



AQUACULTURE SECTION

Pathogen and Ecological Risk Analysis for the Introduction of Blue Shrimp, *Litopenaeus stylirostris*, from Brunei Darussalam to Fiji

by

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Noumea, New Caledonia

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Prepared by

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the Secretariat of the Pacific Community,
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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 blue shrimp (*Litopenaeus stylirostris*) from Brunei Darussalam to Fiji. A separate report will present the results of the risk analysis for the proposed introduction of giant river prawn (*Macrobrachium rosenbergii*) from Fiji to the Cook Islands. 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 (postlarvae (PL) of *L. stylirostris*), 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 Fiji 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, it is recommended that Fiji adopt an appropriate level of protection (ALOP) that is “very conservative”, with an acceptable level of risk that is “very low” (i.e., a very high level of protection).

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 Brunei stock of *L. stylirostris* to be introduced, and the general lack aquatic animal health information for both Brunei and Fiji; while for the latter, it is due to a general lack of information on the ecology of *L. stylirostris* and of follow up studies from previous introductions of this species to other countries.

The absence of historical and current information on the health status of the stock of origin, and the lack of responsiveness of the exporter and Government of Brunei to provide information necessitate the application of the precautionary approach. Because of the high risk of introducing serious pathogens, further importations from this source should not be permitted until adequate information to assess risk is provided by Brunei.

The hazard identification process recognized six viruses and two bacterial pathogens as potentially serious hazards associated with the importation of PL of *Litopenaeus stylirostris*: white spot syndrome virus (WSSV), infectious hypodermal and haematopoietic necrosis virus (IHHNV), Taura syndrome virus (TSV), yellow head virus (YHV), *baculovirus penaei* (BP), hepatopancreatic parvo-like virus (HPV), necrotising hepatopancreatitis (NHP) and *Vibrio penaeicida*. All of these pathogens are considered to have associated levels of risk (release, exposure and consequence) that exceed the appropriate level of protection (ALOP) recommended for Fiji.

Mitigation measures are identified that can be applied to reduce the risk associated with all hazards to below that specified by the ALOP. The most important of these is that all shipments of PL to be imported into Fiji should be of “high health” status and should originate from a facility certified as using specific pathogen free (SPF) broodstock *L. stylirostris*. Additional recommendations are made regarding the operation of the production facility in the exporting country and the post-border requirements for the importing country.

The stock of *L. stylirostris* that was imported into Fiji in December 2003 and is currently being cultured is considered to represent a high risk to the national disease status. Risk management measures are recommended: to reduce this risk.

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.

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

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 Fiji 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.

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1.0 Introduction

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 introduction of blue shrimp (*Litopenaeus stylirostris*) from Brunei Darussalam to Fiji. A separate report will present the results of the risk analysis for the proposed introduction of giant river prawn (*Macrobrachium rosenbergii*) from Fiji to the Cook Islands.

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-related and ecological risks associated with the proposed transfer of blue shrimp (*Litopenaeus stylirostris*) from Brunei Darussalam to Fiji 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 six risk categories (i.e., high, moderate, low, very low extremely low, negligible) 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 blue shrimp (*Litopenaeus stylirostris*) from Brunei to Fiji.

Species to be introduced: *Litopenaeus stylirostris* Stimpson (blue shrimp)

Proposed date of importation: On-going, as of December 2003

Life cycle stage to be imported: Postlarvae (PL)

Importers:

1. Gulf Seafood Fiji Ltd., Mr. Roger Black, General Manager, 257 Princes Rd., Tamavua, Fiji, Tel.: 3591847/9921848, E-mail: gulfsfds@connect.com.fj.
2. Pacific Prawns (Fiji), Mr. James Tilbury, Managing Director, P.O. Box 466, Navua, Fiji, Tel.: 3460825/9249890, E-mail: tilbury@connect.com.fj

Exporter: Semaun Marine Resources Sdn Bhd, Richard Chuang (Hsi Shan Chuang)
Office Tel: +673-2772955, Mobile: +673-8777186, e-mail: richuanghs@yahoo.com

Source: Hatchery operated by exporter

Proposed number of shipments: Three shipments per year for Gulf Seafood Fiji Ltd. and two shipments per year for Pacific Prawns (Fiji) until such time as local hatchery production is available.

Volume: Total volume is undefined. An initial shipment of 300,000 PL imported by Gulf Seafood Fiji Ltd. arrived in December 2003. Subsequent shipments for Gulf Seafood Fiji Ltd. could be increased to an estimated maximum of 70,000,000 PL per year if all ponds are brought into production. Estimated annual PL requirement for Pacific Prawns (Fiji) Ltd. is 100,000 per year. This annual volume may be required until such time as a reliable broodstock can be established.

Proposed destination: The initial PL shipment of December 2003 was stocked directly upon arrival into culture ponds of Gulf Seafood Fiji, Ltd., at Culanuku Point (Lat. 18° 15.75'; Long. 178° 6.90'). Additional shipments will be stocked directly into these ponds or into the ponds of Pacific Prawns (Fiji), which is located at the mouth of the Navua River (Lat. 18° 15.95'; Long. 177° 58.65').

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). 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."

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.¹

1.5 Aquatic Animal Biosecurity Framework and Biosanitary Requirements for Fiji

1.5.1 Biosecurity Framework

There is no specific legislation dealing with biosanitary requirements for aquatic animals. The Fijian Ministry of Agriculture, Quarantine and Inspection Division (QID) is designated the Competent Authority for animal and plant diseases under Section 4 of the Animal Importation Act, Cap. 159, Ed. 1978.

1.5.2 Biosanitary Requirements

In practice, the QID requires that requests to import aquatic animals to be approved by the Ministry of Fisheries and Forestry (MFF), which may set the requirements for importation, including any sanitary measures deemed appropriate. Control of importations of live aquatic animals and their products is regulated through an import permit issued by the Fisheries Department that specifies the conditions under which each consignment may be imported (which can include, for example, requirements for an accompanying health certificate (a statement of general healthiness) issued by the Competent Authority of the exporting country, post-import quarantine and monitoring, etc.). In practice, quarantine for aquatic animals is not strictly enforced, there is no quarantine inspection and little follow up after release. Importers simply apply to the QID for release of animals from "quarantine", and the quarantine officer accompanies the shipment to the ponds.

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

⁶ 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.

hazards, as reflected in its legislation and other official documents, policies and procedures (see Wilson 2000). Although the Government of Fiji has not issued a formal statement as to ALOP, it is clear that its general policy towards risk for other (non-fisheries) commodities is rather stringent (J. Vakabua, Director, Animal Health and Production, Fiji pers. comm.). Thus, a “very conservative” approach to protecting Fiji’s aquatic animal health status is recommended and the level of risk considered acceptable for Fiji 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-related 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 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)
- 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. Bondad-Reantaso and Arthur were responsible for the pathogen risk analysis, while the ecological risk analysis was undertaken jointly by Drs. Lovell, Hurwood and 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 and Edward Lovell. Activities undertaken included collecting relevant information from Competent Authorities and other concerned agencies in Fiji, meetings with the proponents of the proposed translocation, visits to the destination for the species, assessment of existing aquatic animal health capabilities and infrastructure in Fiji, 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 *et al.* (2004).

The outstanding feature of this risk analysis as determined by the scoping exercise is the unresponsiveness of the exporting company and the Government of Brunei Darussalam to provide essential information on the history of origin and the current health status of stock of origin for the postlarval *Litopenaeus stylirostris*. Also, there is a general lack of background information of the country status of either Brunei or Fiji 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 *et al.* 1999) for translocation of postlarval *L. stylirostris*. 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); and
- risk management (discussion and recommendation of possible risk management measures that may be applied, rather than detailed risk evaluation and option evaluation using likelihood estimates).

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 *Litopenaeus stylirostris* 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.² Important factors that need to be considered in release assessment include: (a) biological factors, such as the susceptibility of the animals from which the commodity is derived to their potential hazard and their infectiousness; the means of transmission of the potential hazard; the infectivity, virulence and stability of the potential hazard; and the routes of infection; and (b) country factors, such as an evaluation of the exporting country’s aquatic animal health services, the incidence and/or prevalence of the disease, farming and husbandry practices, and geographical and environmental characteristics; and (c) commodity factors, such as the ease of contamination; relevant of any processes and production methods; the effect of processing, storage and transport; and the quantity of commodity to be imported.
- *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. The factors to be considered include those considered for the release assessment. Additional factors include: (a) country factors such as the presence of potential intermediate hosts or vectors, and customs and cultural practices; and (b) commodity factors, such as the intended use of the imported animals and waste disposal practice.

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. Risk management measures for a given hazard (risk mitigation) are only considered when the estimated level of risk for the hazard exceeds the country’s ALOP. The level of unmitigated risk, the ALOP and the individual nature of the hazard will determine what risk management measures, if any, can be applied to reduce the risk to an acceptable level. It should also be noted that risk management measures should only be applied to the extent necessary to reduce the risk to below the country’s ALOP.

⁷ 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.

Due to the absence of country-specific information on the pathogens of *Litopenaeus stylirostris* in Brunei, risk management is presented in the form of various recommendations that, if implemented, would significantly reduce the risk of introducing serious pathogens.

3.1.2.4 Risk Communication

Risk communication is the process by which information and opinions regarding hazards and risks are gathered from potentially affected and interested parties during a risk analysis, and by which the results of the risk assessment and proposed risk management measures are communicated to the decision makers and interested parties in the importing and exporting countries. It is a multidimensional and iterative process and should ideally begin at the start of the risk analysis process and continue through out (OIE 2004). Good risk communication is thus an essential component of any risk analysis; however, it is not an activity of the current pathogen and ecological risk analysis, which is itself a component of the larger risk analysis process. Information of achieving good risk communication is given in Arthur *et al.* (2004).

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 *L. stylirostris* into Fiji was to review the applicable scientific literature and technical reports covering the ecology of the species as well as those dealing with local species that could potentially be negatively impacted. In broad terms, the assessment examined:

- the risk of escape,
- the potential for *L. stylirostris* to establish sustaining local populations,
- the potential for widespread dispersal, and
- the possible effects on native species should a population of *L. stylirostris* 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, were obtained and verified, as far as possible, during an on-site visit to the destination (proposed sites of the culture facilities in Fiji) and were reviewed for accuracy by the proponents and by stakeholders (relevant government authorities and university staff in Fiji) prior to commencement of the actual risk analysis.

Following completion of the risk analysis, the draft document was circulated to two experts (J.P. Fisher and V. Alday-Sanz) for critical comment. While the comments and suggestions 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 provides technical guidance and assessment on the likely 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 Fiji to approve or disapprove a 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 historical and current information on the health status of the stock of origin, and the lack of responsiveness of the exporter and Government of Brunei to requests for information put forward by the consultants on behalf of the SPC and the Government of Fiji is

unacceptable within the context of Brunei's membership in the OIE and the WTO, and has necessitated the application of the precautionary approach. The Government of Fiji is thus urged make an official request to the Government of Brunei, both directly and through the offices of the SPC and OIE, to obtain this crucial information, which should be carefully evaluated prior to making a final decision as to whether or not to permit these introductions to continue. ***Because of the high risk of introducing serious pathogens, further importations from this source should not be permitted until this requirement has been met.***

4.0 Background on the Species Proposed for Introduction

4.1 Taxonomy, Distribution and Life Cycle of the Blue Shrimp (*Litopenaeus stylirostris*)

4.1.1 Taxonomy and Distribution

Litopenaeus stylirostris is a decapod crustacean in the superfamily Penaeoidea, which contains about 376 species (Chan 1998). The two divisions of the natantian decapod crustaceans, the Penaeidea and Caridea, contain the most commonly exploited species and are interchangeably referred to as either shrimps or prawns. The penaeids include the widespread tropical and subtropical exploited species of the genus *Penaeus* sensu lato (King 1993).

The decision of Farfante and Kensley (1997) to include the blue shrimp, previously known as *Penaeus stylirostris*, in the genus *Litopenaeus* as *Litopenaeus stylirostris* is accepted.

The taxonomic framework presented below is taken from the Integrated Taxonomic Information System (ITIS 2004):

Kingdom Animalia
Phylum Anthropoda
Subphylum Crustacea
Class Malacostraca
Subclass Eumalacostraca
Superorder Eucarida
Order Decapoda
Suborder Dendrobranchiata
Superfamily Penaeoidea
Family Penaeidae
Genus *Litopenaeus*

Litopenaeus stylirostris (Stimpson, 1874)

Litopenaeus stylirostris originated on the western Pacific coast of Latin America and has a natural range extending from Peru to Mexico (Fig. 2). During the late 1970s and early 1980s, the species was introduced to Hawaii and the eastern Atlantic coast of the Americas, from South Carolina and Texas to Central America and Brazil. The culture industry for *L. stylirostris* in Latin America is largely confined to Mexico.

4.1.2 Life Cycle

Penaeid prawns generally have an annual life cycle, with adults spawning in deeper nearshore waters (Fig. 3).

The following information, obtained from Choy (1982, 1988), summarizes the life cycle of a closely related species, *Penaeus canaliculatus*, in Fijian waters. *Penaeus canaliculatus* spawns in deeper channels of the Laucala Bay Lagoon where the water is of high salinity (>30 ppt). Unlike most other prawns, lobsters and crabs, penaeids shed their eggs directly into sea water. The planktonic larvae drift into estuarine areas, where they grow to maturity through a succession of moults. At 1-month old, with a carapace length (CL) of 4.0 cm, PL of *P. canaliculatus* in Laucala Bay become benthic, and settle on the seagrass beds of the intertidal mudflats. Settlement occurs twice a year, in June and November. The PL recruited in June grow in the nursery grounds for approximately five months, until they are juveniles measuring 16-20 mm CL. These juveniles are then recruited into the adult stocks offshore, eventually mating and spawning in October-November. Age at first maturity is between 5-7 months; the males and females of this age being about 16 mm and 20 mm CL, respectively. The number of eggs released at a single spawning ranges between 20,000-100,000 for wild females, the number increasing with the size of the female.

Most species of penaeid shrimp favor soft bottoms where they feed on particulate matter. *Penaeus canaliculatus* was shown by Choy (1982) to be an opportunistic omnivore, the gut contents of juveniles and adults containing crustaceans, molluscs, polychaetes, fish and plant material. Feeding activity was observed to be highest just at the onset of darkness, especially when it coincided with high tide (see Richards *et al.* 1994).

The larger *L. stylirostris* conforms generally to these life cycle characteristics (GSMFC 2004). *Litopenaeus stylirostris* is not so tolerant of low salinities, but will tolerate a wide range of temperatures. It grows best between 23-30 °C (a range that encompasses temperatures found throughout most of the tropical and subtropical world), with optimal growth occurring at 30 °C for small (1 g) and 27 °C for larger (12-18 g) shrimp. The species will also tolerate temperatures down to 15 °C and up to 33 °C without problems, but at reduced growth rates (Wyban and Sweeny 1991). In Asia, the species can be profitably cultured during the cool season (October-February). *Litopenaeus stylirostris* can tolerate colder temperatures than *L. vannamei*, *P. monodon* and *Fenneropenaeus indicus*, but requires higher oxygen levels (Rosenberry 2002)

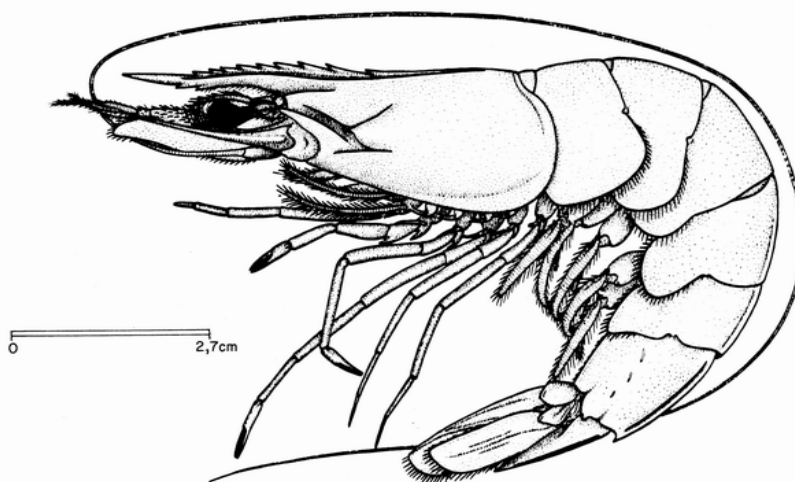


Figure 1. Adult *Litopenaeus stylirostris*.



Figure 2. Map showing the natural range of *Litopenaeus stylirostris*.

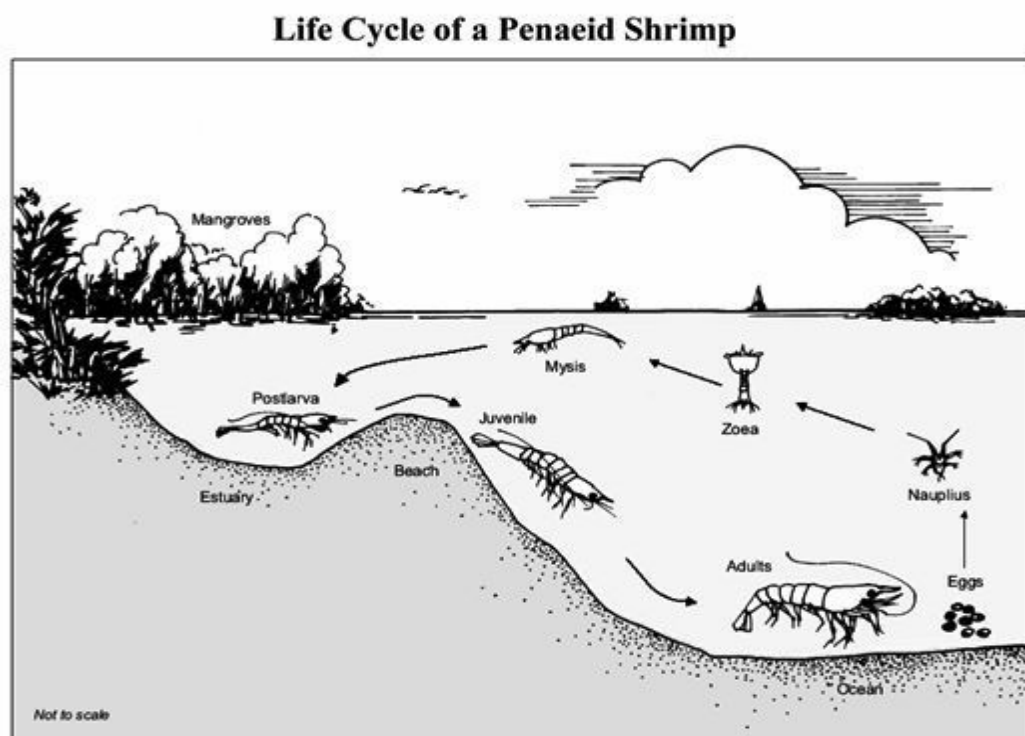


Figure 3. Generalized penaeid life cycle.

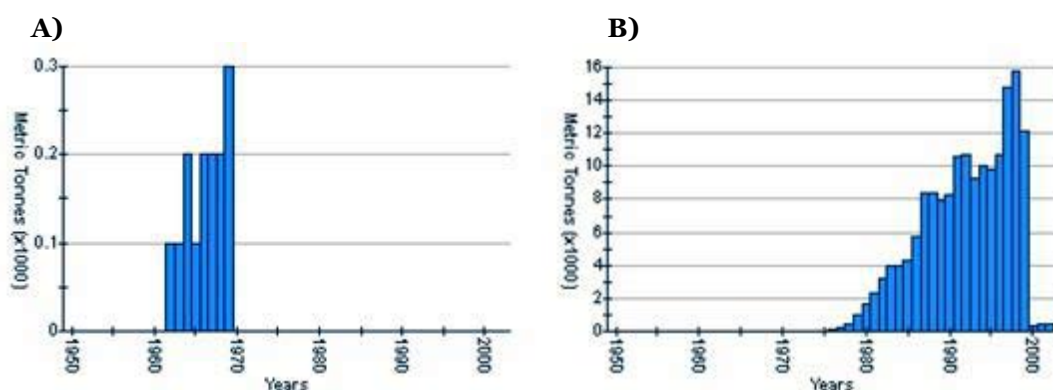


Figure 4. Global production of *Penaeus stylirostris*: A) capture production. B) aquaculture production.

4.2 Significance to Aquaculture and Capture Fisheries

Beginning in 2000, specific pathogen free (SPF) “super shrimp” *L. stylirostris* have been experimentally introduced to a number of Asian countries (including Brunei, Taiwan Province of China, Myanmar, Indonesia and Singapore) from secure breeding facilities in Mexico and the United States (see Briggs *et al.* 2004). To date, Brunei is the only Asian country to develop an industry based on this species, having increased its total shrimp production from 66 MT since the importation of *L. stylirostris* to 445 MT in 2003, with almost 90% of the total production value now being contributed by *L. stylirostris* (Hamid 2004). With a total production of 2,272 MT in 2002 (mostly *L. stylirostris* from New Caledonia), marine shrimp aquaculture is a small industry in the Pacific Islands (Briggs *et al.* 2004).

However, concerns about the potential risk of introducing serious viral disease along with exotic *Litopenaeus* spp. have led several Asian countries (Malaysia, Myanmar, the Philippines) to ban importations. Other countries are allowing controlled importations of *L. vannamei* only from certified SPF sources (Thailand) or by certified facilities (Indonesia). The primary concern is that *Litopenaeus* spp. may carry Taura syndrome virus (TSV), which has now been detected in Indonesia, Thailand, Vietnam and Taiwan in cultured *L. vannamei* (see de la Pena 2004, Sunarto *et al.* 2004, Van 2004).

4.3 Status of Knowledge of Pathogens and Parasites of *L. stylirostris*

The state of knowledge on pathogens and parasites of *L. stylirostris* is generally poor, with adequate information available only for a few pathogens such as infectious hypodermal and haematopoietic necrosis virus (IHHNV), *baculovirus penaei* (BP) and necrotising hepatopancreatitis (NHP).

4.4 Penaeid spp. in Fiji

4.4.1 Native Species

There are at least five species of penaeid shrimp native to Fiji. Choy (1982) notes the presence of the giant tiger prawn (“urakeirasaqa” - *Penaeus monodon*), witch prawn (“uranicakau” - *P. canaliculatus*), green tiger prawn (*P. semisulcatus*), and the western king prawn (*P. latisulcatus*) and two species of greasy prawn, *Metapenaeus anchistus* and *M. elegans*. Although con-

sidered indigenous by Rabanal *et al.* (1981), the banana prawn, (*Fenneropenaeus merguensis*) is an exotic species that has established a local population in Fiji from animals released from a prawn culture experiment conducted during the 1970s.

4.4.2 History of Previous Introductions

Although penaeid shrimps have been imported to Fiji for aquaculture development on a number of occasions, only one of these introductions has led to the establishment of a wild population (Uwate *et al.* 1984, Eldredge 1994). At the conclusion of culture experiments at Raviravi, all remaining individuals of the banana prawn (*F. merguensis*), which was introduced from Tahiti during 1974-975, were released into the wild and now naturally occur in the Ba Estuary (Choy 1983, Andrews 1985). Although Kuruma prawn (*Marsupenaeus japonicus*), introduced to Fiji from Japan for culture at Raviravi, was also released into the wild (Gundermann and Popper 1977), it failed to establish, since it was not found during a 1979 survey (see Eldredge 1994).

According to Eldredge (1994) the following introductions and transfers into Fiji have also been made:

- Indian white prawn (*Fenneropenaeus indicus*)
- Giant tiger prawn (*P. monodon*)
 - 1975: stock imported to Fiji from New Caledonia
 - 1990-1991: PL to ponds at Navua (Viti Levu) from Australia

Although it has been suggested (T. Adams, in Richards *et al.* 1994) that wild populations of the blue prawn (*L. stylirostris*) derived from stock imported to Raviravi from New Caledonia for aquaculture in 1985/86, probably exist, this is a questionable assertion that would require sampling of the Ba River to be supported.

4.5 History and Status of *Litopenaeus stylirostris* in Brunei

The culture of *Litopenaeus stylirostris* in Brunei was begun in 2000, and in April 2002, a Broodstock Development Center was established to stop dependency on importations and due to the high demand for PL from farmers. PL production has risen from 18 million in 2001 to 42 million in 2003. Initially, specific pathogen free broodstock were imported from Super Shrimp Group Mexico and High Health Aquaculture, Hawaii (H.L.H. Hamid pers. comm). However, precise information on the history of the parent broodstock from which PL to be sent to Fiji will be derived could not be obtained from the supplier or the Government of Brunei.

4.6 History and Status of *Litopenaeus stylirostris* in Fiji

Postlarvae of *L. stylirostris* have been imported to Fiji on three previous occasions. In 1985-86, shrimp imported from Tahiti were stocked in ponds at Raviravi, north Viti Levu, for trial culture. In 1999, PL were imported from Hawaii for Pacific Prawns (Fiji) Ltd. in Navua, southern Viti Levu. No stock remains from these two importations. In December 2003, a total of 300,000 PL were imported from Brunei and stocked in culture ponds owned by Gulf Seafood Fiji Ltd. at grow-out ponds west of Navua near Culunuku village. These shrimp have been successfully cultured to approximately 30 g and will soon be harvested. About 300 females and 1000 males of this shipment are being retained to develop a broodstock. Additionally, 70 specimens were taken by the Fisheries Department to develop broodstock at the Galoa Hatchery. Also, some broodstock derived from this importation are being kept at the Marine Studies Programme at the University of the South Pacific (USP) in Suva.

5.0 Justification for Introduction and Alternate Strategies

5.1 Justification for Introduction

Litopenaeus stylirostris is believed to offer advantages over the presently cultured *Penaeus monodon*, the only indigenous species that might be suitable, that include:

- a readily closed life cycle that could allow broodstock free of serious viral pathogens to be established in Fiji;
- a reliable supply of PL free from certain serious viral infections; (Difficulty in obtaining sufficient broodstock due to the highly seasonal nature and large inter-annual variations in availability of *P. monodon* broodstock from the wild in Fiji has lead to inadequate quantities and irregular supply of PL, restricting sustainable grow-out production and the future expansion of the industry. Additionally, PL production from wild-caught *P. monodon* broodstock has been very low due to low egg production and low PL survival.)
- better and faster growth than *P. monodon*; and
- better tolerance of low water temperatures and of temperature fluctuations than *P. monodon*, which is near the southern end of its natural distribution; this is expected to allow reliable production of two crops annually.

Additionally, should Fiji be demonstrated to be free from serious viral diseases of penaeid shrimp, lucrative overseas markets could exist for high health (HH) hatchery-produced PL and for Fijian production from grow-out (e.g., “green labeled” shrimp).

The goal of both proponents from industry and of the Fisheries Department is to develop hatchery broodstock within the country. This will forego the need to import PL from abroad with the inherent risks of translocation of pathogens and other associated organisms and the hazards of transportation. The Fisheries Department intends that the hatchery at Galoa will provide adequate quantities of PL to supply a growing industry. Additionally, the University of the South Pacific (USP) has developed hatchery facilities capable of producing PL.

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5.2 Alternate Strategies

The only alternate strategies available are to continue culture of *Penaeus monodon*, with the inherent constraints to production noted above, or to introduce another exotic species, such as *Litopenaeus vannamei*, which would entail an unknown level of pathogen and ecological risk.

Alternate sources of PL and broodstock of *L. stylirostris* have not been explored by the importers. Although these sources may entail greater cost to importers, they can offer assurances of high health status (origin from SPF facilities) that are currently unavailable or impossible for Brunei stocks. Suppliers for such high health shrimp exist in both Hawaii and the mainland United States. An accreditation scheme, similar to that being set up by Thailand for importations of *L. vannamei*, could be developed by SPC for *L. stylirostris* and perhaps other penaeid species, which would simplify importations of PL originating from pre-approved hatchery facilities.

6.0 Description of the Culture Systems and Current Practice

6.1 Culture Systems

There are currently two functioning prawn farms in Fiji (see Fig. 5).

6.1.1 *Pacific Prawns (Fiji) Ltd.*

Pacific Prawns (Fiji) is located at the mouth of the Navua River (Lat. 18° 15.75'; Long. 178° 6.90') (see Fig. 6). The ponds are excavated in an area adjacent to the river bank on what is a vegetated and partly mangrove-lined headland.

The farm has six adjacent, square ponds with the following areas: 1.1 ha, 0.3 ha, and four ponds of 0.8 ha each. The latter four ponds are currently operational. The pond water depth varies between 1-1.4 m. The banks allow access by vehicle all around the ponds. Water exchange is from the river; the ponds are filled by pumping, and drained by discharging into the river through drainage gates (Figs. 7 and 8).



Figure 5. Map of the Fiji Islands showing the location of the prawn farms.



Figure 6. Location of the currently operating prawn farms.



Figure 7. Pond at Pacific Prawns (Fiji) culture facility.



Figure 8. Chlorination of empty pond.

6.1.2 *Gulf Seafood Fiji Ltd.*

The Gulf Seafood Fiji Ltd. prawn farm is located on Culanuku Point and settlement (Lat. 18° 15.95'; Long. 177° 58.65') (see Fig. 6), and comprises four above-ground ponds, each with an area of 3000 m² and a depth of 2 m. The ponds are lined with heavy plastic sheeting. The center of each pond has a large drain and there is a seawater inlet on one side. A powerful air pump is housed on the other side with aerators placed across the bottom. Several paddle units keep the waters circulating (Fig. 8).

For the growing of PL, there are 20 plastic-lined raceways that can be covered and warmed for winter conditions (Fig. 9).

The inlet for sea water is offshore at a depth of 24 m. It is adjacent to the coast, with the bathymetry deepening to 30 m depth. The receiving waters for the outflow are in the Wainikuluku pass and inlet, within the eastern portion of Korovou Bay. The outflow discharges into the mangrove-lined inlet.



Figure 8. Pond during cleaning period. Note the plastic lining with the central drain. High capacity aeration and paddle devices maintain suitable environmental conditions.



Figure 9. Plastic-lined raceways for cultivation of postlarvae

6.2 Current Practice

6.2.1 “Quarantine” and Acclimatization

Government-regulated quarantine procedures are documented in Chapter 159 of the Animals Importation Act of the Laws of Fiji. The Act as it pertains to mariculture, is not practical due to a lack of facilities; hence the following procedures are employed.

Upon entering Fiji, the PL are delivered directly to the farm in their water-filled shipping bags and held for acclimatization for three hours in a receiving tank where pond water is progressively mixed. The bag water and the pond water are mixed. The water in the bag is tested as well as the PL. A quarantine officer is present.

Between batches, the ponds are scrubbed out and filled with chlorinated water prior to the arrival of the next batch.

6.2.2 Disease Testing

The stated general procedure for the introduction of new PL is to import a sample batch and have it tested for certain serious viral diseases using the polymerase chain reaction (PCR). The batch is then consigned and tested again upon arrival. A third testing is conducted during the mid-grow out phase.

The following outlines the procedures that were actually followed during the importation of PL from Brunei in December 2003:

- No testing of PL was done in Brunei before shipment.⁸
- Two sets of testing were conducted in Fiji:
 1. Prior to importation of live PL, in December 2003, four glass vials each containing more than 50 PL of unknown age but estimated to be >PL50, fixed in ethanol and noted to be "...representative of the batch of post larval animals being shipped from Brunei to Fiji." were received by the Institute of Marine Resources, University of the South Pacific. These samples, which originated from two different cohorts (two samples/cohort), were examined at IMR by RT-PCR and found to be negative for infectious hypodermal and haematopoietic necrosis virus (IHHNV), *monodon* baculovirus (MBV), whitespot syndrome virus (WSSV) and yellowhead virus (YHV)/gill associated virus (GAV). A total of 16 tests were conducted (4 viral diseases x 4 vials, using a combined 50 PL from each vial). All tests involved use of whole animals.

8 The consultants were advised that there a “certificate of health” was supplied by the Government of Brunei, however, during the field visits an attempt was made through the Quarantine and Inspection Division and the Licensing office of the Fisheries Department to obtain copies of import permits for recent shipments of live penaeid shrimps, however, these documents could not be located. The nature of any health certification needs to be determined.

2. In April of 2004, before these shrimp were harvested from grow-out ponds as Gulf Seafood Fiji Ltd., six live juvenile animals provided to IMR by Mr. Roger Black were tested for WSSV, IHHNV, MBV, YHV/GAV and Taura syndrome virus (TSV) using pleopod clips. All results were negative.

7.0 Description of the Receiving Environment and Contiguous Coastal Areas

Receiving environments for prawn culture in Fiji are varied. The previous and intended translocations of *Litopenaeus stylirostris* have occurred at sites around Viti Levu (Fig. 5), the largest and most populated island in the Fiji group. Culture farms have been set up near the Ba River estuary on the north coast and are currently being considered for re-development in a joint venture with a Taiwanese company. Another farm is planned for the coastal city of Lautoka on the northwest coast of the island. A government farm located in Dreketi, Vanua Levu is non-functioning, but future activity is intended. The two farms currently operating are on the south coast and are adjacent to different types of receiving waters. Both hatchery operations are also on southern coast locations.

7.1 Gulf Seafood Fiji Ltd.

Gulf Seafood Fiji Ltd. is located at the entrance to an embayment and is adjacent to Wainikulu Pass, which enters into Korovou Bay (Figs. 11 and 12). Offshore of the site is Volei Reef, within the broadly, semi-enclosed Serua Waters inshore of the Cakaulevu Reef (Serua Reef). Other reefs adjacent are Taqove and Wainisitima reefs, and there is an extensive band of coral reef to the west.

The immediate receiving waters are a mangrove-lined bay (Fig. 13). The depth in the bay is less than 10 m. The general coastal environment is comprised of an irregular coastline margined with inshore coral reefs on the headlands and dense mangrove forests in the bay. The coastal area ranges from intertidal mud/mangrove and fringing coral reefs to a channel depth of 30 m with 40 m patches. There are many creeks, which flow from limited catchments during rainy periods; the Navua River, a large estuary, is 17 km to the east.

The intake is adjacent to the facility at a depth of 24 m. The salinity of the inshore waters ranges from normal oceanic salinities (36 ‰) to waters diluted by rainfall run-off in the shallow areas. The seasonal temperature range is 17.5–31 °C. The shallow water is subject to fluctuations due to air temperature changes. Turbidity fluctuates due to run-off and wind-generated wave action resuspending soft bottom sediments.

7.2 Pacific Prawns (Fiji) Ltd.

The Pacific Prawns (Fiji) Ltd. farm is on the southern shore of the mouth of the Navua River, opposite Vunibau on adjacent Deuba Island. (Figs. 13 and 14). Mangrove forests exist at the river mouth and along Waimate Creek into Drekeilobi Bay and the Navua Roads. Naitata Reef is located at the river mouth. The depth in the river is 5 m, which increases to 13 m seaward, then to 289 m within one km and to 1000 m within 12 km in the Beqa Passage to the east of Beqa Island.

The farm draws its water from the depths of the river at high tide when sea water flows into the estuary. The pond water is discharged into the mangroves lining the river. Water is progressively flushed out of the river mouth into the coastal water. Due to the tidal range, the intake water has characteristics similar to that of the coastal waters. High current flow and the proximity of deep water adjacent to the river delta allow for a supply of quality oceanic water.



Figure 11. Location of Gulf Seafood Fiji Ltd. prawn farm.



Figure 12. Aerial view of Gulf Seafood Fiji Ltd.



Figure 15. Location of Pacific Prawn farm on the Navua River. Coral reefs are seen offshore of the river mouth.

7.3 Existing Hatchery Operations

The Fisheries Department hatchery is located at Galoa on the coast, 2 km to the east of the Gulf Shrimp (Fiji) Ltd. prawn farm. The Marine Studies Program hatchery at the University of the South Pacific is located on the shore of Laucala Bay on the eastern side of the Suva Peninsula.

7.4 Weather Conditions

Weather is important to the cultivation of prawns, in that temperature is important in moderating growth rate and in extremes, mortality. Destructive storms can cause loss of infrastructure due to wind and flooding. This may give rise to the accidental escape of cultivated organisms into the wild.

The Fiji Islands experiences tropical conditions, with an air temperature range of 18-31 °C for monthly averages over 29 years. There is a distinct wet season between November and April that coincides with the cyclone season. Viti Levu has a wet side on the eastern portion of the island and a dry side on the western portion (see Annex V). The prawn farms are located in the moderately wet zone. Details of the environment in this zone are contained in Appendix III. Cyclone tracts for the Fiji Islands are found in Appendix IV. The rainfall average for Viti Levu Island is illustrated in Appendix V.

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

8.1 Source

The current source of PL of *Litopenaeus stylirostris* is a hatchery facility owned by Semaun Marine Resources Sdn Bhd, Brunei. Further details on the production facilities and protocols are not available at this time.

8.2 Number of Organisms to be Introduced

The total number of organisms to be introduced is undefined. An initial shipment of 300,000 PL imported by Gulf Seafood Fiji Ltd. arrived in December 2003. Subsequent shipments for Gulf Seafood Fiji Ltd. could be increased to an estimated maximum of 70,000,000 PL per year if all ponds are brought into production. Estimated annual PL requirement for Pacific Prawns (Fiji) Ltd. is 100,000 per year. This annual volume may be required until such time as a reliable broodstock can be established.

9.0 History and Disease Status of the Stock to be Imported and the Exporting Country

9.1 History of the Stock to be Introduced

The history of the stock could not be reliably ascertained. It is known that in 2000 Brunei imported specific pathogen free (SPF) broodstock from Super Shrimp Group (SSG) Mexico and High Health Aquaculture Ltd., Hawaii (H.L.H. Hamid pers. comm). However, precise relationship of these importations to the parent broodstock from which PL to be sent to Fiji will be derived could not be verified through queries to the supplier and the Government of Brunei.

9.2 Disease Status of the Stock of Origin

As the exporter and the Government of Brunei have not responded to queries regarding the stock history, current culture practices, protocols for any disease testing and assurances of freedom from serious pathogens, the health status of the parent stock must be regarded as unknown.

9.3 Disease status of the Exporting Country

The aquatic animal disease status of Brunei is unknown. Although Brunei has recently become a member of the OIE, there is no data for Brunei in the OIE's *International Database on Aquatic Animal Diseases* (<http://www.collabcen.net/toWeb/aq2.asp>).

According to Hamid (2004) there have been no recorded outbreaks of Taura syndrome or white spot disease (WSD) in Brunei, however, the country lacks diagnostics capability.

10.0 Disease Status of the Importing Country

10.1 Disease Status of Fiji

The aquatic animal disease status of Fiji is unknown. Fiji is not a member of the OIE, however, the SPC 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>).

In December, 2003, two shipments of 70 live *Penaeus monodon* each, one destined for shipment to Charoen Pokphand Group (CP) in Bangkok, Thailand and the other to the Oceanic Institute in Honolulu, Hawaii, were examined using PCR at the Institute of Marine Resources (IMR) for MBV and YHV/GSV (fecal material and periopods clippings) and tested negative. Additional testing of these *monodon* broodstock was done in Thailand by CP and at the laboratory of Dr. Donald Lightner at the University of Arizona. Attempts made to confirm the nature and results of viral testing were unsuccessful; the results, which are proprietary, could not be obtained from the two importers.

11.0 Pathogen Risk Analysis

11.1 Preliminary Hazard Identification

Due to the lack of information on the diseases of penaeid shrimp (Penaeidae) in the exporting (Brunei Darussalam) and importing countries (Fiji), the preliminary hazard identification will consider all pathogens and diseases reported from *Litopenaeus stylirostris*. The following criteria must be met for a pathogen or disease to be considered in the preliminary hazard identification:

- 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 *L. stylirostris* or it must be listed by the OIE as a serious disease affecting other penaeid shrimp. Pathogens reported from any life cycle stage and any geographical locality are included.

The results of the preliminary hazard identification are presented in Table 2. Table 3 lists the agents identified in the preliminary hazard identification for *L. stylirostris* and their known or probable infectivity to the seven species of penaeid shrimp reported to occur in the waters of the importing country.

Table 2. Results of the 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	Wongteerasupaya <i>et al.</i> 1995, Lo <i>et al.</i> 1996, Flegel 1997, Tapay <i>et al.</i> 1997, OIE 2003	Significant pathogen of penaeid shrimp; global distribution; wide host range; experimental infections lethal to <i>Litopenaeus stylirostris</i> .
Infectious hypodermal and haematopoietic necrosis virus (IHHNV)	Y	Y	Y	Lightner <i>et al.</i> 1983a,b, 1995; Bell and Lightner 1984; Bonami <i>et al.</i> 1990; Lightner 1996a,b; Pantoja <i>et al.</i> 1999; OIE 2003	Significant pathogen of penaeid shrimp; infects a wide range of penaeids; occurs both in wild and cultured shrimp; a major pathogen of <i>L. stylirostris</i> .
Taura syndrome virus (TSV)	Y	Y	Y	Hasson <i>et al.</i> 1995, 1999; Lightner 1996a,b; Bonami <i>et al.</i> 1997; Brock <i>et al.</i> 1997; Erickson 2002; OIE 2003	Significant pathogen of penaeid shrimp; <i>L. stylirostris</i> recently found to be susceptible.
Yellow head virus (YHV)	Y	Y	Y	Boonyaratpalin <i>et al.</i> 1993, Lu <i>et al.</i> 1994, Wongteerasupaya <i>et al.</i> 1997, Nadala <i>et al.</i> 1997, OIE 2003	Natural infections in <i>Penaeus monodon</i> , lethal experimental infections in <i>L. stylirostris</i> and other species.
Other Pathogens Considered					
Viruses					

Pathogen	Infects PL stage	Causes significant disease	Further consideration required	References	Comments
<i>Baculovirus penaei</i> (BP)	Y	Y	Y	Lightner 1983, 1988; Lightner <i>et al.</i> 1989	Causes serious disease in <i>arfanteopenaeus duorarum</i> , <i>F. aztecus</i> , <i>L. vannamei</i> and <i>P. marginatus</i> .
Hepatopancreatic parvo-like virus (HPV)	Y	Y	Y	Lightner 1996b	Natural infection in <i>P. monodon</i> , <i>Fenneropenaeus merguensis</i> , <i>P. semisulcatus</i> and <i>L. stylirostris</i> .
Lymphoid organ vacuolization virus (LOVV)	Y	N	N	Lightner, 1996b, Bonami <i>et al.</i> 1992	Identical histopathology occasionally observed in <i>L. stylirostris</i> .
Rhabdovirus of penaeid shrimp (RPS)	Y	N	N	Lightner 1996b	Uncertain if a true pathogen of penaeid shrimp.
Bacteria					
Necrotising hepatopancreatitis (NHP)	Y	Y	Y	Frelter <i>et al.</i> 1993, Lightner <i>et al.</i> 1992, Lightner 1996b	Reported only from American penaeids (<i>L. vannamei</i> , <i>F. aztecus</i> , <i>L. stylirostris</i> , <i>L. setiferus</i> and <i>F. californiensis</i>).
<i>Vibrio harveyi</i>	Y	Y	N	Lightner and Redman 1985; Lightner 1988, 1996; Alvarez <i>et al.</i> 1998	<i>Vibriosis</i> affects all penaeid species; mortality ranges from inconsequential to 100%; worldwide distribution.
<i>V. vulnificus</i>	Y	Y	N		
<i>V. parahaemolyticus</i>	Y	Y	N		

Pathogen	Infects PL stage	Causes significant disease	Further consideration required	References	Comments
<i>V. penaeicida</i>	Y	Y	Y	de la Pena <i>et al.</i> 1993, 1995, 1997, 1998; Ishimaru <i>et al.</i> 1995; Costa <i>et al.</i> 1998	Reported from New Caledonia; a significant pathogen of <i>Marsupenaeus japonicus</i> .
Shrimp tuberculosis (<i>Mycobacterium marinum</i> , <i>M. fortuitum</i> and <i>Mycobacterium</i> sp.)	?	N	N	Lightner 1988, 1996b	Ubiquitous; potentially infectious to all penaeids
Rickettsia-like organisms	P	N	N	Brock 1988, Lightner 1996b	<i>L. stylirostris</i> experimentally infected by rickettsia of <i>P. marginatus</i> .
Parasites					
<i>Haplosporidium</i> sp.	?	N	N	Lightner 1996b	In cultured and wild penaeid shrimp including <i>L. stylirostris</i> .
Fungi					
<i>Lagenidium</i> spp.	Y	N	N	Lightner 1988, 1996b	Affects all penaeids
<i>Sirolpidium</i> spp.	Y	N	N	Lightner 1988 1996b	Affects all penaeids
<i>Fusarium solani</i>	P	N	N	Lightner 1996b	Opportunistic pathogen; isolated form both cultured and wild crustaceans. All penaeids probably susceptible; <i>L. stylirostris</i> moderately susceptible.

Table 3. Known or probable infectivity of important pathogens in *Litopenaeus stylirostris* and seven penaeid species reported to occur in Fiji. (Y=Yes, N=No, P=Plausible, NI=No Information)

Pathogen¹									
	<i>Litopenaeus stylirostris</i>	<i>Penaeus monodon</i>	<i>P. candiculatus</i>	<i>P. semisulcatus</i>	<i>P. latisulcatus</i>	<i>Fenneropenaeus merguensis</i> ²	<i>Metapenaeus anchistus</i>	<i>M. elegans</i>	
Viruses									
IHHNV	Y	Y	NI	Y	NI	N	NI	NI	
TSV	Y	Y	NI	NI	NI	Y	NI	NI	
WSSV	Y	Y	NI	Y	NI	Y	NI	NI	
YHV	Y	Y	NI	NI	NI	Y	NI	NI	
BP	Y	N	NI	NI	NI	NI	NI	NI	
HPV	Y	Y	NI	Y	NI	Y	NI	NI	
LOVV	Y	Y	NI	NI	NI	NI	NI	NI	
RPS	Y	NI	NI	NI	NI	NI	NI	NI	
Bacteria									
NHP	Y	NI	NI	NI	NI	NI	NI	NI	
<i>Vibrio</i> spp.	P	P	P	P	P	P	P	P	
<i>V. penaeicida</i>	Y	NI	NI	NI	NI	NI	NI	NI	
<i>Mycobacterium</i> spp.	P	P	P	P	P	P	P	P	
Rickettsia-like organisms	Y	NI	NI	NI	NI	Y	NI	NI	
Parasites									
<i>Haplosporidium</i> sp.	Y	NI	NI	NI	NI	NI	NI	NI	

Fungi											
<i>Lagenidium</i> spp.	P	P	P	P	P	P	P	P	P	P	P
<i>Sirolopidium</i> spp.	P	P	P	P	P	P	P	P	P	P	P
<i>Fusarium solani</i>	Y	N	NI	NI	NI	NI	NI	N	NI	NI	NI

¹Infectious hypodermal and haematopoietic necrosis virus (IHHNV), Taura syndrome virus (TSV), white spot syndrome virus (WSSV), yellow head virus (YHV), *Baculovirus penaei* (BP), hepatopancreatic parvovirus (HPV), lymphoid organ vacuolization virus (LOVV), rhabdovirus of penaeid shrimp (RPS), necrotising hepatopancreatitis (NHP).

²Established exotic species.

11.2 Detailed Hazard Identification

11.2.1 Criteria for Further Consideration

In order for a potential hazard to be given further consideration, the following criteria must be fulfilled:

- the pathogen must have been reported to infect, or is suspected of being capable of infecting postlarval *L. stylirostris*;
- 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 *L. stylirostris* under certain environmental or culture conditions);
- the agent must cause significant disease outbreaks and associated losses in populations of *L. stylirostris* or, if not a significant pathogen of *L. stylirostris*, it must cause serious disease outbreaks in populations of other species of penaeid shrimp; and
- it must be plausible that the agent might be present in populations of *L. stylirostris* in Brunei.

11.2.2 Pathogens Not Considered Further

The following sections present brief comments on some of the pathogens not given further consideration. Unless otherwise indicated, the information presented below is taken from the summaries of Lightner (1983, 1996a), Sindermann and Lightner (1988), Sindermann (1990), (Dall *et al.* 1990) or Fulks and Main (1992).

11.2.2.1 Viruses

Two crustacean viruses are not considered further in the risk analysis. These are: (i) lymphoid organ vacuolization virus (LOVV) and (ii) rhabdovirus of penaeid shrimp (RPS).

Lymphoid organ vacuolization virus (LOVV). Lymphoid organ vacuolization virus disease is a poorly understood disease of penaeid shrimp. LOVV is a cytoplasmic, enveloped RNA virus belonging to the Togaviridae. LOVV is distributed in virtually all areas where *Litopenaeus vannamei* is cultured. Although described only in *L. vannamei*, identical histopathology has been occasionally observed in *L. stylirostris*, and it is therefore very likely that LOVV also infects this species. However, no serious infection or disease has been reported from *L. vannamei*, *L. stylirostris* or other penaeids exposed to carriers of the virus. LOVV is not considered further in this analysis because it does not cause significant disease.

Rhabdovirus of penaeid shrimp (RPS). Rhabdovirus of penaeid shrimp (RPS) may use penaeid shrimp as carrier hosts. It is very similar to certain fish rhabdoviruses in its morphology; it replicates in a fish cell line and it may not replicate in shrimp. It does not cause disease in shrimp following massive challenge and it causes no distinctive histopathology (other than minor changes to the lymphoid organ) in challenged shrimp. To date, RPS has been isolated only from the American penaeids *L. vannamei* and *L. stylirostris* from Hawaii and Ecuador. RPS is a poorly understood virus found in penaeid shrimp, and while similar pathological conditions of the lymphoid organ are common in Asia and the Americas, especially in *Penaeus monodon* and *L. vannamei*, it is not known if RPS is a true pathogen of penaeid shrimp or if it

uses shrimp as carrier hosts while having finfish as its principal hosts. RPS is not considered further because: (a) it does not cause significant disease; and (b) it is unknown whether or not it is a true pathogen of shrimp.

11.2.2.2 Bacteria

Vibrio harveyi, *V. vulnificus* and *V. parahaemolyticus*. The majority of bacteria reported from penaeid shrimp are common in estuarine and marine environments. Lightner (1983) and Lightner *et al.* (1984) summarized the important aspects of vibriosis in penaeid shrimp: (a) infections may be chronic, subacute or acute and mortality may reach 100% in cultured populations; (b) most outbreaks are consequences of extreme stresses and opportunistic pathogens; (c) isolates of *Vibrio* spp. from shrimp may not always produce experimental infection, except when massive doses are injected; (d) larval, postlarval, juvenile and adult shrimp may be infected; (e) *Vibrio* spp. that infect shrimp are ubiquitous and have been reported from all major shrimp culture regions; and (f) as for other hosts, *Vibrio* species and strains differ markedly in their virulence for penaeids.

Some species are found associated with shrimp both as pathogens and as part of their normal microflora. Infections are secondary in nature, occurring as a result of other primary conditions, including other highly virulent pathogens or as a result of trauma, environmental stress or nutritional diseases.

These *Vibrio* spp. are not considered further because: (a) they are ubiquitous; and (b) infection is secondary in nature and can be controlled through proper management.

Mycobacterium marinum, *M. fortuitum* and *Mycobacterium* sp. *Mycobacterium* spp. causing shrimp tuberculosis are seldom considered as shrimp pathogens but are usually regarded as a marketing problem causing value loss due to the presence of unsightly melanized nodules or lesions on the shell or in the muscle of infected shrimp. They also cause accidental infection of the hands of shrimp farm and packing plant workers, who may become infected during post-harvest processing, resulting in nodular skin lesions that are difficult to treat. *Mycobacterium* spp. are not considered further because: (a) there is no direct evidence of infections in *L. stylirostris*; and (b) they do not cause significant disease.

Rickettsia-like Infections. Rickettsia or rickettsia-like microorganisms with a size range of 0.2–0.7 x 0.8–1.6 μm have been described in wild penaeid shrimp from Hawaii and in cultured penaeids from Mexico and Southeast Asia. Three penaeid species (*P. marginatus*, *F. merguensis* and *P. monodon*) have shown infections by rickettsial-like bacteria in the epithelial cells of the hepatopancreatic tubules. Gross signs in heavily infected animals include lethargy, reduction in feeding, and atrophic and pale hepatopancreas. *Litopenaeus stylirostris* was experimentally infected by the hepatopancreas rickettsia from wild *P. marginatus* with high mortality. Rickettsia-like infections will not be considered further because: (a) *L. stylirostris* has only been infected experimentally; and (b) these pathogens do not seem to cause significant disease.

11.2.2.3 Parasites

Haplosporidium spp. Hepatopancreatic haplosporidiosis caused by one or more putative haplosporidians has been recognized in penaeid shrimp. However, no exhaustive investigation

has been conducted and therefore, the taxonomic position of these organisms has not been precisely determined. Haplosporidiosis has been observed in cultured and/or wild penaeid shrimp in Cuba and Nicaragua (in *L. vannamei*), in Mexico (in *L. stylirostris*), in Indonesia (in *P. monodon*) and in the Philippines. These parasites will not be considered further because they do not appear to cause significant disease.

11.2.2.4 Fungi

***Lagenidium* spp. and *Sirolopidium* spp.** Larval mycosis, a common disease problem affecting all penaeid species, is caused by phycomycetous fungi belonging to the genera *Lagenidium* and *Sirolopidium*. Larval mycosis is ubiquitous, occurring in most areas where shrimp farming exists. Clinical signs include a sudden onset of mortalities in the larval or early PL stages followed by systemic infections that are accompanied by little or no host response. Larval mycosis will not be considered further because it is a ubiquitous disease problem.

***Fusarium solani*.** Fusariosis most often affects subadult and adult shrimp. All penaeid shrimp are probably susceptible, the most susceptible species being *Marsupenaeus japonicus* and *Farfantepenaeus californiensis*. *Litopenaeus stylirostris* and *L. vannamei* are considered moderately susceptible, while *P. monodon* and *Fenneropenaeus merguensis* are relatively resistant. *Fusarium solani* is an opportunistic pathogen of penaeids that is capable of establishing infections only in shrimp that have been compromised by other infectious diseases, exposure to chemical irritants or certain heavy metals, or excessive crowding. Commonly isolated from both cultured and wild crustaceans, *Fusarium* spp. are also common pathogens of plants and occasionally of terrestrial animals. *Fusarium solani* will not be considered further because it does not appear to cause significant disease.

11.2.3 Pathogens for Further Consideration

Based on the preliminary hazard identification, six viruses and two bacterial pathogens were recognized as requiring further consideration:

- White spot syndrome virus (WSSV)
- Infectious hypodermal and haematopoietic necrosis virus (IHHNV)
- Taura syndrome virus (TSV)
- Yellow head virus (YHV)
- *Baculovirus penaei* (BP)
- Hepatopancreatic parvo-like virus (HPV)
- Necrotising hepatopancreatitis (NHP)
- *Vibrio penaeicida*

Unless otherwise indicated, the information presented below is taken from Lightner (1996a), Bondad-Reantaso *et al.* (2001) and OIE (2003).

11.2.3.1 White Spot Syndrome Virus

The white spot syndrome virus (WSSV), the causative agent of white spot disease (WSD), is a double-stranded DNA (dsDNA) virus. Several other names have been used to describe the virus: baculoviral hypodermal and haematopoietic necrosis virus (HHNBV), shrimp explosive epidemic disease (SEED), China virus disease, rod-shaped nuclear virus of *Penaeus japonicus* (RV-PJ); systemic ectodermal and mesodermal baculovirus (SEMBV) and white spot baculovirus (WSBV).

WSSV has a wide host range that includes both marine and freshwater shrimp species and other decapods, such as crabs and marine and freshwater crayfish. Wild broodstock and fry used to stock rearing ponds, as well as numerous other crustaceans and even aquatic insect larvae are known to carry WSSV. Transmission studies have also demonstrated that non-penaeid carriers of WSSV transmit WSSV to shrimp. WSSV can be transmitted via frozen shrimp products (Nunan *et al.* 1999, Durand *et al.* 2000). Some of the factors that can trigger outbreaks of WSD in shrimp with subclinical infections include rapid changes in water temperature, hardness and salinity, or reduced oxygen levels (<2 ppm) for extended periods.

Tapay *et al.* (1997) experimentally demonstrated that WSSV could be similarly pathogenic and highly infectious for *Litopenaus stylirostris* and *L. vannamei* and could cause up to 100% mortality in both species within four days post-infection.

WSSV will be considered further because: (a) it is infectious; (b) it is an OIE-listed pathogen; (c) although only experimental infections have been reported for *L. stylirostris*, two native shrimp species (*P. monodon* and *P. semisulcatus*) and one established exotic species (*Fenneropenaeus merguensis*) in Fiji are susceptible to WSSV; d) it occurs in PL; and (e) it causes significant disease.

Release assessment

WSSV is one of the most highly translocated and introduced pathogens affecting global aquaculture. WSSV has a wide geographic and host range. There is no reliable assurance that the *L. stylirostris* to be imported from Brunei will be WSSV-free. Because of the complete lack of information on the health status of the parent stocks in the country of origin, it is impossible to provide an accurate risk estimate. However, because WSSV is one of the most widely introduced pathogens of penaeid shrimp, because it has a very broad geographic and host range, including an extensive range of carriers and vectors, and because past procedures for screening of PL do not assure that infections will be detected, the risk of the virus being present in an imported sample and it being introduced to Fiji is conservatively considered to be **moderate**.

Exposure assessment

WSSV has a wide geographic and host range, and thus the probability that suitable hosts are present in the vicinity of the receiving facilities in Fiji is high. WSSV is also transmitted horizontally via infected shrimp or via water, infecting all life stages of shrimp. The receiving farms do not presently have the necessary facilities and operating procedures in place to prevent the potential escape of infected imported stocks (e.g., quarantine or isolation ponds) nor to prevent the entry of potential carriers and vectors (e.g. filtration of incoming sea water, fencing and control programs); nor are there sufficient safeguards (e.g., reservoir ponds for holding of water prior to discharge, treatment ponds, etc) to prevent the escape of infected shrimp or of WSSV virions in effluent waters. If WSSV enters Fiji through imported *L. stylirostris*, the probability that susceptible prawns or other crustaceans will be exposed to a dose sufficient to cause infection is conservatively estimated to be **moderate**.

Consequence assessment

Two native species (*P. monodon*, *P. semisulcatus*) and one established exotic species (*Fenneropenaeus merguensis*) in Fiji are susceptible to WSSV; with *P. monodon* being the main host species. Although the susceptibility of other crustacean species in Fiji has not been studied, the fact that WSSV has a wide range of hosts, carrier hosts and other vectors suggests that many wild crustacean species in Fiji are likely to be susceptible. WSSV is known to have established infections in wild populations of penaeids with high level of prevalence. Most shrimp pathogens are transmitted through introduction of live infected hosts to naïve and susceptible populations that readily become infected, the disease organism rapidly disseminating into the environment.

The consequences of exposure to Fiji include possible impacts on local wild penaeid stocks, affecting local biodiversity and the artisanal fishery for *Penaeus monodon*. More significantly, should WSSV become established in carrier hosts, it will probably be impossible to eradicate, with negative consequences for the future development of shrimp aquaculture in Fiji and the marketability of Fijian product internationally. The consequence of WSSV establishing in Fiji is considered **moderate**.

Risk management

The risk mitigation measures recommended below should allow the proponents to reduce the potential risk due to WSSV to a level below the ALOP suggested for Fiji:

- All shipments of PL to be imported into Fiji should be of "high health" status and should originate from a facility certified as using specific pathogen free (SPF) broodstock *L. stylirostris*. The facility must demonstrate a proven track record of producing WSSV-free PL through a documented history of pathogen surveillance and evidence of adherence to strict biosecurity protocols and an over-all health management plan. The facility must provide Fiji with sufficient guarantees as to the health status and history of its stock. An on-site inspection visit to the production facility by an internationally recognized shrimp health expert on behalf of the Government of Fiji should be made to assure that the protocols, diagnostic procedures, security, etc. are adequate to validate guarantees of health status. **In no case should shipments of PL from sources of questionable health status be permitted to enter Fiji.** Importations from countries with a known history of occurrence of this pathogen should also be avoided unless the country of origin is able to convincingly demonstrate freedom from WSSV in the supplying facility.
- The production facility in the exporting country should also meet the following pre-border requirements:
 - o The batch of PL destined for export should be separated as early as possible from other stocks reared in the facility of origin and should be maintained in tanks separate from the rest of the stocks;
 - o Detailed records should be kept of the health status and mortality rates of each batch of *L. stylirostris*. Such records should be made available to the Competent Authority responsible for health certification;
 - o A statistically appropriate sample taken from the batch intended for export should be tested for WSSV using the methods recommended by the OIE;
 - o The testing should be performed by a recognized aquatic animal health laboratory in the exporting country that has been approved to undertake such work by the Competent Authorities of both the importing and exporting countries. If such a laboratory is not available in the exporting country, a qualified laboratory in a third country should be identified to perform the health certification.
 - o Should a batch of PL test positive for WSSV, the batch will be rejected and future importations from the infected production facility prohibited until such a time that freedom of the facility from WSSV can be clearly demonstrated through regular pathogen testing and health monitoring.
- The importing country should implement the following post-border requirements:
 - o The receiving facility should meet minimum requirements with regard to its design and operation such that the risk of pathogen exposure is minimized. Suggested standards are outlined in Annex I.

- o A health monitoring system should be in place at the receiving facility so that a new historical record of health and mortality status can be established.
- o No animals are to be removed from the receiving facility without prior permission from the Ministry of Fisheries and Forestry (MFF), Fiji;
- o The operators must report any occurrences of serious mortalities or disease outbreak; and
- o A farm level contingency plan should 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 II.
- o As processing plants can play an important role in the transfer of infected commodity, they should implement appropriate measures (e.g., HACCP) to avoid transfer of infection from processed products, transport containers and processing wastes.

11.2.3.2 Infectious Hypodermal and Haematopoietic Necrosis (IHHNV)

IHHNV, the smallest of known penaeid shrimp viruses, is classified as a member of the family Parvoviridae. The IHHNV virion is a 22 nm, nonenveloped icosahedron, with a density of 1.40 g/ml in CsCl, contains linear single-stranded DNA with an estimated size of 4.1 kb, and has a capsid with four polypeptides of molecular weight 74, 47, 39 and 37.3 kD.

IHHNV causes acute mass mortality, greater than 90% in *Litopenaeus stylirostris*, most severely affecting juveniles and subadults. IHHNV infects a wide range of penaeid shrimps, but does not appear to infect other decapod crustaceans. Natural infections have been reported in *L. vannamei*, *L. stylirostris*, *L. occidentalis*, *P. monodon*, *P. semisulcatus*, *Farfantepenaeus californiensis* and *Marsupenaeus japonicus*. Experimental infections have also been reported for *L. setiferus*, *Farfantepenaeus aztecus* and *F. duorarum*. *Fenneropenaeus indicus* and *F. merguensis* appear to be refractory to infection.

IHHNV occurs in wild and cultured penaeid shrimps in Central America, Ecuador, India, Indonesia, Malaysia, the Philippines, Peru, Taiwan Province of China, and Thailand. Although IHHNV has been reported from cultured penaeid shrimp from most regions of the western hemisphere and in wild penaeids throughout their geographic range along the Pacific coast of the Americas (Peru to northern Mexico), it has not been found in penaeids on the Atlantic side of the Americas. IHHNV has been reported in cultured penaeid shrimp from Guam, French Polynesia, Hawaii, Israel and New Caledonia. An IHHNV-like virus has also been reported from Australia.

Infection by IHHNV causes acute epizootics and mass mortality (>90%) in *L. stylirostris*. Although vertically infected larvae and early PL do not become diseased, juveniles >35 days old appear susceptible, showing gross signs followed by mass mortalities. In horizontally infected juveniles, the incubation period and severity of the disease appear to be size and/or age dependent, with young juveniles always being the most severely affected. Infected adults seldom show signs of disease or mortalities.

IHHNV will be considered further because: (a) it causes significant disease in *L. stylirostris*; (b) it occurs in PL; and (c) because two native species (*P. monodon* and *P. semisulcatus*) in Fiji are susceptible to infection.

Release assessment

IHHNV has a wide geographic and host range and is a major pathogen of *L. stylirostris*. There is no reliable assurance that the *L. stylirostris* to be imported from Brunei will be IHHNV-free. Because of the complete lack of information on the health status of the parent stocks in the country of origin, it is impossible to provide an accurate risk estimate. However, because IHHNV is one of the most widely introduced pathogens of penaeid shrimp, because it has a broad geographic range and infects many penaeid shrimp species, and because past procedures for screening of PL do not assure that infections will be detected, the risk of the virus being present in an imported sample and it being introduced to Fiji is conservatively considered to be **moderate**.

Exposure assessment

Survivors of IHHNV infections may carry the virus for life and pass it on to their progeny and other populations by vertical and horizontal transmission (Bell and Lightner 1984, Lightner 1996b, Morales-Covarrubias *et al.* 1999). Vertically infected larvae and early PL do not become diseased, but in approximately 35-day old or older juveniles, gross signs of the disease may be observed, followed by mass mortalities (Lightner *et al.* 1983, 1987; Bell and Lightner 1984, 1987; Lightner 1988, 1993, 1996b; Brock and Lightner 1990; Mari *et al.* 1993). In horizontally infected juveniles, the incubation period and severity of the disease are somewhat size and/or age dependent, with young juveniles always being the most severely affected. Infected adults seldom show signs of the disease or mortalities (Bell and Lightner 1984, 1987).

The possibility of IHHNV establishing in the wild has been proven in *L. stylirostris*, *L. vannamei* and *Farfantepenaeus californiensis* (Pantoja *et al.* 1999). At least two crustacean species native to Fiji are known to be susceptible (*P. monodon* and *P. semisulcatus*) to IHHNV. Individual *L. stylirostris* and *L. vannamei* that survive IHHNV infections and/or epizootics may carry subclinical infections for life. The virus may then be passed horizontally to other stocks, or vertically to offspring, if infected individuals are used as broodstock.

The receiving farms do not presently have the necessary facilities and operating procedures in place to prevent the potential escape of infected imported stocks (e.g., quarantine or isolation ponds) nor to prevent the entry of potential carriers and vectors (e.g. filtration of incoming sea water, fencing and control programs); nor are there sufficient safeguards (e.g., reservoir ponds for holding of water prior to discharge, treatment ponds, etc) to prevent the escape of infected shrimp or of WSSV virions in effluent waters. If IHHNV enters Fiji through imported *L. stylirostris*, the probability that susceptible prawns or other crustaceans will be exposed to a dose sufficient to cause infection is conservatively estimated to be **moderate**.

Consequence assessment

Two native species (*Penaeus monodon* and *P. semisulcatus*) in Fiji are natural hosts for IHHNV. Although the susceptibility of other crustacean species in Fiji has not been studied, the fact that IHHNV has a wide host range suggests that many of the wild crustacean species present in Fiji may be susceptible. IHHNV is transmitted vertically and horizontally, and has proven capacity to establish in wild populations.

The consequences of exposure to Fiji include possible impacts on local wild penaeid stocks, affecting local biodiversity and the artesian fishery for *Penaeus monodon*. More significantly, should IHHNV become established in carrier hosts, it will probably be impossible to eradicate, with negative consequences for the future development of shrimp aquaculture in Fiji and the marketability of Fijian product internationally. The consequence of IHHNV establishing in Fiji is considered **moderate**.

Risk management

Risk management measures should be implemented such that the ALOP recommended for Fiji is met. These mitigation measures are the same as those outlined in Section 11.3.2.1 for risk management for WSSV, the disease testing methods to follow those outlined by the OIE (2003) for IHNV.

11.2.3.3 Taura syndrome virus (TSV)

Although Taura syndrome virus (TSV) has been tentatively placed in the family Picornaviridae (Bonami *et al.* 1997), recent work has shown that it belongs within a proposed new grouping to include the 'Cricket paralysis-like viruses' because it more closely resembles certain presently unclassified insect ssRNA viruses, such as *Drosophila C virus* (DCV) (Mari *et al.* 2002). TSV is a 32 nm, icosahedral, non-enveloped viral particle with a buoyant density of 1.338g/ml. Its protein capsid is comprised of 3 major polypeptides and 1 minor polypeptide. The TSV genome consists of a linear, positive-sense, single stranded ribonucleic acid (ssRNA) of 10,205 bases (Mari *et al.* 2002).

Taura syndrome was first detected in shrimp farms near the Taura River, Ecuador (hence the name of the disease) in 1992. It then spread throughout most shrimp growing regions of Latin America and the Pacific coasts of Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama and Peru. It was also introduced to Hawaii but was successfully eradicated.

TSV has also been reported from cultured shrimp along the Atlantic coasts of Belize, Brazil, Columbia, Mexico and Venezuela and the southeastern U.S. states of Florida, South Carolina and Texas. TSV has, however, been successfully eradicated from cultured stocks in Florida and Belize. TSV is found in wild penaeids in Ecuador, El Salvador, Honduras and Mexico. TSV has recently spread to Asia through the introduction of *Litopenaeus vannamei* and has now been reported from Taiwan, Province of China; Indonesia, Thailand and Vietnam (Sunarto *et al.* 2004, de la Pena 2004, Van 2004).

Erickson *et al.* (2002) reported that anecdotal evidence of occurrences of TS epizootics in *L. stylirostris* since 1999 in Mexico suggests that a closely related virus might have evolved from the original Ecuadorian/Hawaiian isolate characterized by Bonami *et al.* (1997) and Mari *et al.* (2002). They noted the possibility that since 1994 a change in TSV structural protein may have occurred and that this change is now responsible for the emergence of TS in *L. stylirostris*, a previously refractive species (Brock *et al.* 1997).

TSV will be considered further because: (a) it causes significant disease; (b) *L. stylirostris* is a susceptible species; (c) it occurs in PL; and (d) at least two species (*P. monodon* and *P. semi-sulcatus*) in Fiji are susceptible.

Release assessment

There is no reliable assurance that the *L. stylirostris* to be imported from Brunei will be TSV-free. Because of the complete lack of information on the health status of the parent stocks in the country of origin, it is impossible to provide an accurate risk estimate. However, because TSV is one of the most serious pathogens affecting shrimp aquaculture, because it has spread rapidly between countries and regions due to the movement of infected broodstock and PL, and because past procedures for screening of PL do not assure that infections will be detected, the risk of the virus being present in an imported sample and it being introduced to Fiji is conservatively considered to be **moderate**.

Exposure assessment.

Shrimp that have survived the acute and transitional phases of TS can maintain chronic sub-clinical infections within the lymphoid organ for the remainder of their lives. These shrimp may transmit the virus horizontally to other susceptible shrimp. Vertical transmission is suspected, but this has yet to be conclusively demonstrated. In addition to human-mediated movement of subclinical carriers of TSV, aquatic insects and sea birds have been implicated in its transmission. The water boatman, *Trichocorixa reticulata* (Corixidae), feeds on dead shrimp and is believed to spread TSV by flying from pond to pond. Feces of laughing gull, *Larus atricilla*, collected from around TSV-infected ponds in Texas during the 1995 epizootic were also found to contain viable TSV Garza *et al.* 1997). Viable TSV has also been found in frozen shrimp products.

Survivors of acute TSV infection pass through a brief transitional phase and enter the chronic phase, which may persist for the rest of their lives. This subclinical phase of infection is believed to have contributed to the spread of the disease via carriage of viable TSV.

The receiving farms do not presently have the necessary facilities and operating procedures in place to prevent the potential escape of infected imported stocks (e.g., quarantine or isolation ponds) nor to prevent the entry of potential carriers and vectors (e.g., filtration of incoming sea water, fencing and control programs); nor are there sufficient safeguards (e.g., reservoir ponds for holding of water prior to discharge, treatment ponds, etc) to prevent the escape of infected shrimp or of TSV virions in effluent waters. If TSV enters Fiji through imported *L. stylirostris*, the probability that susceptible prawns or other crustaceans will be exposed to a dose sufficient to cause infection is conservatively estimated to be **moderate**.

Consequence assessment

At least two species in Fiji, one native (*P. monodon*) and the other an established exotic species (*F. merguensis*) are susceptible to TSV. Although the susceptibility of other crustacean species in Fiji has not been studied, the fact that TSV has a wide host range suggests that many wild crustacean species in Fiji may be susceptible.

The consequences of exposure to Fiji include possible impacts on local wild penaeid stocks, affecting local biodiversity; the artisanal fishery for *Penaeus monodon* is less likely to be impacted, as this species has only been infected experimentally and is considered probably to be resistant. More significantly, should TSV become established in carrier hosts, it will probably be impossible to eradicate, with negative consequences for the future development of shrimp aquaculture in Fiji and the marketability of Fijian product internationally. The consequence of TSV establishing in Fiji is considered **low**.

Risk management

Risk management measures should be implemented such that the ALOP recommended for Fiji is met. These mitigation measures are the same as those outlined in Section 11.3.2.1 for risk management for WSSV, the disease testing methods to follow those outlined by the OIE (2003) for TSV.

11.2.3.4 Yellow Head Virus (YHV)

Yellowhead disease (YHD) is caused by yellow head virus (YHV) (also reported in the older literature as yellowhead baculovirus (YBV) and yellowhead disease baculovirus (YHDBV). It is now known not to be a member of the Baculoviridae. YHV is a single stranded RNA, rod-shaped ($44\pm6 \times 173\pm13$ nm), enveloped cytoplasmic virus, likely related to viruses in the Family Coronaviridae. Agarose gel electrophoresis indicates a genome size of approximately 22 kb. Lymphoid organ vacuolization virus (LOVV) and gill associated virus (GAV) of *Penaeus monodon* in Australia are related to the YHV complex of viruses, although, of the two, only GAV is known to cause mortality.

Natural infections occur in *Penaeus monodon*, but experimental infections have been shown in *Marsupenaeus japonicus*, *L. vannamei*, *L. setiferus*, *Farfantepenaeus aztecus*, *F. duorarum* and *L. stylirostris*. *Fenneropenaeus merguensis* appears to be resistant to disease (but not necessarily infection). *Palaemon styliferus* has been shown to be a carrier of viable virus. *Euphausia* spp. (krill), *Acetes* spp. and other small shrimp are also reported to carry YHD viruses.

YHD affects cultivated shrimp in Asia, including China PR, India, Malaysia, the Philippines, Sri Lanka and Thailand. YHD has also been reported from cultured shrimp in Texas. YHV will be considered further because: (a) it causes significant disease; and (b) although *L. stylirostris* has only been infected experimentally, a shrimp species native to Fiji (*P. monodon*) is its main host, while another species native to Fiji (*P. semisulcatus*) is also known to become infected.

Release assessment

YHV is one of the most highly translocated and introduced pathogens affecting global aquaculture. It has a wide geographic and host range. There is no reliable assurance that the *L. stylirostris* to be imported from Brunei will be YHV-free. Because of the complete lack of information on the health status of the parent stocks in the country of origin, it is impossible to provide an accurate risk estimate. However, because YHV is one of the most serious pathogens affecting shrimp aquaculture, because it has spread rapidly between countries and regions due to the movement of infected broodstock and PL, and because past procedures for screening of PL do not assure that infections will be detected, the risk of the virus being present in an imported sample and it being introduced to Fiji is conservatively considered to be **moderate**.

Exposure assessment

As YHD has a wide geographic and host range, the probability of establishing infection is high. YHV, which infects all life stages of shrimp, is transmitted horizontally via infected shrimp (transmission is facilitated by cannibalism of weak or moribund shrimp) or via water. The major source of infection for rearing ponds is animate vectors (including infected but nondiseased carrier crustaceans) from pond inlet water. Survivors of YHV infection maintain chronic subclinical infections and vertical transmission is suspected with such individuals. There are a number of known or suspected carrier crustaceans, including the brackishwater shrimp *Palaemon styliferus* and *Acetes* sp., which can potentially transmit YHD to farmed shrimp.

The receiving farms do not presently have the necessary facilities and operating procedures in place to prevent the potential escape of infected imported stocks (e.g., quarantine or isolation ponds) nor to prevent the entry of potential carriers and vectors (e.g., filtration of incoming sea water, fencing and control programs); nor are there sufficient safeguards (e.g., reservoir ponds for holding of water prior to discharge, treatment ponds, etc) to prevent the escape of infected

shrimp or of YHV virions in effluent waters. If YHV enters Fiji through imported *L. stylirostris*, the probability that susceptible prawns or other crustaceans will be exposed to a dose sufficient to cause infection is conservatively estimated to be **moderate**.

Consequence assessment

One native species (*P. monodon*) and one established exotic species (*F. merguiensis*) in Fiji are susceptible to YHV, with *P. monodon* being the main host species. Although the susceptibility of other crustacean species in Fiji has not been studied, the fact that YHV has a wide host range suggests that many wild crustaceans present in Fiji may be susceptible.

The consequences of exposure to Fiji include possible impacts on local wild penaeid stocks, affecting local biodiversity and the artisanal fishery for *Penaeus monodon*. More significantly, should YHV become established in carrier hosts, it will probably be impossible to eradicate, with negative consequences for the future development of shrimp aquaculture in Fiji and the marketability of Fijian product internationally. The consequence of YHV establishing in Fiji is considered **moderate**.

Risk management

Risk management measures should be implemented such that the ALOP recommended for Fiji is met. These mitigation measures are the same as those outlined in Section 11.3.2.1 for risk management for WSSV, the disease testing methods to follow those outlined by the OIE (2003) for YHV.

11.2.3.5 *Baculovirus penaei* (BP)

Baculovirus penaei (BP - PvSNPV) and Mondon baculovirus (MBV – PmSNPV) are two Baculoviridae that cause nuclear polyhedrosis baculoviroses (NPB) infections. A number of names are associated with the diseases caused by these viruses - baculovirus disease, nuclear polyhedrosis disease, polyhedral inclusion body virus disease (PIB), polyhedral occlusion body virus disease (POB) and *Baculovirus penaei* (BP) virus disease.

Baculovirus penaei (BP) infects a wide range of penaeid shrimp including *Farfantepenaeus duorarum*, *F. aztecus*, *Litopenaeus setiferus*, *L. vannamei*, *L. stylirostris* and *Penaeus marginatus*. It has also been reported from *Fenneropenaeus penicillatus*, *L. schmitti*, *Farfantepenaeus subtilis* and *F. paulensis*.

The geographic distribution of BP covers the Americas from the Gulf of Mexico to Central Brazil on the East Coast and from Peru to Mexico on the Pacific Coast. BP has also been found in wild shrimp in Hawaii. Multiple strains of BP are recorded within this geographic range.

The impact of BP varies from species to species. *Farfantepenaeus aztecus* and *L. vannamei* are highly susceptible. *Litopenaeus stylirostris* is moderately susceptible and *Penaeus monodon* and *L. setiferus* appear to be resistant/tolerant. In susceptible species, BP infection is characterized by a sudden onset of high morbidity and mortality in larval and postlarval stages. Growth rates decrease, the shrimp stop feeding, appear lethargic and show signs of epibiont fouling (due to reduced grooming activity). The virus attacks the nuclei of hepatopancreas epithelia but can also infect mid-gut epithelia. Although infections may be chronic to acute, with high cumulative mortality, the presence of the BP virus is not always associated with disease and PL older than 63 days show no clinical signs of infection.

BP will be considered further because: (a) it affects *L. stylirostris* (moderately susceptible); and (b) it causes high cumulative mortalities.

Release assessment

There is no reliable assurance that the *L. stylirostris* to be imported from Brunei will be BP-free. Because of the complete lack of information on the health status of the parent stocks in the country of origin, it is impossible to provide an accurate risk estimate. However, BP is considered to be a potentially serious pathogen because it infects the larval, postlarval and early juvenile stages of host shrimps and possesses a wide host and geographic distribution. Also, as multiple strains of the virus have been documented and because past procedures for screening of PL do not assure that infections will be detected, the risk of the virus being present in an imported sample and it being introduced to Fiji is conservatively considered to be **moderate**.

Exposure assessment

BP is transmitted orally via uptake of virus shed with the feces of infected shrimp or cannibalism on dead and dying shrimp. Infected adults have also been shown to infect their offspring via fecal contamination of the spawned egg masses. If BP enters Fiji through imported *L. stylirostris*, the probability that susceptible prawns or other crustaceans will be exposed to a dose sufficient to cause infection is **moderate**.

Consequence assessment

BP infects cultured and wild *L. stylirostris*. Should BP find its way into wild populations, it will probably be impossible to eradicate, with negative consequences for the future development of shrimp aquaculture in Fiji and the marketability of Fijian product internationally. Thus, the consequence of HPV establishing in Fiji is **low**.

Risk management. Risk management measures should be implemented such that the ALOP recommended for Fiji is met. These mitigation measures are the same as those outlined in Section 11.3.2.1 for risk management for WSSV. The disease testing methods should follow those outlined by the OIE (2003) for BP.

11.2.3.6 Hepatopancreatic parvo-like virus (HPV)

A small (22 to 24 nm dia.) DNA parvovirus, hepatopancreatic parvovirus (HPV) has been observed in wild and cultured penaeids in Australia, and in cultured penaeids in the Yellow Sea area of China, Korea, Taiwan, the Philippines, Indonesia, Malaysia, Singapore, Kenya, Kuwait and Israel. As HPV was discovered in Asia and because all initial reports were from Asia and the Indo-Pacific region, it was previously considered to be a virus of Asian, African and Australian penaeids. However, HPV now has a cosmopolitan distribution. Since 1987, it has been found in Asian penaeid shrimp imported and cultured in South America and in cultured *Litopenaeus vannamei* in North and South America. Since 1990, HPV was found annually in native and wild *L. vannamei* and *L. stylirostris* along the Pacific coast of western Mexico and in wild adults from coastal El Salvador.

Ten penaeid species (*Fenneropenaeus merguensis*, *F. chinensis*, *F. penicillatus*, *F. indicus*, *Penaeus semisulcatus*, *P. esculentus*, *P. monodon*, *Marsupenaeus japonicus*, *Litopenaeus vannamei* and *L. stylirostris*) have been reported to be naturally infected.

HPV will be considered further because: (a) it affects *L. stylirostris*; and (b) it causes severe infections and has been reported in mortalities associated with multiple agent epizootics.

Release assessment

There is no reliable assurance that the *L. stylirostris* to be imported from Brunei will be HPV-free. Because of the complete lack of information on the health status of the parent stocks in the country of origin, it is impossible to provide an accurate risk estimate. HPV is an important pathogen of the Asian region. HPV naturally infects at least 10 penaeid species, both in native and wild hosts. Because past procedures for screening of PL do not assure that infections will be detected, the risk of the virus being present in an imported sample and it being introduced to Fiji is conservatively considered to be **moderate**.

Exposure assessment

HPV is transmitted either vertically from parent stock, or horizontally from shrimp to shrimp with efficiency only during the larval stages. If HPV enters Fiji through imported *L. stylirostris*, the likelihood that susceptible prawns or other crustaceans would be exposed to a dose sufficient to cause infection is considered **moderate**.

Consequence assessment

Aside from affecting cultured and wild *L. stylirostris*, HPV affects three other penaeid species in Fiji (*P. monodon*, *P. semisulcatus* and *F. merguensis*). Should HPV find its way into wild populations, it will probably be impossible to eradicate, with negative consequences for the future development of shrimp aquaculture in Fiji and the marketability of Fijian product internationally. Thus, the consequence of HPV establishing in Fiji is **moderate**.

Risk management

Risk management measures should be implemented such that the ALOP recommended for Fiji is met. These mitigation measures are the same as those outlined in Section 11.3.2.1 for risk management for WSSV. As HPV is not an OIE-listed disease, disease testing methods can follow those outlined by Lightner (1996).

11.2.3.7 Necrotising hepatopancreatitis (NHP)

Necrotising hepatopancreatitis (NHP) is caused by a bacterium that is relatively small, highly pleomorphic, Gram negative, and an apparent obligate intracellular pathogen. The NHP bacterium has two morphologically different forms: one is a small pleomorphic rod and lacks flagella, while the other is a longer helical rod possessing eight flagella on the basal apex and an additional flagellum (or possibly two) on the crest of the helix. The NHP bacterium occupies a new genus in the alpha Proteobacteria and is closely related to other bacterial endosymbionts of protozoans.

NHP was first described in Texas in 1985 and is also known as Texas necrotizing hepatopancreatitis (TNHP), Texas pond mortality syndrome (TPMS) and Peru necrotizing hepatopancreatitis (PNHP). NHP can infect both *Litopenaeus vannamei* and *L. stylirostris* but causes higher mortalities in the former species. NHP has also been reported in *Farfantepenaeus aztecus*, *F. californiensis* and *L. setiferus*. Outbreaks have also been reported in most Latin American countries on both the Pacific and Atlantic Ocean coasts, including Brazil, Costa Rica, Ecuador, Mexico, Panama, Peru and Venezuela. Early detection of clinical NHP is important for successful treatment because of the potential for cannibalism to amplify and transmit the disease. Molecular testing of PL from infected broodstock indicates that vertical transmission does not occur. Various environmental factors appear to be important for the onset of NHP clinical signs; the most prominent ones are water salinity over 16 ppt and water temperature of 26 °C or higher. Periodic population sampling and examination (through histopathology, TEM or

commercial gene probe) are highly recommended in farms with a history of NHP occurrence and where environmental conditions favor outbreaks. The use of the antibiotic oxytetracycline (OTC) in medicated feeds is probably the best treatment currently available, particularly if disease presence is detected early.

NHP will be considered further because it: (a) infects *L. stylirostris*; and (b) it causes significant mortalities in infected shrimp, although it causes higher mortalities in *L. vannamei* than *L. stylirostris*.

Release assessment

There is no reliable assurance that the *L. stylirostris* to be imported from Brunei will be NHP-free. The past procedures for screening of PL do not assure that infections will be detected. The risk of the bacterium being present in an imported sample and it being introduced to Fiji is conservatively considered to be **low**.

Exposure assessment

There is no evidence that NHP is transmitted vertically. NHP is transmitted horizontally from shrimp to shrimp with efficiency only during the larval stages. Cannibalism amplifies disease transmission. If NHP enters Fiji through imported *L. stylirostris*, the probability of susceptible prawns or other crustaceans to be exposed to a dose sufficient to cause infection is **low**.

Consequence assessment

NHP has a narrow host range. If detected early, NHP responds to antibiotic treatment. The consequence of HPV establishing in Fiji is **low**.

Risk management

As NHP is not an OIE-listed disease, disease testing methods can follow those outlined by Lightner (1996).

11.2.3.8 *Vibrio penaeicida*

De la Pena *et al.* (1993) isolated this distinct *Vibrio* from diseased Kuruma prawn, *Marsupenaeus japonicus*. Ishimaru *et al.* (1995), who named this new species, also detected it in apparently healthy prawns and water samples obtained from aquaculture ponds associated with diseased shrimp. *Vibrio penaeicida* has since been recognized as a true pathogen rather than an opportunistic invader as are other *Vibrio* spp. Costa *et al.* (1998) also reported that *V. penaeicida* causes a seasonal vibriosis (also known as “Syndrome 93”) affecting juvenile and broodstock of *L. stylirostris* in New Caledonia.

Vibrio penaeicida will be further considered because: (a) it infects *L. stylirostris*; and (b) it causes significant disease.

Release assessment

There is no reliable assurance that the *L. stylirostris* to be imported from Brunei will not be infected with *V. penaeicida*. Shrimp subjected to stress conditions (e.g., transport and handling) are made highly susceptible to *Vibrio* infection. The risk of the bacterium being present in an imported sample and it being introduced to Fiji is conservatively considered to be **low**.

Exposure assessment

Vibrio penaeicida has a narrow host range, and has so far been reported from only two species, *M. japonicus* and *L. stylirostris*. De la Pena *et al.* (1998) reported two possible routes of transmission (i) orally via ingestion of contaminated food (e.g., *M. japonicus* fed with *V. penaeicida* in feed caused 10-20% mortality) and (ii) entry through deep wounds in the cuticle via water (i.e., when physically injured shrimp are immersed in *V. penaeicida* contaminated water). If *V. penaeicida* enters Fiji through imported *L. stylirostris*, the likelihood of susceptible prawns or other crustaceans being exposed to a dose sufficient to cause infection is considered **low**.

Consequence assessment

So far *V. penaeicida* has only been reported from Japan and New Caledonia. To date, there is no report that it affects wild shrimp populations. The consequence of *V. penaeicida* establishing in Fiji is **low**.

Risk management

Risk management measures should be implemented such that the ALOP recommended for Fiji is met. As vibriosis caused by *Vibrio penaeicida* is not an OIE listed disease, diagnostic methods can follow those outlined by Costa *et al.* (1998).

11.3 Past Practice

This risk analysis is unusual in that importations of PL of *Litopenaeus stylirostris* had already commenced prior to the SPC commissioning the analysis. The procedures followed by the importer during the December 2003 importation of PL are considered to involve an unacceptably high level of pathogen risk. None the less, the parties involved are to be lauded for the efforts they have made to minimize the risk of pathogen transfer, even though these efforts are considered to be inadequate. There is little point in discussing these shortcomings after the fact; they can be corrected by following the recommendations made in this risk analysis, notably assuring that:

- Guarantees of the health status of the parent stock are adequate and have been verified.
- Samples of PL to be tested prior to shipment originate from the actual batch that will be imported.
- PL are tested for the hazards identified using the recommended diagnostic tests and with statistically appropriate sample sizes.
- All testing will be conducted by a laboratory with adequate experience and capability.
- Adequate government regulation of importations is applied.
- Infrastructure and biosecurity measures at the receiving farms are sufficient to minimize the chance of pathogen escape into natural waters
- There is adequate planning to recognize, control and eradicate exotic disease outbreaks in the receiving facilities.

11.4 Conclusions of the Pathogen Risk Analysis

Both Fiji and Brunei Darussalam, as members of the World Trade Organization (WTO), and Brunei, as a member of the Office International des Épizooties (OIE) are bound to fulfill their obligations as WTO/OIE members, particularly in implementing new agreements such as the *Agreement on the Application of Sanitary and Phytosanitary Measures* (the ‘SPS Agreement’). The principal objective of the SPS Agreement is to ensure that governments do not use food safety and quarantine requirements as unjustified trade barriers to protect their domestic agricultural industries from competitive imports. The SPS agreement also ensures that governments can give health protection priority over trade.

The absence of historical and current information on the health status of the stock of origin, and the lack of responsiveness of the exporter and Government of Brunei to provide information necessitate the application of the precautionary approach. ***Because of the high risk of introducing serious pathogens, further importations from this source should not be permitted until adequate information to assess risk is provided by Brunei.*** The Government of Fiji is urged make an official request to the Government of Brunei, both directly and through the offices of the SPC and OIE, to obtain this crucial information, which should be carefully evaluated prior to making a final decision as to whether or not to permit these introductions to continue. Fiji and Brunei should cooperate fully in order to address the critical information gaps in a timely and transparent manner.

Based on the preliminary hazard identification, six viruses and two bacteria were recognized as potentially serious hazards associated with the importation of PL of *Litopenaeus stylirostris* from Brunei Darussalam:

- White spot syndrome virus (WSSV)
- Infectious hypodermal and haematopoietic necrosis virus (IHHNV)
- Taura syndrome virus (TSV)
- Yellow head virus (YHV)
- *Baculovirus penaei* (BP)
- Hepatopancreatic parvo-like virus (HPV)
- Necrotising hepatopancreatitis (NHP)
- *Vibrio penaeicida*

Four of the six viruses (WSSV, IHHNV, TSV and YHV) are among the most serious pathogens of both cultured and wild shrimp. These pathogens have been introduced and spread on a global scale due to the irresponsible movement of shrimp broodstock and PL for aquaculture development, and perhaps through other means, such as via aquaculture products (e.g., frozen shrimp), other animal carriers (reservoir hosts, passive carriers), and other abiotic factors.

The associated levels of risk (release, exposure and consequence) for these pathogens exceed the appropriate level of protection (ALOP) recommended for Fiji (see Table 4). From an economic, social and biological perspective, it is well worth the cost and effort to protect Fiji, as far as possible, from the potential irreversible impacts of these pathogens.

Table 4. Summary of the results of assessment of unmitigated risk for eight potential hazards.

Pathogen ¹	Likelihood of Release	Likelihood of Escape	Probable Consequence
IHHNV	moderate	moderate	moderate
TSV	moderate	moderate	low
WSSV	moderate	moderate	moderate
YHV	moderate	moderate	moderate
BP	moderate	moderate	low
HPV	moderate	moderate	moderate
NHP	low	low	low
<i>V. penaeicida</i>	low	low	low

¹Infectious hypodermal and haematopoietic necrosis virus (IHHNV), Taura syndrome virus (TSV), white spot syndrome virus (WSSV), yellow head virus (YHV), *Baculovirus penaei* (BP), hepatopancreatic parvo-like virus (HPV), necrotising hepatopancreatitis (NHP).

Mitigation measures are available that can be applied to reduce the risk associated with all hazards to below that specified by the ALOP. The most important of these are:

- All shipments of PL to be imported into Fiji should be of "high health" status and should originate from a facility certified as using specific pathogen free (SPF) broodstock *L. stylirostris*. The facility must demonstrate a proven track record of producing PL free of the specific diseases through a documented history of pathogen surveillance, evidence of adherence to strict biosecurity protocols and an over-all health management plan. The facility must provide sufficient guarantees as to the health status and history of its stock. An on-site inspection visit to the production facility by an internationally recognized shrimp health expert on behalf of the Government of Fiji should be made to assure that the protocols, diagnostic procedures, security, etc. are adequate to validate guarantees of health status.^{10, 11}
- The production facility in the exporting country should also meet the following pre-border requirements:
 - o The batch of PL destined for export should be separated as early as possible from other stocks reared in the facility of origin and should be maintained in tanks separate from the rest of the stocks;
 - o Detailed records should be kept of the health status and mortality rates of each batch of *L. stylirostris*. Such records should be made available to the Competent Authority responsible for health certification;

10 SPF is a concept that is generally poorly understood (see Carr 1996, Lotz 1997). Once broodstock or PL produced by an SPF facility leave that facility, they are no longer considered to have SPF status for the specific pathogens indicated, because the level of biosecurity under which they are being maintained is now decreased. When transferred to a commercial hatchery or grow-out facility having adequate, albeit lower level health security, they and any nauplii and PL derived from them may be referred to as 'high health' shrimp. Because their health status is now less certain, a new historical record for that facility must be established.

11 An alternate approach, and one that would provide a higher level of protection from exotic disease, would be a single importation of a limited number of SPF broodstock *L. stylirostris* that would be used to establish a breeding program in a biosecure facility in Fiji.

- o A statistically appropriate sample taken from the batch intended for export should be tested for the eight pathogens using the recommended methods (for OIE listed diseases, these are the methods specified by OIE (2003));
 - o The testing should be performed by a recognized aquatic animal health laboratory in the exporting country that has been approved to undertake such work by the Competent Authorities of both the importing and exporting countries. If such a laboratory is not available in the exporting country, a competent laboratory in another country should be identified to perform the health certification.
 - o Should a batch of PL test positive for any of the eight hazards, the batch will be rejected and future importations from the infected production facility prohibited until such a time that freedom of the facility from disease can be clearly demonstrated.
- The importing country should implement the following post-border requirements:
 - o The receiving facility should meet minimum requirements with regard to its design and operation such that the risk of pathogen exposure is minimized. (see Annex I).
 - o A health monitoring system should be in place at the receiving facility so that a new historical record of health and mortality status can be established.
 - o No animals are to be removed from the receiving facility without prior permission from the Ministry of Fisheries and Forestry (MFF), Fiji;
 - o The operators must report any occurrences of serious mortalities or disease outbreak; and
 - o A farm level contingency plan should 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 (see Annex II).
- Importations from countries with a known history of occurrence of serious shrimp pathogens should be avoided unless the production facility is able to clearly demonstrate freedom from serious pathogens. Ideally, the country of origin should have capable veterinary or aquatic animal health services (an evaluation of the Competent Authority may be necessary) and an established program of disease surveillance and control in place to manage the disease.
- The stock of *Litopenaeus stylirostris* currently being cultured in Fiji is considered to represent a high risk to the national disease status. To reduce this risk, the following risk management measures are recommended:
 - o No animals should to be moved from the receiving facility (Gulf Seafood Fiji Ltd.) without prior permission from the Ministry of Fisheries and Forestry (MFF);
 - o The operators should be required to report any occurrences of serious mortalities or disease outbreak.
 - o The production facility should meet minimum standards of construction and operation so as to minimize the possibility that pathogens will gain access to natural waters through escapes, exposure of potential carriers, transfer by birds and other vectors, and release of virus into natural waters. Suggested standards are given in Annex I.

- o A contingency plan should 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 II.

12.0 Ecological Risk Analysis

12.1 Potential Invasiveness

Past experiences with exotic penaeid species introduced for aquaculture elsewhere in the world indicate that the escape of *L. stylirostris* from grow-out ponds in Fiji can be expected, due to accidents during harvesting and occasional flooding. In Thailand, a closely related exotic shrimp, *L. vannamei*, escaped into coastal waters and has been reported in fishermen's catches on the Andaman and Gulf of Thailand coasts. *Penaeus monodon*, originally from Hawaii, were introduced to the Atlantic coast of the United States when they were accidentally released by the Waddell Mariculture Center in 1988. Commercial shrimpers have subsequently captured giant tiger prawns as far south as Florida, although the species is not believed to have become established (McCann *et al.* 1996). Similarly, *P. monodon*, *L. vannamei*, *L. stylirostris* and *Marsupenaeus japonicus* are all known to have escaped culture facilities in Hawaii, although none are known to be locally established (Brock 1992a, Eldredge 1994). In the Pacific Islands, *M. japonicus* has escaped culture facilities but has failed to establish, while *F. merguensis* has become established in the wild in Fiji (Eldredge 1994). The effects, if any, that these exotic species have had on wild shrimp populations remain unknown (Briggs *et al.* 2004). There are no reports that escapes of *L. vannamei* have led to any perceivable impact on wild shrimp populations in Thailand. However, further research is needed on the ecology of this species in the wild and its impacts on fishermen's catches and native species (Briggs *et al.* 2004).

The potential area of Fiji for wild colonization includes contiguous waters that may have suitable habitat. The predicted spread, referenced from the site of culture, would initially include southern and western Viti Levu, with colonization eventually extending around the island and to Vanua Levu. Subsequent range expansion would be due to the westerly flowing South Equatorial current that sweeps the Fiji Archipelago and to the trade-wind generated current. Islands such as Kadavu and the Lau Group may be much more difficult to colonize, due the wide expanses of water and currents.

As populations of *L. stylirostris*, as with native prawns, are likely to establish in the estuaries of the larger rivers, the distances between these rivers may delay the spread of *L. stylirostris*, and ultimately, confine the larger populations to these areas.

12.2 Potential Ecological Impacts

Knowledge of the effects of cultured shrimp on wild populations and on biodiversity in general is lacking. The concern is that non-indigenous cultured shrimp may escape to the wild, displacing native shrimp populations thorough competition, hybridization and/or the transfer of serious pathogens (e.g., viruses) to naive stocks. In Fiji, the perceived risk would be if *L. stylirostris* were to occupy the same "ecological niche" as native species, competing for habitat (space) or feed or adversely interfering with the breeding success of native penaeid species.

If *L. stylirostris* occupies a "vacant" niche or if the abundance of other shrimp species is limited by other factors, it is possible that *L. stylirostris* has the potential to add to shrimp catches. However, if *L. stylirostris* does not breed and become established in the wild, any positive or negative impacts would likely be localized and limited in time.

12.2.1 Native Species Likely to be Impacted

Native species that may be impacted are the local penaeid prawns. *Penaeus monodon* and *P. semisulcatus* are widely distributed in the Indo-West Pacific from East and Southeast Africa and Pakistan to Japan, the Malay Archipelago, northern Australia, and east as far as Fiji and Tonga (Braley 1979, Holthuis 1980). *Penaeus latisulcatus* is also wide-ranging in the Indo-Pacific, from the Red Sea to Malaysia, the Moluccas to Korea, Japan and further east to Australia and Fiji (Racek and Dall 1965, Choy 1982). *Metapenaeus elegans* and *M. anchistus* are known from Sri Lanka, Malaysia, Indonesia and Fiji (Holthuis 1980, Choy 1982), while *P. canaliculatus* is distributed throughout an extensive area of the Indo-West Pacific, occurring from southeastern Africa to Taiwan, the Malay Archipelago, Fiji and Polynesia (Hothuis 1980).

Choy (1982), in a survey of penaeid prawns around Viti Levu, found *F. merguiensis* only at Ravi-ravi, Ba, in the vicinity of a discontinued Food and Agriculture of the United Nations/United Nations Development Programme (FAO/UNDP) fishpond project. The other species listed above were found in Laucala Bay near Suva, and in the estuaries of the Ba and Navua rivers and their adjacent lagoonal areas (Richards *et al.* 1994).

12.2.2 Predation

Litopenaeus stylirostris is omnivorous, preying on small marine invertebrates (e.g., worms, larval fish etc.). When raised at high stocking densities, they can exhibit inter-specific aggressive behavior; however, in the wild, the expansive habitat should preclude this behavior.

Prawns are generally considered prey for larger predatory marine organisms such as fish.

12.2.3 Competition

Litopenaeus stylirostris has a typical penaeid life cycle in which the postlarval stages develop in coastal areas. Inshore areas such as bays, estuaries, creeks and river mouths are extensive, and the litter fields utilized by *Penaeus monodon* are common. The two areas where there is some understanding are Laucala Bay for *P. canaliculus*, and the south arm of the Nadi River delta for *P. monodon*. In this latter case, the abundance of prawns is locally correlated to the amount of rainfall. High and consistent rainfall removes mangrove litter from the intertidal forests and deposits it on the margin of the delta, where prawns are harvested from November to April.

Due to the large spatial areas available to populations of penaeid prawns, it is unlikely that there will be a loss of native species due the escape and establishment of *L. stylirostris* in Fijian waters. The potential for alteration of the trophic structure is not believed to be a problem due to the omnivorous nature of the prawns and their naturally sparse occurrence.

12.2.4 Genetic Impacts

Aggregations of *L. stylirostris* occur in their natural wild range, and breeding aggregations are characteristic of this species in the wild. This feature differentiates *L. stylirostris* from *P. monodon*, which doesn't exhibit large "boils" reflecting breeding aggregations. It is because of this characteristic that hybridization with *P. monodon* is considered unlikely to occur.

Benzie (2000) found no conclusive evidence that aquaculture escapees had altered the genetic constitution of wild stocks of *P. monodon* in Thailand. However, this research was conducted before the introduction of *L. vannamei*.

12.3 Qualitative Ecological Risk Assessment

12.3.1 Results

The results of a qualitative ecological risk assessment are presented in Tables 5-7. Table 5 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 6 and 7 follow the review and decision model of Kohler (1992), where questions are answered to appraise the proposed introduction of *Litopenaeus stylirostris*. In Table 6, questions are answered with a numerical value. The scores derived from this model are utilized at the decision points in the model in Table 7.

Table 5. Ecological risk assessment criteria for *Litopenaeus stylirostris* (modified from ICES 2003).

Assessment Parameter	Supportive Report Sections	Risk Assessment ¹	Uncertainty Estimate ²
Estimate the probability of <i>L. stylirostris</i> successfully colonizing and maintaining a population in the receiving waters of the culture facilities	Sections 2.0, 11.5	2	3
Inadequate food supply	12.2.2,12.2.3	1	3
Predation on native species	Sections 11.1, 11.4	1	3
Inadequate prey availability	Sections. 2.0, 11.1, 11.2	1	3
Qualitatively or quantitatively affecting the availability of food for native species	Section 11.2	1	3
Inadequate habitat availability	Sections 11.3, 11.5	1	3
Unsuitable habitat	Section 11.5	1	3
Likely establishment of breeding population	Sections 11.3, 11.5	1	2
Ability for dispersal	Section 9.0	2	3
Human intervention to retard or enhance spread	Sections 4.2.1, 10.0	1	3
Ecological impact on native ecosystems locally or in a broader sense	Section 11.3	1	3
Alteration of native habitat	Section 2.0	1	4

¹Risk assessment scale: 3 = high probability, 2 = medium probability, 1 = low probability, ND = no data.

²Uncertainty estimate scale: 4 = very certain, 3 = reasonably certain, 2 = reasonably uncertain, 1 = very uncertain, ND = No data.

Table 6. Results of the questionnaire for appraisal of the introduction of *Litopenaeus stylirostris* to Fiji, used in conjunction with the review and decision model given in Table 7 (modified from Kohler 1992).

	Question	Response					
		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 and 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. If established, 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

¹This issue is addressed in the pathogen risk analysis section of this report.

Eldredge (1994) notes that although escapes of *L. vannamei*, *L. stylirostris*, *P. monodon* and *Marsupenaeus japonicus* due to pond flooding have occurred in Pacific Island countries, they are not known to have led to the establishment of local populations. Thus, although escapes of *L. stylirostris* from Fijian aquaculture sites are likely, such escapes may not necessarily lead to the establishment of wild populations. The fact that previous introductions of *L. stylirostris* to other areas of the Pacific have not led to the establishment of local populations indicates a low ecological impact. In the case of the escape and establishment of *F. merguensis* in Fiji, the population has remained localized in a single estuary, possibly due to the spatial distance between low saline water sources essential for breeding.

The breeding characteristics of *L. stylirostris*, which include prominent mid-water aggregations, suggest that the escape of a few individuals may not be adequate to establish a wild population.

Although the escape of *L. stylirostris* at some point in time is probable, this risk analysis indicates that if a wild population is established, its impacts are more likely to be beneficial, due to its potential to increase local fisheries resources, than detrimental, due to adverse ecological impacts. Although lack of data is always a problem in considering the likely ecological impacts of an exotic species introduction, the existing information indicates that the introduction of *L. stylirostris* to Fiji is unlikely to be detrimental to the local ecosystem.

13.0 Recommendations

- Based on past practices, it is recommended that Fiji adopt an appropriate level of protection (ALOP) that is "very conservative" and with an acceptable level of risk that is "very low".
- Because of the absence of historical and current information on the health status of the proposed stock of origin in Brunei, the precautionary approach should be applied. ***Because of the high risk of introducing serious pathogens, further importations from this source should not be permitted until adequate information to assess risk is provided by Brunei.***
- The Government of Fiji should make an official request to the Government of Brunei Darussalam, both directly and, if necessary, through the offices of the SPC and OIE, to obtain this crucial information, which should be carefully evaluated prior to making a final decision as to whether or not to permit these introductions to continue.
- Mitigation measures should be applied to reduce the risk that imported PL will be infected with the six viruses and two bacteria that were identified as potentially serious hazards having risk levels exceeding the ALOP suggested for Fiji: WSSV, IHHNV, TSV, YHV, BP, HPV, NHP and *Vibrio penaeicida*. These include that:
 - o All shipments of PL to be imported into Fiji should be of "high health" status and should originate from a facility certified as using specific pathogen free (SPF) brood-stock *L. stylirostris*. The facility must demonstrate a proven track record of producing PL free of the specific diseases through a documented history of pathogen surveillance and evidence of adherence to strict biosecurity protocols and an over-all health management plan. The facility must provide sufficient guarantees as to the health status and history of its stock. An on-site inspection visit to the production facility by an internationally recognized shrimp health expert on behalf of the Government of Fiji should be made to assure that the protocols, diagnostic procedures, security, etc. are adequate to validate guarantees of health status.

- o The production facility in the exporting country should also meet the following pre-border requirements:
 - The batch of PL destined for export should be separated as early as possible from other stocks reared in the facility of origin and should be maintained in tanks separate from the rest of the stocks;
 - Detailed records should be kept of the health status and mortality rates of each batch of *L. stylirostris*. Such records should be made available to the Competent Authority responsible for health certification;
 - A statistically appropriate sample taken from the batch intended for export should be tested for the eight pathogens using the recommended methods (for OIE-listed diseases, these are the methods specified by OIE (2003));
 - The testing should be performed by a recognized aquatic animal health laboratory in the exporting country that has been approved to undertake such work by the Competent Authorities of both the importing and exporting countries. If such a laboratory is not available in the exporting country, a competent laboratory in another country should be identified to perform the health certification.
 - Should a batch of PL test positive for any of the eight hazards, the batch will be rejected and future importations from the infected production facility prohibited until such a time that freedom of the facility from disease can be clearly demonstrated.
- o The importing country should implement the following post-border requirements:
 - The receiving facility should meet minimum requirements with regard to its design and operation such that the risk of pathogen exposure is minimized. Suggested standards are outlined in Annex I.
 - A health monitoring system should be in place at the receiving facility so that a new historical record of health and mortality status can be established.
 - No animals are to be removed from the receiving facility without prior permission from the Ministry of Fisheries and Forestry (MFF), Fiji;
 - That the operators must report any occurrences of serious mortalities or disease outbreak; and
 - A farm level 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 II.
- To reduce the high risk to the national disease status posed by the stock of *Litopenaeus stylirostris* currently being cultured in Fiji, the following risk management measures are recommended:
 - o No animals should be moved from the receiving facility (Gulf Seafood Fiji Ltd.) without prior permission from the Ministry of Fisheries and Forestry (MFF);
 - o The operators should be required to report any occurrences of serious mortalities or disease outbreak;

- o The production facility should meet minimum standards of construction and operation so as to minimize the possibility that pathogens will gain access to natural waters through escapes, exposure of potential carriers, transfer by birds and other vectors, and release of virus into natural waters (see Annex I).
 - o A contingency plan should 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 methods, and the facility fully disinfected before restocking. **(see Annex II).**
- In order to better understand why local stocks of *Penaeus monodon* have not performed satisfactorily under culture conditions, studies on Fijian stocks of wild *P. monodon* should be conducted to answer such basic questions as species distribution and seasonal movements, fecundity, morphology, reproductive performance, pathogens, etc.
 - 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).
 - As a long-term goal, the Ministry of Fisheries and Forestry, Fiji should obtain access to appropriate aquatic animal health expertise and capacity to meet national needs, and that as part of its national aquatic animal health strategy, a disease surveillance program should be implemented to determine the national aquatic animal health status. The USP, the SPC and other bilateral and multilateral agencies should be approached to assist in this effort on a regional basis.

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Some Minimum Standards for Marine Shrimp Production Facilities to Reduce the Risk of Pathogen Movement to and from Natural Waters

This annex briefly presents some actions that can be taken to minimize the possibility of pathogen movement to and from natural waters via wild carriers and other vectors. More detailed information regarding farm location and design, general health management measures and other biosecurity measures for shrimp farms (including hatcheries) can be found in Chanratchakool *et al.* (1998), FAO/NACA (2000), Fegan *et al.* (2000), Fegan and Clifford (2001) and FAO (2003). The specifics of a quarantine facility should be carefully planned and constructed with input from farm engineers, biologists and farm staff to make sure that the design serves the purpose and is practical, cost-effective and commensurate to the level of risks posed.

- Design quarantine areas in such a way that allows easy isolation of a problem or an infected pond to minimize spread within a farm.
- Hold incoming shrimp stocks off-site or in a restricted portion of the farm (quarantine area) until testing procedures have established that they are free of disease, at least to an acceptable level.
- For farmers who have no access to holding facilities, stock PL for 2-3 weeks in 9-m³ floating cages (300-500 micrometer mesh) at a density of 1500/m² in order to reduce contact with potential pathogen carriers and to facilitate disease observation.
- Enhance severity or prevalence of a disease, if present, during quarantine, through crowding or stressing of shrimp to allow for easier disease detection.
- Provide areas for disposal of diseased stocks and holding of water from infected ponds for treatment before disposal.
- Sterilize effluents from quarantine facilities in an appropriate manner.
- Do not discharge effluent waters directly into natural waters.
- All equipment (nets, containers, pumps, hoses, pipes, etc.) should remain with the containment facility and not removed nor used for any other purpose unless disinfected.
- Provide vehicle wheel baths and washing arches similar to those in terrestrial animal quarantine stations.
- Set water exchange to minimum levels, as this offers two main advantages: (a) it excludes viral carriers of free virions from the ponds, and (b) it avoids fluctuations in water quality, which is a source of stress and can trigger an outbreak of disease.
- Prevent water from the affected ponds from coming into contact with the inlet water for the affected farm or any neighboring farms.
- Provide reservoir ponds for water storage and treatment of incoming and outgoing (drained) water.
- Filter incoming sea water through the fine-mesh filter bags.
- Use selective screens at the entrance to the farm or individual ponds.
- Use small fences to prevent the movement of crabs between ponds and canals.
- Use proven chemical treatment to eliminate potential vectors in the vicinity of ponds (e.g., chlorine compounds, insecticides).

- Take measures to prevent access by birds (e.g., bird repelling techniques like the use of thin monofilament mesh across ponds) and small mammals to culture facilities.
- Implement health monitoring and record keeping, as essential activities.
- Take actions to avoid possible escapes brought about by extreme weather conditions (storms, flooding, etc.).
- Samples leaving the quarantine facility should be delivered by approved quarantine personnel or be preserved or secured for handling by non-quarantine personnel (e.g., clear handling and delivery instructions, sealed water proof containers, documentation, etc.).
- Develop a farm-level contingency plan for actions to be taken in the event of an outbreak (see Annex II).

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

Capacity and procedures should be developed so that the following actions can be accomplished, as appropriate, on an emergency basis:

- 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.
- Avoiding the re-introduction of the pathogen from nearby culture facilities, wild shrimp or subclinical carriers.

ANNEX III

Summary records for temperature, sunshine and rainfall for the period of 1971-2001 for the town of Navua.

Weather for Stations in Fiji

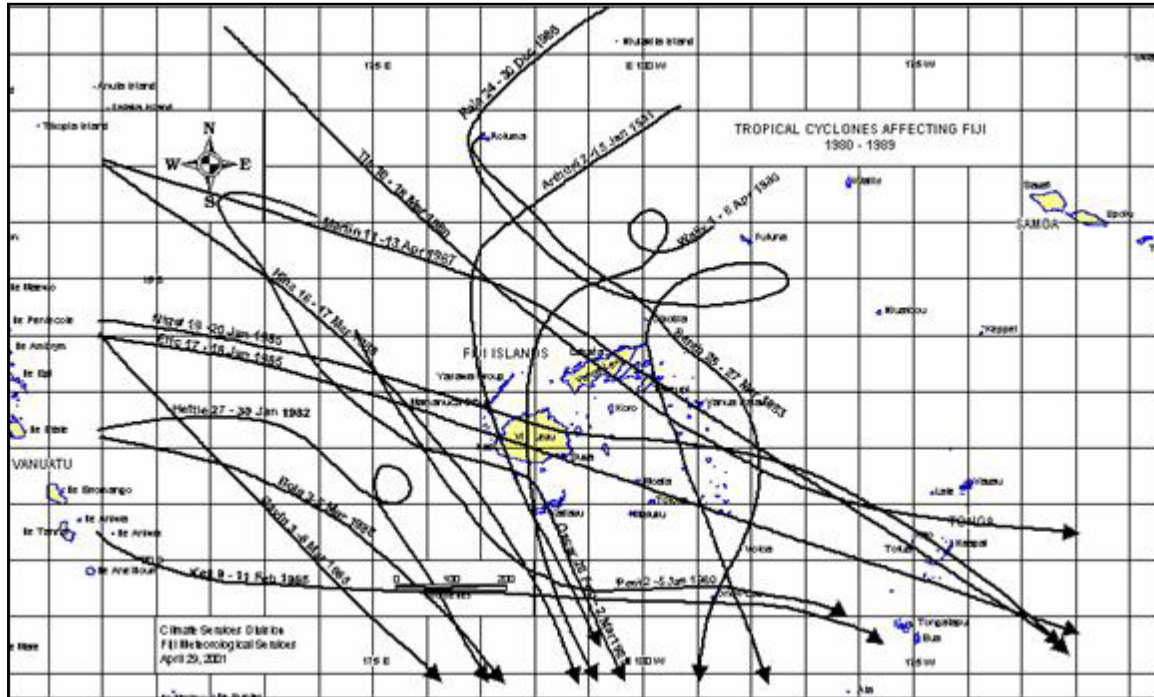
Navua

Latitude 18° 13S; Longitude 178° 10E

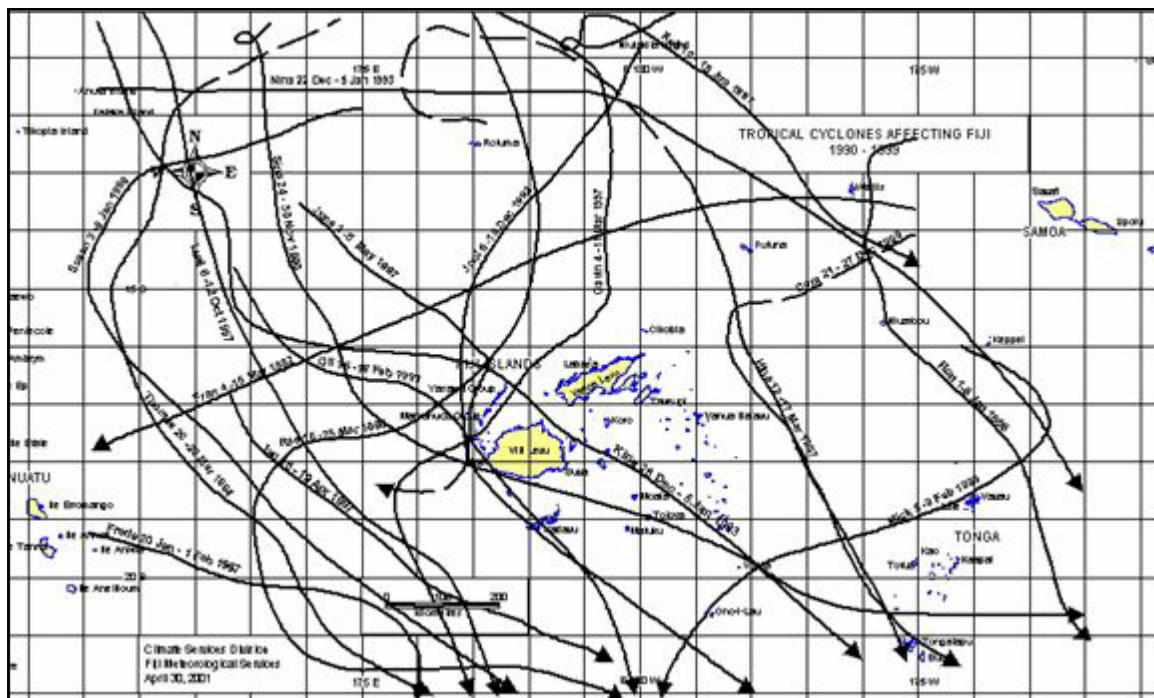
Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maximum temp °C for 1971-2000	30	31	31	30	29	28	27	27	27	28	29	30
Minimum temp °C 1971-2000	22	22	22	21	20	19	18	18	18	19	20	21
Sunshine (hrs) 1971-1993	203	158	156	129	113	115	114	128	142	150	152	164
Rainfall (mm) 1971-2001 Aver. Annual Total 3599mm	396	278	431	442	303	194	185	198	230	281	312	349

Cyclones in Fiji during the periods of 1980-1989 and 1990-1999.

A. 1989-1989



B. 1990-1999



Average rainfall for Viti Levu (Fiji Meterological Service 1984)

