diseases; while for the latter, there is a certain lack of information regarding biophysical characteristics of Kavieng Lagoon. On the other hand, the environmental risk analysis suggests that although there is a general paucity of country-specific and species-specific data to support the analysis, the benefits of introduction outweigh any potential negative effects.

Mitigation measures are identified that can be applied to reduce the risk associated with all hazards to below that specified by the 'appropriate level of protection'. The most important of these is that all shipments of cobia fingerlings to be imported into PNG should be of 'high health' status and should originate from a facility certified as using specific pathogen free brood-stock. Additional recommendations are made regarding the operation of the production facility in the exporting country and the post-border requirements for the importing country (see Table 8).

Based on past practices, it is recommended that PNG adopts an ‘appropriate level of protection’ that is ‘conservative’, with an acceptable level of risk that is ‘medium’ (i.e. a moderate level of protection).

The pathogen risk analysis concludes that the proposed introduction could be accomplished within the recommended ‘appropriate level of protection’ if the necessary appropriate disease mitigation measures are adopted to minimize the risk that the cobia fingerlings to be introduced are infected.

The ecological risk analysis suggests that although there is a general paucity of country-specific and species-specific data to support the analysis, the benefits of introduction outweigh any potential negative effects.

It is emphasized that the results of this IRA should not be taken as a sole basis for a decision by the Government of PNG to approve or disapprove a request for the proposed species translocation. Such a decision requires additional consideration by the government of policy, legislation, technical capability, etc. and should include extensive stakeholder consultation.

Overall though, the introduction of highly demanded species, both in the domestic and in export market, which are easy to rear, either for restocking or aquaculture purposes, as is the case of the cobia, could lead to the development of economically viable activities in the Kavieng area; and decision makers should balance benefits and risks of such introductions.

1. Introduction

The objective of this document is to undertake an Introduction Risk Analysis (IRA) of the potential pathogen-related, ecological, and socio-economic risks associated with the proposed introduction of an improved strain of cobia (*Rachycentron canadum*) from the Philippines into Papua New Guinea (PNG) for aquaculture development. As cobia are already found in PNG waters, the introduction of cobia from the Philippines, should be regarded rather as a trans-location.

The proposed location for grow out of cobia is the Kavieng Lagoon in the New Ireland Province (Figure 1) and will be undertaken by a private company which is based in Kavieng, with technical and quarantine support from the National Fisheries Authority (NFA) and their Nago Island Mariculture and Research Facility (NIMRF) which is located in the Kavieng Lagoon; and the National Agriculture and Quarantine Inspection Authority (NAQIA). Further species may also be considered in the future depending on technological developments and the economics of production.

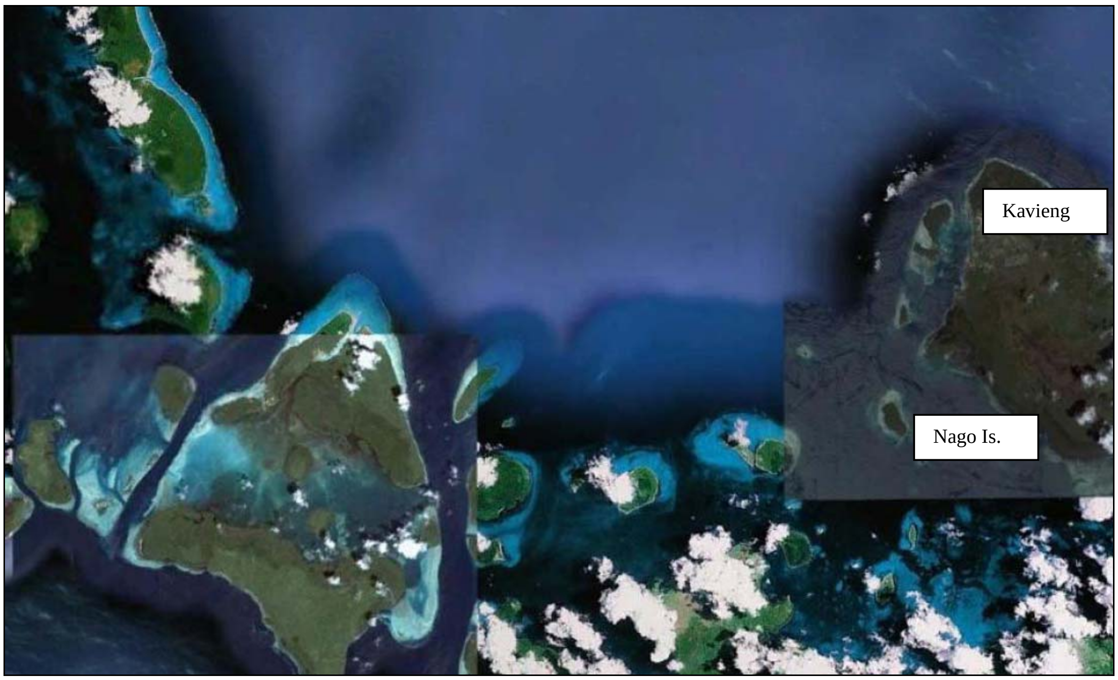


Figure 1: Kavieng Lagoon

The current objectives of the project are:

- To produce a variety of fresh and frozen whole fish and fillets in order to supply an increasing domestic demand from catering companies that supply mining camps, prisons, hospitals, as well as larger learning and academic institutions; and restaurants and hotels in different areas of PNG;
- To produce a variety of frozen fish and fillets in order to supply an increasing export demand in Australia, the United States of America (USA), and Asia;
- To develop and maintain infrastructure for the farming of up to 60-100 tonnes during the first year of production in the Kavieng lagoon involving 8-10 local coastal communities;
- To develop and maintain infrastructure for the production of compound aqua-feeds for cobia culture in the existing coconut oil making facility, which is owned by the same company; and
- To maintain the existing infrastructure for processing (filleting and packing) of 60-100 tonnes of cobia at the existing fish processing plant in Kavieng that is leased by the same company.

In total, 18 cages of 300 m³ (six sets of three cages with each one set, involving one coastal community in its management) will be established during the first year of the project, with a final stocking density of 10-15 kg/m³ with final total production is expected to be around 60-100 tonnes, and between 210-250 local people employed in cage farming, fish processing and aqua-feed production.

The movement of fish beyond their natural distribution range has been associated with human migration since ancient times, and species introductions are a valid means to improve production and economic benefits. For example, approximately 17 % of the world's finfish production today is now due to introduced species creating substantial socio-economic benefits, and out of the top six species currently being cultured by many Pacific Island Countries and Territories, four of them are introduced species. Introductions also however, require careful consideration of the potential environmental impacts on aquatic ecosystems that may be affected by the introduced species through predation, competition, mixing of genes, habitat modification and the introduction of aquatic pathogens. Human communities may also be impacted through changes in fishing patterns due to newly-established fisheries or through changes in resource use and access. Subsequently, there is a need to assess associated risks and benefits.

While great successes have been achieved by the introduction of aquatic species, leading to the creation of new and important fisheries and aquaculture resources, challenges that have surfaced relative to IRAs and the introduction of species include the paucity of data and other information available for the area of introduction to allow for the assessment of:

- Ecological and environmental impacts of introduced and transferred species, especially those that may escape the confines of cultivation and become established in the receiving environment;
- Potential genetic impact of introduced and transferred species, relative to the mixing of farmed and wild stocks as well as to the release of genetically modified organisms; and the
- Inadvertent coincident movement of harmful organisms associated with the target species.

PNG has little experience with IRAs for aquatic animals, and as there has been recent requests for the importation of exotic aquatic species for aquaculture development (e.g. the introduction of seaweed in the Milne Bay Province from Malaysia), it is hoped, that this IRA will serve as an example to both the NFA and the National Agriculture and Quarantine Inspection Authority (NAQIA) which can be used for evaluating pathogen and ecological risks associated with future proposals to introduce other exotic aquatic species. The IRA presented here uses both a qualitative and/or semi-qualitative approach, depending on the availability of specific information, which has been determined during the scoping exercise.

The pathogen risk analysis examines the potential risks due to pathogen introduction along with the movement of the species and considers ways to reduce these risks. The ecological risk analysis focuses on the invasiveness and 'pest potential' of the species to be translocated and will consider the likelihood of its escape and/or release into the natural environment of the receiving country and the nature and extent of any potential ecological impacts such escape or release may entail.

The pathogen risk analysis uses six risk categories for the probability of an event occurring, and these are:

- High: The event would be very likely occur;
- Moderate: The event would occur with an even probability;
- Low: The event would be unlikely to occur;
- Very low: The event would be very unlikely to occur;
- Extremely low: The event would be extremely unlikely to occur; and
- Negligible: The event would almost certainly not occur

It also uses five categories to describe the consequences of an adverse event occurring, and these include:

- Catastrophic: Establishment of disease would be expected to cause significant economic harm at a national level, and/or cause serious and irreversible harm to the environment;

- High: Establishment of disease would have serious biological consequences (e.g., high mortality or morbidity) and would not be amenable to control or eradication, and which could significantly harm economic performance at an industry level and/or may cause serious harm to the environment;
- Moderate: Establishment of disease would have less pronounced biological consequences and may be amenable to control or eradication, these diseases could harm economic performance at an industry level and/or may cause some environmental effects, which would not be serious or irreversible;
- Low: Establishment of disease would have mild biological consequences and would normally be amenable to control or eradication, these diseases may harm economic performance at an industry level for a short period and/or may cause some minor environmental effects, which would not be serious or irreversible; and
- Negligible: Establishment of disease would have no significant biological consequences and would require no control or eradication; these diseases would not affect economic performance at an industry level and would cause negligible environmental effects.

The qualitative ecological risk analysis assesses the mmagnitude of possible impacts on the basis of accepted methodologies and the 2003 '*ICES Code of Practice on the Introductions and Transfers of Marine Organisms'*, comprises of the relative scale, size and severity of impacts, which are then considered against the importance, value and sensitivity of the receptor, spatial and temporal incidence of any impacts and ability of receptors to recover. In determining the significance of an impact, 'magnitude' is assessed against 'importance' to provide a range of significance from 'negligible' to 'major':

- High: Wider and longer term impacts occurring and likelyto result in a highly changed structure, composition and function. Return to pre impact levels unlikely to occur even with mitigation and intervention.
- Medium: Detectable impacts, characterized by significant changes in structure, composition and function. Recovery from impacts is achievable over the medium term once management initiatives are implemented.
- Low: Possibly detectable impacts but minimal changes to the established structure and function. The impact and its magnitude are small relative to the wider context of the population / area being impacted. Return to pre impact levels achievable and expected to occur over the short term once management initiatives are implemented.
- Negligible: Very insignificant impacts. Unlikely to be measurable against benchmarks;

The IRA also gives an estimate of the certainty or uncertainty for the parameter being assessed.

As management and control of introduced species also takes place in the context of a variety of international, regional and national obligations; priorities, opportunities and resources, these also need to be taken into account in order to assess benefits and risks.

1.1 Commodity Description

Table 1 describes summary details of the proposed introduction of cobia from the Phillipines to PNG.

Table 1: Summary Details of the Proposed cobia Introduction to Papua New Guinea

Item	**Details**
Species to be introduced:	Cobia, *Rachycentron canadum*
Proposed date of importation	2012
Life cycle stage to be imported:	fingerling (20 grs)
Importer	Alian SeaFoods Ltd. Kavieng, P.O.BOX. 500, New Ireland Province, PNG
State Agency submitting the proposal	National Fisheries Authority's Aquaculture and Mariculture Business Unit
Proposed exporter	Marine finfish public hatchery, and the Aquaculture Division of the Philippines Fisheries Department
Proposed source	Marine finfish public hatchery, and the Aquaculture Division of the Philippines Fisheries Department
Proposed number of shipments	Six shipments per year for Alian SeaFoods Ltd. until such time as local hatchery production is available and a reliable source of brood-stock can be established
Volume	1,000 fingerling per shipment every two months
Proposed destination	Nago Island Mariculture and Research Facility's Quarantine Section

1.2 Justification for the Introduction

Cobia is considered an excellent species for culture because of its fast growth rate, adaptability to captive breeding, lower cost of production producing good quality flesh. This combined with suitable environmental conditions, and the demand for food fish products, both in the domestic and the export market, make the introduction of cobia quite promising issue regarding the aquaculture sector in PNG. The current status of cobia farming in Asia and the activities being demonstrated elsewhere suggest that the farming of this species has significant potential, and global production is increasing.

Commercial producers in China, the Taiwan Province of China, and the USA have established pond and tank spawning of cobia brood-stock, and both larval and juvenile rearing protocols are continuously being refined.

The goal of the proponent for the introduction is to develop economically viable and technically feasible aquaculture strategies for cobia production in PNG at a commercial scale, by the introduction of a species that is highly demanded within the domestic and Australasian market, which is suitable for aquaculture production within the PNG environment context, and that is considerably easy to farm and to maintain.

The expected results of the present introduction will be:

- Increased availability of high value animal protein at domestic level (as a way of improving food security);
- Improved livelihoods at the rural and peri-urban level;
- Diversification of income generating activities in PNG (being aquaculture a sustainable alternative to capture fisheries in certain areas) taking into account the current depletion of fish stocks; and
- Reduction of existing pressure in the fisheries sector.

Currently, there is a local demand of more than seven tones per week of fish fillets that cannot be covered by the production from capture fisheries. Furthermore, it should be also mentioned that the same company possesses a coconut oil mill, whereby by-products from both facilities could be used in small-scale feed processing and aqua-feeds easily produced.

1.3 Proposed Source of Stock

The company is planning to bring improved strains of cobia fingerling into PNG from the Philippines, where cobia production has been developed for more than a decade now, and improved domesticated and healthy strains are currently available. Fingerlings of an average weight of 15-20 g could be easily transported after implementing the pre-border quarantine measures, which will be described below.

The facility of origin will be the Public Marine Finfish Hatchery managed under the Aquaculture Division of the Ministry of Fisheries, which has the necessary staff and equipment in order to issue the required health status certificate and to implement all pre-border quarantine measures (screening for viral, bacterial and parasitic diseases of relevance, bacterial and parasitic preventive treatments, and health monitoring and reporting).

1.4 Description of the Receiving Facility

The NIMRF is located on Nago Island in the Kavieng Lagoon of the New Ireland Province and is jointly administered by NFA's Aquaculture and Mariculture Business Unit headquartered in the nation's capital city, Port Moresby; and the National Fisheries College (NFC), also a Business Unit of the NFA, but based on a large campus just outside of Kavieng town.

The NIMRF consists of a large covered shed with 30 operational culture tanks, six raceways and associated water pumping and filtration systems. The shed also houses a laboratory building, workshop, dive shop and store room. There is a separate main office. The NIMRF also includes a substantial wharf for easy vessel access.

The NIMRF quarantine area is physically separated from the rest of the facility, and is fenced and roofed, with an independent entrance, where visitors are logged, followed by a changing room, an independent laboratory and office, as well as an independent storage area. Foot baths and several hand wash areas are also planned. The NIMRF quarantine area also has its own water filtration and disinfection system for both inlet and outlet. A set of equipment for each individual tank will be available, that will be easily disinfected and managed. Tanks are separated from other tanks by a 50 cm spacing, and would be covered if required. The quarantine area will follow the quarantine protocols approved by NAQIA for aquatic organisms, under the '*Animal Diseases and Control Act*', and '*Regulation*', and will be certified by NAQIA to be PNG's National Quarantine Centre for Aquatic Imports.

2. Regulatory Mechanisms

2.1 International Regulatory Frameworks

Significant international instruments have been established to address the issue of species introductions, such as the United Nations (UN) Convention on Biological Diversity (CBD), or the Food and Agriculture Origination (FAO) Code of Conduct for Responsible Fisheries, among others (Table 2). These codes and conventions call for accurate assessments of the risks of using exotic species and are aimed at promoting the creation of information sources and an exchange of information on introduced species, their biological and ecological attributes, and potential impacts (both positive and negative).

Table 2: International Regulatory Frameworks

Area	Regulation
Conservation and sustainable use of biological diversity	• Convention on Biological Diversity, including the Cartagena Protocol on Bio-safety; • Global Convention on Migratory Species; • UN Convention on the Law of the Sea; • FAO Code of Conduct for Responsible Fisheries; • Convention on Wetlands (Ramsar); • ICES Code of Practice on the Introductions and Transfers of Marine Organisms; and the • EIFAC Code of Conduct and Manual of Procedures.
Plant, animal and human health	• International Plant Protection Convention; • FAO Code of Conduct for the Import and Release of Exotic Biological Control Agents; • World Animal Health Organization (OIE); and the • FAO/NACA Asia Regional Guidelines on Fish Health.
Multi-lateral trade	• World Trade Organization (WTO); • Sanitary and Phyto-sanitary (SPS) agreements; and the • Convention on the International Trade of Endangered Species of Wild Fauna and Flora.

2.2 Regional Strategies and Regulatory Frameworks

In its recent '*SPC Division of Fisheries, Aquaculture and Marine Ecosystems Strategic Plan*' for 2010-2013, the Secretariat of the Pacific Community (SPC) has emphasized the need to develop a regional approach to put in place adequate bio-security controls that can be implemented at national levels, as a strategy to minimize bio-security risks in the Pacific Islands Region overall. The Strategic Plan has also identified a number of relevant cross-cutting issues to deal with, such as governance and environment, in order to evaluate and mitigate the impact of major developments in the fishing and aquaculture industries. Moreover, in the 2007 *'SPC Aquaculture Action Plan'*, bio-security concerns and the need for planning and policies for sustainable aquaculture development are among the most relevant cross-cutting issues: These include:

- Safeguarding the aquaculture environment to maintain the Pacific's comparative advantage;
- Raising awareness of potential effects of introductions and/or translocations and/or exports;
- The need to conduct IRAs;
- Coordinating regional disease testing and certification;
- Development of regional guidelines and codes of conduct;
- Inter-agency collaboration between fishery, veterinary and quarantine services regarding planning and policies for sustainable aquaculture;
- Development of national aquaculture plans; aquaculture policy and; and
- Meeting international obligations.

The Secretariat of the Pacific Regional Environment Program in its '*Guidelines for Invasive species in the Pacific*', recognizes that invasive species are an international problem, and that efficient management in the PIR requires a comprehensive approach, and coordinated action by national and territorial governments, the private sector, local communities and regional agencies. The guidelines are intended to assist PICTs in planning the effective management of invasive species, thereby reducing the negative impacts of invasive species on their rich and fragile natural heritage, communities and livelihoods. They identify major limitations within the region regarding management of alien and invasive species. These are:

- Shortage and inaccessibility of information on invasive species and best practice management;
- Lack of awareness of the impacts of invasive species;
- Insufficient networking, coordination and collaboration;
- Inadequate legislation, regulations, cross-sectoral policies, and enforcement;
- Shortage of trained personnel and inadequate facilities; and
- Sufficient funding

Lastly, with regard to the evaluation of risks associated with the introduction of species, due to the establishment of the WTO and its Agreement on the Application of Sanitary and Phyto-sanitary Measures (SPS Agreement), WTO members are now required to use the IRA process as a means to justify any restrictions on international trade. IRA has thus become an internationally accepted standard method for assessing whether trade in a particular commodity poses a significant risk to human, animal or plant health, and if so, what measures could be adopted to reduce that risk to an acceptable level.

2.3 National Regulatory Frameworks

2.3.1 Fisheries Management Act (1998)

The '*Fisheries Management Act'* aims to promote the management and sustainable development of fisheries within PNG. In the Act, aquaculture is described as the 'cultivation, propagation or farming of fish, whether from eggs, spawn, spat or seed, including rearing fish lawfully taken from the wild or lawfully imported into the country, or by other similar process'. The NFA is also responsible for issuing the necessary import licenses for exotic aquatic species introductions (for aquaculture and capture fisheries purposes), as well as issuing aquaculture licenses.

Main functions and powers of the NFA are described as:

(a) Manage the fisheries within the fisheries waters in accordance with this Act and taking into account the international obligations of PNG in relation to tuna and other highly migratory fish stocks;

(b) Make recommendations to the NFA Board on the granting of licenses and implement any licensing scheme in accordance with this Act;

(c) Liaise with other agencies and persons, including regional and international organizations and consultants, whether local or foreign, on matters concerning fisheries; and

(d) Operate research facilities aimed at the assessment of fish stocks and their commercial potential for marketing.

The 2004 '*National Aquaculture Development Policy'* mentions that the policy is based on a vision to foster development of commercial aquaculture by the private sector, using economic profit as the motive, and subsistence aquaculture to enhance food security and provide some alternative income source.

The vision of the '*National Aquaculture Development Policy'* is:

- To establish aquaculture as a viable business industry by facilitating and supporting the private sector to establish economically, socially and environmentally sustainable aquaculture ventures, with NFA facilitating development when appropriate;
- To enhance food security by producing sufficient fish or fish products to feed the people of PNG;
- To ensure that the PNG aquaculture industry is protected against harmful diseases;
- To promote information and communication, and educate [people] about aquaculture as an alternative means of producing fish and other aquatic products for economic profit and food;
- To integrate aquaculture with agriculture by encouraging farmers to adopt subsistence/artisanal aquaculture into their existing agriculture options;
- To encourage foreign investment; and.
- To develop aquaculture on the basis of ultimate self-sufficiency within the sector with decreasing dependence on imports.

2.3.2 Fisheries Management Regulation (2000)

The '*Fisheries Management Regulation'* defines an 'aquaculture facility; as any place in the waters or on land where aquaculture is authorized by an aquaculture license.

Aquaculture licenses are detailed under Section 5 of the Regulation, whereby aquaculture licenses should be issued:

(a) For a specified type, class or species of fish;
(b) In respect of a specified area of fisheries waters or a specified place;
(c) May require a vessel used in conjunction with the aquaculture facility to be:
 (i) licensed; or
 (ii) subject to such terms and conditions as are specified in the aquaculture licence;
and
(d) Shall be subject to such further terms and conditions as may be specified in it.

The Regulation also defines that the application for a licence shall be made:

(a) In the approved form;
(b) Lodged with the Managing Director; and
(c) Accompanied by the prescribed application fee, which shall be non refundable.

Regarding aquaculture licenses, the '*National Aquaculture Development Policy*' states that:

- All commercial operations with an annual production turnover of ten (10) tonnes or more or utilizing more than one (1) hectare of land or water surface area, whether in sole use for aquaculture or multiple use for other activities must be licensed;
- Small non-commercial or semi-commercial projects with an annual production capacity of less than ten (10) tonnes require no licence;
- All sea cage, pearl shell, oyster, aquarium species and other species not covered in the two-above paragraphs must be licensed regardless of size; and
- Aquarium dealers, whether small or large, require license.

2.3.3 Environmental Act (2000)

The main aim of the '*Environment Act'* is to provide protection of the environment in accordance with the Fourth National Goal and Directive Principle on Natural Resources and Environment of the Constitution; and to regulate the environmental impacts of development activities in order to promote sustainable development of the environment and the economic, social and physical well-being of people by safeguarding the life-supporting capacity of air, water, soil and ecosystems for present and future generations and avoiding, remedying and mitigating any adverse effects of activities on the environment; and to protect the environment from environmental harm; and to provide for the management of national water resources and the responsibility for their management.

The Act also defines in which specific cases Environmental Licenses and/or Permits are required, describing three different levels of activities that could cause negative environmental impacts. It is mentioned that a person carries out an activity where s/he carries out:

(a) Construction of works, land clearance, demolition, excavation or other works in relation to land or water;
(b) Installation, operation or maintenance of plant or equipment;
(c) Activities for the purpose of extracting or harvesting natural resources; or
(d) Release of contaminants to air, land or water, in connection with any of the activities specified in (a), (b) or (c).

It should also be noted that a person carries out an activity if he has effective control over that activity at the site at which the activity is carried out, and where a person has such effective control no other person is regarded as carrying out the activity.

Under the 2002 '*Environment (Prescribed Activities) Regulation'*, aquaculture is either a Level 2 or a Level 3 activity and has to be conducted in accordance with specific rules that apply to those levels.

A Level 2 activity refers to operations of aquaculture facilities with a design discharge flow rate greater than 1 per day or 100 tonnes of wet product per year or aquaculture carried out in open sea/cage operations (the present proposal will be under Level 2 activities), whereas a Level 3 activity means operations designed to discharge a volume of waste greater than 10 million litres per day.

The Act considers activities to be Level 3 if it:

(a) Involve matters of national importance; or

(b) May result in serious environmental harm.

Only in the cases where a Level 3 activity will be carried out, an Environmental Impact Assessment (EIA) submitted in the form of an Environmental Impact Statement should be prepared. If the activity planned will need an environmental license prior to implementation, then an Environmental Inception Report (EIR) should be prepared as a preliminary step towards the elaboration of a detailed EIA. An EIR covers the following aspects:

- Introduction;
- Purpose;
- Viability;
- Description of the project;
- Development timetable;
- Bio-physical environmental issues;
- Socio-economic issues;
- Impacts;
- Baseline information available;
- Site selection; and
- Qualification of environmental experts to carry out the assessment.

The '*Environment Act* 'also stipulates that a permit is needed in order to operate an aquaculture facility. To obtain the permit, the interested person has to first register his intention to carry out an aquaculture activity with the Director of Environment and Conservation. One month after giving notice of his intention to carry out such a project, preparatory work should be prepared in relation to the activity. The term 'preparatory work' means:

(a) Undertaking a feasibility study;

(b) Carrying out other studies relevant to environmental issues;

(c) Applying for approval under the 1992 Investment Promotion Act to carry out an activity; or

(d) Applying for an approval or a permit or license under another Act; in relation to a proposed activity".

As previously mentioned, for Level 3 activities, an EIA is mandatory; whereas for aquaculture Level 2 activities, it is not. If the preparatory work is conclusive, the interested person should be issued an aquaculture permit.

2.3.4 Environment 'Water Quality Criteria' Regulation (2002)

The '*Environment 'Water Quality Criteria' Regulation'* is focused on the minimum water quality criteria that should be maintained, for both fresh and marine water, when implementing activities or projects which could have an environmental negative impact. Regarding this regulation, the activity proposed in the present proposal will not imply any serious modification of water quality parameters (according to the regulation criteria), and not cause serious harm to the marine aquatic life in the location where it is planned.

2.3.5 Animal Disease and Control Act (1952)

The '*Animal Disease and Control Act'* is focused on both terrestrial and aquatic animal health management strategies, and includes detailed management measures to minimize the release and exposure of native species to trans-boundary animal diseases through the introduction and transfer of exotic organisms. The Act is therefore focussed on diseases of animals; and on controlling and restricting the importation into and the keeping in PNG of certain animals, and for related purposes.

Under this act, the Minister for Agriculture may, by notice in the National Gazette, prohibit or restrict:

(a) The introduction or importation of any animal or kind of animal into the country; or
(b) The movement of any animal or kind of animal within the country.

A notice under this Sub-section may:

(a) Require a permit or consent to be obtained; or
(b) Impose, or authorize the imposition of, conditions by a permit or consent, or both.

A person who is concerned with the attempted introduction, importation or movement, of an animal in contravention of a notice under these sub-sections is guilty of an offence.

A person who wishes to import fish into the country shall obtain permission under the 1973 '*Customs 'Prohibited Imports' Regulation*'. Before they are delivered to the importer, imported animals, including fish and molluscs, shall be submitted for inspection to a Quarantine Officer. As a general rule, all aquaculture operators must exercise appropriate caution to prevent escape of culture organism into the natural environment. If it happens, the escape into natural waterways should immediately be reported to the NFA.

Under the 1997 '*National Agriculture Quarantine and Inspection Authority Act'*, animal quarantine, including fish quarantine, is a function of NAQIA. Under this Act, 'animal' means 'any living stage of any member of the animal kingdom including mammals, birds and fish except human beings and, in the case of mammals, birds and fish, includes their egg, semen or carcass', 'fish' means 'any water dwelling aquatic or marine mammal or plant alive or dead and includes their eggs, spawn, spat and any parts of their body'.

NAQIA's main object is the conduct:

- Quarantine and inspection of any fish species; and
- To prevent pests or diseases from entering in or going out of the country.

'Quarantine' is defined as the 'measures for the inspection, exclusion, detention, observation, segregation, isolation, treatment, sanitary disinfection of vessels, aircraft, goods, animals and plants for the prevention of the introduction or spread of disease or pests affecting animals and plants'.

The functions of the NAQIA are therefore:

(b) To monitor and inspect all imports of animals, fish and plants and their parts and products, including fresh, frozen and processed food to ensure the imports are free from pests, diseases, weeds and any other symptoms;
(d) To undertake all necessary actions to prevent arrival and spread of pests, diseases, contamination, weeds, and any undesirable changes pertaining to animals, fish and plants and their parts and products, including fresh, frozen and processed foods;
(f) To undertake all necessary actions to ensure that the export of animals, plants, fish and their parts and products are free from pests, diseases, weeds and any other symptoms so as to provide quality assurance to meet the import requirements of importing countries;
(g) To issue permits, certificates and endorsements pertaining to imports and exports of animals, fish and plants and their parts and products to provide quality assurance and to ensure that they are free from pests, diseases, weeds, and any other symptoms;
(i) To regulate the movement of animals and plants from one part of the country to another; and
(j) To undertake and maintain inspection and quarantine surveillance pertaining to pests, diseases, weeds, and any other symptoms on animals, fish and plants within and on the borders of the country.

2.3.6 Animal Disease and Control Regulation (1955) Quarantine Protocols

The '*Animal Disease and Control Regulation'* defines a set of quarantine protocols to be implemented when introducing exotic animals into PNG, or when transferring animals within the PNG between zones of different health status. Regarding aquatic animals, only two quarantine protocols have been developed and approved so far, the:

- Importation of salmonids eggs; and the
- Importation of freshwater finfish.

These quarantine protocols are extremely detailed and comprehensive; the risk management measures put forward in the present proposal have been extrapolated from them, including some modifications and adaptations to the specific species to be introduced and the specific context. It should also be noted though that quarantine measures and protocols are just one of the possible management strategies to consider when planning an introduction, among many other pre-border and post-border actions.

2.3.7 Draft National Bio-safety Framework

This draft '*National Bio-safety Framework'* is devoted to increase awareness on bio-safety and bio-technology, with special emphasis on assessing and minimizing the bio-risks posed by the use of Genetically-modified Organisms (GMOs). The framework focuses on:

- Conducting an inventory to establish number of GMOs in PNG either as food, feed, food processes or pharmaceuticals;
- Developing an institutional framework for the assessment of GMOs;
- Developing regulations and guidelines for the safe assessment, handling, use, management and transfer of a GMO;
- Strengthening and improving human and institutional capacities for the identification, handling, storing and assessing of risks related to a GMO;
- Formulating appropriate policy and regulatory framework on bio-safety and bio-technology;
- Strengthening and promoting the precautionary approach;
- Strengthening and promoting community participation in the determination, assessment, use, management and transfer of a GMO; and
- Strengthening institutional networking and coordination.

Because the draft '*National Bio-safety Framework'* deals with GMOs, it has no relevant link to the introduction of cobia as described in this proposal.

2.4 National stakeholders

2.4.1 National Fisheries Authority

The NFA was established under the 1998 *'Fisheries Management Act'* and has the sole responsibility for the management and development of fisheries in PNG. Aquaculture is one of the main activities of the NFA within the Aquaculture and Mariculture Business Unit. Research, development and promotion are currently the focus of the section, especially with freshwater aquaculture, in conjunction with the National Department of Agriculture and Livestock aquaculture stations.

Regarding mariculture activities development and promotion, the NIMRF has been established on Nago Island in the Kavieng Lagoon of the New Ireland Province.

2.4.2 National Agriculture Quarantine and Inspection Authority

NAQIA is responsible for investigating and compiling reports on animal disease occurrences for both terrestrial and aquatic animal diseases (through disease diagnosis, disease investigation, disease surveillance, disease monitoring and reporting) as well as being responsible for all quarantine measures and protocols related to the movement or introduction of animals, and being the competent authority in issuing import licenses for any kind of live animal. Disease investigation and surveillance is carried out by Provincial and District Livestock officers and private community animal health workers.

2.4.3 Department of Agriculture and Livestock

The National Department of Agriculture and Livestock promotes agricultural and aquaculture development. provincial governments also have provincial Departments of Agriculture and Livestock. The most important provincial DAL aquaculture centre is the Highlands Aquaculture Development Centre in Aiyura, which was previously operated by the Eastern Highlands Provincial Government, but is now been taken over by the NFA.

2.4.4 Department of Environment and Conservation

DEC is in charge of issuing environmental licenses for Level 1, 2 and 3 activities as defined in the 2008 *'Environmental Act'*, and which have been described above.

3. Biological Information of Cobia

3.1 Biological Features

The body shape of cobia is elongate and torpedo-shaped with a long, depressed head. The eyes are small and the snout is broad, with the lower jaw projecting past the upper jaw. The skin looks smooth with very small embedded scales.

Cobia is easily distinguished by the first dorsal fin which is composed of 7-9 short, strong isolated spines, which are not connected by a membrane. The second dorsal fin is long with the anterior portion elevated, whilst the caudal fin is round to truncated in young fishes, and lunate in adults with the upper lobe extending past the lower. The origin of the anal fin is beneath the second dorsal apex and the pectoral fin is pointed. Cobia lack an air bladder.

The colour of cobia is dark brown to silver, paler on the sides and grayish white to silvery below, with two narrow dark bands extending from the snout to base of caudal fin. These dark bands are bordered above and below by paler bands. Young cobia have pronounced dark lateral bands, which tend to become obscured in the adult fish. Most fins are deep brown, with gray markings on the anal and pelvic fins.

3.2 Distribution

The cobia is distributed worldwide in tropical, subtropical and warm-temperate waters (Figure 2). In the western Atlantic Ocean this pelagic fish occurs from Nova Scotia (Canada), south to Argentina, including the Caribbean Sea. During autumn and winter months, cobia migrate south and offshore to warmer waters, seeking shelter in harbors and around wrecks and reefs. In early spring, migration occurs northward along the Atlantic coast. In the eastern Atlantic Ocean, cobia range from Morocco to South Africa.

Cobia are widespread in the Indo-West Pacific, but absent from the eastern Pacific and from the Pacific Plate, except marginally (Figure 3). Within the western Pacific, cobia can be found around the northern coast of Australia, north to New Guinea, Indonesia, Borneo, the Philippines, and Japan.

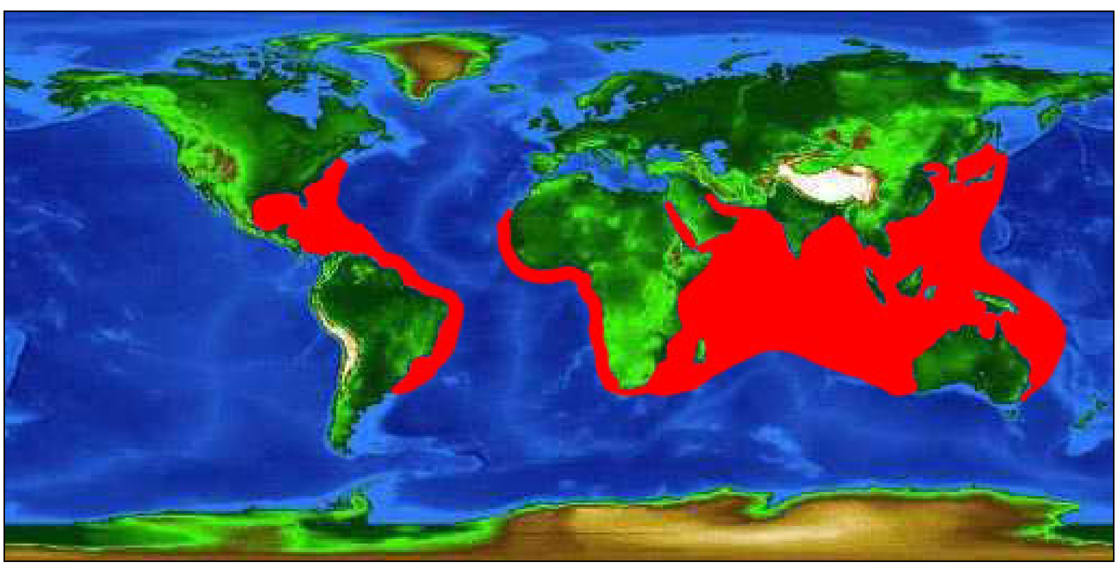


Figure 2: Cobia Global Range

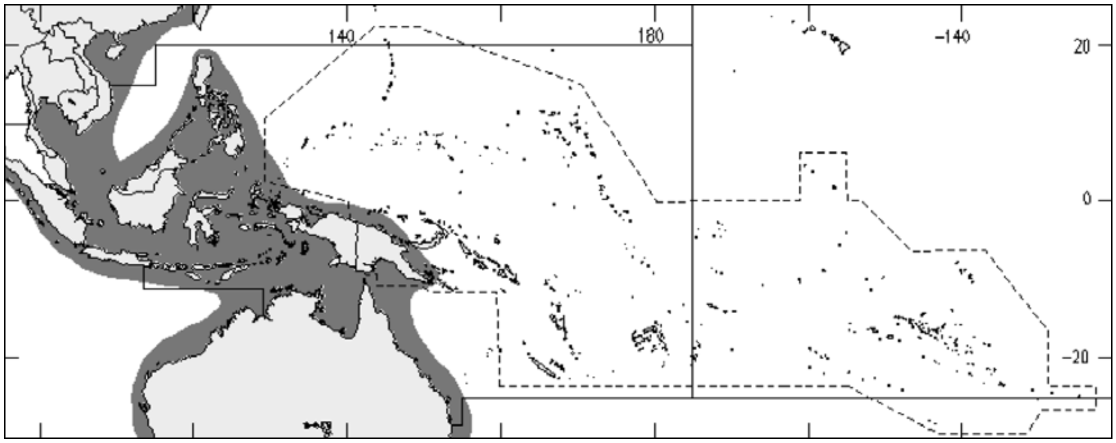


Figure 3: Cobia Range in the Western Pacific

Cobia are pelagic and are normally solitary except for annual spawning aggregations; however, they will congregate at reefs, wrecks, harbors, buoys and other structural oases. They may also enter estuaries and mangroves in search of prey.

Cobia can tolerate wide variations in temperature (16.8-32.2 ° C) and salinity (22.5-44.5 ppt). Juveniles handle temperatures as low as 17.7° C, but cease feeding at 18.3 ° C. Larvae have been raised in salinities as low as 19 ppt.

3.3 Taxonomy

The cobia was originally described as *Gasterosteus canadus* by Linnaeus in 1766, and changed later to *Rachycentron candum* (Linnaeus, 1766). Cobia is the sole representative of their family, Rachycentridae (Table 3). Other common names for cobia include black kingfish, black salmon, cabio, crabeater, cubby yew, kingfish, lemonfish, ling, prodigal son, runner, sergeant fish, and sergeantfish.

Table 3: Taxonomic Details for Cobia

Order	**Details**
Kingdom	Animalia
Phylum	Chordata
Subphylum	Vertebrata
Super-class	Osteichthyes
Class	Actinoptergii
Subclass	Neopterygii
Infraclass	Teleostei
Super-order	Acanthopterygii
Order	Perciformes
Suborder	Percoidei
Family	Rachycentridae
Genus	*Rachycentron*
Species	*Rachycentron canadum*

Synonyms for the cobia include *Apolectus niger* (Bloch 1793), *Scomber niger* (Bloch 1793), *Naucrates niger* (Bloch 1793), *Elacate nigra* (Bloch 1793), *Centronotus gardenii* (Lacepede 1801), *Centronotus spinosus* (Mitchill 1815), *Rachycentron typus* (Kaup 1826), *Elacate motta* (Cuvier and Valenciennes 1829), *Elacate atlantica* (Cuvier and Valenciennes 1832), *Elacate bivittata* (Cuvier and Valenciennes 1832), *Elacate malabarica* (Cuvier and Valenciennes 1832), *Elacate pondiceriana* (Cuvier and Valenciennes 1832), *Meloderma nigerrima* (Swainson 1839), *Naucrates niger* (Swainson 1839), *Elacate falcipinnis* (Gosse 1851), *Thynnus canadensis* (Gronow 1854), *Elacate nigra* (Gunther 1860), *Rachycentron canadus* (Jordan and Evermann 1896), and *Rachycentron pondicerrianum* (Jordan 1905).

3.4 Reproductive Ecology

Sexual maturity is reported in males at 1-2 years (at about 52 cm fork length) and in females at 2-3 years (70 cm fork length, though there are reports of cobia having ripe ovaries at the smaller size of 43-cm total length), with females growing both larger and faster with maximum sizes up to 60 kg. Spawning occurs in both near-shore and offshore waters where females release several hundred thousand to several million eggs (1.24 mm diameter) which are then fertilized by the attending males. The viable eggs begin development, are heavily pigmented, buoyant, and hatch in approximately 24 hours. Cobia larvae grow rapidly and are large in comparison to most marine species at 3.5 mm total length at hatching. Juvenile fish are found in both near-shore and offshore waters, often among *Sargassum* patches or weed lines where they seek shelter from predators and can feed.

In the wild, cobia spawns from the spring through fall in subtropical and tropical regions. Populations from more temperate areas have a more pronounced summer spawning peak. Cobia form spawning aggregations and are gonochoristic (i.e. no sexual dimorphism is observed). Spawning frequency is once every 9-12 days, spawning 15-20 times during the season. During spawning, cobia undergoes changes in body coloration from brown to a light horizontal-striped pattern, releasing eggs and sperm into offshore open water. Cobia has also been observed to spawn in estuaries and shallow bays with the young heading offshore soon after hatching.

Larvae are released approximately 24-36 hours after fertilization. These larvae are 2.5 mm long and lack pigmentation. Five days after hatching, the mouth and eyes develop, allowing for active feeding. At this time, a pale yellow streak becomes visible, extending the length of the body. By day 30, the juvenile takes on the appearance of the adult cobia with two color bands running from the head to the posterior end of the juvenile.

3.5 Diet

As voracious eaters, cobia often engulf their prey whole. They are carnivores, feeding on crustaceans, cephalopods, and small fishes such as mullet, eels, jacks, snappers, pinfish, croakers, grunts, and herring. A favourite food is crabs, hence the common name of ‘crab eater’. Cobia will also follow rays, turtles, and sharks, sneaking in to scavenge whatever is left behind.

Weighing up to a record 61 kg, cobia are more common at weights of around 23 kg, and can reach lengths of 50-120 cm, with a maximum of 200 cm. Cobia grows quickly and has a moderately long life span. Food Conversion Ratios (FCRs) have been reported to be 2-1.5:1 in average for the whole growing period.

3.6 Associated Pathogens

Cobia are susceptible to many viruses, bacteria, and parasites that commonly afflict other warm water marine finfish species. Table 4 below lists some of the potential pathogens that can affect cobia in aquaculture units, as well as symptoms and management measures.

Table 4: Potential Pathogens, Symptoms and Management Measures

Pathogen	Agent	Type	Symptoms	Management Measures
Encephalopathy and retinopathy inodavirus (VER and VNN)	Encephalopathy and Retinopathy inodavirus	Virus		• Vaccine being developed; • Carrier brood-stock can be a source of inoculum of the virus to their larvae; and • Screening of Pre- and post-spawning brood-stocks
Red seabream iridovirus (RSVID)	Red seabream iridovirus	Virus	Mortality	• Vaccine being developed; and • Best practices for facility hygeine
Marine velvet disease (Amyloodiniosis)	*Amyloodinium ocellatum*	Parasitic dino-flagellate	Coughing; flashing; operculum flare out; and reluctance to feed; appears as small dark spots on gill filaments under a stereoscope	• Use of copper treatment; • Freshwater dip; and/or formalin bath/treatment; • Flush system; and • Use of mechanical filtration down to at least 40 microns.
Marine white spot (Cryptocaryonosis)	*Cryptocaryon irritans*	External protozoan	White foci visible on skin	• Prolonged copper immersion; • Freshwater dip; flush system; and/or formalin bath/treatment • Decrease salinity to 15 ‰ or less for 2 weeks; and • Decrease system temperature to < 19 ° C.
Licmophorasis	*Licmophora* sp.	External parasite	Rusty or yellow sheen on the skin visible in cobia fingerlings within one month after stocking	• Changing of nets every 5days
Sea lice infestation	*Parapetalu occidentalis*(gills) and *Caligus oviceps* (body surface)	External parasite	Affects cobia in all stages of culture; resulting in gill and dermal necrosis	• No treatment required as mortality due to infestation is low
Sessile, colonial, and ciliate infestation	*Epistylis* spp.	Stalked ciliate	White or reddish masses on the skin/fins, gill arches, or in mouth during larval stage	• Freshwater dip; and/or formalin bath/treatment; and • Administer antibiotics
Trichodinosis	*Trichodina* sp.	Protozoan parasite	Found on skin and gills during nursery stage; and results in loss of appetite; and secondary infections	• Use of copper treatment; • Freshwater dip; and/or formalin bath/treatment; and • Use of praziquantel bath
Monogenean infestation	*Neobenedenia* sp.	Monogenean flatworm parasite	Skin damage and ulceration; eroded fins; eye lesions which can lead to blindness during grow-out stage	• Use of copper treatment; • Freshwater dip; and/or formalin bath/treatment; and • Use of praziquantel bath
Myxidiosis	Sphaerospora-like myxosporidean	Myxosporidian parasite	Poor appetite and ascites; enlarged kidney exhibiting patches or nodules; skin ulcers; and spores in the digestive tract	• Disinfect system; and • Quarantine affected fish
Coccidiosis	*Coccidia* spp.	Protozoan parasite	Abdominal swelling; exopthalamy; cysts in liver tissue; varies with organ affected	• Use of oral monensin; and • Reduce stress
Lymphocystis	Iridovirus	Virus	White bumpy growths on skin, fins and gills during nursery stage	• Disinfect system; and • Quarantine affected fish
Pasteurellosis	*Photobacterium damsela* subsp. *Piscicida*	Bacterium	Whitish, granulomatous deposits on kidney, liver and spleen	• Vaccine being developed
Vibriosis	*Vibrio alginolyticus; V. vulnificus* and *V. parahaemolyticus*	Bacteria	Swollen abdomen; skin ulcers; protruded eyes; lethargy; darkening of skin; ascites in peritoneal cavity	• Administer antibiotics; • Remove diseased fish; • Disinfect system; and • Reduce stress
Secondary bacterial infection (after Neobenedenia infestation)	*Streptococcus* sp.	Bacterium	Blindness, protruded eyes; skin ulcers; and skin darkening	• Administer antibiotics; • Remove diseased fish; • Disinfect system; and • Reduce stress

3.6.1 Pathogen Status in the Philippines

The Philippines is a member of the OIE and accepts the OIE list of notifiable aquatic animal diseases, which are described under the OIE code for aquatic animals. The Competent Authorities of the Philippines report on any notifiable aquatic animal diseases to other relevant National Authorities and to the OIE, as it is required. The Ministry of Agriculture is in charge of investigating, compiling, monitoring and reporting on aquatic animal diseases, through the information provided by provincial and district animal health officers. The Philippines is, therefore, an appropriate option as 'country of origin', taking into account its current aquatic health status and reporting system. On the other hand, as it will be described in detailed in the section dealing with pathogen risk management measures, strict pre-border mitigation protocols will be implemented to the selected stock (the specimens to be transported) in order to assure that fingerling transported are free of any OIE-listed diseases, as well as being free of any relevant trans-boundary diseases for marine finfish organisms.

3.6.2 Pathogen Status in Papua New Guinea

NAQIA, as mentioned before, is the authority responsible of implementing these activities within PNG. Regarding relevant transboundary animal diseases, PNG accepts the OIE-listed diseases as notifiable, and the OIE as an SPS setting standard body under the World Trade Organization.

NAQIA, through District and Provincial Livestock Officers is in charge of compiling, analyzing and reporting on animal diseases to the Ministry of Agriculture, other relevant national stakeholders and the OIE. It should be mentioned that the NFA has been in charge of certifying aquatic products exported to the EU and USA, acting on behalf of NAQIA; and it has also been in charge of food safety issues for food fish products (although most food products are just tested for heavy metals).

The aquatic animal health status in PNG is considerably unknown, therefore, quarantine and other pre-border and post-border risk management measures proposed in the present document are quite conservative, in order to achieve an appropriate level of protection.

3.7 Mariculture

3.7.1 Seed Supply

Brood-stock collection generally involves capturing and transporting juvenile or adult wild-caught cobia (often during their natural spawning season) into the NIMRF tank systems, where 2-3 year old fish will spawn either naturally or after being induced with photo-period and temperature manipulations. The tanks will have an egg collector and are either operated as re-circulating systems, flow-through, or a combination of both, depending on the biological filtration capacity of the system.

3.7.2 Hatchery Production:

After hatching and absorbing the yolk sac (usually by the third day), the larval cobia must initially be provided adequate amounts of the proper size food, such as enriched rotifers (*Brachionus plicatilis*) or *copepod nauplii*. In tank systems this food should be offered for at least the first four days, after which enriched, newly hatched enriched Artemia can be introduced, followed by weaning to dry feed at approximately 25-30 days post-hatch.

3.7.3 Nursery

Cobia could be raised in a series of tanks until they reach a large enough size to be stocked into a nearshore or offshore grow-out cage system (see Figure below for pictorial diagram of aquaculture process). During the larval rearing stage, 'green-water' with an adequate bloom of Chlorella, copepods, and rotifers are utilized.

To reduce cannibalism and size variability cobia are graded weekly after day 45 post-hatch until they reach approximately 30 g (around day 75 post-hatch), which is considered the minimum size for stocking in sea-cages.

Cobia are fed 5-6 times a day to satiation at a rate of 5 % body weight up to 30 g; after this the feeding rate is reduced to 2-3 percent body weight as the fish approaches 200 g. From this point onwards the overall goal, is to raise the young cobia to a point where they are large enough to be stocked into a sea-cage system, yet small enough to be transported in large numbers with minimal mortality.

3.7.4 On-growing Techniques

Grow-out methods utilize net pens or sea-cages of various sizes and types (Figure 4) to rear the cobia to harvestable size. Successful grow-out of cobia has been reported utilising both surface and submerged systems.

In order to minimize grow-out time as well as disease issues, cobia produced in sea-cages should be located in sites that provide warm clean water and adequate flow rates through the cage system to provide high dissolved oxygen levels continuously. These conditions exist in the Kavieng Lagoon.

Harvest numbers vary depending on the stocking rates and water temperature, but the grow-out period for pellet fed cobia is generally about 1-1.5 years, with fish reaching a final weight of 6-10 kg at harvest densities of 10-15 kg/m^3.

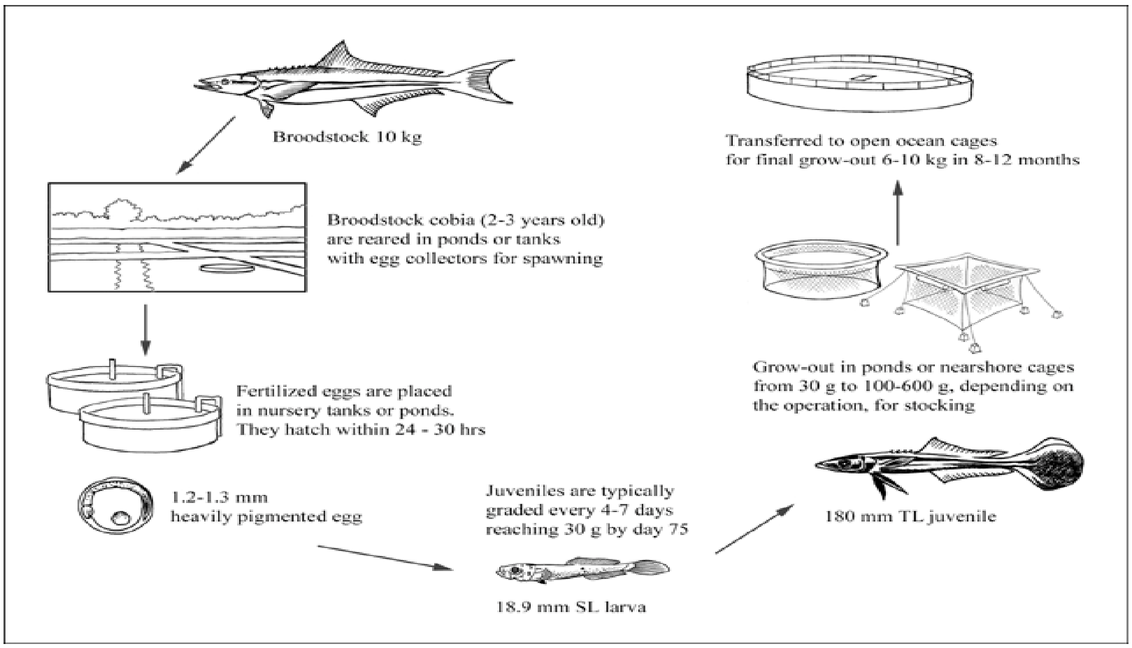


Figure 4: Aquaculture Production Cycle of cCobia

3.7.5 Feed Supply

Both floating and sinking pellets (42-45 percent crude protein, and 15-16 percent lipid) should be used, with fish typically fed six days a week at a rate of 0.5-0.7 % body-weight per day towards the end of the grow-out phase. Cobia feed conversion in the Taiwan Chinese Province is reported to be approximately 1.5:1.

4. Approaches for the Risk Analysis.

4.1 Definition

Risk analysis is a structured process for:

- Determining what events can occur (identifying hazards);
- Analysing the probability that the event will occur (determining likelihood);
- Assessing the potential impact once it occurs (determining consequence); and
- Identifying the potential management options and communicating the elements and magnitude of identified risks.

In simple terms, risk analysis is used to determine the likelihood that an undesired event will occur and the consequences of such an event. This is generally developed in a repeatable and iterative process where we seek answers to the following questions:

- What can occur? (Hazard identification);
- How likely is it to occur? (Risk assessment: likelihood assessment through release assessment and exposure assessment);
- What would be the consequences of it occurring? (Risk assessment: consequence assessment and risk estimation; risk management: risk evaluation);
- What can be done to reduce either the likelihood or the consequences of it occurring? (Risk management: option evaluation, implementation, monitoring and review); and
- The entire process includes risk communication, the communication of the risk to others in order to generate a change in management, regulation or operation.

4.2 Purpose

The purpose of risk analysis is to provide a structured means by which risks to or from a sector can be evaluated and communicated in order to guarantee a uniform and transparent process of decision making. It is highly desirable for decision-making to be consistent, repeatable, objective, and to provide a clear methodology that makes the information feeding into the decision-making process and its use transparent to all relevant stakeholders.

4.3 Risks and Mechanisms

Examples of relevant biological and socio-economic risks are provided below in Table 5.

Table 5: Examples of Biological and Socio-economic Risks

Risks	**Biological impacts**	**Social impacts**
Reduction or elimination of native aquatic species	Competition, hybridization, predation, disease transmission	Change in fishing pressure and access to resources; treatment measures to either eliminate or enhance alien species
Change in native terrestrial fauna	Change in abundance of preferred prey	Fish farms providing more food for birds and animals, or fish farms killing predatory birds
Change in composition of fishery	Addition of alien species and associated ecological impacts on native species	Successful introductions lead to other introductions; new fishers enter fishery; different fishing techniques or simply more fishing pressure result from introduction of alien species and impact non-target species
Alteration in native habitat	Burrowing, sediment mobilization, removal of vegetation	Change in land use, e.g. creation of fish farms, access roads, development, etc.
Socioeconomic impacts, e.g. loss of income, employment or means of livelihood	Change in species abundance or distribution lead to change in fishing or consumption practices	Change in access rights, land tenure; financial liability for damages through national and international legislation

4.4 Approaches for the Pathogen Risk Analysis.

The general approach used in the pathogen risk analysis follows that outlined by the OIE and the 2003 *'ICES Code of Practice on the Introductions and Transfers of Marine Organisms'*. The pathogen risk analysis has been conducted as a 'generic' risk analysis for introduction, including:

- A preliminary hazard identification (all pathogens reported on cobia are considered);
- A detailed hazard identification for those pathogens meeting the criteria for further consideration;
- Risk assessment: possibilities that hazards might be released and the pathways by which this might occur, the potential for exposure of native species, and the probable consequences of exposure; and
- Risk management.

The following criteria should be fulfilled in order for a potential pathogen hazard to be given further consideration:

- The agent must have been reported to infect, or is suspected of being capable of infecting cobia at any live stage;
- The agent must be an obligate pathogen; it is not a ubiquitous free-living organism that is capable of becoming an opportunistic pathogen of cobia under certain environmental or culture conditions;
- The agent must cause significant disease outbreaks and associated losses in populations of cobia or, if not a significant pathogen of cobia, it must cause serious disease outbreaks in populations of other species of aquatic organisms; and
- It must be plausible that the pathogen might be present in populations of cobia in the origin of the stock.

A hazard is any pathogenic agent that could produce adverse consequences upon the importation of a commodity. Hazard identification is the process of identifying pathogens that could potentially be introduced in the commodity considered for importation. In this analysis, the hazard identification process has been separated into two steps:

- Preliminary hazard identification, in which all pathogens reported from cobia are considered; and
- Detailed hazard identification, in which only those pathogens that meet the criteria mentioned above are considered.

Risk assessment is the process of identifying and estimating the risks associated with the importation of a commodity and evaluating the consequences of taking those risks. It consists of a:

- Release assessment which is the process of describing the biological pathways necessary for an importation activity to introduce a pathogen into a particular environment, and estimating the likelihood of that complete process occurring; and
- Exposure assessment which is the process of describing the biological pathways necessary for exposure of humans and aquatic and terrestrial animals in the importing country to the hazards and estimating the likelihood of the exposure occurring.

When an exposure assessment determines that there is more than a negligible risk of introduction of a disease agent, a consequence assessment will consider the possible biological and socioeconomic consequences that could result from the disease agent being released into the natural environment.

Risk management is the process of identifying, documenting and implementing measures that can be applied to reduce or eliminate the level of risk. Risk management is presented in the form of various recommendations which, if implemented, would significantly reduce the risk of introducing serious pathogens.

4.5 Approaches for the Ecological Risk Analysis

The approach taken for assessing the ecological risks of the introduction of cobia into PNG was to review the applicable scientific literature and technical reports covering the ecology (habitat, distribution, feeding strategies and so on that are presented in section 3) of the species as well as other local species that could potentially be negatively impacted. In broad terms, the assessment examined the:

- Risk of escape;
- Potential for cobia to establish sustaining populations in the area where it will be introduced;
- Potential for widespread dispersal; and the
- Possible effects on native species should a population of cobia become established in the wild.

Results from the literature review were summarized and tabulated using a modification of the method promoted by the *'ICES Code of Practice on the Introductions and Transfers of Marine Organisms'* and the FAO technical Guidelines on responsible use and control of introduced species (under preparation).

4.6 Approaches for the Socioeconomic Risk Analysis

Socio-economic risks should be quantified prior to considering associated biological factors as it is the socio-economic aspect of the program that utilizes introduced species that determine the need for the introduced species. However, in the subsequent process of evaluating the ecological and disease impacts, other socio-economic risks may be discovered. The social and economic assessment attempts to:

- Identify and quantify those people most at risk from the use of the introduced species;
- Identify and quantify how the human community will change as a result of the introduction. Such changes may be in the form of market changes, changes in activity patterns, changes in food consumption/availability, changes in access to resources, necessary infrastructure changes or inadequacies, changes in resource allocation, and changes in power structure;
- Determine the acceptability of the species the demand, the target market, and the estimated price; and
- Monitoring the social and economic impacts of an introduction will be necessary to determine if the desired beneficiaries are actually benefiting and if other groups are being adversely impacted.

4.7 Previous Introduction Risk Assessments within the Pacific Islands Region

There have been several species introductions (e.g. giant clams) in many PICTs, though most of these introductions did not have formal IRAs conducted. The most notable IRAs in the PIR that have been conducted for species introduction for aquaculture production include:

- Pathogen and Ecological Risk Analysis for the introduction of Giant River Prawn, *Macrobrachium rosenbergii*, from Fiji to the Cook Islands;
- Pathogen and Ecological Risk Analysis for the introduction of Blue Shrimp, *Litopenaeus stylirostris*, from Brunei Darussalam to Fiji; and an
- Environmental Impact Assessment for the introduction of Cobia, *Rachycentron canadum* from Australia to Marshall Islands.

These previous IRAs have been used in formulating this current IRA.

4.8 Previous Introductions of Aquatic Species into Papua New Guinea

PNG has a history of species introduction with many showing adverse ecological effects (Table 6). Within the fisheries realm, fresh-water species introductions in the Sepik River in the north, and cross-border introductions of species in Western Province have been detrimental to local fish populations.

The origin of most of these introductions remains a mystery, though some are known to have been introduced during an ill-conceived fish stock enhancement program sponsored by the FAO in the 1980s.

Table 6: Aquatic Species Introductions to Papua New Guinea

Scientific name	**Country from**	**Date**
Acrossocheilus hexagonolepis	Nepal	1993
Anabas testudineus	Indonesia	1985
Barbonymus gonionotus	Malaysia	1970
Bidyanus bidyanus	Australia	Unknown
Carassius auratus auratus	Unknown	Unknown
Channa striata	Unknown	Unknown
Clarias batrachus	Unknown	Unknown
Colossoma bidens	South America	Unknown
Ctenopharyngodon idella	Unknown	Unknown
Cyprinus carpio	Australia	1959
Gambusia affinis	Unknown	1930
Hypophthalmichthys molitrix	Unknown	Unknown
Macquaria ambigua	Unknown	Unknown
Macquaria colonorum	Australia	Unknown
Neolissochilus hexagonolepis	Nepal	1995
Oncorhynchus mykiss	New Zealand	1952
Oreochromis mossambicus	Malaysia	1954
Osphronemus goramy	Unknown	1957
Petroscirtes breviceps	Australia	1972
Piaractus brachypomus	Malaysia	1995
Poecilia reticulata	Unknown	1967
Pomacea canaliculata	Brazil	1993
Prochilodus argenteus	Brazil	Unknown
Prochilodus margravii	Brazil	1996
Puntius gonionotus	Malaysia	1970
Puntius javanicus	Malaysia	1970
Puntius semifasciolatus	unknown	unknown
Retropinna semoni	unknown	unknown
Salmo trutta	Australia	1949
Salvelinus fontinalis	Australia	1974
Sarotherodon spp.	Unknown	Unknown
Schizothorax richardsonii	Nepal	1995
Tandanus tandanus	Unknown	Unknown
Tilapia rendalli	United Kingdom	1991
Tor putitora	India	1995
Trichogaster pectoralis	Malaysia	1957
Trichogaster trichopterus	unknown	1970
Xiphophorus hellerii	Mexico	1935

5. Pathology Risk Analysis.

5.1 Preliminary Hazard Identification

The preliminary hazard identification will consider all relevant pathogens and diseases reported from cobia. The following criteria must be met for a pathogen or disease to be considered in this preliminary hazard identification:

- The potential pathogen or disease must be an identifiable biological agent or a disease believed to be produced by a single biological agent, and not as an opportunistic pathogen.
- The agent must have been recorded from cobia as a cause of significant disease. Pathogens reported from any life cycle stage and any geographical locality are included.

The results of the preliminary hazard identification are presented Table 7 below:

Table 7: Preliminary hazard identification for aquacultured cobia

Pathogen	**Causes significant disease**	**Further considerati on required**	**Comments**
Iridovirus Lymphocystis	No	No	• Common among cobia fingerlings during the nursery phase of culture
Encephalopathy and Retinopathy inodavirus (VER or VNN)	Yes	Yes	• It has been reported as a serious disease of larval and juvenile and sometimes older marine fish
Red seabream iridovirus (RSVID)	Yes	Yes	• It is a significant cause of mortality among cultured marine fish
Photobacterium damselae subsp. *piscicida*	No	No	• Affects cobia fingerlings when water temperature is <28 C;
Streptococcus iniae	No	No	• Occurs in both nursery and grow-out culture stages
Vibrio anguillarum	No	No	• Affects fingerlings, juveniles and adults; outbreaks occur when water temperature is 24- 26 ° C
Bacterial Enteritis *Vibrio alginolyticus; Vibrio* spp.	No	No	• Affects stressed cobia during low water temperature condition <22 ° C
Mycobacterium Infection *Mycobacterium* sp.; secondary infection by *Aeromonas hydrophila*;	No	No	• Infects fingerlings (15-20 cm total length
Neobenedeniasis *Neobenedenia melleni*	No	No	• Affects cobia in all stages of culture
Sea Lice Infestation *Parapetalu occidentalis* (gills) and *Caligus oviceps* (body surface)	No	No	• Affects cobia in all stages of culture
Amyloodiniosis *Amyloodinium ocellatum*	No	No	• Affects cobia during hatchery and nursery phases
Licmophorasis *Licmophora* sp.	No	No	• Affects cobia fingerlings within one month after stocking
Cryptocaryon irritans	No	No	
Epistylis spp.	No	No	• Reported during larval stage
Trichodina sp.	No	No	• Reported during nursery stage
Myxidiosis	No	No	
Coccidia spp.	No	No	

5.2 Criteria for Further Consideration

The following criteria should be fulfilled in order for a potential hazard (pathogen) to be given further consideration:

- The agent must have been reported to infect, or is suspected of being capable of infecting cobia at any live stage;
- The agent must be an obligate pathogen; it is not a ubiquitous free-living organism that is capable of becoming an opportunistic pathogen of cobia under certain environmental or culture conditions;
- The agent must cause significant disease outbreaks and associated losses in populations of cobia or, if not a significant pathogen of cobia, it must cause serious disease outbreaks in populations of other species of aquatic organisms; and

- It must be plausible that the pathogen might be present in populations of cobia in the origin of the stock.

Animal diseases notifiable to the OIE for finfish include:
- Fish Epizootic haematopoietic necrosis;
- Infectious haematopoietic necrosis;
- Spring viraemia of carp;
- Viral haemorrhagic septicaemia;
- Infectious salmon anaemia;
- Epizootic ulcerative syndrome;
- Gyrodactylosis (Gyrodactylus salaris);
- Red sea bream iridoviral disease;
- Koi herpesvirus disease; and
- Encephalopathy and Retinopathy nodavirus disease.

Presently, only two of these have been reported to affect cobia, and these are the:
- Red sea bream iridoviral disease; and the
- Encephalopathy and retinopathy nodavirus (VER and VNN).

5.3 Pathogens not Considered Further

Taking into account the criteria for a pathogen to be considered in the preliminary hazard identification, and considering the criteria for further consideration of pathogens, it should be noted that most of the viral, bacterial and parasitic pathogens (apart from the VNN virus - Encephalopathy and Retinopathy nodavirus, and the Red seabream iridovirus) described in the above section could be considered as opportunistic and quite ubiquitous agents, which do not meet, in an strict way, none of criteria lists.

Some of the pathogens listed above could cause serious mortality and morbidity in cobia (e.g. the parasitic infestations caused by amylodinium when affecting juveniles), but in all cases their occurrence is very much related to specific stressing factors. However, the mitigation and containment measures recommended in the present document under the risk management section are designed to prevent possible release of any pathogens through the introduction of cobia into PNG, as well as to prevent possible exposure to these pathogens of sensitive native species, once released into the receiving environment.

5.4 Pathogens for Further Consideration

5.4.1 Encephalopathy and Retinopathy Inodavirus

The VNN disease is the most devastating viral infection among marine finfish. Outbreaks of VNN caused up to 70 % mortality in fry, up to 100 % mortality in 2.5-7.5 cm fish and <20 % mortality in >15 cm size fish. VER or VNN has been reported as a serious disease of larval and juvenile and sometimes older marine fish that occurs almost world-wide except for Africa.

To date, the disease has been reported in at least 30 fish species, with the greatest impact being in sea bass (*Lates calcarifer* and *Dicentrarchus labrax*), groupers (*Epinephelus akaara*, *E. fuscogutatus*, *E. malabaricus*, *E. moara*, *E. septemfasciatus*, *E. tauvina*, *E. coioides* and *Cromileptes altivelis*), jacks (*Pseudocaranx dentex*), parrotfish (*Oplegnathus fasciatus*), puffers (*Takifugu rubripes*), flatfish (*Verasper moseri*, *Hippoglossus hippoglossus*, *Paralichthys olivaceus, Scophthalmus maximus*), and cobia.

Diseased fish swim in darting, corkscrew manner. Some fish sink to the bottom then float to the surface again. Affected juvenile and brood-stock fish develop bloated belly. In addition, affected fish also show lethargy, pale coloration and loss of appetite. Internal disease signs include pale livers, empty digestive tracts and intestines filled with greenish to brownish fluid. The virus propagates in the eye, brain and distal spinal cord of affected fish causing marked vacuolations of the central nervous tissues leading to vacuolating encephalopathy and retinopathy. Usually there is also vacuolation of the nuclear layers of the retina. It also multiplies in the gonad, livers, kidney, stomach and intestine.

In general, younger fish have more severe lesions; older fish have less extensive lesions and these may show a predilection for the retina. Intracytoplasmic inclusions have been described in brain cells. There are considerable variations in the age at which disease is first noted and the period over which mortality occurs. In general, the earlier the signs of disease occur, the greater is the rate of mortality. Although disease occurrence at the juvenile stages in some species is very rare, mass mortalities often occur at juvenile to young stages in the other fish species, but usually do not reach 100 %, indicating the age-dependence of susceptibility.

It has been demonstrated that vertical transmission of the causative agent occurs in some species, and this fact is reflected by the early occurrence of clinical disease. This finding has led to the successful control of VNN of larvae, where elimination of virus-carrying broodstock by reverse-transcription polymerase chain reaction and disinfection of fertilized eggs by ozone were applied.

The mode of transmission/introduction of the viruses, other than in gametes and by cohabitation, has not been demonstrated, but the possibilities include influent water, juvenile fish held on the same site, and carriage on utensils, vehicles, etc. It is possible that these small viruses are quite resistant to environmental conditions and therefore readily translocated by commercial activities.

Vaccination using a recombinant capsid protein is at the experimental stage has proven effective. VNN-carrier broodstocks were also found to be a source of inoculum of the virus to their larvae. Pre- and post-spawning screening of broodstocks for VNN is very important, and only VNN-negative broodstocks should be allowed to spawn, followed by disinfection of the fertilized eggs using ozone or iodine. These procedures are very effective in preventing the vertical transmission of the virus.

Strict husbandry management in the hatchery phase is also very important in the management of VNN infection. Betanodaviruses are quite resistant to some environmental parameters, thus it is highly possible that the virus could be easily translocated via contaminated rearing water and paraphernalia, and the use of non-recycled, chemically treated rearing water and decontamination of tanks after every hatching cycle can prevent VNN infection.

Other measures in the control of VNN in larval finfish are:

- Disinfection of eggs with iodine or ozone and hatchery paraphernalia with chlorine;
- Rearing of each batch of larvae and juveniles in separate tanks supplied with UV or ozone-sterilized seawater; and
- Separation of larvae and juveniles from brood-fish.

In addition, reduction of identified stress factors in the culture system is very important; reduction of larval stocking density in the tank may also help reduce the possibility of viral transmission. Rearing water temperature has been shown to influence disease development wherein higher mortality and earlier appearance of the disease signs were observed at higher rearing water temperatures. This suggests that manipulation of water temperature will help reduce disease outbreaks.

5.4.2 Red sea bream Iridovirus

RSIVD is a significant cause of mortality among cultured marine fish. The causative agent is the red sea bream iridovirus. Overt infections have been recognized not only in red sea bream (*Pagrus major*), but also among other cultured marine fish, including cobia.

The first outbreak of RSIVD was recorded in cultured red sea bream in Shikoku Island, Japan in 1990. Since 1991, the disease has produced mass mortalities in cultured fish populations in the western part of Japan, mainly among juvenile red sea bream, but also in some cases, market-sized fish.

Affected fish are lethargic, exhibit severe anaemia, petechiae of the gills, and enlargement of the spleen. The disease is characterized by the appearance of enlarged cells stained deeply with Giemsa solution on microscopic observation of tissue sections of the spleen, heart, kidney, liver and gills of infected fish.

The principal mode of transmission of RSIVD is by horizontal means via the water.

The RSIVD has shown some weak cross-reactivity in indirect fluorescent antibody tests using polyclonal rabbit anti-RSIVD serum with the systemic ranaviruses resembling epizootic haematopoietic necrosis virus (or FV-3). Diagnostic methods, such as the observation of stained impression smears or tissue sections, an immunofluorescence test with an MAb, and a polymerase chain reaction, have been reported for RSIVD.

Control methods currently rely on the implementation of hygiene practices at the farm (best management practices and bio-security protocols, as mentioned above for the VNN infection). A commercial vaccine may soon be available for RSIVD in red sea bream. Vaccination for other marine fish species is at the experimental stage.

5.5 Risk Management

The following pathogen risk mitigation (including quarantine) measures are recommended for both the Philippines as the exporting country and PNG as the importing country are detailed in Table 8.

Table 8: Pathogen Risk Management for the Philippines and Papua New Guinea

<table>
<tr><th>Exporting Country – the Philippines</th><th>Importing Country – Papua New Guinea</th></tr>
<tr><td>

The shipment of cobia fingerling to be introduced into PNG should be of ‘high health’ status and have a clear sanitary certification provided by the Philippine Competent Authority in charge of Bio-security and Aquatic Animal Health Management;
A detailed health check list of each individual before transportation from the facility of origin should be followed;
The facility of origin in the Philippines will demonstrate a proven track record of main diseases and pathogens, including clinic signs, differential diagnosis, final diagnosis, mortalities and morbidities occurred in the specimens to be introduced into PNG;
The facility of origin will present the screening results for VNN and red seabream iridovirus disease for the stock to be introduced into PNG, following the OIE Manual of Diagnostic Tests for Aquatic Animals;
The facility of origin in the Philippines will have evidence of adherence to strict bio-security protocols and an over-all health management plan;
The facility must provide PNG with sufficient guarantees as to the health status and history of its stock;
The following treatments will be carried out at the facility of origin to the stock to be introduced into PNG, prior transportation:

Anti-parasitic treatment, for external parasites control: one day formaldehyde bath at 150 ppm/1 hour, during the week prior transportation; and.
Antibiotic treatment, for subclinical bacterial infections: oxitetracycline (10mg/Kg BW) oral treatment for 5 days, one week prior transportation;

An on-site inspection visit to the production facility by a recognized expert on behalf of the Government of PNG will be made to assure that the protocols, diagnostic procedures, security, etc are adequate to validate guarantees of health status; and
The production facility in the exporting country will also meet the following pre-border requirements:

The batch of the stock destined for export should be separated as early as possible from other stocks reared in the facility of origin and should be maintained in tanks separate from the rest of the stocks and
Detailed records should be kept of the health status and mortality rates of each batch of cobia fingerlings to be transported. Such records should be made available to the Competent Authority responsible for health certification at the importing country.

</td><td>

The receiving facility must implement standardised and adapted quarantine measures operations such that the risk of pathogen exposure is minimized (the quarantine protocol is described below; it has been adapted from the ‘NAQIA quarantine protocol for freshwater finfish’);
The stock will be received at the Quarantine area of the NIMRF;
The sanitary certification and related documentation provided by the Philippine Competent Authority will be analyzed and reviewed, either at the airport or at the quarantine area by the PNG Competent Authority;
General health status of the specimens received will be checked at the reception into the quarantine area, and monitored weekly during the quarantine period (two months);
Approximately 1,000 fingerling will be introduced; and these will be counted and measured at NIMRF’s quarantine facility, and later once again after acclimation to the water temperature and water quality before being released into the stocking tanks (stocking tanks will be cleaned and disinfected with hypochlorite at 200 ppm or other disinfectant solution prior reception of the stock);
The specimens will be stocked in three 3,000 lts circular tanks located at the quarantine area of the facility, with approximately 330 specimens will be stocked at each tank, with an average stocking density of 2kg per 1000 lts;
Sea water will be sand filtered, passed by a 1 micrometer cartridge filter and disinfected by an ultra-violet (UV) filter, with 100 % water exchange done daily;
Water outlet will be filtered by a 1 micrometer cartridge filter and disinfected by an UV filter before being released; independent water inlets and outlets are available for each tank at the quarantine area, for easy of filtration and disinfection treatments;
Antiparasitic treatment, for external parasite control using formaldehyde (100ppm per 1 hour) will be administered during the first week after transportation;
The stock will be maintained during two months at the hatchery facilities; after this period, the general health status of the specimens will be checked prior stoking them for culture in sea cages;
After the quarantine, relevant virus (VNN and red seabream iridovirus) will be screened following the OIE recommended tests before stocking for grow-out in sea cages;
The hatchery operators will follow a general health monitoring system, testing at least once a week, and keeping a time-series ecord of health, morbidity and mortality status will be established; they will also report any occurrences of serious mortalities or disease outbreak;
No animals will be removed from the receiving facility without prior permission from the NFA and NAQIA; and finally
All animals will be destroyed and disposed of in an approved sanitary method and the facility fully disinfected before stocking if there is a serious mortality or disease outbreak.

</td></tr>
</table>

5.6 Conclusions of the Pathogen Risk Analysis

Regarding health status of the importing country, it should be noted that there is a current lack of information regarding aquatic animal health and diseases status in PNG. On the other hand, aquatic animal health management and bio-security protocols applied to aquaculture are considerably well developed in the Philippines, since it is one of the first aquaculture producing countries in the world, which assures that all pre-border measures detailed in the present proposal will be carried out in a very efficient and precise way.

Moreover, since both the facility of origin and the facility of destiny are very well equipped and managed, it is highly unlikely that any relevant pathogen will be spread or transmitted to the natural environment during the introduction process. It should also be mentioned that most of the listed pathogens affecting cobia are ubiquitous and opportunistic agents (always linked to stressing factors) that do not cause big mortalities or morbidities, apart from the VER or VNN, and RSVID. Opportunistic and ubiquitous agents cannot be easily spread, without the necessary stressing factors present; therefore, the hazard likelihood and possible occurrence expected could be considered very low. Release and exposure occurrence would also be extremely low.

6. Ecological Risk Analysis

6.1 Introduction

Cobia is a migratory species that is found naturally in PNG waters, and has been caught in and around the Kavieng Lagoon, where it is proposed to be introduced. The aim of the introducer is to bring domesticated and improved strains of cobia to PNG, in order to develop a long-term sustainable, technically feasible and economically viable aquaculture activity within PNG, using a strain that is easy to rear and that has suitable growth characteristics.

The introduction of domesticated and improved cobia strains is seen as a way to diversity the aquaculture sector in PNG, since local wild strains cannot be farmed in such an efficient and sustainable way (i.e. artificial spawning cannot be implemented easily with wild stocks, stocking densities and growth rates are extremely low).

The introduction of cobia into PNG is believed to offer relevant advantages over local marine species available, as well as to over local cobia strains. Some of the comparative advantages of the introduction of domesticated specimens are detailed below:

- Ease of working: regarding life cycle, feeding technologies, etc.;
- Improved technologies already exist: farming and feeding strategies are well known and easier than for other marine finish species;
- It has high growth rates and efficient FCR;
- Survival rates during larval rearing are quite high;
- Has a quite high tolerance to changes in water quality parameters, such as temperature, oxygen and pH;
- Tolerates low salinity and low dissolved oxygen rates;
- High value and demand;
- Well established market acceptance in Asia;
- Range of culture systems developed;
- Easy to produce, harvest, process and store;
- Wide spread distribution;
- Low cost, low technology hatchery production;
- Potential high stocking density;
- Relatively hardy species, adaptable to a range of environments;
- Suitable to coastal environments;
- Large number of potential land-based sites for hatchery installation; and the
- Potential sea-based sites for grow-out;

As part of the IRA exercise, some of these culture characteristics will be analysed in a detailed way as relevant invasiveness factors that should be taken into account.

6.2 Proposed Grow-out Sites

Proposed grow-out sites within the Kavieng Lagoon will be located in different suitable locations. The Kavieng Lagoon consists of a large area of water with a relatively flat bottom consisting of coral aggregate and sand. Key features of the environment with regards to the fish farm project are:

- Coral reefs on the rim of the atoll with the most pristine being those on the northern shore;
- Relatively low value environment of coral aggregate flats in the areas within and surrounding the proposed fish farm sites;
- Surrounding ocean and strong currents, and swells during the summer months.

Kavieng Lagoon has a number of physical features that make it well suited to minimize the environmental impacts of fish farming. Key to the ability of the Kavieng Lagoon to assimilate the impacts of fish farming are its sheer size and strong flush rates to the open ocean.

Relative to other locations, Kavieng Lagoon is favoured by the company and the NFA for aquaculture as:

- The lagoon displays relatively consistent water temperature and quality throughout the year which favors the best outcomes with regards to fish growth and health;
- The NIMRF is operated by the NFA, and is the only mariculture centre in the northern part of PNG, and it is located in the Kavieng lagoon; and grow-out locations can be found close to the NIMRF;
- Large parts of the lagoon are well flushed to the open ocean ensuring that impacts are minimized;
- The lagoon provides protection from large seas enabling regular activity on the sea cages;
- Kavieng is relatively well serviced with sea and air linkages and a workforce;
- Kavieng is well located in terms of domestic and export market and trade; and
- As previously mentioned, a fish processing plant and the ability to make aqua-feed is available at Kavieng town and operated by the same company which is requesting the introduction of cobia, therefore the complete vertical integration of the production cycle is assured.

For the first year, six farming sites to hold a set of three sea cages of 300 m³ per site have been selected (Table 9), involving six coastal communities that will carry out the sea cage management. Selected sites will be located within an area of 4-5 km radius from the main Kavieng Port.

Table 9: Criteria for Site Selection within the Kavieng Lagoon

Criteria	**Details**
Flushing	Zones are the best flushed throughout the year to the open ocean through the existing channels
Water circulation	Nutrients added to these zones will have minimal impact on the lagoon
Sensitive habitats	Zones are located away from significant areas of coral habitat
Depth	Zones are exclusively in water greater than 20 m in depth; the depth of water provides both a large buffer to water quality and a significant distance for waste remediation in the water column
Visual impacts	Sites will be well marked for marine navigation, and away from major shipping routes, population centers, and recreational and tourist destinations
Access	Zones are extremely accessible under most conditions by boat

For each fish farm site, the following equipment shall be located:

- Marker buoys surrounding the extent of the site;
- Mooring buoys for boats and ships;
- One or more work barges, which will be semi-permanently moored on the site; barges will be used for storing feed, equipment and supplies on site and as overnight accommodation for some staff;
- Small work boats; and
- 300 m³ floating squared cages which will be moored in a number of arrays within the site.

6.3 Alternative Strategies

Alternative strategies and locations considered other than sea-cages in the Kavieng Lagoon include:

- The Do Nothing option;
- Alternative Lagoon in PNG;
- Cages located external to Kavieng Lagoon;
- Land-based operation; and
- Location within Kavieng Lagoon.

The alternative staregies detailed above are considered below in more detail. Only the last strategy, '*Location within Kavieng Lagoon*' is considered the most viable option, and is the focus of this IRA.

6.3.1 Do Nothing

The Do-Nothing option involves:

- The loss of an opportunity to establish a sustainable, viable and feasible aquaculture activity with associated job creation, economic stimulus and revenues;
- No additional environmental impacts from the fish farming activity;

- The loss of an opportunity to conduct significant ongoing environmental monitoring of the Kavieng lagoon at limited cost to the government;
- The loss of an opportunity to establish an industry in Kavieng lagoon with a vested interest in maintaining the quality of the aquatic environment;
- The creation of a negative signal to other potential investors in PNG, and the region; and
- The loss of the opportunity to train local people and coastal communities in aquaculture,

6.3.2 Alternative Lagoon Area in Papua New Guinea
Other areas are currently unviable due to their remoteness and subsequent difficulty with logistics and size of workforce, and the fact that no similar facility of the NIMRF exists.

6.3.3 Sea-cages Located External to the Area
Offshore cage systems are emerging technologies that currently involve considerable additional cost and risk. Strong currents, waves and big depths are permanently present outside the area, and at this stage, there is no aquaculture technology available for these extreme conditions.

6.3.4 Land-based Operation
Land-based systems require three main commodities to ensure a viable facility:
- Clean abundant high quality water supply;
- High capacity reliable energy supply; and
- Large suitable land area available.

The Kavieng area has an abundant supply of high quality water for the operation; however the second and third commodities are in poor supply. The cost and risk associated with operating a land-based facility in Kavieng would not be economically viable and the loss of significant areas of land is unlikely to cause conflict.

6.3.5 Location within Kavieng Lagoon
The physical conditions within Kavieng Lagoon are well within those experienced by inshore sea-cage fish farms in other parts of the world. As such the technical requirements for aquaculture in this environment are understood and commercially viable using existing technologies. There are potential impacts associated with this option (as there are with all of the options) however these can be minimized by:
- Locating the aquaculture sites in areas that do not interfere with other activities in the area, and that have minimal impact;
- Ensuring that total production levels are such that associated nutrient production is appropriate to the level of flushing and tolerance of the natural environment; and
- Ensuring that aquaculture sites are located where flushing is greatest and distances from the most sensitive environments is maximized.

The location within Kavieng Lagoon is associated with the least infrastructure requirements, with the only fixed infrastructure required being the actual sea cages and associated mooring systems.

6.4 Conclusion on Alternative Strategies
The options for fish aquaculture at Kavieng Lagoon are reduced due to the great depths very close to the lagoonal rim. Sea cages located within the high flushing protected environment of the central and inner-lagoon provide the best balance of commercial viability and environmental risk.

For most impacts there is no potential for cumulative impacts in combination with other sources of hazards, such as anthropogenic ones. The proposed fish farm activity will not involve chemical pollution and will not add to water quality impacts associated with chemical pollution (e.g. heavy metals, pesticides, solvents). Nutrient excretion from the fish farms does have the potential to have a cumulative effect when combined with other anthropogenic nutrient enhancement; however, the for the area proposed, this will not be an issue as there is no land clearance or other sources of nutrient inputs.

The huge water volumes in the Kavieng lagoon and the relatively high flush rates ensures the nutrient impacts are confined to areas close to discharge points and areas of poor flushing. Nutrient impacts from the city centre area and agricultural runoff will be diluted and assimilated to close to background levels by the time they reach the fish farm sites.

6.5 Ecological Enhancements

Ecological enhancements expected from the establishment of the project are:

- Increased water quality monitoring conducted by the company and the NFA (in conjunction with the University of Natural Resources and Environment) will be the first long-term monitoring of Kavieng's water quality conducted; this will improve the knowledge of the baseline for future developments and environmental studies; and
- Compensatory habitat (fish farm structures) as the fish farm structures will aggregate fish in the otherwise low structure area and develop a significant population of fish in an area of otherwise little value as a fish habitat; and,

6.6 Qualitative Assessment of Risks

A qualitative risk assessment of potential ecological impacts during construction and operations is provided in Tables 10, 11, and 12.

Table 10: Risk Assessment and Uncertainty for the Probability of Alien Species Establishment

Assessment parameter and relevant considerations	Risk estimate	Uncertainty estimate
Alien species successfully colonises and maintains a viable population where it is introduced or where it escaped	Low	Relatively certain
Alien species has high biological potential for dispersion (e.g. migratory habits, long larval stages, high fecundity, short generation time, etc.)	Medium	Very certain
Alien species has high human-assisted potential for dispersion (e.g. human migration, transportation of fish, etc.)	Medium	Relatively certain
Final rating for probability of establishment	**Medium**	**Relatively certain**

Table 11: Risk Assessment and Uncertainty for the Consequences of Alien Species Establishment

Assessment parameter and relevant considerations	Risk estimate	Uncertainty estimate
Negative economic impact if alien species becomes established	Low	Relatively certain
Negative economic impacts from alien species' impact on commercially important species	Low	Relatively certain
Economic development associated with alien species will adversely impact some stakeholders	Low	Relatively certain
Economic costs if alien species becomes established (e.g. loss of trade, increased treatment and quarantine due to presence of new pathogen, etc.)	High	Relatively uncertain
Costs of monitoring program	Medium	Relatively certain
Costs of mitigation measures	Low	Relatively certain
Economic costs of eradication efforts, if necessary	Medium	Relatively certain
Environmental impact if alien species becomes established	Medium	Relatively certain
Alien species competes with important native species for food, space, mates, and breeding sites.	Medium	Relatively certain
Alien species preys on important native species	Medium	Relatively certain
Alien species disrupts or modifies habitat or water quality	Low	Relatively certain
Alien species reduce native species population size to a point where inbreeding would occur	Low	Relatively certain
Genetic impact of alien species	Low	Relatively certain
Alien species hybridises or breeds with local species	Low	Relatively certain
Hybridised alien species are capable of reproducing either with other hybrids or with parental species	Low	Relatively certain
Final rating for consequence of establishment	**Low**	**Relatively certain**

Table 12: Risk Assessment and Uncertainty for the Consequences of Pathogen or Parasite Establishment

Assessment parameter and relevant considerations	Risk estimate	Uncertainty estimate
Pathogen or parasite introduced along with the alien species	Low	Relatively certain
Pathogen or parasite escapes from aquaculture facility into environment	Low	Relatively certain
Pathogen or parasite encounters susceptible species or habitat in the environment	High	Relatively certain
Ecological impacts of pathogen or parasite on local habitat	Medium	Relatively certain
Important species susceptible	High	Relatively certain
Disease outbreak reduces competitive ability of indigenous species	Medium	Relatively certain
Disease outbreak reduces the marketability of important species	Medium	Relatively certain
Final rating for pathogens risks	**Medium**	**Relatively certain**

6.7 Ecological Impacts and Mitigation Measures

Impact and mitigation measures for identified ecological risks during construction and operations are provided in Tables 13, 14 and 14.

Table 13: Ecological Risk Assessment during Construction

Description of Impact	Mitigation measure
Placement of mooring blocks	• Use of permanent moorings for boats in order to minimize the need for dropping anchors in various parts of the farm; and • Sites where moorings are to be placed will be inspected to ensure any coral outcrops (bommies) or potential higher value habitat is avoided
Disturbance of sediments	• Use mooring blocks and anchors designed to ‘dig and hold’ rather than drag.

Table 14: Ecological Risk Assessment during Operations

Description of Impact	Mitigation measure
Aggregation of wild fish assemblages	• Consumption of fish waste
Changes to macro-benthic assemblages	• Moving of cages around the area to provide fallowing; • Use high digestible pellets for feeding and appropriate feeding management practices in order to minimize wastes; and • Monitoring of feeding to minimize waste
Pathogen transfer to wild susceptible species	• Remove mortality from cages weekly; • Use appropriate aquatic animal health protocols and better management practices (e.g. stress management, sampling for disease where appropriate); • Avoid overstocking cages
Entanglement of mega-fauna	• Separate predator nets not to be used; • Removal of any dead fish from cages to minimize attraction to cages; • Use of rigid netting material for cages; and • Ensure all ropes/cables etc and cage material is taut
Escaped stock	• Regular checking of cage material to ensure integrity; • Ensure cage material and structures are engineered to withstand extreme weather events; and • Ensure good site security.
Food web changes	• Moving of cages around the lease area to provide fallowing; • Use high digestible pellets for feeding and appropriate feeding management practices in order to minimize wastes; • Use a feeding regime that minimizes waste; and • Remove any dead fish from sea cages
Seabird interactions	• Use of bird nets to cover sea cages
Sediment changes	• Ensure sea cages are sited in an area with a high flushing rate; • Ensure cages are in relatively deep water; • Moving of cages around the lease area to provide fallowing if sediment deteriorates; • Use high digestible pellets for feeding and appropriate feeding management practices in order to minimize wastes; and • Remove any dead fish from sea cages
Increase in nutrient levels	• Avoid overfeeding; • Ensure sea cages are sited in an area with a high flushing rate; • Cap fish production to levels within assimilation capacity of the environment; and • Monitor water quality.
Introduction of chemicals	• Maintain equipment in good order to minimize the chance of fuel or oil leaks; and • Avoid the utilization of chemicals for disease treatment by applying better management practices and aquatic animal health protocols (i.e. prevention is better than treatment)

Table 15: Ecological Risk Assessment for Water Quality

Description of Impact	Mitigation measure
Water quality (near field)	• Ensure cages are sited in an area with a high flushing rate; • Use high digestible pellets for feeding and appropriate feeding management practices in order to minimize wastes; • Remove any dead fish from cages; and • Monitor water quality parameters (e.g. pH, Nitrogen, Phosphorus and Chlorophyll a)
Water quality (intermediate field)	• Ensure cages are sited in an area with a high flushing rate; • Use high digestible pellets for feeding and appropriate feeding management practices in order to minimize wastes; • Remove any dead fish from cages; and • Monitor water quality parameters (e.g. pH, Nitrogen, Phosphorus and Chlorophyll a)
Translocation of species	• Exchange ballast water at least 45 km from Kavieng when transporting the stock; • Ensure all fish imported are from controlled hatcheries; and • Use of prophylactic treatments and screening of stock prior transportation, in order to avoid any potential hitch hikers in the tanks

6.8 Conclusions of the Ecological Risk Analysis

In summary, key environmental impact points are:

- The fish farm sites are likely to see changes to some ecological communities in the near field associated with natural responses to assimilating fish farm wastes;
- Numerous studies of similar fish farms and water quality modelling indicates that the intermediate field impacts will be at the limit of detection and well below the level where impacts on the marine environment are possible; and
- Through the application of appropriate bio-security measures the risk of unwanted introductions will be reduced to no greater than that associated with normal shipping to Kavieng.

The project and farm design is intended to accommodate the majority of equipment and activity associated with the construction and operation of the fish farm within the fish farm sites in the Kavieng Lagoon. In this way, the proposed farm will have minimal negative impacts on the land areas of Kavieng.

The Kavieng Lagoon is well situated to mitigate the environmental impacts of an appropriately sized, located and operated fish farm. The proposed fish farm sites have been selected to be distant from high value habitats and to maximize water exchange with the open ocean. All fish fingerling and feed inputs will be from controlled sources and water quality and nearby habitats will be monitored to ensure that the environmental impacts remain within acceptable parameters.

7. Socio-economic Risk Analysis.

7.1 Introduction

The project is being established by a private company for the purpose of business profit. In the process, the project will bring very substantial economic benefits to Kavieng region and PNG. Expected benefits include the creation of approximately 210-250 full time jobs directly through the farming activities, aqua-feed production and fish processing; with these positions being sourced from the local population of Kavieng who will receive specific training and follow up throughout the project with other full-time jobs possibly being created in support industries in Kavieng and in other regions (e.g. marketing, distribution, catering, etc.).

7.1 Socio-economic Impacts and Mitigation Measures

Impact and mitigation measures for identified ecological risks during construction and operations are provided in Tables 16 and 17.

Table 16: Socio-economic Risk Assessment during Construction

Description of Impact	Mitigation measure
Increased boat traffic	• Mooring large service barges on site to store feed, supplies and some equipment; • Involving local communities in most of the fish farming operations; and • Working with local authorities to develop procedures for import, customs and quarantine inspections at sea to avoid double transfer of goods and unnecessary use of the boats
Employment generation	• Nil, positive impact
Increased skills of local communities	• Nil, positive impact
Visual impact at component assemblage sites	• Utilize existing industrial localities for land-based construction

Table 17: Socio-economic Risk Assessment during Operations

Description of Impact	Mitigation measure
Restricted access	• Position fish farm sites in low use areas
Restriction of recreational fishing	• Position fish farm sites in areas of low value to recreational fishing
Impact on other businesses	• Position fish farm sites distant from other businesses
Restriction of boat traffic	• Position fish farm sites in areas of low boat traffic; • Allow passage between fish farm sites; and • Ensure sites are clearly marked for marine navigation day and night
Employment generation	• Nil, positive impact
Increased skills of local communities	• Nil, positive impact
Visual impact of farm and service vessels	• Maximize distance of fish farm sites from residential and tourism areas; and • Minimize lighting from 10pm to sunrise to that required for safety and navigation

7.2 Conclusions of the Socio-economic Risk Analysis

The proposed project will imply considerably high positive socioeconomic impacts for the Kavieng region and PNG, due to local employment generation, increased skills of local communities, as well as increased food fish availability for domestic consumption, as an import substitution strategy; and any possible negative socioeconomic impacts will be minimized by adopting the appropriate mitigation measures.

8. Final Recommendations

Both the pathogen and ecological sections of the risk analysis are characterized by a moderate level of uncertainty. For the former, there is sufficient accurate information regarding the general health status of the stock to be introduced, the sanitary status of the facility of origin and the country (the Philippines).

Regarding PNG, there is a general lack of information on aquatic animal diseases; while for the latter, there is a certain lack of information regarding biophysical characteristics of Kavieng Lagoon. The environmental risk analysis suggests that although there is a general paucity of country-specific and species-specific data to support the analysis, the benefits of introduction outweigh any potential negative effects.

Based on past practices, it is recommended that PNG adopts an 'appropriate level of protection' that is 'conservative'; with an acceptable level of risk that is 'medium' (i.e. offers a moderate level of protection).

It is emphasized that the results of this IRA should not be taken as a sole basis for a decision by the Government of PNG to approve or disapprove a request for the proposed species translocation. Such a decision requires additional consideration by the government of policy, legislation, technical capability, etc. and should include extensive stakeholder consultation.

Overall though, the introduction of highly demanded species, both in the domestic and in export market, which are easy to rear, either for restocking or aquaculture purposes, as is the case of the cobia, could lead to the development of economically viable activities in the Kavieng area; and decision makers should balance benefits and risks of such introductions.

Resource Materials

AFFA. 2001. *Guidelines for Import Risk Analysis*. Canberra: Agriculture, Fisheries and Forestry Australia.

AQIS. 1999. *Import Risk Analysis on Non-Viable Salmonids and Non-salmonid Marine Finfish*. Canberra: Australian Quarantine and Inspection Service.

Arendt, M.; Olney, J. and Lucy, J. 2001. Stomach content analysis of cobia, *Rachycentron canadum*, from lower Chesapeake Bay. *Fisheries Bulletin*. 99:665-670.

Arthur, J.; Hurwood, D.; Lovell, E.; Bondad-Reantaso, M. and Mather, P. 2004. *Pathogen and ecological risk analysis for the introduction of Giant River prawn,* Macrobrachium rosenbergii, *from Fiji to the Cook Islands*. Noumea: Secretariat of the Pacific Community.

Arthur, J.; Bondad-Reantaso, M. and Subasinghe, R. 2008. *Procedures for the quarantine of live aquatic animals: A manual*. FAO Fisheries Technical Paper. No.: 502. Rome: Food and Agriculture Organisation.

Arnold, C.; Kaiser, J. and Holt, G.. 2002. Spawning of cobia Rachycentron canadum in captivity. *Journal of the World Aquaculture Society*. 33: 205-208.

Arulampalam, P.; Yusoff, F.; Shariff, M.; Law, A. and Rao, P. 1998. Water quality and bacterial populations in a tropical marine cage culture farm. *Aquaculture Research*. 29: 617-624.

Benetti, D.; Alarcon, J.; Stevens, O.; O'Hanlon, B.; Rivera, J.; Banner-Stevens, G. and Rotman, F.J. 2003. Advances in hatchery and growout technology of marine finfish candidate species for offshore aquaculture in the Caribbean. *Proceedings of the Gulf and Caribbean Fisheries Institute*. 54: 475-487.

Benetti, D.; Orhun, M.; Zink, I.; Cavalin, F.; Sardenberg, B.; Palmer, K.; Dnlinger, B.; Bacoat, D. and O'Hanlon, B. 2007. Aquaculture of cobia (*Rachycentron canadum*) in the Americas and the Caribbean. *RSMAS.* 1-21.

Bjorn, P.; Finstad, B. and Kritoffersen, R. 2001. Salmon lice infection of wild sea trout and Arctic char in marine and freshwaters: the effects of salmon farms. *Aquaculture Research*. 32 (12): 947-962.

Bondad-Reantaso, M.; Lovell, L.; Arthur, J.; Hurwood, D. and Mather, P. 2005. *Pathogen and Ecological Risk Analysis for the Introduction of Blue Shrimp,* Litopenaeus stylirostris, *from Brunei Darussalam to Fiji*. Noumea: SPC.

Bondad-Reantaso, M.; Arthur, J. and Subasinghe, R. 2008. (eds.). *Understanding and applying risk analysis in aquaculture.* FAO Fisheries and Aquaculture Technical Paper, No.: 519. Rome: FAO.

Bondad-Reantaso, M. and Subasinghe, R. 2009. *Understanding and applying risk analysis in aquaculture: A manual for decision-makers.* FAO Fisheries Technical Paper, No. 519/1. Rome: Food and Agriculture Organsiation.

Brown-Peterson, N.; Overstreet, R. and Lotz, J. 2001. Reproductive biology of cobia, *Rachycentron canadum*, from coastal waters of the southern United States. *Fisheries Bulletin.* 99: 15-28.

Capone, D.; Dunham, S.; Horrigan, S. and Duguay, L. 1992. Microbial nitrogen transformations in unconsolidated coral reef sediments. *Marine Ecology Progress Series*. 80: 75-88

Chen, S.; Kou, R.; Wu, C.; Wang, P. and Su, F. 2001. Mass mortality associated with a Sphaerospora-like myxosporidean infestation in juvenile cobia, *Rachycentron canadum* (L.), marine cage cultured in Taiwan. *Journal of Fish Diseases*. 24: 189-195.

Chou, R.; Su, M. and Chen, H.. 2001. Optimal dietary protein and lipid levels for juvenile cobia (*Rachycentron canadum*). *Aquaculture*. 193: 81-89.

Chou, R.; Her, B.; Su, M.; Hwang, G.; Wu, Y. and Chen, H. 2004. Substituting fish meal with soybean meal in diets of juvenile cobia Rachycentron canadum. *Aquaculture*. 229: 325-333.

Collette, B. 2003. Rachycentridae: Cobia. In: Carpenter, K. and Niem, V. (eds.). *FAO species identification guide for fishery purposes - The living marine resources of the Western Central Pacific - Volume 4 - Bony fishes: Part 2 (Mugilidae to Carangidae).* p: 2655. Rome: FAO.

Craig, S.; Schwarz, M.; and McLean, E. 2006. Juvenile cobia (*Rachycentron canadum*) can utilize a wide range of protein and lipid levels without impacts on production characteristics. *Aquaculture*. 261: 384-391.

DAL. 2001. *National Agriculture Development Strategy; Horizon 2002-2012*. Port Moresby: Department of Agriculture and Livestock.

Davies, I.; Greathead, C. and Black, E. 2008. Risk analysis of the potential interbreeding of wild and escaped farmed cod (*Gadus morhua* Linnaeus). In: FAO. Assessment and communication of environmental risks in coastal aquaculture. pp. 112–132. GESAMP Reports and Studies, No.: 76. Rome: Food and Agriculture Organisation.

DEC. 2005. *Draft Papua New Guinea's National Biosafety Framework.* Port Moresby: Department of Environment and Conservation.

Dempster, T.; Sanchez-Jerez, P.; Bayle-Sempere, J. and Kingsford, M. 2004. Extensive aggregations of wild fish at coastal sea-cage fish farms. *Hydrobiologia*. 525 (1-3): 245-248.

Dempster, T.; Fernandez-Jover, D.; Sanchez-Jerez, P.; Tuya, F.; Bayle-Sempere, J.; Boyra, A. and Haroun, R. 2005. Vertical variability of wild fish assemblages around sea-cage fish farms: implications for management. *Marine Ecology Progress Series*. 304: 15-29

Denson, M.; Stuart, K.; Smith, T.; Weirich, C. and Segars, A. 2003. Effects of salinity on growth, survival, and selected hematological parameters of juvenile cobia *Rachycentron canadum*. *Journal of the World Aquaculture Society*. 34: 496-504.

De Silva, S. and Turchini, G. 2009. Use of wild fish and other aquatic organisms as feed in aquaculture – a review of practices and implications in the Asia-Pacific. In: Hasan, M. and Halwart, M. (eds.). *Fish as feed inputs for aquaculture: practices, sustainability and implications.* FAO Fisheries and Aquaculture Technical Paper, No.: 518. pp: 63-217. Rome: Food and Agriculture Organisation.

Ditty, J. and Shaw, R. 1992. Larval development, distribution, and ecology of cobia *Rachycentron canadum* (Family: Rachycentridae) in the northern Gulf of Mexico. *Fishery Bulletin.* 90: 668-677.

Dufour, P., and Berland, B. (1999) *Nutrient control of phytoplanktonic biomass in atoll lagoons and Pacific ocean waters: studies with factorial enrichment bioassays*. J Exp Mar Biol Ecol 234

Eldredge, L. 1994. *Perspectives in aquatic exotic species management in the Pacific Islands – Volume 1: Introductions of commercially significant aquatic organisms to the Pacific Islands.* Noumea: Secretariat of the Pacific Community.

FAO. 2001. *Manual of Procedures for the Implementation of the Asia Regional Technical Guidelines on Health Management for the Responsible Movement of Live Aquatic Animals and the Beijing Consensus and Implementation Strategy*. FAO Fisheries Technical Paper, No.: 402. Rome: Food and Agriculture Organization.

FAO. 1995. Code of Conduct for Responsible Fisheries. Rome: Food and Agriculture Organization. Nations.

Faulk, C. and Holt, G. 2003. Lipid nutrition and feeding of cobia *Rachycentron canadum* larvae. *Journal of the World Aquaculture Society*. 34: 368-378.

Faulk, C. and Holt, G. 2005. Advances in rearing cobia *Rachycentron canadum* larvae in recirculating aquaculture systems: live prey enrichment and greenwater culture. *Aquaculture*. 249: 231-243.

Faulk, C. and Holt, G. 2006. Responses of cobia *Rachycentron canadum* larvae to abrupt or gradual changes in salinity. *Aquaculture*. 254: 275-283.

Faulk, C.; Benninghoff, A. and Holt, G. 2007. Ontogeny of the gastrointestinal tract and selected digestive enzymes in cobia *Rachycentron canadum*. *Journal of Fish Biology*. 70: 1-17.

Felsing, M.; Glencross, B. and Telfer, T. 2004. Preliminary study on the effects of exclusion of wild fauna from aquaculture cages in a shallow marine environment. *Aquaculture*. 243: 159-174.

Fernandez-Jover, D.; Arechavala-Lopez, P.; Martinez-Rubio, L.; Tocher, D.; Bayle-Sempere, J.; Angel Lopez-Jimenez, J.; Martinez-Lopez, F. and Sanchez-Jerez, P. 2011. Monitoring the influence of marine aquaculture on wild fish communities: benefits and limitations of fatty acid profiles. *Aquaculture Environment Interactions.* 2: 39–47.

Franks, J.; Ogle, J.; Lotz J.; Nicholson, L.; Barnes, D. and Larson, K. 2001. Spontaneous spawning of cobia, *Rachycentron canadum*, induced by human chorionic gonadotropin (HCG), with comments on fertilization, hatching, and larval development. *Proceedings of the Gulf and Caribbean Fisheries Institute*. 52: 598-609.

Franks, J.; Warren, J. and Buchanan, M. 1999. Age and growth of cobia, *Rachycentron canadum*, from the northeastern Gulf of Mexico. *Fisheries Bulletin*. 97: 459-471.

Franks, J.; Garber, N. and Warren, J. 1996. Stomach contents of juvenile cobia, *Rachycentron canadum*, from the northern Gulf of Mexico. *Fisheries Bulletin*. 94 (2): 374-380.

Froese, R. and D. Pauly. 2007 (eds.). *FishBase*. World Wide Web electronic publication. www.fishbase.org.

GFB RMI Inc. 2008. *Majuro Aquaculture Farm, Majuro Lagoon, Environmental Impact Assessment*. Report prepared for the Marshall Islands Minsitry of Fisheries, Majouro, the Marshall Islands.

Gopakumar, G.; Syda Rao, G.; Abdul Nazar, A.; Kalidas, C.; Tamilmani, G.; Sakthivel, M.; Ashok Maharshi, V. and Srinivasa Rao, K. 2010. Successful seed production of cobia *Rachycentron canadum* and its prospects for farming in India. *Marine Fisheries Information Service.* 206: 1-7.

GovPNG. 1952. *Animal Disease and Control Act.* Port Moresby: Government of Papua New Guinea.

GovPNG. 1955. *Animal Disease and Control Regulation - Quarantine Protocols.* Port Moresby: Government of Papua New Guinea.

GovPNG. 1998. *Fisheries Management Act.* Port Moresby: Government of Papua New Guinea.

GovPNG. 2000a. *Environment Act.* Port Moresby: Government of Papua New Guinea.

GovPNG. 2000b. *Fisheries Management Regulation.* Port Moresby: Government of Papua New Guinea.

GovPNG. 2002a. *Environment (Prescribed Activities) Regulation.* Port Moresby: Government of Papua New Guinea.

GovPNG. 2002b. *Environment 'Water Quality Criteria' Regulation.* Port Moresby: Government of Papua New Guinea.

GovPNG. 2005. *The Medium Term Development Strategy: Our Plan for Economic and Social Advancement*. Port Moresby: Government of Papua New Guinea.

GovPNG. 2006. *National Agriculture Development Plan: 2007-2016*. Port Moresby: Government of Papua New Guinea.

GovPNG. 2007. *Papua New Guinea: National Biodiversity Strategy and Action Plan.* Port Moresby: Government of Papua New Guinea.

GovPNG. 2009. *Vision 2050 - National Strategic Plan: 2010-2050.* Port Moresby: Government of Papua New Guinea.

GovPNG and UNDP. 2009. *Millenium Development Goals: Progress Report for Papua New Guinea – 2009 (Concise Version).* Port Moresby: United Nations Development Program.

Hayes, K. 1997. *A Review of ecological risk assessment methodologies*. CSIRO CRIMP Technical Report, No.: 13. Hobart: Commonwealth Science and Industry Research Organisation.

Hitzfelder, G.; Holt, G.; Fox, J. and McKee, D. 2006. The effect of rearing density on growth and survival of cobia, *Rachycentron canadum*, larvae in a closed recirculating aquaculture system. *Journal of the World Aquaculture Society*. 37: 204-209.

ICES. 2003. *ICES Code of Practice on the Introductions and Transfers of Marine Organisms*. 2003. International Council for the Exploration of the Sea.

Kahn, S.; Wilson, D.; Perera, R.; Hayder, H. and Gerrity, S. 1999. *Import Risk Analysis on Live Ornamental Finfish*. Canberra: Australian Quarantine and Inspection Service.

Kaiser, J. and Holt, G. 2004. Cobia: a new species for aquaculture in the US. *World Aquaculture.* 35: 12-14.

Kaiser, J. and Holt, G. 2005. Cobia aquaculture. In: Kelly, A. and Silverstein, J. (eds.), *Aquaculture in the 21st Century*. pp. 465-469. Bethesda: American Fisheries Society.

Kilduff, P.; DuPaul, W.; Osterling, M.; Olney, J, Jr. and Tellock, J. 2002. Induced tank spawning of cobia, *Rachycentron canadum*, and early larval husbandry. *World Aquaculture*. 33 (2): 35-38.

Kohler, C. 1992. Environmental risk management of introduced aquatic organisms in aquaculture. *ICES Marine Science Symposium*. 194: 15-20.

Kuk, R. and Tioti, J. 2004. *Fisheries Policy and Management in Papua New Guinea*. Canberra: Australian Centre for International Agriculture Research.

Lavilla-Pitogo, C. and Cruz-Lacierda, E. (eds..). 2002. *Diseases in Asian Aquaculture IV*. Manila: Asian Fisheries Society.

Liao, I. 2003. Candidate species for open ocean aquaculture: the successful case of cobia *Rachycentron canadum* in Taiwan. In: Bridger, C. and Costa-Pierce, B. (eds.), *Open Ocean Aquaculture: From Research to Commercial Reality*. pp. 205-213. Baton Rouge: World Aquaculture Society.

Liao, I.; Huang, T.; Tsai, W.; Hsueh, C.; Chang, S. and Leano, E. 2004. Cobia culture in Taiwan: current status and problems. *Aquaculture.* 237: 155-165.

Liao, I. and Leaño, E. 2007. (eds.). *Cobia Aquaculture: Research, Developments and Commercial Production*. Manila: Asian Fisheries Society.

Liao, I.; Huang, T.; Tsai, W.; Hsueh, C.; Chang, S. and Leano, E. 2004. Cobia culture in Taiwan: current status and problems. *Aquaculture.* 237: 155-165.

Lin, J.; Chen, T.; Chen, M-S.; Chen, H-Y.; Chou, R-L.; Chen, T-I.; Su, M-S. and Yang, H-L. 2006. Vaccination with three inactivated pathogens of cobia (*Rachycentron canadum*) stimulates protective immunity. *Aquaculture.* 255: 125-132.

Liu, P.; Lin, J.; and Lee. K. 2003. Virulence of *Photobacterium damselae* subsp. *piscicida* in cultured cobia *Rachycentron canadum*. *Journal of Basic Microbiology*. 43: 499-507.

Liu, P.; Lin, J.; Hsiao, P. and Lee, K. 2004. Isolation and characterization of pathogenic *Vibrio alginolyticus* from diseased cobia *Rachycentron canadum*. *Journal of Basic Microbiology*. 44: 23-28.

Lopez, C.; Rajan, P.; Lin, J.; Kuo, T. and Huey-Lang, Y. 2002. Disease outbreak in seafarmed cobia (*Rachycentron canadum*) associated with Vibrio spp., *Photobacterium damselae* ssp. *piscicida*, monogenean and myxosporean parasites. *Bulletin of the European Association of Fish Pathologists*. 22: 206-211.

Lotz, J.; Overstreet, R. and Franks, J. 1996. Gonadal maturation in the cobia, *Rachycentron canadum*, from the north central Gulf of Mexico. *Gulf Research Reports.* 9: 147-159.

Lunger, A.; Craig, S. and McLean, E. 2006. Replacement of fish meal in cobia (Rachycentron canadum) diets using an organically certified protein. *Aquaculture.* 257: 393-399.

MacDiarmid, S. 1997. Risk analysis, international trade, and animal health, In: *Fundamentals of risk analysis and risk management.* pp. 377-387. Boca Raton: CRC Lewis Publications.

Machen. J. 2008. *Vibrio spp. disinfection and immunization of cobia (Rachycentron canadum) for the prevention of disease in aquaculture facilities.* Master of Science Thesis In Biomedical Veterinary Science, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. United States of America.

McClure, J. 2001. *Predicting the dispersion of nutrients from aquaculture cages*. Perth: Centre for Water Research.

McLean, E.; Salze, G. and Craig, S. 2008. *Parasites, Diseases and Deformaties of Cobia.* Ribarstvo. 66 (1): 1-16.

Machias, A.; Karakassis, I.; Somarakis, S.; Giannoulaki, M.; Papadopoulou, K. and Smith, C. 2005. The response of demersal fish communities to the presence of fish farms. *Marine Ecology Progress Series.* 288: 241-250.

Miao, S.; Jen, C.; Huang, C.. and Hu, S. 2009. Ecological and economic analysis for cobia *Rachycentron canadum* commercial cage culture in Taiwan. *Aquaculture International* 17:125-141.

Meyer, G. and Franks, J. 1996. Food of cobia, *Rachycentron canadum*, from the north cental Gulf of Mexico. *Gulf Research Reports*. 9: 161-167.

Naylor, R.; Hindar, K.; Fleming, I.; Goldburg, R.; Williams, S.; Volpe, J.; Whoriskey, F.; Eagle, J.; Kelso, D. and Mangel, M. 2005. Fugitive salmon: assessing the risks of escaped fish from netpen aquaculture. *Bioscience*. 55 (5): 427-437.

NAQIA. 2007. *Business and Operational Plan: 2008-2012.* Port Moresby: National Agriculture Quarantine and Inspection Authority.

NAQIA. 2007. *Corporate Plan: 2008-2012.* Port Moresby: National Agriculture Quarantine and Inspection Authority.

NARI. 2005. *Draft Plant Genetic Resources Strategy for Papua New Guinea*. Lae: National Agricultural Research Institute.
NFA. 2004. *National Aquaculture Development Policy*. Port Moresby: National Fisheries Authority.

NFA. 2007. *Corporate Plan: 2008-2012.* Port Moresby: National Fisheries Authority.

Nash, C.; Burbridge, P. and Volkman, J. 2005. *Guidelines for ecological risk assessment of marine fish aquaculture*. NOAA Technical Memorandum NMFS-NWFSC-71.

Nhu, N.; Dierckens, K.; Nguyen, T.; Tran, M. and Sorgeloos, P. 2009. Can umbrella-stage Artemia franciscana substitute enriched rotifers for Cobia (*Rachycentron canadum*) fish larvae? *Aquaculture.* 289: 64-69.

Nhu, V.; Dierckens, K.; Nguyen, H.; Hoang, T.; Le, T.; Tran, M.; Nys, C. and Sorgeloos, P. 2010. Effect of early co-feeding and different weaning diets on the performance of cobia (*Rachycentron canadum*) larvae and juveniles. *Aquaculture.* 305: 52-58.

Nhu, V.; Nguyen, H.; Le, T.; Tran, M.; Sorgeloos, P.; Dierckens, K.; Reinertsen H.; Kjorsvik, E. and Svennevig, N. 2011. Cobia *Rachycentron canadum* aquaculture in Vietnam: recent developments and prospects. *Aquaculture.* 315: 20-25.

Ogawa, K.; Miyaamoto, J.; Wang, H-C.; Lo, C-F. and Kou, G-H. 2006. Neobenedenia girelle (Monogenea) Infection of Cultured Cobia *Rachycentron canadum* in Taiwan. *Fish Pathology.* 42 (2): 51-56.

OIE. 2003. *Manual of Diagnostics Tests for Aquatic Animals*. Paris: Office International des Épizooties.

OIE. 2004. *International Aquatic Animal Health Code*. Paris: Office International des Épizooties.

Petersen, E. 2011. *Bioeconomic analysis of improving feed sustainability for marine aquaculture in Vietnam*. ACE Discussion Paper, No.: 2011/6. Perth: University of Western Australia.

Petersen, E.; Luan, T.; Chinh, D.; Tuan, V.; Binh, T. and Truc, L. 2011. *Bioeconomics of cobia,* Rachycentron canadum, *culture in Vietnam*. ACE Discussion Paper, No.: 2011/2. Perth: University of Western Australia.

Resley, M.; Webb, K. and Holt, G. 2006. Growth and survival of juvenile cobia *Rachycentron canadum* cultured at different salinities in recirculating aquaculture systems. *Aquaculture.* 253: 398-407.

Riche, M.; Weirich, C.; Pfeiffer, T.; Wills, P. and Davis, M. 2009. Trials Advance Low-Salinity Culture of Cobia, Pompano, Other Species. *Global Aquaculture Advocate*. Jan-Feb: 32-34.

Rodrigues, R.; Schwarz, M.; Delbos, B. and Sampaio, L. 2007. Acute toxicity and sublethal effects of ammonia and nitrite for juvenile cobia *Rachycentron canadum. Aquaculture.* 271: 553-557.

Shaffer, R.; and Nakamura, E. 1989. *Synopsis of biological data on the cobia* Rachycentron canadum *(Pisces:* Rachycentridae*)*. FAO Fisheries Synopsis, No.: 153. Washington, D.C.: National Marine Fisheries Service.

SPC. 2003. *The SPC Aquaculture Action Plan*. Noumea: Secretariat of the Pacific Community.

SPC. 2007. *SPC Aquaculture Action Plan.* Noumea: Secretariat of the Pacific Community.

SPC. 2009. *SPC Division of Fisheries, Aquaculture and Marine Ecosystems (FAME) Strategic Plan*' for 2010-2013.

SPREP. 2010. *Guidelines for Invasive species in the Pacific*. Apia: Secretariat of the Pacific Regional Environment Program.

Stevens, O.; Alarcon, J. and Banner-Stevens, G. 2004. ACFK: Cobia fingerling update. *Global Aquaculture Advocate*. 7 (1): 46-47.

Stone, M.; MacDiarmid, and Pharo, H. 1997. *Import health risk analysis: salmonids for human consumption*. Wellington: Ministry of Agriculture Regulatory Authority.

Su, M. and Liao, I. 2001. Present status and prospects of marine cage aquaculture in Taiwan. In: Liao, I. and Baker, J. (eds.). *Aquaculture and Fisheries Resource Management*. pp. 193-201. TFRI Conference Proceedings, Volume 4. Keelung: Taiwan Fisheries Research Institute.

Su, M.; Chien, Y. and Liao, I. 2000. Potential of marine cage aquaculture in Taiwan: cobia culture. In: Liao, I. and Lin, C. (eds.). *Cage Aquaculture in Asia*. pp. 97-106. Manila: Asian Fisheries Society.

Sun, L.; Chen, H.; Huang, L; Wang, Z. and Yan, Y. 2006. Growth and energy budget of juvenile cobia (Rachycentron canadum) relative to ration. *Aquaculture*. 257: 214-220.

Tacon, A.; Metian, M. and Hasan, M. 2009. *Feed ingredients and fertilizers for farmed aquatic animals: Sources and composition.* FAO Fisheries and Aquaculture Technical Paper, No.: 540. Rome: Food and Agriculture Organisation.

Teitlebaum, A. and Kinch, J. 2011. *Mariculture in Papua New Guinea: The role of the Nago Island Mariculture Research Facility.* Report prepared for the National Fisheries Authority, Port Moresby, Papua New Guinea; and the Secretariat of the Pacific Community, Noumea, New Caledonia.

Tuya, F.; Boyra, A.; Sanchez-Jerez, P. and Haroun, R. 2005. Non-metric multivariate analysis of the demersal ichthyofauna along soft bottoms of the Eastern Atlantic: comparison between unvegetated substrates, seagrass meadows and sandy bottoms under the influence of seacage fish farms. *Marine Biology*. 147: 1229-1237.

Wang, J.; Liu, Y.; Tian, L.; Mai, K.; Du, Z.; Wang, Y. and Yang, H. 2005. Effect of dietary lipid level on growth performance, lipid deposition, hepatic lipogenesis in juvenile cobia (*Rachycentron canadum*). *Aquaculture*. 249: 439-447.

Webb, K.; Hitzfelder, G.; Faulk, C. and Holt, G. 2007. Growth of juvenile cobia, *Rachycentron canadum*, at three different densities in a recirculating aquaculture system. *Aquaculture*. 264: 223-227.

Weigle, S.; Smith, L.; Carlton, J. and Pederson, J. 2005. Assessing the risk of introducing exotic species via the live marine species trade. *Conservation Biology*. 9: 213–223.

Weirich, C.; Smith, T.; Denson, M.; Stokes, A. and Jenkins, W.. 2004. Pond culture of larval and juvenile cobia, *Rachycentron canadum*, in the southeastern United States: Initial observations. *Journal of Applied Aquaculture*. 16 (1/2): 27-44.

Weirich, C.; Wills, P.; Baptister, R. and Riche, M. 2010. Production Characteristics and Body Composition of Juvenile Cobia Fed Three Different Commercial Diets in Recirculating Aquaculture Systems. *North American Journal of Aquaculture.* 72: 43-49.

Werry,. 1998. A review of freshwater fish introductions in Papua New Guinea. *Science New Guinea*. 24: 33–36.

WTO. 1994. Agreement on the Application of Sanitary and Phytosanitary Measures. In: *The results of the Uruguay Round of multilateral trade negotiations: General Agreement on Tariffs and Trade*. pp. 69-84. Geneva: World Trade Organization.

Wu, R.; Lam, K.; MacKay, D.; Lau, T. and Yam, V. 1994. Impact of marine fish farming on water quality and bottom sediment: A case study in the sub-tropical environment. *Marine Environmental Research*. 38: 115-145.

Zhou, Q.; Tan, B.; Mai, K. and Liu, Y. 2004. Apparent digestibility of selected feed ingredients for juvenile cobia *Rachycentron canadum*. *Aquaculture*. 241: 441-451.

Zhou, Q.; Wu, Z.; Tan, B.; Chi, S. and Yang, Q. 2006. Optimal dietary methionine requirement for juvenile cobia (*Rachycentron canadum*). *Aquaculture*. 258: 551-557.