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Pathogen and Ecological Risk Analysis for the Introduction of Giant River Prawn, *Macrobrachium rosenbergii*, from Fiji to the Cook Islands

by

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Executive summary

Under contract Pro 7/54/8, the consultants were engaged by the Secretariat of the Pacific Community (SPC) to undertake two risk analyses involving the proposed introduction of aquatic species. This report covers the results of the risk analysis for the proposed introduction of giant river prawn (*Macrobrachium rosenbergii*) from Fiji to the Cook Islands. A separate report will present the results of the risk analysis for the proposed introduction of blue shrimp (*Litopenaeus stylirostris*) from Brunei to Fiji. These risk analyses are developed to serve as models for consideration of other such translocations for countries in the South Pacific.

The pathogen risk analysis examines the potential risks due to pathogen introduction along with the movement of the commodity (postlarval *M. rosenbergii*), identifies hazards (pathogens) requiring further consideration, and recommends ways to reduce the risk of their introduction to an acceptable level. The pathogen risk analysis was conducted using a qualitative approach with six risk categories (i.e. high, moderate, low, very low, extremely low, negligible).

The ecological risk analysis focuses on the invasiveness and "pest potential" of the species to be translocated and considers the likelihood of its escape and/or release into the natural environment of the Cook Islands and the nature and extent of any potential ecological impacts such escape or release may entail. To assist in assessing the ecological risks, a questionnaire and decision making process based on Kohler (1992) was used.

Based on past practices and trading partners, it is recommended that the Cook Islands adopt an appropriate level of protection (ALOP) that is "very conservative", and a risk tolerance (acceptable level of risk) that is "very low".

Both the pathogen and ecological sections of the risk analysis are characterized by a high level of uncertainty. For the former, this is due to an absence of information on the health history and current health status of the Fijian stock of *Macrobrachium* to be introduced, and the general lack of any aquatic animal health information for both Fiji and the Cook Islands; while for the latter, it is due to a general lack of information on the ecology of *M. rosenbergii* and of follow up studies from previous introductions of this species to other countries. If the Cook Islands wishes to act very conservatively, it could apply the precautionary approach until such a time as data on health status of the parent stock and on important ecological issues, such as potential interactions of *M. rosenbergii* with native *Macrobrachium* spp. have been obtained.

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

The pathogen risk analysis concludes that the proposed introduction could be accomplished within the recommended ALOP if appropriate disease mitigation measures are adopted to minimize the risk that the postlarvae (PL) to be introduced are infected with whitespot syndrome virus (WSSV) and white tail disease (WTD). These include that:

- statistically appropriate samples of the PL to be introduced are tested for WSSV using the methods specified by the Office International des Épizooties (OIE 2003), and for *Macrobrachium rosenbergii* nodavirus (MrNV) and extra small virus (XSV) using the genome-based methods cited in this report;
- no animals will be removed from the receiving facility without prior permission from the Ministry of Marine Resources (MMR);
- the operator will keep detailed records of mortalities and will report any occurrences of serious disease outbreak or mortality to MMR; and

- a contingency plan will be developed requiring that in the event of serious disease outbreak or mortality, all animals will be destroyed and disposed of using an approved sanitary method, and the facility fully disinfected.

Because of its origins and history in Fiji, the Naduruloulou stock of *Macrobrachium* is unlikely to be infected with serious diseases such as WTD, which are currently affecting *Macrobrachium* culture in other countries. Fiji should thus be very cautious in importing any new stocks of *Macrobrachium* for genetic improvement. In this regard, it should be emphasized that the pathogens of *M. rosenbergii* are poorly known and that stocks of specific pathogen free (SPF) animals have not yet been developed.

Finally, it is emphasized that the results of this risk analysis should not be taken as a sole basis for a decision by the Government of the Cook Islands 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.

Acknowledgements

The consultants wish to acknowledge the kind assistance of the following people who provided information and/or logistical support essential to the completion of this risk analysis: Mr. Ben Ponia and Mr. Satya Nandlal (Secretariat of the Pacific Community, New Caledonia), Dr. Timothy Pickering (Acting Director, Institute of Marine Resources, University of the South Pacific, Fiji), Mr. Filomone Mate (Ministry of Fisheries and Forestry, Fiji), Dr. Joeli Vakabua (Director, Animal Health and Production, Fiji), Dr. Binendra Pratap (Head, Veterinary Pathology Laboratory, Fiji), Mr. Hiagi Munivai Foraete (Acting Director, Quarantine and Inspection Division, Fiji), Mr. Ian Bertram (Director of Fisheries, Ministry of Marine Resources, Cook Islands), Ms. Tania Temata (Senior Environmental Officer, Cook Islands), Mr. Ngatoko Ngatoko (Chief Quarantine Officer, Cook Islands) and Mr. Tap Pryor (Papa Tap's Products, Cook Islands).

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1.1 Purpose

Under contract Pro 7/54/8, the Secretariat of the Pacific Community (SPC) has engaged the consultants to undertake two risk analyses involving the proposed introduction of aquatic species. This report covers the results of the risk analysis for the proposed introduction of giant river prawn (*Macrobrachium rosenbergii*) from Fiji to the Cook Islands. A separate report will present the results of the risk analysis for the proposed introduction of blue shrimp (*Litopenaeus stylirostris*) from Brunei to Fiji.

1.2 Terms of Reference (TOR)

The objective of this component of the consultancy is to undertake a risk analysis (RA) of the potential pathogen and ecological risks associated with the proposed transfer of giant river prawn (*Macrobrachium rosenbergii*) from Fiji to the Cook Islands for aquaculture development.

The consultancy will entail the following:

1. An ecological risk analysis will focus 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.

2. A pathogen risk analysis will examine the potential risks due to pathogen introduction along with the movement of the species and will consider ways to reduce these risks. The RA will be conducted using five risk categories (i.e. high, moderate, low, extremely low, negligible)[6] and will be developed to serve as a model for consideration of other such translocations for countries in the South Pacific. The RA will use a qualitative and/or semi-qualitative approach, depending on the availability of specific information that will be determined during the scoping exercise.

3. A final report of an estimated 60-80 pages integrating the ecological and pathogen risk analyses for the commodity will be submitted to SPC in MS Word format.

1.3 Commodity Description

Table 1 defines the precise nature of the commodity to be imported.

Table 1. Commodity description for the proposed introduction of giant river prawn, *Macrobrachium rosenbergii*, from Fiji to Rarotonga, Cook Islands.
***Species to be introduced**:* *Macrobrachium rosenbergii* (De Man) (giant river prawn)
Proposed date of importation: within the current year (2004)
Life cycle stage to be imported: Postlarvae (PL)
Importer: Mr. Tap Pryor, Papa Tap's Products, P.O. Box 16, Titikaveka, Rarotonga, Cook Islands, Tel.: (682) 20051, E-mail: pryor@tangaroaci.co.ck

6. As subsequent study revealed that a sex-category system is now routinely used by Australia (i.e., high, moderate, low, very low, extremely low and negligible), we have adopted this sytem for use in the risk analysis.

Proposed exporter: Department of Fisheries, Ministry of Fisheries and Forestry, Government of Fiji
Proposed source*:* Culture ponds at the Ministry of Fisheries and Forestry Aquaculture Center, Naduruloulou, Fiji.
Proposed number of shipments**:** One shipment; if the initial culture trial is successful, other shipments of similar volume may be required at intervals of approximately six months until such time as a reliable broodstock can be established.
Volume: 5,000 PL
Proposed destination: Culture ponds at Papa Tap's Products, Rarotonga, Cook Islands.

1.4 International and Regional Context of the Risk Analysis

With the liberalization of international trade through the General Agreement on Tariffs and Trade (GATT), the establishment of the World Trade Organization (WTO) and its *Agreement on the Application of Sanitary and Phytosanitary Measures* (SPS Agreement), WTO member countries are now required to use the risk analysis process as a means to justify any restrictions on international trade based on risks to human, animal or plant health (see WTO 1994, Rodgers 2004).[7] Risk analysis has thus become an internationally accepted standard method for assessing whether trade in a particular commodity (e.g., a live aquatic animal or its product) 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.

In its recent *SPC Aquaculture Action Plan* (SPC 2003), the Secretariat of the Pacific Community (SPC) has emphasized several "cross-cutting" issues for member countries that stress the need for strategies to reduce the risk of translocation of aquatic animal diseases, the importance of national policy and legislative frameworks, and the need for SPC member countries to develop national strategies that are consistent with regional strategies:

- "All development strategies need to include actions to minimise the threat of disease introduction and undertake preparations for control and management in the event of disease incursion/outbreaks."
- "There is an urgent requirement across the region to address policy and legislative frameworks for the successful introduction and management of the priority commodities."
- "Country strategies, consistent with regional strategies, need to be developed focusing on policy, legislation, and development plans. It will be important that countries assemble as much objective information as possible in the process of addressing their own priorities."

As member countries of the SPC have little experience with risk analysis for aquatic animals, and as a number of member countries are currently contemplating the importation of exotic aquatic species for aquaculture development, the SPC has commissioned this risk analysis in the hope that in addition to providing a useful analysis for the commodity analyzed, it will also serve as an example that member countries may follow in evaluating the pathogen and ecological risks associated with future proposals to introduce other exotic aquatic species.[8]

7. It should be noted that Fiji, as a member of the WTO since 1996, is obligated to follow the spirit and letter of the SPS Agreement. The Cook Islands is not a WTO member. Although neither country is a member of the Office International des Épizooties (OIE), they are both represented by the SPC, which has OIE Observer status, Australia, E-mail: p.mather@qut.edu.au.
8. To assist member countries, the SPC has prepared "A risk analysis framework for South Pacific Islands" (http://www.spc.int/rahs/riskanalysis/framework.htm). The procedures followed in the current risk analysis for Macrobrachium rosenbergii are in agreement with those recommended by the SPC.

1.5 Aquatic Animal Biosecurity Framework and Biosanitary Requirements for the Cook Islands

1.5.1 Biosecurity Framework

The Cook Islands imports almost all plants and animals and their products from New Zealand and Australia, thus providing a good measure of protection from exotic diseases. There is cooperation with New Zealand's Ministry of Agriculture, Fishery and Forestry (MAFF) and the Australian Quarantine and Inspection Service (AQIS). In relation to aquatic species, the Quarantine Service is only concerned with the importation of goldfish; requests to import other aquatic animals are handled by the Ministry of Marine Resources (MMR) and are covered, in a very general way, under the Environment Act. There is no veterinary expertise within the Quarantine Service. Although the Quarantine Act probably gives the mandate (Competent Authority) for aquatic animals to the Quarantine Service, in practice both the Quarantine Service and the Environment Service recognize the expertise of MMR in this area. A new Fishery Act (pending) will formalize MMR as the responsible agency for aquatic animal imports (Mr. N. Ngatoko, Chief Quarantine Officer, pers. comm.).

1.5.2 Biosanitary Requirements

There is no specific legislation dealing with biosanitary requirements for aquatic animals. National environmental legislation (22. Environment Act 2003), requires an Environmental Impact Assessment (EIA), which in the case of aquaculture development may include potential impacts on native fauna and biodiversity (and *inter alia*, take into consideration potential disease impacts). Environment Service is currently responsible for issuing permits to import aquatic animals. In practice, any preborder, border or postborder biosanitary requirements will be set by the Ministry of Marine Resources (MMR) on a case-by-case basis.

1.6 Appropriate Level of Protection

The appropriate level of protection (ALOP, also referred to as "acceptable level of risk"), is the level of protection deemed appropriate by a country establishing a sanitary or phytosanitary measure to protect human, animal or plant life or health within its territory (see WTO 1994). As such, establishing an ALOP is a political, rather than a scientific decision, and must be made at the highest level of government. Where no formal statement of ALOP exists, a country's ALOP may often be defined by its practices in protecting its human, animal and plant life from hazards, as reflected in its legislation and other official documents, policies and procedures (see Wilson 2000). Although the Government of the Cook Islands has not issued a formal statement as to ALOP, it is clear that its general policy towards risk for other, non-fisheries, commodities is similar to that of its major trading partners, Australia and New Zealand. As the policy of these countries with regard to risk is "very conservative," (ie., very risk adverse) for the purpose of this risk analysis, the level of risk considered acceptable for the Cook Islands is characterized as "very low" (see AQIS 1999).

1.7 Precautionary Approach

The concept of the precautionary approach is widely used in fisheries management and elsewhere where governments must take action based on incomplete knowledge (see Garcia 1996). The *Code of Conduct for Responsible Fisheries*, Section 7.5.1 (FAO 1995) states that:

> "States should apply the precautionary approach widely to conservation, management and exploitation of living aquatic resources in order to protect them and preserve the aquatic environment. The absence of adequate scientific information should not be used as a reason for postponing or failing to take conservation and management measures."

In the assessment of potential pathogen and ecological risks associated with the proposed introduction or transfer of a live aquatic animal species, a precautionary approach requires that both the importing and exporting nations act responsibly and conservatively to avoid the introduction of potential "pest" species and the spread of serious pathogens (see Arthur *et al.* 2004).

A fully informed decision on the risks involved in a proposed translocation of an aquatic species cannot be made if, due to the existing state of knowledge or its availability, information essential to the risk analysis is lacking. If such a situation exists, application of the precautionary approach would require that the request to import not be approved until such a time as adequate knowledge becomes available to permit an informed assessment as to the likely risks involved. It should be noted that in such a case, both trading partners have an obligation to cooperate fully to attempt to address these critical information gaps in a timely and transparent manner.

2.0 Methods

2.1 Project Team

A Project Team comprised of five scientists having expertise in aquatic animal health, risk analysis, aquatic ecology and crustacean biology was assembled to undertake the work. The team members were:

- Dr. J. Richard Arthur (project leader, aquatic animal health specialist), Professional Consultant (Canada)
- Dr. Melba G. Bondad-Reantaso (aquatic animal health specialist), Aquatic Animal Research Pathologist (United States of America)
- Mr. Edward R. Lovell (aquatic ecologist), Professional Consultant (Fiji)
- Dr. David Hurwood (aquatic ecologist), Post-doctoral Fellow (Australia)
- Dr. Peter B. Mather (aquatic ecologist, crustacean biology), Associate Professor (Ecology and Genetics) (Australia)

Drs. Arthur and Bondad-Reantaso were responsible for the pathogen risk analysis, while the ecological risk analysis was undertaken jointly by Dr. Hurwood, Mr. Lovell and Dr. Mather. Preparation of the final report was co-ordinated by Dr. Arthur, who was also responsible for overall project management.

2.2 Field Visits

Collection of information for scoping of the risk analysis was undertaken during a two week period in May 2004 by site visits undertaken by Richard Arthur (Fiji and Cook Islands) and Edward Lovell (Fiji). Activities undertaken included collecting relevant information from Competent Authorities and other concerned agencies in Fiji and the Cook Islands, meeting with the proponent of the proposed translocation, visits to the proposed source and destination for the species, assessment of existing aquatic animal health capabilities and infrastructure in the two countries, etc.

3.0 Approaches for the Risk Analyses

3.1 Pathogen Risk Analysis

3.1.1 General Approach

The general approach used in the pathogen risk analysis follows that outlined by the OIE (2004), AFFA (2001) and Arthur e*t al*. (2004).

The outstanding feature of this risk analysis as determined by the scoping exercise is the complete absence of any information on the health status of the proposed stock of origin for the postlarval *Macrobrachium rosenbergii* and of any background information of the country status of either Fiji or the Cook Islands with regard to the presence or absence of significant diseases affecting crustaceans. Without this country-specific information, it is impossible to generate estimates of likelihoods for the various pathways of pathogen exposure and pathogen release, and of the potential for risk mitigation to reduce risks to acceptable levels. It was thus necessary to conduct a more "generic" and less formally structured risk analysis (see, for example, Kahn e*t al.* 1999) for translocation of postlarval *M. rosenbergii*. This included:

- A preliminary hazard identification (based on an exhaustive literature search);
- A detailed hazard identification for those pathogens meeting the criteria for further consideration;
- Risk assessment (discussion of the possibilities that hazards might be released and the pathways by which this might occur, the potential for exposure of native stocks, and the probable consequences of exposure);
- Risk management (discussion and recommendation of possible risk management measures that may be applied).

3.1.2 Terminology

The terms used to describe the risk analysis process follow those definitions given by the Office International des Épizooties (OIE 2004).

3.1.2.1 Hazard Identification

A *hazard* is any pathogenic agent that could produce adverse consequences upon the importation of a commodity, while *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 is separated into two steps: (i) preliminary hazard identification, in which all pathogens reported from *Macrobrachium rosenbergii* throughout its world-wide distribution are considered, and (ii) detailed hazard identification, in which only those pathogens that are determined to be serious hazards are given further consideration.

3.1.2.2 Risk Assessment

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:

- *Release assessment* - The process of describing the biological pathway(s) necessary for an importation activity to 'release' (that is, introduce) a hazard into a particular environment, and estimating the likelihood of that complete process occurring.[9]
- *Exposure assessment* - The process of describing the biological pathway(s) necessary for exposure of humans and aquatic and terrestrial animals in the importing country to the hazards and estimating the likelihood of the exposure(s) occurring, and of the spread or establishment of the hazard.

9. Most countries consider that the "release" pathways terminate and the "exposure" pathways begin at the importing country's border, a practice that is followed in this risk analysis.

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, environmental and economic consequences that could result from the disease agent being released into the natural environment.

3.1.2.3 Risk Management

Risk management is the process of identifying, documenting and implementing measures that can be applied to reduce or eliminate the level of risk. Due to the absence of country-specific information on the pathogens of *Macrobrachium rosenbergii* in Fiji, risk management is presented in the form of various recommendations which, if implemented, would significantly reduce the risk of introducing serious pathogens.

Terms used to describe the probability of an event occurring

In assessing the likelihood of an adverse advent occurring, the descriptive definitions for qualitative likelihoods used in this risk analysis follows the six-category system given by AFFA (2001):

- 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
- Negligible: The event would almost certainly not occur

Terms used to describe the consequences of an event occurring

The terms used to describe the consequences of an adverse event occurring follow those outlined by AQIS (1999):

- 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. Such diseases 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. Such 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. Such 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.
- Negligible: Establishment of disease would have no significant biological consequences and would require no control or eradication. Such diseases would not affect economic performance at an industry level and would cause negligible environmental effects.

3.2 General Approach for the Ecological Risk Analysis

The approach taken for assessing the ecological risks of introducing *M. rosenbergii* into the Cook Islands was to review the applicable scientific literature and technical reports covering the ecology 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,
- the potential for *M. rosenbergii* to establish sustaining local populations,
- the potential for widespread dispersal, and
- the possible effects on native species should a population of *M. rosenbergii* 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 2003* (ICES 2003). Additionally, a slightly modified version of the decision model proposed by Kohler (1992) for the *Environmental risk management of introduced aquatic organisms in aquaculture* was used as a decision-making tool to assess the level of risk relative to the potential benefits of introduction.

3.3 Consultation and Review Process

The commodity-specific data presented in Table 1, and other country-specific information essential to completion of the risk analysis, have been obtained and verified through on-site visits to the proposed source (proposed facility of origin in Fiji) and destination (proposed site of the culture facility in Rarotonga, Cook Islands) and have been reviewed for accuracy by the proponent and by stakeholders (relevant government authorities and university staff in both countries) prior to commencement of the actual risk analysis.

Following completion of the risk analysis, the draft document was circulated to experts for critical comment. While the comments and suggests of the reviewers have, where possible, been addressed, the conclusions and recommendations presented herein, and any errors, remain solely those of the consultants.

3.4 Limitations of the Risk Analysis

The consultants and the SPC recognize that this document is to serve as a "model" risk analysis. While it will provides technical guidance and assessment of the risks involved in the proposed translocation and recommends possible mitigation measures, this risk analysis should not be taken, by itself, as a basis for a decision by the Government of the Cook Islands to approve or disapprove the request for a proposed species translocation. Such a decision would require additional consideration by the government of policy, legislation, technical capability, etc. and should include extensive stakeholder consultation.

The absence of any data of the health status of the stock to be translocated, or of the aquatic animal health situations in either the importing or exporting country has made any definitive conclusions as to the risk of introducing serious pathogens impossible, and has necessitated the application of the precautionary approach. The Government of the Cook Islands is thus urged to obtain and evaluate this crucial information prior to making a final decision as to whether or not to permit the introduction to proceed.

4.0 Background on the Species Proposed for Introduction

4.1 Taxonomy, Distribution and Life Cycle of the Giant River Prawn (*Macrobrachium rosenbergii*)

4.1.1 Taxonomy and Distribution

The giant river prawn (*Macrobrachium rosenbergii*) (Fig. 1) is a member of the crustacean family Palaemonidae, which contains some 200 species, almost all completing at least a portion of their life cycle in fresh water (New 2002). The current classification and synonyns are given below (source: Integrated Taxonomic Information System (ITIS) http://www.itis.usda.gov/index.html):

Kingdom Animalia

Phylum Arthropoda

Subphylum Crustacea

Class Malacostraca

Subclass Eumalacostraca

Superorder Eucarida

Order Decapoda

Suborder Pleocyemata

Infraorder Caridea

Superfamily Palaemonoidea

Family Palaemonidae

Subfamily Palaemoninae

Genus *Macrobrachium*

Macrobrachium rosenbergii (De Man, 1879)

Synonyms:

Palaemon rosenbergii (De Man, 1879)

P. carcinus rosenbergii (De Man, 1879)

P. (*Eupalaemon*) *rosenbergii* (De Man, 1879)

P. whitei Sharp, 1893

P. spinipes Schenkel, 1902

P. dacqueti Sunier, 1925

Cryphiops rosenbergii (De Mann, 1879)

C. (*Macrobrachium*) *rosenbergii* (De Man, 1879)

Macrobrachium rosenbergii dacqueti (Sunier, 1925)

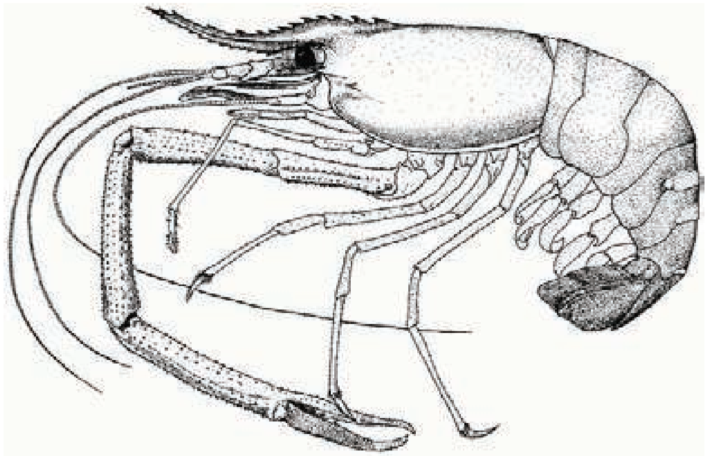

Figure 1. *Macrobrachium rosenbergii* (De Man, 1879) (Source: http://www.fao.org/figis/servlet/species)

Based on morphological differences, two subspecies are recognized by some taxonomists, *M. rosenbergii dacqueti* (Sunier, 1935), which is distributed in western Asia (east coast of India, Bay of Bengal, Gulf of Thailand, Malaysia and the northern Indonesian islands of Sumatra, Java and Kalimantan), and *M. rosenbergii rosenbergii* (De Man, 1879), which is native to the eastern Asia-Pacific, occurring in the Philippines, the Indonesian islands of Sulawesi and Irian Jaya, and in Papua New Guinea and northern Australia. Similarly, a recent study of the genetic diversity of this species has shown the presence of "eastern" and "western" clades (Mather and de Bruyn 2003). The natural distribution of the giant river prawn is shown in Figure 2.

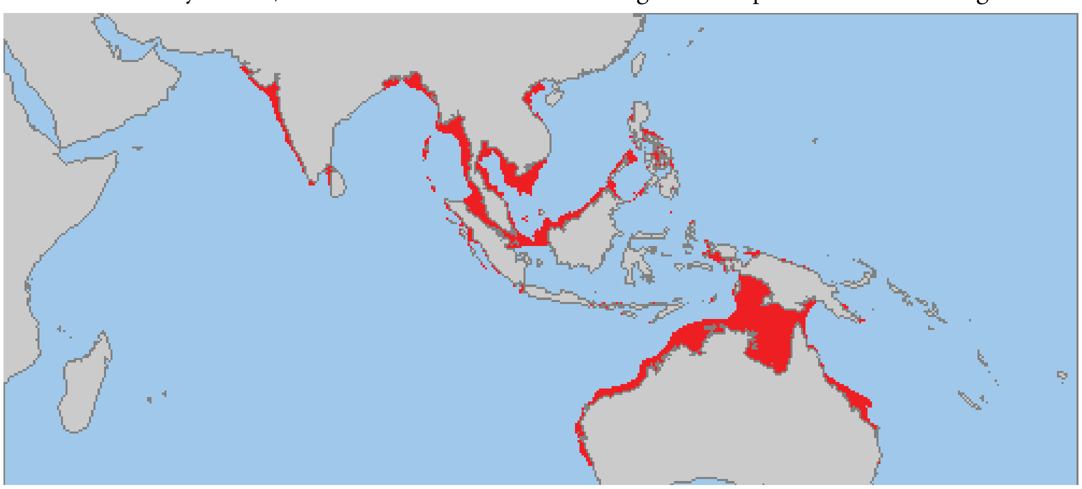

Figure 2. Map showing the natural range of *Macrobrachium rosenbergii*.(N.B. Australian east and west coast distributions are unlikely (M. de Bruyn, pers. comm.)). (Source: http://www.fao.org/figis/servlet/species)

4.1.2 Life Cycle

The following life cycle is summarized from New and Singkolka (1985), D'Abramo and Brunson (1996) and New (2002). It involves four distinct phases, the egg, the larva, the postlarva (PL) and the adult. Fully mature females migrate from freshwater estuaries to spawn. The eggs, when fertilized, are retained in a brood chamber, where they hatch in less than three weeks to produce free-swimming, planktonic larvae (zoeae).

Larvae: Eggs hatch over a 48 hour period, with the larvae being dispersed by rapid movements of the abdominal appendages of the female. The larvae are planktonic and swim actively, upside down and tail first and must reach brackish waters (salinity 10-14 ppt) within approximately two days to survive. The larvae are continuous feeders, with a diet principally of minute crustaceans, small worms and the larval stages of other invertebrates. Depending on food quantity and quality, water temperature and other water quality variables, the larval period lasts 15-40 days, with larvae undergoing 11 molts, each representing a different stage of metamorphosis (see Fig. 3).

Postlarvae: After metamorphosis to postlarvae (PL), the prawns, which look like miniature adults, measure 7-10 mm and weigh 6-9 mg (see Fig. 3). At this stage the behavior changes from swimming in the water column to benthic crawling. When they do swim, they move like adults, with the dorsal side uppermost and in a head-forward direction. Tolerating a range of salinities, the PL migrate back to fresh water within one to two weeks after transformation. At this stage their diet consists of larval and adult insects, molluscs, worms, fish and feces of fish and other animals, in addition to food eaten by the larval stage.

Adults: Older juveniles and adults usually have a distinctive blue-green color, although sometimes they develop a brownish hue. Color is usually determined by the quality and type of diet. Adult males are larger than females, and the sexes are easily identified. Firstly, the chelae and head region of the male is larger than that of the female. The base of the fifth pair of periopods of the male is expanded inwards to form a flap that covers the gonopore, and the periopods are set close together in nearly parallel lines with little open space between them (this trait helps distinguish between juvenile males and females). In the female, a large gap exists between the last pair of periopods, and the genital opening is located at the base of the third pair of periopods.

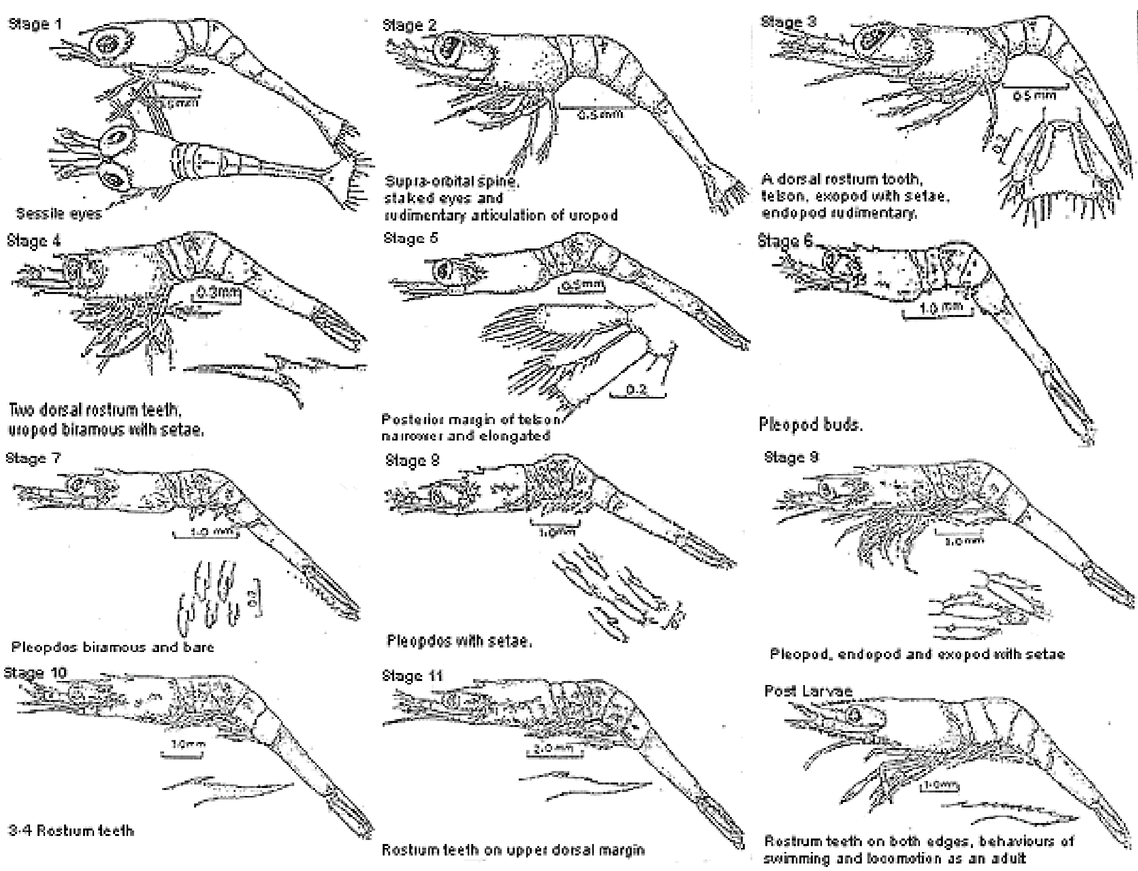

Figure 3. Larval stages of *Macrobrachium rosenbergii*. (Source: C. Bird, Research Services Division, Department of Fisheries, Western Australia).

Adults are omnivorous and their diet includes aquatic insects and their larvae, algae, nuts, grain, seeds, fruit, small molluscs and crustaceans, fish flesh and offal of fish and other animals. They can also be cannibalistic.

4.2 Significance to Aquaculture and Capture Fisheries

As the largest species of its genus, *M. rosenbergii* has been widely used in aquaculture and has thus been introduced throughout most of the tropical and temperate regions of the world. It is now cultured in at least 43 countries across five continents, with Asia contributing more than 98% of global production (see Mather and de Bruyn 2003). Major producers are China, Bangladesh and Thailand. Significant capture fisheries also exist in several countries of South and Southeast Asia.

4.3 Status of Knowledge of Pathogens and Parasites of *M. rosenbergii*

Although the giant river prawn has been cultured for more than 40 years (see New 2002), there have been few comprehensive studies of its pathogens and parasites. Most studies have investigated disease problems occurring in aquaculture, typically focussing on a single disease, syndrome or pathogen. In particular, there have been few comprehensive surveys of the pathogens of wild populations of *M. rosenbergii* or other members of the genus (see Jayasree *et al.* 2001). Additionally, in the few cases where disease surveys have been made of cultured or wild prawns, the specific identities of the organisms encountered have typically not been determined, nor have their roles if any, in causing disease been fully accessed. Thus the identities and geographic distributions of the pathogens of this species, with a few notable exceptions, remain largely unknown.

The health status of the stock of giant river prawn present in Fiji has never been assessed, nor have any health studies been conducted on wild populations of *Macrobrachium* spp. in the Cook Islands. Aside from the negative findings resulting from the examination of a few *Penaeus monodon* broodstock for viral diseases conducted at the University of the South Pacific (T. Pickering, pers. comm.), there is no information available on the health status or pathogens of aquatic animals in either Fiji or the Cook Islands.

4.4 *Macrobrachium* spp. in the Cook Islands

Macrobrachium rosenbergii was previously introduced to Rarotonga from Tahiti in 1992 for pond aquaculture at Matavera; however, the introduction was unsuccessful (see Eldridge 1994) and no survivors remain (I. Bertram, pers. comm.).

Four species of *Macrobrachium* (*M. lar, M. australe, M. latimanus* and *M. aemulum*) have been reported as native to the Cook Islands (G. McCormack, pers. comm.).[10] *Macrobrachium* spp. are known locally as "koura vai" and are found on the islands of Rarotonga, Atiu and Aitutaki (Nandlal 2003), with two species (*M. lar* and *M. latimanus*) being noted as very common or common on the Island of Rarotonga (see Cook Islands Biodiversity Database, http:/www2.bishopmuseum.org/phs/cookislands). In Rarotonga, recent surveys have shown *Macrobrachium* spp. to be present along the length of most freshwater streams. Larger specimens typically occur in deep pools and other sheltered places in the smaller creeks above the tidal reaches. They are also found inland and high up in the mountain creeks. *Macrobrachium* spp., especially *M. lar,* are present in Lake Te roto on Atiu and in the watercress pool at Rakautai on Aitutaki.

In the Cook Islands, wild *Macrobrachium* spp. are harvested on a non-commercial basis. According to Nandlal (2003), this local fishery has declined significantly in some rivers and creeks due to man-made changes to water flow.

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10. Two others species, M. equidens and M. lapidactylus, were listed as reported from the Cook Islands by Nandlal (2003), however, this appears to be based on incorrect information.

4.5 History and Status of *Macrobrachium rosenbergii* in Fiji

Macrobrachium rosenbergii is an exotic introduced species that has been cultured in Fiji since the late 1970s (see Uwate *et al.* 1984, Eldridge 1994). According to Eldridge (1994) the first introduction was from Tahiti in 1975, from stocks believed to have originated in Malaysia and introduced to Hawaii in 1965, and from there to Tahiti in 1973. At least two subsequent introductions were made from Hawaii during the 1980s by the government and private sector aquaculturists (see Uwate *et al.* 1984).

In 1983, a freshwater hatchery was opened at the Ministry of Fisheries and Forestry Aquaculture Center, Naduruloulou, with the capacity to produce 500,000 PL/year and the potential to produce 3-4 times this number (Uwate *et al.* 1984). The hatchery is used to produce postlarvae (PL) for distribution to small-scale aquaculturists.

There is concern that the stock may be stunted due to inbreeding, a problem that appears to be common in many populations of cultured *M. rosenbergii* (see Mather and de Bruyn 2003), and the MFF is currently considering the importation of new broodstock from Southeast Asia to improve growth performance.

5.0 Justification for Introduction and Alternate Strategies

5.1 Justification for Introduction

The introduction will be used in an integrated aquaponic system (plant/prawn/tilapia system) to produce a small volume of river prawns for local consumption. As there is no local marine or freshwater prawn culture or capture fishery, a small but reliable market for fresh prawns (estimated at 10 MT/year) exists for the restaurant and tourist resort trade and for local consumption. The importer has the support of the Ministry of Marine Resources (MMR), who will assist in completion of the required Environmental Impact Assessment (EIA) and importation of *Macrobrachium* and GIFT tilapia. The integrated culture system is expected to serve as a pilot farm for the eventual establishment of small-scale *Macrobrachium* culture elsewhere in the Cook Islands.

5.2 Alternate Strategies

Possible alternate strategies have not been explored in detail by the proponent or by the Ministry of Marine Resources (MMR). Culture of native *Macrobrachium* species, such as *M. lar*, may be feasible, however, the biology of other *Macrobrachium* spp. is poorly known and aquaculture techniques have not been developed. Culture of marine shrimps (Penaeidae) is another possibility, however, this would also involve the importation of exotic species, with perhaps greater inherent potential pathogen and ecological risks, necessitating a separate risk analysis. Additionally, the culture of penaeid shrimp typically requires a higher level of aquaculture technology and financial input and is unlikely to be economically feasible at the "backyard" level of culture envisioned by the proponent.

5.3 Description of the Proposed Culture System

Facilities will consist of three newly constructed above ground, plastic-lined aquaponics ponds, each of 3.6 m wide x 24 m long x 1.5 m depth (388.8 m^3 volume; bottom area of 260 m^2). The water source is the public main drawn from catchments in the hills. The *Macrobrachium* will be cultured in these tanks along with hydroponically grown lettuce and various herbs using a support system of floating Styrofoam sheets that will cover the tanks. The system will use water recirculation and will eventually include the culture of Nile tilapia (*Oreochromis niloticus*, GIFT strain) in 7 m dia. x 1.5 m deep above-ground tanks (total of 7 tanks). Water from the tilapia tanks will be used to fertilize the *Macrobrachium*/vegetable ponds. Effluent water and tank wastes will be used in the fertilization of a noni orchard and other fruit trees. No tank water will be directly discharged into natural waterways. The site where the proposed culture system will be constructed is shown in Figures 4-7.

Based on the proposed importation of 5,000 PL, the proponent intends to use a stocking density of 19 PL/m^2 (note that if a more typical stocking density of 50 PL/m^2 was used, the total number of PL required for the initial culture cycle would be 15,000).

Figure 4. Proposed site of integrated Macrobrachium/vegetable ponds, Rarotonga, Cook Islands..

Figure 5. Freshwater pond adjacent to proposed culture site.

Figure 6. View from proposed culture site towards pond..

Figure 7. Example of aquaponics system used to raise vegetables at Papa Tap's Products.

5.4 Description of the Receiving Environment and Contiguous Watershed

Rarotonga has only a dozen small natural streams with man-made catchments (see Fig. 8). Although the initial introduction is into a closed system, it can be expected, if pilot *Macrobrachium* culture is successful and the industry expands, that escapes and/or intentional releases into natural waters will occur, and that the species will be transported to other islands (see Nandlal (2003) for description of other islands with potential for freshwater prawn culture). A view of the coastline in the vicinity of the proposed culture facility is shown in Figure 9.

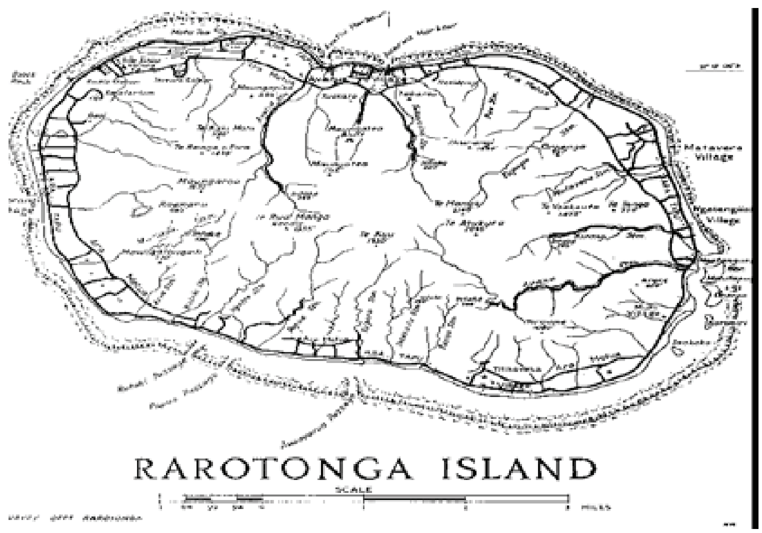


Figure 8. Map of Rarotonga Island showing the general location of the proposed farming site (arrow).

Figure 9. View of the coast of Rarotonga near proposed culture site; note waves breaking on the seaward fringing reef.

6.0 Proposed Source of Stock and Numbers of Organisms to be Introduced

6.1 Source

The proposed parent stock is maintained in culture ponds at the Ministry of Fisheries and Forestry Aquaculture Center, Naduruloulou, Fiji (see Figs. 10 and 11). Although stocks of *M. rosenbergii* have been widely translocated outside of the natural range for several decades, it is likely that most, if not all, of these culture stocks are descendents of farm stocks originating in Malaysia (New and Valenti 2000).

6.2 Number of Organisms to be Introduced

The initial shipment will comprise 5,000 PL.

Figure 10. Larval *Macrobrachrium rosenbergii* culture at the Ministry of Fisheries and Forestry Aquaculture Center, Naduruloulou, Fiji.

Figure 11. Concrete culture tanks at the Ministry of Fisheries and Forestry Aquaculture Center Naduruloulou, Fiji.

7.0 History and Disease Status of the Stock to be Exported and the Exporting Country

7.1 History of the Stock to be Exported

The parent stock from which the PL to be exported to the Cook Islands will be derived are descended from animals that were imported to Fiji from Tahiti in 1975; however, a further importation of additional animals from the same country occurred in 1997 (J. Vasuca, Fisheries Assistant, Naduruloulou and Gerald Billings, previous Fisheries Officer, Naduruloulou, pers. comm.). *Macrobrachium rosenbergii* was introduced from Hawaii to Tahiti in 1973; initial introduction of this species to Hawaii was in 1965 from Malaysia (see Eldridge 1994).

7.2 Disease Status of the Stock

The disease status of the stock to be introduced is unknown.
The stock has not been examined for pathogens since importation to Fiji. No epizootic disease outbreaks have been observed in *Macrobrachium* culture in Fiji.

7.3 Disease Status of the Exporting Country

The aquatic animal disease status of Fiji is unknown. Although Fiji is not a member of the Office International des Épizooties (OIE), it is represented by the Secretariat of the Pacific Community (SPC), which has Observer status. There is no data for Fiji in the OIE's *International Database on Aquatic Animal Diseases* (http://www.collabcen.net/toWeb/aq2.asp).

8.0 Disease Status and Biosanitary Requirements of the Importing Country

8.1 Disease Status of the Importing Country

The aquatic animal disease status of the Cook Islands is unknown. The Cook Islands is not a member of the OIE, however, the SPC has Observer status. There is no data for the Cook Islands in the OIE's *International Database on Aquatic Animal Diseases* (http://www.collabcen.net/toWeb/aq2.asp).

9.0 Pathogen Risk Analysis

9.1 Preliminary Hazard Identification

In the present risk analysis for *Macrobrachium rosenbergii*, due to the absence of any information on the diseases of this species in the proposed stock of origin, or in populations of wild and cultured crustaceans in general in either Fiji or the Cook Islands, we have included in the preliminary hazard identification all pathogens and parasites reported from this species throughout its world-wide distribution. The criteria for consideration during preliminary hazard identification are thus the following:

- The potential hazard must be an identifiable biological agent or a disease believed to be produced by a single (as yet unidentified) biological agent (thus generalized syndromes are not considered)
- The agent must have been recorded from *Macrobrachium rosenbergii.* Pathogens reported for any life cycle stage and any geographical locality are included.

The results of preliminary hazard identification are presented in Table 2.

Table 2. Results of preliminary hazard identification (note: for all pathogens, there is no information available as to occurrence in either the exporting or the importing country) Y=Yes, N=No, P=Plausible, ?=Uncertain.

Pathogen	Infects PL stage	Causes significant disease	Further consideration required	References	Comments
Diseases Listed by the Office International des Épizooties (OIE)					
Viruses					
White Spot syndrome virus (WSSV)	Y	Y	Y	Lo *et al.* 1996; Peng *et al.* 1998; OIE 2004	Significant pathogen of penaeid shrimps
Other Pathogens Considered					
Viruses					
Macrobrachium rosenbergii nodavirus (MrNV), white tail disease (= *Macrobrachium* muscle virus (MMV), whitish muscle disease)	Y	Y	Y	Arcier *et al.* 1999; Tung *et al*. 1999; Qian *et al.* 2003; Romestand and Bonami 2003	
Extra small virus (XSV) (= Extra-small virus-like particles)	Y	?	Y	Qian *et al.* 2003, Sri Widada *et al*. 2004	Associated with MrNV. The individual roles of XSV and MrNVin white tail disease (WTD) are still unclear.
Hepatopancreatic parvo-like virus (HPV-Mac)	Y	N	N	Anderson *et al.* 1990; Lightner *et al.* 1994	Presumptive diagnosis; no cytopathology reported.
Bacteria					
Acinetobacter sp.	P	N	N	Phatarpekar *et al.* 2003	Ubiquitous; isolated from larval homogenate
Aeromonas caviae	P	N	N	Sung *et al*. 2000	Mortality seen in experimentally challenged animals. Ubiquitous and opportunistic; associated with motile aeromonas septicemia (MAS) in fish.
A. formicans	P	N	N	Rodriguez *et al.* 2001	Associated with MAS in fish.
A. hydrophila	P	N	N	Areerat 1988	Isolated from musculature. Associated with MAS in fish.

Pathogen	**Infects PL stage**	**Causes significant disease**	**Further consideration required**	**References**	**Comments**
A. veronii	P	N	N	Sung *et al*. 2000	Mortality seen in experimentally challenged animals. Ubiquitous and opportunistic. Associated with MAS in fish.
Agrobacterium sp.	P	N	N	Phatarpekar *et al*. 2003	Ubiquitous; isolated from egg homogenate.
Alcaligenes sp.	Y	N	N	Taufik and Satyani 1986; Anderson *et al.* 1990; Phatarpekar *et al*. 2003	Ubiquitous and opportunistic; no evidence of pathogenicity seen by Anderson et *al*. (1990).
Arthrobacter sp.	Y	N	N	Rodriguez *et al.* 2001	Ubiquitous
Bacillus sp.	P	N	N	Sung *et al.* 2000 (based on Brady and Lasso 1992)	Ubiquitous
Benekea sp.	P	N	N	Sindermann 1977; Sung *et al.* 2000 (based on Lombardi and Labao 1991a,b)	Ubiquitous
Chromobacter sp.	P	N	N	Taufik and Satyani 1986	Ubiquitous
Chromobacterium sp.	P	N	N	Phatarpekar *et al*. 2003	Ubiquitous; isolated from larval homogenate.
Citrobacter freundii	P	N	N	Sung *et al.* 2000	No mortality seen in experimentally challenged animals.
Cytophaga sp.	P	N	N	Phatarpekar *et al*. 2003	Ubiquitous; isolated from larval homogenate.
Enterobacter sp.	Y	N	N	Taufik and Satyani 1986; Anderson *et al.* 1990	Ubiquitous and opportunistic; not considered pathogenic by Anderson *et al.* (1990).
Flavobacterium sp.	Y	N	N	Rodriguez *et al.* 2001	

Pathogen	Infects PL stage	Causes significant disease	Further consideration required	References	Comments
Lactococcus garvieae (=*Enterococcus*-like bacterium)	P	Y	N	Cheng and Chen 1998a,b,1999, 2002; Cheng *et al.* 2003	
Leucothrix spp.	Y	Y	N	Sindermann 1977; Alimon *et al.* 1982; Lombardi and Labao 1991a,b; Tonguthai 1992 (based on Aquacop 1977); Rodriguez *et al.* 2001	Ubiquitous
Micrococcus sp.	P	N	N	Phatarpekar *et al*. 2003	Ubiquitous; isolated from egg homogenate.
Moraxella sp.	Y	N	N	Rodriguez *et al.* 2001	
Mycobacterium sp.	N	N	N	Brock *et al.* 1986	Reported from a single adult female with systemic infection.
Photobacterium sp.	P	N	N	Vici *et al*. 2000; Phatarpekar *et al.* 2003	Ubiquitous; isolated from larval, ovary and muscle homogenates.
Pseudomonas alcaligenes	Y	?	N	Rodriguez *et al.* 2001	Ubiquitous
Rickettsia-like organism	Y	Y	N	Cohen and Issar 1989; Johnson and Bueno 2000	Ubiquitous
Staphylococcus sp.	P	N	N	Phatarpekar *et al.* 2003	Ubiquitous; isolated from egg and muscle homogenates.
Streptococcus sp.	P	N	N	Taufik and Satyani 1986; Phatarpekar *et al*. 2003	Ubiquitous; isolated from larval homogenate.
Vibrio anguillarum	Y	?	N	Rodriguez *et al.* 2001	Ubiquitous and opportunistic
V. cholerae	Y	N	N	Oanh *et al.* 2002	Ubiquitous and opportunistic; important human pathogen.

Pathogen	Infects PL stage	Causes significant disease	Further consideration required	References	Comments
V. harveyi	Y	Y	N	Tonguthai 1992	Ubiquitous and opportunistic; causes luminescence disease.
Xanthomonas sp.	P	N	N	Phatarpekar *et al.* 2003	Ubiquitous; isolated from larval homogenate.
Fungi					
Achyla sp.	P	N	N	Sindermann 1977; Brock 1988	Ubiquitous and opportunistic
Aphanomyces sp.	P	N	N	Sindermann 1977; Brock 1988	Ubiquitous and opportunistic
Fusarium sp.	Y	N	N	Burns *et al.* 1979; Brock 1988; Rodriguez *et al.* 2001	Ubiquitous and opportunistic
Lagendinium sp.	Y	Y	N	Johnson and Bueno 2000; New 2002	Ubiquitous and opportunistic
Microsporea					
Thelohania sp.	N	N	N	Areerat 1988	
Ciliophora, Peritrichia, Sessilida					
Cothurnia sp.	P	N	N	Tonguthai 1992 (based on Hall 1979)	Epicommensal; reported from grow-out
Epistylis sp.	Y	N	N	Sindermann 1977; Brock 1988; Camacho-Granados and Chinchilla-Carmona 1989; Rodriguez *et al.* 2001; Jayasree *et al.* 2001	Epicommensal
Lagenophrys sp.	P	N	N	Nash 1989; Johnson and Bueno 2000	Epicommensal

Pathogen	Infects PL stage	Causes significant disease	Further consideration required	References	Comments
Opercularia sp.	P	N	N	Camacho-Granados and Chinchilla-Carmona 1989	Epicommensal
Vaginicola sp.	P	N	N	Johnson and Bueno 2000	Epicommensal
Vorticella sp.	Y	N	N	Brock 1988; Camacho-Granados and Chinchilla-Carmona 1989; Rodriguez *et al.* 2001	Epicommensal
Zoothamnium sp.	Y	N	N	Satyani and Haniah 1982; Alimon *et al*. 1983; Brock 1988; Camacho-Granados and Chinchilla-Carmona 1989; Tonguthai 1992; Jayasree *et al.* 2001	Epicommensal
Ciliophora, Suctoria					
Acineta sp.	Y	N	N	Brock 1988; Camacho-Granados and Chinchilla-Carmona 1989;Tonguthai 1992: Rodriguez *et al.* 2001; Jayasree *et al.* 2001	Epicommensal
Acinetides sp.	P	N	N	Camacho-Granados *et al.* 1989	Epicommensal
Ephelota sp.	P	N	N	Camacho-Granados and Chinchilla-Carmona 1989	Epicommnesal
Podophrya sp.	P	N	N	Johnson and Bueno 2000	Epicommensal
Tokophrya sp.	Y	N	N	Camacho-Granados and Chinchilla-Carmona 1989; Rodriguez *et al.* 2001	Epicommensal

Pathogen	Infects PL stage	Causes significant disease	Further consideration required	References	Comments
Ciliophora, Astomatia					
Unidentified apostome ciliate cysts	P	N	N	Jayasree *et al.* 2001	Noted to cause melanization of gill tissue
Apicomplexa					
Nematopsis rosenbergii	?	N	N	Shanavas *et al.* 1989	
Digenea					
Microphallidae gen. sp. metacercaria	N	N	N	Jayasree *et al.* 2001	Possible zoonotic significance
Opecoelidae gen. sp. metacercaria	N	N	N	Jayasree *et al.* 2001	
Digenea gen. sp. metacercariae	N	N	N	Nash 1989	
Isopoda					
Augustogathoma sp.	N	N	N	Tonguthai 1992 (based on Brock 1983)	
Palaegyge bengalensis	N	N	N	Jayasree *et al.* 2001	
Probopyrus buitendjiijki	N	N	N	Tonguthai 1992	
Other					
Yeasts (*Debaryomyces hansenii*, *Metschnikowia biscuspidata, Candidia* spp.)	P	Y	N	Johnson and Bueno 2000; Cheng et *al.* 2003	
Larval mid-cycle disease	Y	Y	N	Anderson *et al.* 1990; Tonguthai 1992; Johnson and Bueno 2000	Unknown etiology; implication of many pathogens, toxic compounds or pesticides suggested.

9.2 Detailed Hazard Identification

9.2.1 Criteria for Further Consideration

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

- The agent must have been reported to infect, or is suspected of being capable of infecting postlarval *M. rosenbergii*;
- The agent must be an obligate pathogen (i.e., it is not a ubiquitous free-living organism that is capable of becoming an opportunistic pathogen of *M. rosenbergii* under certain environmental or culture conditions);
- The agent must cause significant disease outbreaks and associated losses in populations of *M. rosenbergii* or, if not a significant pathogen of *M. rosenbergii*, it must cause serious disease outbreaks in populations of other species of aquatic organisms; and
- It must be plausible that the agent might be present in populations of *M. rosenbergii* in Fiji.

9.2.2 Pathogens Not Considered Further

The following sections present brief comments on some of the pathogens not given further consideration. Additional information on the diseases and conditions affecting cultured giant river prawn can be found in the reviews of Sindermann (1977), Johnson (1982), Brock (1988), Tonguthai (1992) and Johnston and Bueno (2000), among others.

9.2.2.1 Bacteria

A wide range of bacteria has been isolated from rearing water, eggs, larvae, postlarvae and/or adults of *M. rosenbergii*. Most of these genera are part of the normal microflora of cultured crustaceans. These bacteria are common in water and some species may take advantage of ecological changes occurring in hatcheries and grow-out ponds.

A number of genera are chitinoclastic, eroding the surface of the exoskeleton and causing shell necrosis ("shell disease", "black spot" or "brown spot"), a condition characterized by black or brown spots on the carapace (e.g., *Pseudomonas*, *Vibrio*, *Benekea, Leucothrix*) (see Sindermann 1977, Sung *et al.* 2000, New 2000). Such infections are typically of a secondary nature, occurring after physical injury to the exoskeleton. The filamentous bacterium *Leucothrix* and other unidentified species of bacteria have also been associated with "appendage necrosis" and epibiotic fouling diseases (see, for example, Sindermann 1977, Brock 1988).

Under unfavorable rearing conditions, systemic infections by some species may occur. In such cases, bacteria (e.g., *Aeromonas*, *Bacillus, Photobacterium*, *Pseudomonas, Vibrio*) can be isolated from the hemolymph, the internal organs (e.g., ovary, hepatopancreas) and the musculature (see Brady and Lasso 1992, Sung *et al*. 2000, Vici *et al*. 2000). Members of the genera *Aeromonas* and *Vibrio*, in particular, are often pathogenic to crustaceans under hatchery conditions, *Vibrio harveyi*, for example, being associated with luminescence disease causing high losses in crustacean hatcheries.

Recently, the opportunistic pathogenic bacterium *Lactococcus gavieae* has been reported to cause muscle necrosis and mass mortality (30-40% losses) of pond cultured *M. rosenbergii* during the summer months in Taiwan (see Cheng and Chen 1998a, 1999, 2000). Outbreaks of disease have been associated with lowered resistance in prawns due to stressful conditions (high water temperatures and high pH) that occur during phytoplankton blooms (see Cheng and Chen 1998b).

In all cases, the bacteria reported from *Macrobrachium rosenbergii* are ubiquitous components of the natural environment, rearing facilities and grow-out ponds. While most of these genera are harmless, a few may become opportunistic pathogens under conditions stressful to *M. rosenbergii*. They will not be considered further in this risk analysis.

9.2.2.2 Protozoans

A wide variety of epicommensal or "fouling" protozoans (e.g., members of the genera *Achyla*, *Epistylis*, *Vorticella*, *Zoothamnium*, *Acineta* etc.) have been reported from the gills and external surfaces of postlarval and adult *M. rosenbergii*. These sessiline and suctorian ciliates are free living species that may attach to aquatic organisms, occasionally causing problems with respiration and molting. In all cases members of these genera are ubiquitous in aquatic environments and thus will not be given further consideration.

Microsporidians (*Thelohania* sp.), all of which are obligate parasites, have occasionally been reported from adult giant river prawn. Infections of penaeid shrimp by other microsporidian genera are known to cause muscle degeneration (cotton shrimp disease) (see, for example Lightner 1977), however, no losses have been reported in *M. rosenbergii*.

9.2.2.3 Metazoans

A few metazoan parasites such as digenean metacercariae and parasitic isopods have been occasionally reported from *Macrobrachium rosenbergii* (see Table 2). Digenean infections may have zoonotic importance in areas of where *Macrobrachium* is consumed raw. Velasquez (1975), for example, reported the presence of metacercariae of the microphallid *Carneophallus brevicaeca* in the muscle of naturally infected *Macrobrachium* sp. from the Philippines. These parasites have not been reported to cause disease in giant river prawns and thus will not be considered further in the risk analysis.

9.2.2.4 Fungi

Fungi belonging to the genera *Lagenidium* and *Fusarium* have been reported to cause mortalities of postlarval *Macrobrachium rosenbergii* in hatcheries (see New 2002). These organisms are opportunistic and ubiquitous and thus will not be considered further.

9.2.2.5 Other

Disease caused by yeasts has also been recently reported to cause heavy mortalities of *Macrobrachium rosenbergii* in grow-out ponds in Taiwan (see Johnston and Bueno 2000; Cheng *et al.* 2003). Mid-cycle disease of *Macrobrachium* larvae (MCD) is a condition whose cause is still unknown. It is thought to have an infectious etiology, and has been suggested to be possibly due to a bacterium (*Enterobacter aerogenes*), a virus or an unidentified toxin (see Brock 1988, Tonguthai 1992, Johnson and Bueno 2000). Because of the ubiquitous nature and/or uncertain cause of these conditions, they will not be treated further in the risk analysis.

9.2.3 Pathogens for Further Consideration

Based on the preliminary hazard identification, one crustacean virus listed as reportable to the OIE and one other disease associated with concurrent infections by two non-OIE listed viruses were identified as requiring further consideration:

- White spot syndrome virus (WSSV)
- White tail disease (WTD), due to *Macrobrachium rosenbergii* nodavirus (MrNV) and/or Extra small virus (XSV)

9.2.3.1 White Spot Syndrome Virus

White spot syndrome virus (WSSV) is a serious pathogen of penaeid shrimps that is listed by the Office International des Épizooties, and thus its occurrence in OIE member countries where it has not been previously found must be reported to the OIE. Article 4.1.2.1 of the *International Aquatic Animal Health Code* (OIE 2004) states:

"For the purpose of this *Aquatic Code*, all decapod (Order Decapoda) crustaceans from marine, brackish water, or freshwater sources are potential hosts for white spot disease. White spot disease is potentially lethal to most commercially cultivated penaeid (Family Penaeidae) shrimps and prawns. Potential transfers of other decapod crustaceans from marine, brackish water or freshwater sources to white spot disease free zones should be subject to risk analysis when there is evidence from experimental challenge studies that one or more species in the *importing country* and *exporting country* is susceptible to white spot disease."

Although *M. rosenbergii* was initially considered as resistant to WSSV (see Flegel 1996), infections have since been detected using DNA-based techniques (polymerase chain reaction (PCR) and *in situ* hybridization) in both experimentally and naturally exposed larvae, postlarvae, juveniles and adults (Peng *et al.* 1998). However, the fact that there have been no reports of mortality or overt disease in this host has led various authors (e.g, Lo *et al.* 1996, Peng *et al.* 1998, Arcier *et al*. 1999) to conclude that WSSV is not a viral disease of *M. rosenbergii*, but rather, a penaeid shrimp virus that is capable of developing in a large number of crustacean hosts, including *M. rosenbergii*. Similarly, Rajendran *et al*. (1999) showed that experimental infections did not produce high mortality or disease, but that infected *M. rosenbergii* (30-40 g) and *M. idella* (3-5 g) were asymptomatic carriers. In experimental infections, Sahul Hameed *et al*. (2000) reported that *M. rosenbergii* was susceptible (tolerant) to WSSV; however, infections did not produce mortalities in either juveniles or adults.

There appear to be few clinical signs of WSSV infection in *Macrobrachium rosenbergii*. In grossly normal adults, Peng *et al*. (1998) reported the presence of minute (less than 0.5 mm dia.) white spots on the carapace. Sahul Hameed *et al*. (2000) reported that no clinical signs were seen in infected juveniles, while adults were only noted to become lethargic on the second day post-innoculum, their behavior returning to normal by the following day. Other species (*M. lamerrae* and *M. idella*) were susceptible and suffered mortalities.

It thus concluded that postlarval and adult *M. rosenbergii* originating from populations raised in areas where WSSV infections are enzootic in populations of penaeid shrimp should be regarded as potential carriers of this virus.

Release assessment

Circumstantial evidence indicates that it is unlikely that the proposed stock of origin for PL of *Macrobrachium rosenbergii* would be infected with WSSV:

- The stock has been maintained in relative isolation in Fiji since the last importation in 1997 from Tahiti.
- There have been no reports of WSSV occurrence in Tahiti (see OIE's International Database on Aquatic Animal Diseases, http://www.collabcen.net/toWeb/aq2.asp).
- The source stock at Naduruloulou is believed to have never been in contact with penaeid shrimps.
- There is no evidence to suggest that wild or cultured penaeid shrimps in Fiji have ever been exposed to WSSV.

The likelihood of WSSV being present in the proposed stock of origin or in PL derived from this source is thus conservatively estimated to be **low**. A simplified pathways diagram for release of viral diseases of *Macrobrachium rosenbergii* is shown in Figure 12.

Exposure assessment

Should PL introduced to Rarotonga be infected with WSSV, the likelihood of the pathogen escaping from the culture facility and gaining access to susceptible populations is conservatively estimated to be **low**. This is because:

- The prawns will be maintained in covered concrete tanks, making escape unlikely.
- Effluent waters will be disposed of in such a way that they will not directly enter natural waterways.

A simplified pathways diagram for exposure of susceptible native crustaceans to viral diseases of *Macrobrachium rosenbergii* is shown in Figure 13.

Figure 12. Simplified Pathways Diagram for the release of viral pathogens in Macrobrachium rosenbergii postlarvae from Fiji to Cook Islands. Not considered are less probable pathways such as via shipping water or fomites, or failure of the diagnostics tests to detect true positives. In this simplified example, the likelihood that infected PL will be released (LR) is the product of the individual liklihoods = L1 x L2 x L3 x L4.

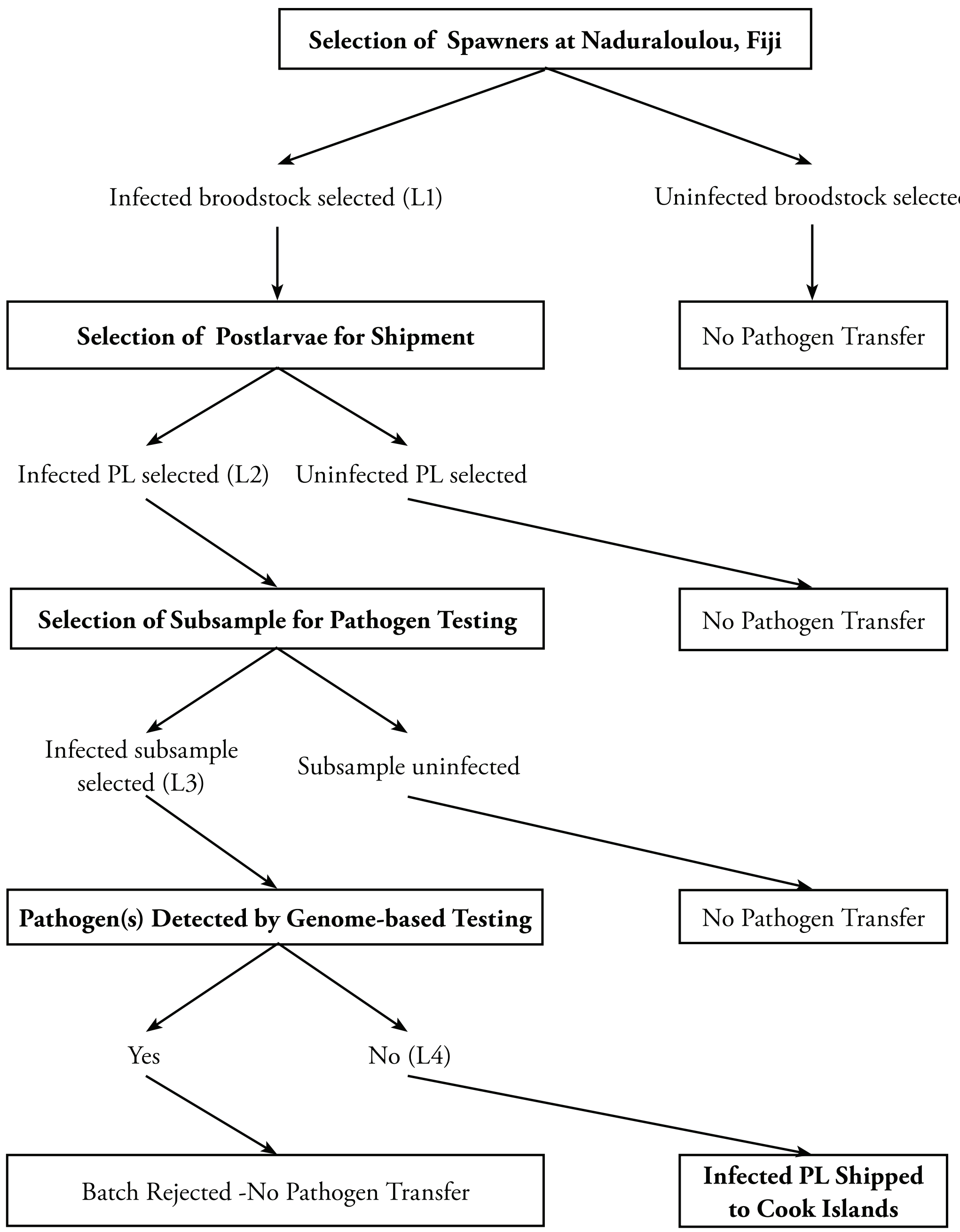
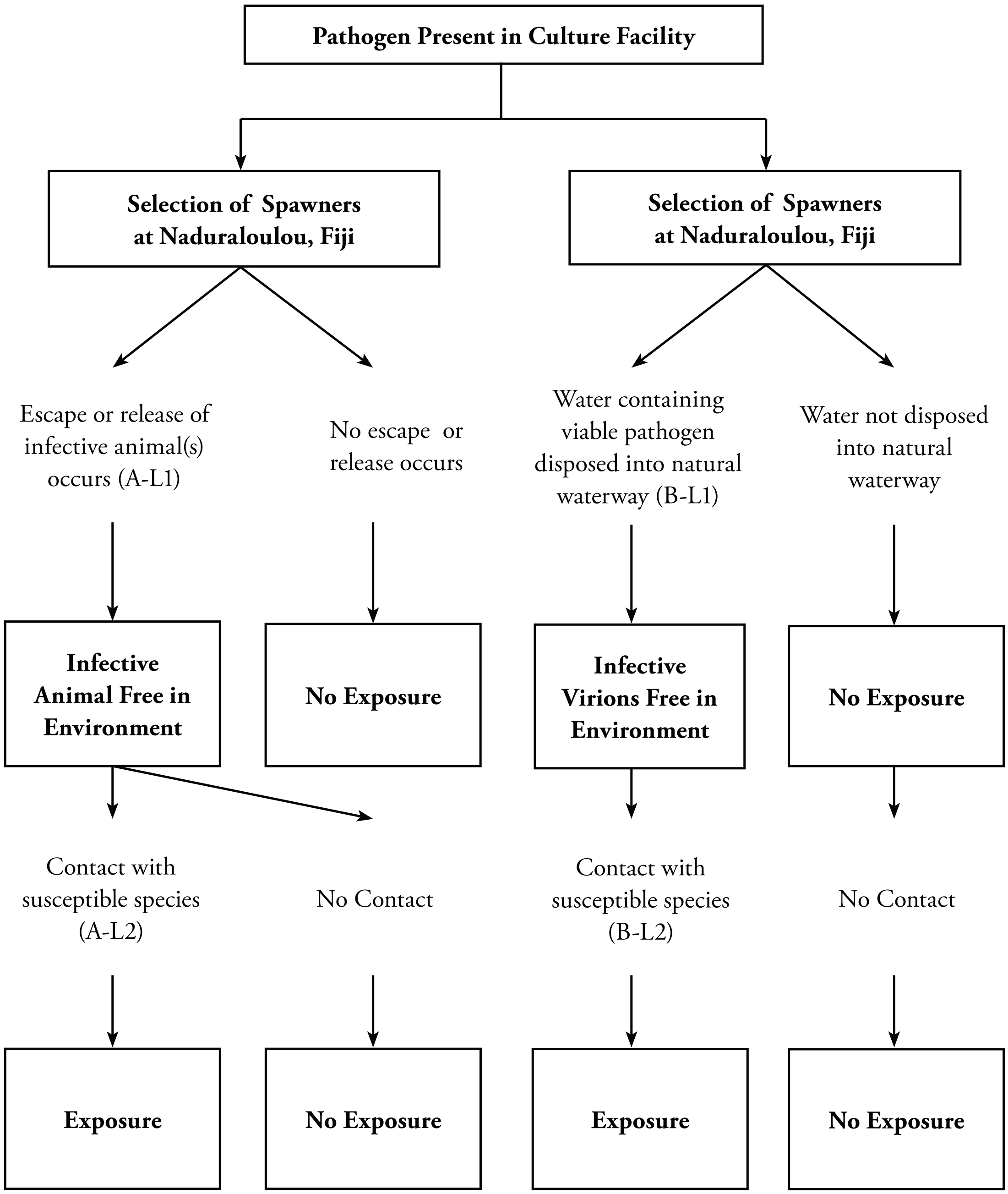


Figure 13. Simplified Pathways Diagram for the exposure of susceptible hosts in the Cook Islands to viral pathogens. Likelihood of Exposure (LE) = Likelihood of exposure via Route A + Likelihood of exposure via route B: LE = (A-L1 x A-L2) + (B-L1 x B-L2).



Consequence assessment

As WSSV does not cause overt disease or mortalities in *Macrobrachium rosenbergii* and as there is currently no penaeid shrimp culture in the Cook Islands, any impacts would be on native penaeid species. Additionally, because of the wide range of crustaceans that can be infected with WSSV, the virus might become endemic in the Cook Islands, with possible effects on future aquaculture development and the ability of prawn growers to export their product. The consequences of this occurring are considered to be **moderate**.

Risk management

The likelihood of PL being infected by WSSV can be reduced to an acceptable level of risk (**very low**) by the testing of broodstock from which the PLs will be derived and/or samples taken from the batches of PL to be exported using the protocols outlined by the OIE (see OIE 2003, 2004).

Additional risk management measures should include that:

- no animals will be removed from the receiving facility without prior permission from the Ministry of Marine Resources (MMR),
- the operator will keep detailed records of mortalities and will report any occurrences of serious disease outbreak or mortality to MMR, and
- a contingency plan will be developed requiring that in the event of a serious mortality, all animals will be destroyed and disposed of in an approved sanitary method, and the facility fully disinfected before restocking. The components of such a contingency plan are given in Annex I.

9.2.3.2 White tail disease (WTD), due to *Macrobrachium rosenbergii* nodavirus (MrNV) and/or extra small virus (XSV)

White tail disease (WTD) (also reported as "whitish muscle disease" by Chinese workers) has caused epizootic losses of postlarval river prawns in southern Taiwan since 1992. The disease, which can cause mortalities of up to 100% of PL in hatcheries, has also been reported from *M. rosenbergii* from mainland China, the French West Indies and India (see Arcier *et al.* 1999, Sri Widada *et al.* 2003, Qian *et al*. 2003, Sahul Hameed 2004). WTD appears to spread rapidly, causing heavy economic losses due to high mortalities.

The probable cause of WTD is the *Macrobrachium rosenbergii* nodavirus (MrNV), also reported as *Macrobrachium* muscle virus (MMV) by Tung *et al.* (1999). However, as noted by Sri Widada *et al.* (2003), the virus-host interactions and modes of transmission of this disease are still unknown.

The clinical signs of the disease in severely affected PL, which are similar to those of idiopathic muscle necrosis (IMN) syndrome (see Nash *et al.* 1987) and thus not sufficient for presumptive diagnosis, include white opaque areas in the abdominal segments, commonly accompanied by lethargy and anorexia (see Tung *et al.* 1999, Arcier *et al*. 1999, Sahul Hameed 2004, NACA 2004). Severe cases may show degeneration of the telson and uropods. Mortalities of 100% may occur within two or three days of the appearance of muscle opacity. Experimental infections indicate that infections may be responsible for branchostegite blister disease (BBD) or "swollen head syndrome" in adults (see Sahul Hameed 2004, NACA 2004).

The histopathological changes seen are similar to those described for IMN and include progressive segmental myofibre degeneration of muscle fibres and necrobiotic myopathy with numerous single, rows, aggregations and sheets of hyperchromatic myonuclei. Centrally or eccentrically placed (nuclear internalization) pyknotic nuclei were also frequently observed. However, unlike IMN, cytoplasmic inclusion bodies have been detected in the necrotic muscle of diseased prawns (see Tung *et al*. 1999). Transmission electron microscopy (TEM) of tissue homogenates from diseased prawns has revealed the presence of numerous non-enveloped virus-like particles of about 30 nm in diameter (Arcier *et al*. 1999).

Initially, the use of pryonin methyl green was recommended (see Tung *et al.* 1999) to distinguish the characteristically green-stained MrNV viral inclusions from hemocyte nuclei. More recently (Sri Widada *et al.* 2003) have developed three complimentary genome-based detection methods (dot-blot hybridization, *in situ* hybridization and reverse transcriptase-polymerase chain reaction (RT-PCR)) for detection of MrNV, dot-blot hybridization being considered the easiest to perform. In addition, Romestand and Bonami (2003) have developed a sandwich enzyme linked immmunosorbent assay (S-ELISA) for detection of this virus.

Extra small virus (XSV) was first reported in *M. rosenbergii* postlarvae from mainland China having concurrent infections with MrNV (Qian *et al*. 2003). The role of this virus, if any, in producing white tail disease is unclear. Qian *et al.* (2003) suggested that XSV, which is located in the muscle and connective cells of diseased animals, could be a helper virus for MrNV or a satellite-like virus, possibly acting as a disease modulator. It has also been considered a satellite virus by Widada and Bonami (2004).

TEM studies have revealed that the XSV viral particle is isocohedral and about 15 nm in diameter. Genome-based diagnostic techniques (dot-blot hybridization and RT-PCR) for XSV have been developed by Sri Widada *et al*. (2004).

Although Qian *et al*. (2003) believed that XSV was always associated with MrNV, results presented by Sri Widada *et al.* (2004) suggest that this is not always the case. These authors concluded that the cause of white tail disease may be more complex than previously thought and thus further investigation is required.

Release assessment

Circumstantial evidence indicates that it is unlikely that the proposed stock of origin for PL *Macrobrachium rosenbergii* would be infected with either virus associated with WTD:

- The stock has been maintained in relative isolation in Fiji since the last importation in 1997 from Tahiti.
- There have been no reports of WTD in Tahiti.

The likelihood of MrNV or XSV being present in the proposed stock of origin or in PL derived from this source is thus conservatively estimated to be **low**.

Exposure assessment

Should PL introduced to Rarotonga be infected with WTD, the likelihood of the pathogen escaping from the culture facility and gaining access to susceptible populations is considered **low**. This is because:

- The PLs will be maintained in covered concrete tanks, making escape unlikely.
- Effluent waters will be disposed of in such a way that they will not directly enter natural waterways.

Consequence assessment

Any consequences resulting from the establishment of WTD in the Cook Islands will impact directly upon the receiving aquaculture facility. Additional negative impacts could accrue to the future development of *Macrobrachium* culture in the Cook Islands, and possibly, upon native species of *Macrobrachium* and the limited local artesanal fishery that they support. The primary concern is that WTD could become established in natural populations of *Macrobrachium* spp., where it could have unknown impacts upon their local abundances. Infected native species or escapees from aquaculture might also serve as reservoirs of infection, from which WTD could potentially affect future aquaculture development. It this regard, it should be noted that the susceptibility of other *Macrobrachium* spp., as well as other crustaceans, to these viruses has not been studied. The consequences of the escape of WTD into the natural waters of the Cook Islands is conservatively estimated as **moderate**.

Risk management

The likelihood of PL being infected by MrNV and/or XSV can be reduced to an acceptable level of risk (**very low**) by the testing of broodstock from which the PLs will be derived and/or samples taken from the batches of PL to be exported using the genome-based detection methods outlined by Sri Widada *et al.* (2003) and Romestand and Bonami (2003) for MrNV and those developed by Sri Widada *et al*. (2004) for XSV.

Additional risk management measures should include that:

- no animals will be removed from the receiving facility without prior permission from the Ministry of Marine Resources,
- that the operator will keep detailed records of mortalities and will report any occurrences of serious disease outbreaks or mortalities to MMR, and
- a contingency plan will be developed requiring that in the event of a serious disease outbreak or mortality, all animals will be destroyed and disposed of in an approved sanitary method, and the facility fully disinfected before restocking. The components of such a contingency plan are given in Annex I.

9.3 Conclusions of the Pathogen Risk Analysis

The results of the pathogen risk analysis indicate that, due to the unknown health status of the Fijian stock of *Macrobrachrium*, mitigation measures should be required to ensure that the PL to be introduced are free of serious pathogens. Of particular concern are the viral diseases white spot syndrome (caused by WSSV) and white tail disease (caused by MrNV and/or XSV).

It is concluded that if the recommended risk mitigation measures are implemented, the level of risk posed by the importation will be below that recommended for the Cook Islands (i.e., very low risk) and the introduction could proceed in a relatively safe and responsible manner.

10.0 Ecological Risk Analysis

10.1 Potential Invasiveness of *Macrobrachium rosenbergii*

10.1.1 Potential to Establish Self-sustaining Populations on Rarotonga

Although the current proposal to introduce *M. rosenbergii* into the Cook Islands does not propose to release animals into natural waters, if the culture of this species becomes established and expands as is hoped, it is probable that escapes or releases will eventually occur. In the event of escape or release, *M. rosenbergii* will potentially colonize any freshwater habitat that has access to estuarine/marine conditions for completion of the life cycle. Adults can survive in freshwater ponds and lakes but will be unable to maintain a viable population. Given the relatively broad habitat requirements of *M. rosenbergii* and its high fecundity, it is conceivable that the escape of only one or a few berried females would be sufficient to successfully establish populations in the natural waterways of Rarotonga.

In the event of escape from culture facilities, it is uncertain whether *M. rosenbergii* will persist in the wild. A previous introduction of this species to the Cook Islands was unsuccessful and the population is no longer extant (I. Bertram, pers. comm.). However, examples exist elsewhere where sustaining populations have been established from accidental release outside the native range. Woodley *et al.* (2002) reported that a population of *M. rosenbergii* has become established in Simmons Bayou, Mississippi, USA, where environmental conditions (salinity, DO) are suboptimal. Furthermore, Popper and Davidson (1982) demonstrated that postlarvae (PL 14) can be reared through to adult in brackish waters (12-25 ppt). Their subsequent laboratory experiments indicated that *M. rosenbergii* grows best between 10-15 ppt. It is therefore reasonable to assume that released individuals could survive through to adulthood in brackish waters, but it is unclear as to whether they could successfully reproduce and establish populations in wholly brackish environments.

10.1.2 Potential for Invasiveness to Other Geographic Areas

Due to the diadromous nature of *M. rosenbergii*, it is possible that dispersal of larvae via the marine environment will result in colonization of other freshwater systems on Rarotonga and also on neighboring islands in the archipelago. Long distance dispersal would depend on the strength and direction of ocean currents (i.e., in a westerly direction). Many islands lie to the west of Rarotonga, such as Fiji, where *M. rosenbergii* is not native (although introduced). However, a phylogeographic study by de Bruyn *et al.* (2003) suggests that the current natural distribution of *M. rosenbergii* has been attained primarily through adult dispersal via fresh and brackish waters at times of significantly lower sea level when river systems exhibited a greater degree of connectivity. It is therefore improbable that marine/estuarine larvae can disperse over long oceanic distances.

10.2 Potential Ecological Impacts

10.2.1 Native Species Likely to be Impacted

Native prawns that may be impacted are local *Macrobrachium* species. These include *M. lar*, *M. australe*, *M. latimanus* and *M. aemulum*. Of these, it would be expected that *M. lar* will be subject to the greatest potential impact due to its similar size, life history traits and habitat requirements. *Macrobrachium lar* has a significantly wider natural range than *M. rosenbergii*, stretching from the western Indian Ocean (Mauritius) to the Indo-West Pacific. The extent of *M. lar*'s distribution is most likely attributable to the length of time of larval metamorphosis (89 days in full marine conditions (Short 2000)), greatly enhancing dispersal capability via ocean currents.

10.2.2 Predation

As with the native *Macrobrachium* species, adult *M. rosenbergii* are omnivorous, with a diet consisting of aquatic insects and their larvae, algae, nuts, grain, seeds, fruit, small molluscs and crustaceans, fish flesh and offal of fish and other animals. It is unlikely that *M. rosenbergii* will significantly impact on natural food web dynamics. When in high density they can exhibit intra-specific aggressive behavior. This behavior may also extend to other *Macrobrachium* species.

Larvae and postlarvae of *M. rosenbergii* would in turn provide a food source for fish and other large crustaceans.

10.2.3 Competition

Due to similarities in life history characteristics, competition for resources could potentially occur between *M. rosenbergii* and other *Macrobrachium* species, particularly with *M. lar,* which reaches a similar size. Introductions of *M. rosenbergii* to other Pacific Island groups where *M. lar* is native have been undertaken over the last few decades (e.g. Solomon Islands, Fiji) yet there is no documented evidence suggesting negative impacts due to interspecific interactions. The two species naturally co-occur in areas where their respective ranges overlap. While both species are found in northern Australia, they are largely allopatric. Where they do co-occur (McIvor River, N.E. Queensland) they tend to occupy different habitats within the stream, with *M. lar* preferring running water in rocky areas, while *M. rosenbergii* is found in backwaters with fallen timber (Short 2000). The likelihood of competition with other native *Macrobrachium* species is unknown.

10.2.4 Genetic Impacts

The potential for introduced *M. rosenbergii* to hybridize with native *Macrobrachium* species is a primary concern. However, this would be an unlikely outcome, as there is no evidence to suggest that this species has hybridized with sympatric congeners. However, several studies have successfully demonstrated artificial fertilization between *Macrobrachium* species. Successful hybridizations among *Macrobrachium* spp. include crosses between *M. nipponense* and *M. formosense* (Uno and Fujita 1972), *M. asperulum* and *M. shokitai* (Shokita 1978) and between *M. rosenbergii* and *M. malcolmsonii* (Sankolli *et al*. 1982, Soundarapandian and Kannupandi 2000). Graziani *et al*. (2003) attempted to cross *M. rosenbergii* with *M. carcinus* both naturally and artificially. Although these authors used allozyme analysis to infer a close genetic relationship between *M. rosenbergii* and *M. carcinus*, the natural crossing experiments yielded no matings due to behavioral differences and possibly pheromone incompatibility, while the artificial crosses resulted in 20-40% successful fertilizations. However, no larvae survived past the gastrula stage. Genetic divergence between *M. rosenbergii* and *M. lar* is considerable, with >12% sequence divergence at the 16s mitochondrial gene (de Bruyn *et al.* 2003). It should be noted however, that the degree of genetic similarity between crustacean species is not necessarily a good indicator of hybridization potential (Malecha 1986). Levels of genetic divergence of *M. rosenbergii* and other *Macrobrachium* species native to the Cook Islands are unknown.

10.3 Qualitative Ecological Risk Assessment

10.3.1 Results

The results of a qualitative ecological risk assessment are presented in Tables 3-5. Table 3 is based on the spreadsheet given in Appendix B of the *ICES Code of Practice on the Introductions and Transfers of Marine Organisms 2003* (ICES (2003), which has been modified to increase its applicability to SPC countries. It outlines the parameters used for assessment, the supporting sections of this report, the assessment of risk for the parameter (estimated on a scale of 1-3) and an estimate of the uncertainty for the parameter being assessed (estimated on a scale of 1-4).

Tables 4 and 5 follow the review and decision model of Kohler (1992), where questions are answered to appraise the proposed introduction of *Macrobrachium rosenbergii.*
In Table 4, questions are answered with a numerical value. The scores derived from this model are utilized at the decision points in the model in Table 5.

Table 3. Ecological risk assessment criteria for *Macrobrachium rosenbergii* (modified from ICES 2003).

Assessment Parameter	Supportive Report Sections	Risk Assessment[1]	Uncertainty Estimate[2]
Estimate probability of *M. rosenbergii* successfully colonizing and maintaining a population in the receiving waters of the culture facility.	Section 10.1	2	3
Inadequate food supply	Section 4.1, 10.2.3	1	3
Predation on native species	Section 10.2.1, 10.2.2, 10.2.3	2	3
Inadequate prey availability	Section 4.1, 10.2.3	1	3
Qualitatively or quantitatively affecting the availability of food for native species	Section 4.1, 10.2.1, 10.2.3	1	3
Inadequate habitat availability	Section 4.1, 10.2.3	1	3
Unsuitable habitat	Section 10.1.1	1	3
Likely establishment of breeding population	Section 4.1,10.1	2	2
Ability for dispersal	Section 10.1	2	3
Human intervention to retard or enhance spread		ND	ND
Ecological impact on native ecosystems locally or in a broader sense	Section 10.1,10.2	1	3
Alteration of native habitat	Section 10.1,10.2	1	3

[1]Risk assessment scale: 3 = high probability, 2 = medium probability, 1 = low probability, ND = no data.
[2]Uncertainty estimate scale: 4 = Very certain, 3 = reasonably certain, 2 = reasonably uncertain, 1 = Very uncertain, ND = No data.

Table 4. Results of the questionnaire for appraisal of the introduction of Macrobrachium rosenbergii to the Cook Islands, used in conjunction with the review and decision model given in Table 5 (modified from Kohler 1992).

	Response					
Question	**No**	**Unlikely**	**Possibly**	**Probably**	**Yes**	**Unsure**
1. Is the need valid and are no native species available that could serve the stated need?	1	2	3	**4**	5	x
2. Is the organism safe from over exploitation in its native range?	1	2	3	4	**5**	x
3. Are safeguards adequate to guard against importation of diseases or parasites?[1]	1	2	**3**	4	5	x
4. Would the introduction be limited to closed systems?	1	2	3	4	**5**	x
5. Would the organism be unable to establish a self-sustaining population in the range of habitats that would be available?	1	2	**3**	4	5	x
6. Would the organism have mostly positive ecological impacts?	1	2	**3**	4	5	x
7. Would most consequences of the introduction be beneficial to humans?	1	2	3	4	**5**	x
8. Is the database adequate to develop a complete species synopsis?	1	2	**3**	4	5	x
9. Does the database indicate desirability for introduction?	1	2	**3**	4	5	x
10. Based on all available information, do the benefits of the introduction outweigh the risks?	1	2	3	**4**	5	x

1. Disease issues are addressed separately in the pathogen risk analysis component of this report.

Table 5. Ecological risk assessment for the proposed introduction of Macrobrachium rosenbergii to the Cook Islands (modified from Kohler 1992).

Level of Review	Decision Boxes	Question Responses (based on Table 3)
Level of Review I 1. Determine validity for introduction	Decision Box I 1. Are the reasons for introduction valid? >2 2 next reject	4
2. Determine population abundance in native range and current level of exploitation	2. Is the exotic species safe from over-exploitation its native range? >2 2 next reject	5
3. Determine potential for inadvertent introduction of diseases and parasites	3. Would adequate safeguards be taken to guard against introduction of disease and parasites? >2 2 next reject	3
4. Characterize site of proposed introduction	4. Would the exotic species be maintained in a closed system with little chance of escapement? Go to IV (all scores)	5
	Approve	4.25
Level of Review II 1. Determine acclimatization potential	Decision Box II 1. Would the exotic species be unable to establish a self-sustaining population in the range of habitats that would be available? ≥3 2 next reject	3
	Approve	3
Level of Review III 1. Predict the benefits and risks	Decision Box III 1. Would the exotic species only have positive ecological impacts? ≥3 2 next reject	3
	2. Would all consequences of the exotic species introduction be beneficial to humans? ≥3 2 next reject	5
	Approve	4

<u>Level of Review IV</u> 1. Conduct detailed literature review to develop a FAO species synopsis	<u>Decision Box IV</u> 1. Was the database adequate to develop a complete species synopsis? ≥3 2 next reject	3
	2. Does the database indicate desirability for introduction? ≥3 2	3
	Approve	3
<u>Level of Review V</u> 1. Assessment of all available information	<u>Decision Box V</u> 1. Based on all available information, do the benefits of the introduction outweigh the risks? ≥3 2 next reject	4
	Approve	4

10.4 Conclusions of the Ecological Risk Analysis

The wide-scale translocation of aquatic species for the purposes of culture has clearly demonstrated the potential for unintentional escapes of individuals from aquaculture facilities. It is therefore of critical importance to investigate fully the potential ecological impacts that such escapes would create prior to introduction. Of principle concern is the possible impact that translocated individuals may have on the receiving environment in terms of competing with or predating on native species, interbreeding with them, modifying habitat or altering the natural ecological processes.

Macrobrachium rosenbergii has been the species of choice for freshwater prawn culture for the last few decades and as a result, has been translocated widely both within and outside its natural range. Although there have been a number of documented cases of escape into the wild, there is a surprising paucity of rigorous investigation of the ecological consequences of such events. Thus any potential deleterious ecological impacts resulting from the introduction of *M. rosenbergii* into the Cook Islands cannot be determined with a high degree of certainty.

Ecologically, the greatest potential risk in the event of escape is likely to involve interactions between *M. rosenbergii* and other *Macrobrachium* species native to the region. Although data exist showing potential for hybridization of *M. rosenbergii* with other congenerics, there is no data available to indicate the potential for successful crossbreeding between this species and other *Macrobrachium* species native to Rarotonga. However, there are no records suggesting that hybridization has occurred where *M. rosenbergii* has been translocated outside its natural range and subsequently escaped. Similarly, data do not exist regarding the effects of potential competition or predation on native species.

The above-mentioned ecological impacts are contingent on individuals escaping and colonizing natural waterways. Considering the broad habitat specificity and high fecundity of *M. rosenbergii*, it must be assumed that there is a potential for a sustaining population to be successfully established on Rarotonga in the event of release or escape. Also, it is likely that the population would have the capacity to extend its range to other water bodies on the island. However, there are good data to suggest that dispersing further afield (i.e., to neighboring islands) is improbable. Therefore, any adverse effects can probably be contained.

Although data are too few to make definite conclusions regarding possible ecological impacts, Tables 4 and 5 suggest that the benefits of introduction appear to outweigh the potential negative effects.

11.0 Recommendations

- Based on past practices and trading partners, it is recommended that the Cook Islands adopt an appropriate level of protection (ALOP) that is "highly conservative" and of "very low risk" tolerance.

- Both the pathogen and ecological sections of the risk analysis involve a high degree of uncertainty. The former due to an absence of information on the health history and current health status of the stock of *Macrobrachium* to be introduced, and the general lack of any aquatic animal health information for both the exporting and importing countries; the latter, to a general lack of information on the ecology of *M. rosenbergii* and of follow up studies from previous introductions of this species to other countries. If the Cook Islands wishes to act very conservatively, it may wish to apply the precautionary approach until such a time as data on health status of the parent stock and on important ecological issues, such as interactions with native *Macrobrachium* spp. have been obtained.

- Although there is a general paucity of country-specific and species-specific data to support both the pathogen and ecological portions of this risk analysis, the analysis indicates that the proposed introduction could be accomplished within the recommended ALOP if appropriate disease mitigation measures are adopted to minimize the risk that the postlarvae (PL) to be introduced are infected with whitespot syndrome virus (WSSV) and white tail disease (WTD). These include that:

    - tatistically appropriate samples of the PL to be introduced are tested for WSSV using the methods specified by the Office International des Épizooties (OIE 2003), and for *Macrobrachium rosenbergii* nodavirus (MrNV) and extra small virus (XSV) using the genome-based methods cited in this report;

    - no animals will be removed from the receiving facility without prior permission from the Ministry of Marine Resources (MMR);

    - the operator will keep detailed records of mortalities and will report any occurrences of serious disease outbreak or mortality to MMR; and

    - a contingency plan will be developed requiring that in the event of serious disease outbreak or mortality, all animals will be destroyed and disposed of using an approved sanitary method, and the facility fully disinfected.

- Although not essential to achieve ALOP within the context of the present risk analysis, samples of the *Macrobrachium* broodstock being held at Naduruloulou should to be sent to a recognized laboratory specializing in crustacean pathology for a complete virological, histopathological and parasitological examination. This is particularly important if this stock is likely to serve as a source for future introductions of *M. rosenbergii* in SPC countries.

- Because of its origins and history, the Naduruloulou stock of *Macrobrachium* is unlikely to be infected with serious diseases such as WTD, which are affecting *Macrobrachium* culture in other countries. Fiji should thus be very cautious in importing any new stocks of *Macrobrachium* for genetic improvement. In this regard, it should be emphasized that the pathogens of *M. rosenbergii* are poorly known and that stocks of specific pathogen free (SPF) animals are not available.

- In order to facilitate future risk analyses, the Competent Authority of the importing country should require the proponent of a proposed introduction or transfer to complete a detailed standardized prospectus on the proposed introduction, including a description of the commodity to be translocated, the propose and justification for the proposed movement, the history and disease status of the stock to be moved, description of any disease mitigation measures to be applied and other pertinent data. An example form can be found in Anon. (2003).

- Due to the lack of ecological data regarding *M. rosenbergii* and particularly, native species likely to be impacted in the event of escape, it is recommended that studies be initiated to investigate the biology (e.g., habitat specificity, endemicity) and life history characteristics of local *Macrobrachium* species. Such studies may elucidate whether or not their ecological niches are likely to overlap significantly with *M. rosenbergii* and if the potential exists for recolonization should population declines result from escapes from culture facilities. Extensive data exists for *M. lar,* so it would be appropriate to target the other native *Macrobrachium* as a priority.

- As a long-term goal, the Ministry of Fisheries and Forestry, Fiji and the Ministry of Marine Resources, Cook Islands, should obtain access to appropriate aquatic animal health expertise and capacity to meet national needs, and that as part of their national aquatic animal health strategies, disease surveillance programs should be implemented to determine national aquatic animal health status. The SPC and other bilateral and multilateral agencies should be approached to assist in this effort on a regional basis.

- An additional long-term goal for SPC should be the development of techniques for the culture of native *Macrobrachium* spp. such as *M. lar*.

12.0 Literature Cited

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ANNEX I

Key Components of a Farm Contingency Plan for Containment and Eradication of a Serious Crustacean Disease

The following actions should be taken, as appropriate:

- Destroying (e.g., via incineration or burial) all infected animals and disposing of them in an approved sanitary method.
- Disinfecting all contaminated equipment and rearing water.
- Treating all affected tanks and ponds to destroy infected shrimp and any potential carriers.
- Holding of water for a minimum of 4 days before discharge.
- Immediately notifying neighboring pond owners.
- Prohibiting any water exchange for a minimum of 4 days after water is discharged from an outbreak pond if it is likely to come into contact with the farm's own supply water.
- If the outbreak pond is emergency harvested, pumping of the discharge water into an adjacent pond or reservoir for disinfection with chlorine and holding for a minimum of 4 days before discharge.
- Discharging all water from the harvested tank or pond into the treatment pond and burning or burying any waste materials.
- Changing of clothing of harvesting personnel and showering at the site with water that will be discharged into the treatment pond.
- Placing all clothing used during harvesting in a specific container and their disinfection and laundering.
- Disinfecting equipment, vehicles, footwear and the outside of shrimp containers.
- Discarding all waste water into the treatment pond.
- Notifying the processing plant that the specific lot of shrimp is infected and that appropriate measures should be taken at the plant to avoid transfer of the disease via transport containers and processing wastes.