As part of the import risk analysis process, this document has been prepared by the prawn risk analysis panel. This draft document is for review purposes only and does not constitute Australian Government Policy.

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EXECUTIVE SUMMARY

In 1996, the National Taskforce on Imported Fish and Fish Products identified non-viable prawns as a high priority for import risk analysis (IRA). The IRA commenced shortly thereafter but was delayed due to modification of the AQIS IRA process, an appeal against the risk analysis panel membership, and recently due to the considerable resource demands required for the salmon and related IRAs.

This draft report describes in detail the IRA for non-viable prawns.

Consultation

AQIS has taken several steps to ensure the scientific validity of the risk analysis, including considering the reports of several consultancies on identified gaps in information relating to the risk analysis. As the IRA is non-routine, a risk analysis panel (RAP) consisting of AQIS officers and external scientific experts was established to conduct the IRA. The RAP consists of Dr Sarah Kahn (Chair, AQIS), Dr Glenn Hurry (AFFA), Dr Dick Callinan (NSW Fisheries), Dr Leigh Owens (James Cook University, who replaced Dr Steve Percival in 1998) and Dr Brett Edgerton (Secretariat, AQIS). Additional comments on consultancy reports and technical documents were provided by Dr Don Lightner (University of Arizona).

AQIS did not ask independent scientists to advise on Australia’s appropriate level of protection (ALOP) as this is the responsibility of the Australian Government, having regard to the broad range of quarantine decisions and precedents within AQIS’s purview.

The process for non-routine IRA has been followed which provides for periods of 30 days to comment on the type of risk analysis to be conducted (ie. routine or non-routine), 30 days to comment on timing and RAP membership, and 60 days to comment on a technical issues paper. Stakeholders have a period of 60 days to provide comment on this draft IRA report.

Scope of the risk analysis

This IRA considers the quarantine risks associated with the importation to Australia of non-viable prawns and prawn products. The IRA is ‘generic’ and addresses all relevant pests and diseases, to facilitate assessment of individual access requests according to the health status of the source country and product factors. For simplicity, and unless otherwise indicated by the text, in this IRA the term ‘prawn product’ is used to collectively refer to non-viable whole prawns, processed prawns and other products containing materials derived from prawns.

In this IRA, the term ‘prawn’ refers to the marine and freshwater prawns within the families Aristeidae, Peneidae, Solenoceridae, Palaemonidae and Pandalidae which contains all species commonly traded internationally.

International codes

In preparing this IRA, AQIS has drawn upon principals outlined in the Office International des Epizooties (OIE, or World Organisation for Animal Health) International Aquatic Animal Health Code (the Aquatic Code) and the OIE International Animal Health Code.
The Aquatic Code classifies aquatic animal diseases as diseases notifiable to the OIE (transmissible diseases that are important for public health and/or trade reasons); and other significant diseases (diseases that are of current or potential international significance in aquaculture but of less importance than the notifiable diseases, are less widespread, or have less well-defined aetiology).

**Australian quarantine policies**

The Quarantine Act 1908 and subordinate legislation, including Quarantine Proclamation 1998 (QP 1998), are the legislative basis of human, animal and plant quarantine in Australia.

AQIS’s objective is to adopt quarantine policies that provide the health safeguards required by government policy in the least trade-restrictive way. Wherever appropriate, measures are based on international standards.

Under the Quarantine Act, the importation into Australia of any articles likely to introduce any infectious or contagious disease, or disease or pest affecting persons, animals or plants can be prohibited under proclamation of the Governor General, generally or subject to any specified conditions or restrictions.

In developing quarantine policies, the disease risks associated with importations are analysed using IRA, which is a structured, transparent and science-based process that provides the scientific and technical basis for quarantine policies and determines whether an import may be permitted and, if so, the conditions to be applied.

**Import risk analysis**

AQIS has evaluated the risks associated with individual diseases and disease agents, and has proposed measures appropriate to the risks presented by the importation of non-viable prawns. The IRA is ‘generic’ and addresses all relevant pests and diseases.

The IRA is being conducted according to the method previously set out by AQIS in its publication *The AQIS Import Risk Analysis Process Handbook* (1998). This process, which involves the risk analysis steps of hazard identification and characterisation, risk assessment and risk management, is consistent with Australia’s obligations under the SPS Agreement and relevant recommendations of the OIE.

In the light of consultations with independent scientists and risk analysts, AQIS conducted this risk analysis on a qualitative, rather than a quantitative basis. This was due to the complexity of the analysis (the large number of species and disease agents considered), the limited data on some key questions (such as the minimum infective dose of many pathogens) and the uncertainty about some important issues, such as the susceptibility of native species to the disease agents under consideration. In deciding to use the qualitative approach, AQIS also took into account the fact that this is consistent with OIE recommendations and the obligations of WTO members.

**Hazard identification**

AQIS used the following criteria to identify the disease agents of quarantine concern that required further consideration in the IRA. A disease agent was given detailed consideration in the IRA if it was assessed to be:
1. infectious;
2. (a) exotic to Australia, or
   (b) present in Australia but subject to official control; and
3. (a) OIE listed, and/or
   (b) would be expected to cause significant harm in Australia.

Where there were no definitive data relevant to categorisation, AQIS made conservative judgments, drawing upon scientific knowledge and observations made in similar situations, and other appropriate information.

**Risk assessment**
Quarantine risk is composed of two related factors — the probability of the disease agent entering and becoming established in Australia, and the expected impact or significance (consequences) of such establishment. The IRA method used by AQIS addressed both these factors in a standardised manner to allow consistency in the overall approach to risk management, as follows.

- **Release assessment** — the probability that the agent will enter Australia as a consequence of the importation of non-viable prawns.
- **Exposure assessment** — if the disease agent entered Australia in non-viable prawns, the probability of susceptible prawns or other crustaceans being exposed to a dose sufficient to cause infection.
- **Probability of disease establishment** — combining assessment 1 and 2.
- **Consequence assessment** — the consequences of the disease agent establishing in Australia.

These factors were categorised for each disease of concern, using standardised criteria to obtain qualitative measures of the probability of disease establishment and the consequences. These measures were applied to a risk evaluation matrix to determine if for non-viable prawns imports, Australia’s acceptable level of protection (ALOP) would be met and whether risk management measures were warranted.

**Risk management**
For non-viable prawns, the disease agents for which control measures are required in order to meet Australia’s ALOP were identified as:

- white spot syndrome virus (WSSV); and
- yellowhead virus (YHV).

In the case of each disease, AQIS considered risk management measures that would be required if the importation of non-viable prawns was to be permitted while meeting the ALOP. These proposed measures include pre-export requirements for the country of origin and post-import measures that could be imposed in Australia.

It is noted that the implementation of measures required for WSSV and YHV would reduce the risks associated with emerging but as yet unknown pathogens, and would effectively manage risks associated with pathogens such as Taura syndrome virus in the unlikely event that such agents enter Australia and Australian prawn species prove susceptible.
Finally, measures are proposed specifically for prawn feed which may contain prawn material.

**Policies for import of non-viable prawns**

Based on the above procedures, the following risk management measures are proposed for the import of non-viable prawns:

- The prawns are cooked;
- or
- The prawns are processed in a premises approved by and under the control of a competent authority;
- Consignments exported to Australia are accompanied by official certification confirming that the exported prawns meet Australia’s import conditions in full;
- Prawns are inspected and graded under the supervision of a competent authority;
- The product for export is free from visible lesions associated with infectious disease and fit for human consumption; and
- Prawns of less than a certain size are processed to a minimum standard, ie removal of the cephalothorax.

Commercial processing of imported green prawns in Australia must be conducted at a premises approved by AQIS.

The following risk management measures are proposed for the import of prawn feed containing material derived from prawns or other crustacea:

- Consignments of prawn feeds are accompanied by official certification confirming that:
  1. all crustacean tissue in the prawn feed has been heated at 85°C for 15 minutes or 80°C for 20 minutes; and
  2. The prawn feed has been processed in a premises that uses a program (eg. Quality Assurance) approved and audited to the satisfaction of the certifying agency that ensures the product is manufactured to specification.
CHAPTER 1: INTRODUCTION

This report contains the draft findings by the Australian Quarantine and Inspection Service (AQIS) from its import risk analysis (IRA) on non-viable prawns and prawn products. This report is being circulated for comment before finalisation.

Chapter 1 provides an introduction to the IRA dealing with the process to date, scope of the analysis and method used to evaluate quarantine risk. Chapter 2 outlines the socio-economic importance of prawns in Australia. Chapter 3 presents general information on the quarantine risk associated with the importation of the commodities covered by the IRA, including the exposure scenarios through which the pathogens could establish in Australia. In Chapter 4 the pathogens that require detailed consideration are identified (ie hazard identification). In Chapter 5 the unrestricted risk estimate for each of the identified pathogens is determined and conclusions made as to whether risk management measures are required (ie risk assessment). Chapter 6 evaluates the risk management measures that may be applied (ie risk management). Chapter 7 contains conclusions and draft recommendations on the measures to be applied to the importation of non-viable prawns and prawn products. Appendix 1 considers comments made during the IRA process on Technical Issues Paper and consultancy reports.

1.1 Background to import risk analysis

In 1992 AQIS commissioned the then Bureau of Rural Resources, later Bureau of Resource Sciences (BRS), to conduct a major review of aquatic animal health and quarantine. The report, which was released in 1995, was a comprehensive examination of Australia’s quarantine policies and practices in relation to aquatic animals and their products (Nunn 1995). The BRS report identified concerns in relation to quarantine policy on importation on several aquatic species, including prawns. It considered the review of a consultant, Dr J D Humphrey, and identified concerns in relation to quarantine policy on importation of several aquatic species (Humphrey 1995).

In 1995, the National Task Force on Imported Fish and Fish Products (NTF) was established to examine the BRS report and related issues. The NTF included representatives of relevant Commonwealth agencies, State/Territory agencies, commercial and recreational fisheries, importers, aquaculturists, research organisations and environment groups. Inter alia the NTF recommended changes to Australia’s policies on aquatic animal health and quarantine. The NTF considered that AQIS should review aquatic animal quarantine and indicated the specific policies and practices that should be reviewed with high priority; the importation of prawns and prawn products was recommended for review with high priority (Higgins 1996).

In 1996, a committee chaired by Professor Nairn conducted a detailed independent review of Australian quarantine (Nairn et al. 1996). The committee finalised its report in 1996 and its recommendations were accepted by Government.

AQIS advised stakeholders of the commencement of its aquatic animal quarantine policy review in September 1996, and invited stakeholder comment. In November 1996 AQIS imposed interim restrictions on the entry of uncooked prawns not fit for human consumption to address concerns of risks potentially associated with the use of imported prawns as fishing bait.
In September 1997, following the adoption of the revised IRA methodology arising from the Nairn Report (Nairn et al. 1996), AQIS advised stakeholders that it proposed to use the ‘non-routine’ approach to the IRA, involving the formation of a risk analysis panel (RAP). The RAP released a technical issues paper in November 1998\(^1\) for public comment. Comments received were evaluated and are addressed as appropriate in this paper (see Appendix 1). The reports of consultancies commissioned by the RAP to investigate issues relevant to the IRA were made available to the public via the AQIS internet homepage\(^2\). The consultancies are titled as follows:

- ‘Economic impact of the establishment of exotic prawn diseases’ by Alliance Resource Economics;
- ‘Environmental impact of the establishment of exotic prawn pathogens in Australia’ by AusVet Animal Health Services;
- ‘Routes for exposure of aquatic animals to aquatic animal products intended for human consumption’ by Aquaculture Development and Veterinary Services;
- ‘Sampling imported aquatic animal products for quarantine purposes’ by Cannon et al.
- ‘Report on description and processing of ingredients used in the manufacture of prawn feeds’ by AquaTactics; and
- ‘Case study: Charoen Pokphand prawn feed mill in Samut Sakorn Province, Thailand’ by Edgerton and Owens.

### 1.2 Scope of this import risk analysis

This IRA considers the quarantine risks associated with the importation to Australia of non-viable prawns and prawn products. The IRA is ‘generic’ and addresses all relevant pests and diseases, to facilitate assessment of individual access requests according to the health status of the source country and product factors. For simplicity, and unless otherwise indicated by the text, in this IRA the term ‘prawn product’ is used to collectively refer to non-viable whole prawns, processed prawns and other products containing materials derived from prawns.

The base product considered in this IRA is whole, non-viable, green prawns. Whole, non-viable, green prawns are sold for human consumption internationally, reflecting the absence of any recommendation from the Office International des Epizooties (OIE, or World Organisation for Animal Health) for trade in such prawn products. The IRA does not deal with commercially sterile, canned prawn product, live prawns or viable prawn genetic material.

AQIS has evaluated the risks associated with individual diseases and disease agents, and has identified measures appropriate to the risks presented by each agent. Based on this evaluation, risk management measures for non-viable prawns and prawn products have been proposed, including the means for verifying the health certification provided by exporting countries.

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In this IRA, the term ‘prawn’ refers to the marine and freshwater prawns within the families Aristeidae, Penaeidae, Solenoceridae, Palaemonidae and Pandalidae which contains all species commonly traded internationally. They can be taxonomically classified as follows:

Superclass Crustacea
Class Malacostraca
Order Decapoda
Suborder Dendrobranchiata
  Superfamily Penaeoidea
    Family Aristeidae
    Family Penaeidae
    Family Solenoceridae
Suborder Pleocyemata
  Superfamily Caridea
    Family Palaemonidae
    Family Pandalidae

This list was compiled from several sources including the NCBI taxonomy browser and Pérez Farfante and Kensley (1997). Taxonomic classification within the Superfamily Penaeoidea is based on the recent taxonomic revision by Pérez Farfante and Kensley (1997). Relevant to this report is the raising of five subgenera of *Penaeus* to genera, namely *Farfantepenaeus*, *Fenneropenaeus*, *Litopenaeus*, *Marsupenaeus* and *Melicertus*.

1.3 International framework

1.3.1 World Trade Organization

As a member of the World Trade Organization (WTO), Australia has certain rights and obligations under the WTO Agreement, including the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement). The SPS Agreement recognises the standards, guidelines and recommendations developed by the OIE for animal health and zoonoses as the relevant international benchmark (see section 1.3.2). Under the SPS Agreement, measures put in place by a country must be based on an international standard or, if more restrictive than the international standard, must be based upon a scientific risk assessment. A risk assessment must:

- identify the diseases whose entry, establishment or spread a WTO member wants to prevent within its territory, as well as the potential biological and economic consequences associated with the entry, establishment or spread of these diseases;

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• evaluate the likelihood of entry, establishment or spread of these diseases, as well as the associated potential biological and economic consequences; and

• evaluate the likelihood of entry, establishment or spread of these diseases according to the SPS measures which might be applied.4

The evaluation may be undertaken either qualitatively or quantitatively. However, the evaluation must consider ascertainable rather than theoretical risks in the risk assessment, that is, it is necessary to look at the probability of particular events occurring, not just at the theoretical possibility of their occurrence. In other words it is not sufficient to consider that an event may or may not occur (i.e. is possible), consideration must be given to the likelihood or probability that the event will occur. Additionally, an SPS measure must be ‘based on’ a risk assessment, that is there must be a rational relationship between the measure and the risk assessment.

The SPS Agreement defines ‘appropriate level of sanitary or phytosanitary protection’ as the level of protection deemed appropriate by the member country establishing a sanitary or phytosanitary measure to protect human, animal or plant life or health within its territory. In Australia, this is called an ‘appropriate level of protection’ (ALOP). The terms ‘acceptable risk’ and ‘managed risk’ are used with similar meaning.

WTO Members have an obligation to avoid arbitrary or unjustifiable distinctions in the levels of protection applied in different situations, if such distinctions result in discrimination or a disguised restriction on international trade. It is not open to a Member to take varying approaches to the acceptance of risk, in that a Member cannot take a very conservative approach to risk in relation to the entry of one commodity and be willing to accept a much higher level of risk for another commodity. This principle is often referred to as consistency in risk management.

Further information on rights and obligations arising from the SPS Agreement may be found in the unpublished report National Risk Management and the SPS Agreement (Wilson and Gascoine 1999)5. Animal Quarantine Policy Memorandum 1999/266 provides an explanation of ALOP and its relationship with quarantine risk management.

1.3.2 Office International des Epizooties (World Organisation for Animal Health)

Australia is a member of the OIE and actively contributes to the development of international animal health standards. The OIE publication relevant to this IRA is the International Aquatic Animal Health Code7 (referred to in this report as ‘the Aquatic Code’), which states:

The principal aim of the (OIE 1997b) and its companion volume, the Diagnostic Manual for Aquatic Animal Diseases, is to facilitate international trade in aquatic animals and aquatic animal products ... by providing detailed definitions of minimum health guarantees to be required of trading partners in order to avoid the risk of spreading aquatic animal diseases.

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4 WTO Appellate Body ‘Australia – measures affecting importation of salmon’ Report WT/DS18/AB/R, paragraph 121
5 Available at http://www.aqis.gov.au/docs/qdu/riskmgmtoc.htm
7 Available at http://www.oie.int/norms/a_fcode.htm
The OIE International Animal Health Code provides similar information to the Aquatic Code, but in relation to trade in terrestrial animals and their products. Section 1.4 of the Aquatic Code provides guidelines for conducting import risk analysis for aquatic animals. It is proposed to replace these guidelines with ones that are modelled on those in the International Animal Health Code, Section 1.4. AQIS has structured this analysis along the lines set out in the International Animal Health Code.

The Aquatic Code classifies aquatic animal diseases as follows:

- **Diseases notifiable to the OIE**: transmissible diseases that are considered to be of socio-economic and/or public health importance within countries and that are significant in the international trade of aquatic animals and aquatic animal products.

- **Other significant diseases**: diseases that are of current or potential international significance in aquaculture but have not been included in the list of diseases notifiable to the OIE, because they are less important than the notifiable diseases; or because their geographical distribution is limited, or is too wide for notification to be meaningful, or is not yet sufficiently defined; or because the aetiology of the diseases is not well enough understood; or approved diagnostic methods are not available.

In 1999 the International Committee of the OIE adopted revised lists of notifiable and other significant crustacean diseases. The OIE-listed diseases relevant to prawns are shown in Box 1.1. In May 2000 the International Committee adopted new recommendations for the importation of dead crustacean products for human consumption for Taura syndrome, white spot disease and yellowhead disease. For Taura syndrome and yellowhead disease, it is recommended that when importing dead crustaceans countries should require a health certificate providing details of the health status of the country of origin. For white spot disease, it is recommended that when importing dead, head-on shrimp countries should require a health certificate providing details of the health status of the country of origin. The published version of these recommendations is due to be released by the OIE in October 2000.

<table>
<thead>
<tr>
<th>Box 1.1 OIE-Listed Diseases Relevant To Prawns</th>
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<tr>
<td><strong>Diseases notifiable to the OIE</strong></td>
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<tr>
<td>Taura syndrome</td>
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<tr>
<td>White spot disease</td>
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<td>Yellowhead disease</td>
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<tr>
<td><strong>Other significant diseases</strong></td>
</tr>
<tr>
<td>Baculoviral midgut gland necrosis</td>
</tr>
<tr>
<td>Nuclear polyhedrosis baculoviroses (<em>Penaeus monodon</em>-type baculovirus and Baculovirus <em>penaei</em>)</td>
</tr>
<tr>
<td>Infectious hypodermal and haematopoietic necrosis</td>
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<tr>
<td>Spawner-isolated mortality virus disease</td>
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</tbody>
</table>

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8 Available at [http://www.oie.int/norms/A_MCode.htm](http://www.oie.int/norms/A_MCode.htm)
1.4 Australian quarantine policy framework

1.4.1 Legislation and conceptual framework

AQIS’s objective is to adopt quarantine policies that are, wherever appropriate, based on international standards and that provide the health safeguards required by government policy in the least trade-restrictive way. In developing quarantine policies, the disease risks associated with importations are analysed using IRA, a structured, transparent and science-based process.

The *Quarantine Act 1908*\(^9\), as amended by the *Quarantine Amendment Act 1999* on 23 June 2000, and its subordinate legislation, including Quarantine Proclamation 1998 (QP 1998)\(^{10}\), are the legislative basis of human, animal and plant quarantine in Australia. Section 4 of the Quarantine Act defines the scope of quarantine as follows:

In this Act, **quarantine** includes, but is not limited to, measures:

(a) for, or in relation to, the examination, exclusion, detention, observation, segregation, isolation, protection, treatment and regulation of vessels, installations, human beings, animals, plants or other goods or things; and

(b) having as their object the prevention or control of the introduction, establishment or spread of diseases or pests that will or could cause significant damage to human beings, animals, plants, other aspects of the environment or economic activities.

Subsection 13(1) of the Quarantine Act provides that the Governor-General in Executive Council may, by proclamation, prohibit the importation into Australia of any articles or things likely to introduce, establish or spread any disease or pest. The Governor-General may apply this power of prohibition generally or subject to any specified conditions or restrictions.

For goods prohibited by proclamation, the Director of Animal and Plant Quarantine may permit entry of products on an unrestricted basis or subject to compliance with conditions, which are normally specified on a permit. An IRA provides the scientific and technical basis for quarantine policies that determine whether an import may be permitted and, if so, the conditions to be applied. In practice, specific protocols have not been established for all imported aquatic animal products; many imports enter under conditions based on decisions of long standing.

The matters to be considered when deciding whether to issue a permit are set out in Section 70 of QP 1998 and include the quarantine risk, whether the imposition of conditions would be necessary to limit the quarantine risk to a level that would be acceptably low and anything else that is considered relevant. Quarantine risk means the likelihood the importation will lead to the introduction, establishment or spread of a disease or a pest in Australia, the likelihood that harm will result (to humans, animals, plants, the environment or economic activities) and the likely extent of any such harm.

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This IRA provides the basis for future consideration of applications to import non-viable prawns and prawn products, including in relation to QP 1998. In keeping with the scope of the Quarantine Act, only the factors relevant to the evaluation of quarantine risk (ie the risk associated with the entry, establishment and spread of unwanted pests and diseases, including the impact of such pest and disease incursions) are considered in the IRA. Questions related to the potential economic consequences of importation (other than the economic impact arising from the incursion of a disease) are not part of AQIS’s process of evaluation.

The actions of the Director of Animal and Plant Quarantine or his delegate in reaching a decision under the Quarantine Act takes into account the risk of significant harm to the environment. The recent amendments to the Quarantine Act introduced new procedures for decisions affecting the environment and clarified arrangements between quarantine decision-making and environment protection legislation, in particular the Environment Protection and Biodiversity Conservation Act 1999.

Decisions made by AQIS to permit the entry of animal products, made under the Quarantine Act and consistent with Australia’s conservative approach to risk, are unlikely to lead to significant adverse effects on the environment. Nevertheless, AQIS would inform the Environment Minister of any intention to make a decision which is likely to result in a significant risk of harm to the environment. Furthermore, Environment Australia (EA) is given the opportunity to comment on proposals to develop new quarantine policies. In consultation with EA, AQIS is also developing guidelines to assist quarantine officers when making decisions to ensure that the likely effects on the environment are taken into account.

The new arrangements will formalise the existing consultation processes with the EA. They include formal notification of the Environment Minister that consideration is being given to making a decision (the implementation of which is likely to result in significant harm to the environment) and the risk assessment process to be followed. Preliminary findings of the risk assessment will also be notified to the Environment Minister. Any advice received from the Environment Minister will be considered in making a decision and the Environment Minister will be informed of how the advice was taken into account.

1.4.2 Domestic policy environment

In 1996, a committee chaired by Professor Nairn conducted a detailed independent review of Australian quarantine (Nairn et al. 1996). Noting that the IRA process underpins Australia’s quarantine policies and procedures, the Nairn committee identified six principles that should apply. The committee recommended that IRA should be:

- conducted in a consultative framework;
- a scientific process and therefore politically independent;
- a transparent and open process;
- consistent with both government policy and Australia’s international obligations (under the SPS Agreement);
- harmonised, by taking account of international standards and guidelines; and
- subject to appeal on the process.
In its response (DPIE (Department of Primary Industries and Energy) 1997) the Australian Government accepted the recommendations of the Nairn report relevant to the IRA process. The AQIS publication *The AQIS Import Risk Analysis Process Handbook* (AQIS 1998) sets out AQIS’s approach to IRA, which is consistent with Australia’s obligations under the SPS Agreement and with relevant recommendations of the OIE. Copies of the handbook can be obtained from AQIS or viewed on the AQIS homepage.\(^\text{11}\)

### 1.4.3 Quarantine policy on prawns

The current specific requirements for the importation of non-viable prawns and prawn products are found in QP 1998\(^\text{10}\) and can be summarised as follows:

- Prior permission is not required to import cooked prawns or their products;
- Prior permission is not required to import uncooked non-viable prawns or their products intended for human consumption;
- Compounded animal feeds containing prawns require prior permission but may be imported subject to compliance with the requirements (including heat processing and inspection) set out in an AQIS import permit;
- Prawn meals require prior permission but may be imported subject to compliance with the requirements (including heat processing and inspection) set out in an AQIS import permit; and
- Prior permission is required to import live prawns. AQIS has never approved such an importation.

### 1.4.4 Interstate quarantine

While the Commonwealth Government is responsible for regulating the movement of animals and their products into and out of Australia, the State and Territory governments have primary responsibility for animal health controls within Australia. Legislation relating to resource management or animal health may be used by State and Territory government agencies to control interstate movement of aquatic animals and their products.

Prawn disease agents that have a restricted or regional distribution in Australia include spawner-isolated mortality virus (found in Queensland), *Penaeus monodon*-type baculovirus (found in Queensland, New South Wales (NSW) and WA), *Plebejus* baculovirus (found in NSW), hepatopancreatic parovirus (found in Queensland and NSW), infectious hypodermal and haematopoietic necrosis-like virus (found in Queensland), lymphoidal parvo-like virus (found in Queensland), lymphoid organ virus (found in Queensland), gill-associated virus (found in Queensland and NSW), and baculoviral midgut gland necrosis-like virus (found in Queensland). In some cases, State and Territory governments impose mandatory control over the movement of live prawns within Australia to prevent the spread of these disease agents. There are no mandatory controls on account of prawn pathogens over the movement of non-viable prawns within Australia.

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The Commonwealth *Mutual Recognition Act 1992* has the objective of reducing barriers (including requirements set out in legislation) to the free movement of goods between States and Territories. Quarantine measures enacted by State and Territory governments are exempt from the requirements of this Act, provided that the measures are required to prevent the entry of diseases that are not present in that region and that would have a long-term and substantially detrimental effect on the State or Territory. State and Territory measures must also meet Australia’s obligations under the SPS Agreement.

**1.5 IRA method**

The IRA conducted by the process described in the AQIS IRA Process Handbook\(^1\) provides the scientific underpinning of quarantine policy and practice. QP 1998 states that the Director of Quarantine, when making a decision on whether to permit an import access request, must consider the quarantine risk and the conditions that would be necessary to reduce quarantine risk to an acceptably low level. The IRA report documents relevant information for the Director of Quarantine to consider when making a decision on an import access request.

Quarantine risk is composed of two factors — the probability of the disease agent entering and becoming established in Australia, and the expected impact or significance of such establishment. Describing and addressing both in a standardised manner aids consistency in the management of quarantine risks and consistency in the overall approach to risk management.

This risk analysis has been conducted on a qualitative rather than a quantitative basis due to the complexity of the analysis (the large number of species and disease agents considered) and in recognition of the limited data on some key questions, such as the minimum infective dose of many pathogens, and the uncertainty about some important issues, such as the susceptibility of native species to the disease agents under consideration. A qualitative approach is consistent with OIE recommendations and the obligations of WTO members.

This IRA utilises reports by and for the U.S. Joint Subcommittee on Aquaculture, a U.S. Federal interagency advisory group, on prawn viral disease risk assessment (JSA (Joint Subcommittee on Aquaculture) 1997; ERG (Eastern Research Group) 1998). Furthermore, import risks associated with the movement of salmonid fish are the most intensively analysed of all aquatic animal products and this IRA draws upon the reports by Australian and New Zealand governments on the quarantine risks associated with the importation of salmonid and non-salmonid marine finfish (DPIE (Department of Primary Industries and Energy) 1995; DPIE (Department of Primary Industries and Energy) 1996; Stone et al. 1997; McVicar 1998; Kahn et al. 1999).

**General note on dealing with uncertainty and gaps in data**

Many of the observations and assumptions in this risk analysis are generalisations and, as such, stakeholders may challenge them. However, AQIS contends that it is valid to generalise, provided that the nature of factors that may affect the applicability of key assumptions is understood and the implications of such factors for the analysis are properly taken into account. In the absence of definitive, quantitative data on factors relevant to quarantine risk, AQIS applies appropriately conservative professional judgment based on available scientific information and the advice of experts in relevant fields. This is a scientifically valid approach that is adopted by quarantine authorities throughout the world in the face of limited scientific data. Thus, AQIS’s approach is consistent with international practice.
1.5.1 Hazard identification

In November 1998, as a part of this IRA, AQIS released a technical issues paper which included a draft hazard identification (AQPM 98/86)\(^\text{12}\). AQIS used the following criteria to identify the disease agents of quarantine concern that require further consideration in the IRA. A disease agent will be given detailed consideration in the IRA if it is:

1. infectious; **and**

2. (a) exotic to Australia, **or**
   
   (b) present in Australia but subject to official control; **and**

3. (a) OIE listed, **and/or**
   
   (b) would be expected to cause significant harm in Australia.

Further details of these criteria are shown in Box 1.2. If there are no definitive data relevant to categorisation, AQIS makes conservative judgments that draw upon scientific knowledge and observations made in similar situations and any other appropriate information.

Box 1.2  Criteria for categorising disease agents

1  **The disease agent is infectious**
A putative disease agent must cause or be causally associated with a recognised disease and the disease must have been shown to have an infectious aetiology.

The disease agent must have been found in association with animals that are the subject of the IRA. The disease agent must be transmissible to susceptible hosts and may have been isolated. Ideally, Koch’s\(^\text{13}\), River’s or Evans’s (Rivers 1937; Thrusfield 1995) postulates should be satisfied. This criterion excludes diseases of non-infectious aetiology, for example those caused by environmental (eg toxicosis), genetic or nutritional factors.

2(a)  **The disease agent is exotic to Australia**

The disease agent is considered to be exotic if there is no report of the disease or detection of the causal agent in susceptible animals in Australia. The level of confidence that can be attributed to such a determination depends on factors such as the virulence of the organism, severity of expression of clinical disease and nature of targeted surveillance applied to the disease or disease agent in question.

Where a disease agent is present in Australia, but the strain(s) present in other countries is/are considered to be significantly more virulent, these strains will be considered in a similar manner to exotic disease agents.

2(b)  **The disease agent is present in Australia but subject to official control**

If a disease agent or disease occurs in Australia, one or more State/Territory Government(s) must have enacted legislation and be taking action to control or eradicate the disease or disease agent. For the purpose of this process, mandatory control measures would be deemed to exist if such measures relate to products within the scope of this analysis.

3(a)  **The disease agent is listed by the OIE (World Organisation for Animal Health)**

The disease agent causes a notifiable or other significant disease as listed by the OIE.

3(b)  **The disease agent would be expected to cause significant harm in Australia**

The disease agent must satisfy one or more of the following criteria:
- it would be expected to cause significant economic harm (eg increased mortality, reduced growth rates, decreased product quality, loss of market access, increased management costs);
- it would be expected to cause significant damage to the environment and/or native species;
- it would be expected to cause significant harm to social amenity (eg degradation of a recreational fishery).

\(^{13}\) Koch’s postulates refer to the experimental evidence required to establish a relationship of causation between a microorganism and a disease. The conditions are: 1) the microorganism must be present in every case of the disease, 2) it must be isolated and cultivated in pure culture, 3) inoculation of such culture must produce the disease in susceptible animals, 4) it must be observed in, and recovered from, experimentally diseased animal.
1.5.2 Risk assessment

Defining the probability of establishment of disease (release and exposure assessments)

The probability of a disease agent entering and becoming established in Australia depends on the factors shown in Box 1.3. Box 1.4 defines the terms used to describe the probability of such an event occurring.

**Box 1.3  Factors affecting the probability of a disease agent entering and becoming established in Australia**

1. The probability of the disease agent being present in the source country/region of origin of the commodity and, if present, its prevalence.
2. The probability of the disease agent being present in a viable/infective form in the commodity on entering Australia.
3. The probability of the disease agent in a viable/infective form entering the aquatic environment in Australia. This depends on the processing, end-use and disposal of the commodity and the capacity of the disease agent to persist, in a viable/infective form, in the commodity after processing/use/disposal.
4. The probability of the disease agent, having entered the Australian aquatic environment, establishing infection in susceptible hosts, including native species. This depends on the capacity of the disease agent to survive in the aquatic environment, in a viable/infective form, and the ease of infection of susceptible hosts and subsequent transmission of infection to others within a population.

**Note:** The OIE describes the factors covered by points 1 and 2 above as the *release assessment* and those covered by 3 and 4 above as the *exposure assessment*. These factors may be evaluated in terms of the probability of key events occurring. The descriptive terms used in this IRA (low, negligible etc) are defined below with a view to clarifying the description of probability in risk analyses.

**Box 1.4  Terms used to describe the probability of an event occurring**

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Event would be expected to occur</td>
</tr>
<tr>
<td>Moderate</td>
<td>There is less than an even chance of the event occurring</td>
</tr>
<tr>
<td>Low</td>
<td>Event would be unlikely to occur</td>
</tr>
<tr>
<td>Very low</td>
<td>Event would occur rarely</td>
</tr>
<tr>
<td>Extremely low</td>
<td>Event would occur very rarely</td>
</tr>
<tr>
<td>Negligible</td>
<td>Chance of event occurring is so small that it can be ignored in practical terms</td>
</tr>
</tbody>
</table>

Defining the consequences of establishment of disease (consequence assessment)

The establishment of a new disease agent may have a biological effect and consequential effects on industry (eg the affected fishery), social amenity and the environment. These consequences can be measured in quantitative terms (in relation to their economic impact) and in qualitative terms (in relation to their impact on society and the environment). It is generally the case that the effects of a disease can be ameliorated to various degrees by the adoption of methods for control or eradication — although these measures are associated with costs that must be included in estimates of economic, social and environmental impact.
The biological effect of the establishment of disease is normally evaluated in terms of morbidity and mortality data. As there are limited data on how the establishment of exotic diseases in Australia would affect Australian prawns, it is not possible to estimate the biological effect of diseases in quantitative terms. Accordingly, the likely consequences of the establishment of disease are evaluated by taking into account the effect of the disease agent on commercially significant and non-significant species overseas and the scientific advice of independent experts. The consultancy reports commissioned by AQIS on the economic and environmental impact of exotic prawn pathogens in Australia were important sources of information.

In considering the biological effect of the establishment of disease, AQIS also takes into account direct costs associated with controlling or eradicating the disease, including the preemptive destruction of in-contact healthy prawns and the effect on productivity in subsequent generations.

The economic effect of the establishment of disease is normally evaluated in terms of the costs arising from the biological effects and the commercial implications for domestic and international marketing of affected animals and their products (which may extend to unaffected animals and products subject to trade restrictions). AQIS does not take into account the economic effects of trade competition when considering the risks associated with importation.

The establishment of disease may also affect the environment in ways that are not readily amenable to evaluation in economic terms. There may be effects that reduce the social amenity of the environment (e.g., recreational fishing and enjoyment of the ecosystem) or result in environmental harm (e.g., by reducing biodiversity or upsetting the ecological balance). For example, the ecological balance and/or the quality of the environment could be disturbed by changes to the normal proportions of different native species as a result of the establishment of disease or the introduction of a predatory exotic species. These effects cannot be quantified in a meaningful way. However, any event that would cause a decline in the number of endangered or threatened species or otherwise damage the environment would be of concern to the Australian community.

In this IRA, the impact or significance of the establishment of disease in Australia is classified into one of five categories, described as catastrophic, high, moderate, low or negligible. The key factors in classifying the significance of a disease are shown in Box 1.5.

**Box 1.5 Key factors in classifying the significance of disease**

1. The biological effects on aquatic species.
2. The availability, cost and effectiveness of methods for control/eradication.
3. The economic effects at an enterprise/industry/national level, including effect on marketing of the product.
4. The duration of effects (long term and short term).
5. The effects on native species and the environment generally, including any loss of social amenity.
6. Any other effects on social amenity (e.g., degradation of recreational fisheries).
Terms used to describe consequences

The categories defined in Box 1.6 lie within a continuous range of consequences. The descriptions are indicative of the expected outcomes.

In the face of uncertainty and some data gaps, AQIS makes conservative judgments regarding the expected impact or significance of disease establishment.

<table>
<thead>
<tr>
<th>Box 1.6 Terms used to describe the severity of the impact (level of significance)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Catastrophic:</strong> associated with the establishment of diseases that would be expected to significantly harm economic performance at a national level. Alternatively, or in addition, they may cause serious, irreversible harm to the environment.</td>
</tr>
<tr>
<td><strong>High:</strong> associated with the establishment of diseases that would have serious biological consequences (e.g., high mortality or high morbidity and causing significant pathological changes in affected animals). Such effects would normally be felt for a prolonged period (greater than or equal to a normal production cycle) and would not be amenable to control or eradication. These diseases would be expected to significantly harm economic performance at an industry level. Alternatively, or in addition, they may cause serious harm to the environment.</td>
</tr>
<tr>
<td><strong>Moderate:</strong> associated with the establishment of diseases that have less pronounced biological consequences. These diseases may harm economic performance significantly at an enterprise/regional level, but they would not have a significant economic effect at the ‘whole industry’ level. These diseases may be amenable to control or eradication at a significant cost, or their effects may be temporary. They may affect the environment, but such harm would not be serious or may be reversible.</td>
</tr>
<tr>
<td><strong>Low:</strong> associated with the establishment of diseases that have mild biological consequences and would normally be amenable to control or eradication. Such diseases would be expected to harm economic performance at the enterprise or regional level but to have negligible significance at the industry level. Effects on the environment would be minor or, if more pronounced, would be temporary.</td>
</tr>
<tr>
<td><strong>Negligible:</strong> associated with the establishment of diseases that have no significant biological consequences, may be transient and/or are readily amenable to control or eradication. The economic effects would be expected to be low to moderate at an individual enterprise level and insignificant at a regional level. Effects on the environment would be negligible.</td>
</tr>
</tbody>
</table>

Note: the “industry” in this IRA is defined as the prawn production industry which encompasses the wild-caught prawn fishery and prawn aquaculture.

Unrestricted estimate of risk (risk evaluation matrix)

AQIS has developed a risk evaluation matrix with the objective of providing a standardised process for evaluating quarantine risk, before and after the implementation of risk management measures. For each disease agent, the combination of probability and consequence (i.e., risk) can be represented by a cell in the matrix (see Figure 1.1). The risk determined on the basis of ‘no risk management’ is the unrestricted estimate of risk. If this is in line with Australia’s ALOP, the risk would be considered acceptable without specific management (‘yes’ in the risk matrix below) and the importation would be permitted.

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However, if the unrestricted risk exceeds the ALOP (‘no’ in Figure 1.1), the next step is to consider whether or how risk management measures may be applied to reduce the quarantine risk to the point where it conforms with Australia’s ALOP. If the application of risk management measures cannot reduce the risk to an acceptably low level, the importation would not be permitted. If after applying risk management measures the risk was in line with Australia’s ALOP, the risk would be considered acceptable (‘yes’ in the risk matrix below) and the importation would be permitted. It should be noted that, where the probability of establishment of a disease is negligible, importation would be permitted regardless of consequences.

**Figure 1.1 Risk evaluation matrix.**

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>L</th>
<th>M</th>
<th>H</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>M</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>L</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>VL</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>EL</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>N</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

‘Yes’ = the risk is acceptable and importation can be permitted
‘No’ = the risk is unacceptable and importation cannot be permitted without further risk management
Level of probability: H=high, M=moderate, L=low, VL=very low, EL=extremely low, N=negligible
Level of significance: C=catastrophic, H=high, M=moderate, L=low, N=negligible

Source: Kahn et al. (1999)
CHAPTER 2: PRAWNS IN AUSTRALIA

2.1 Introduction

Prawns are decapod crustaceans, a group which also includes lobsters and crabs. They belong to the suborder Natantia, which includes the infraorders Penaeidea, Caridea and Stenopodidae. In Australia, almost all prawns caught in commercial quantities are classified in the infraorder Penaeidea; relatively small quantities of caridean shrimp are caught off the northwest coast of Western Australia.

The commercial species of marine prawns belong to the family, Penaedae. Over 50 different species of penaeid prawns have been recorded from Australian waters (Grey et al. 1983), six of which are uniquely Australian. Ten species of penaeid prawns are considered to be of major economic importance, all belonging to two genera, *Penaeus* and *Metapenaeus*. Worldwide, the cultured prawn industry is based on *Penaeus* spp, the most desirable species being *Litopenaeus vannamei*, and *Litopenaeus stylirostris* which are indigenous to the Pacific west coast of the Americas; and *P. monodon* and *Marsupenaeus japonicus* which are Indo-Pacific species. Of the six uniquely Australian species, four have been cultured commercially: *P. esculentus*, *Metapenaeus bennettae*, *Metapenaeus macleayi* and *Melicertus plebejus*.

The freshwater prawns belong to the genus, *Macrobrachium* which is a large genus comprising over 150 species of which several occur in Australia. The genus is widely distributed, mainly throughout the tropics but to a lesser degree within the subtropical and temperate zones. Many of these species provide significant local fisheries where they occur. By far the most popular species for aquaculture is *M. rosenbergii* which has been transplanted to many places outside of its natural range.

2.2 Distribution, habitats and commercial importance

All Australian primary species of prawns are largely limited to the Indo-West Pacific region to a greater or lesser extent except where transplantations have occurred. Penaeid prawns in the genera *Penaeus* and *Metapenaeus* contribute to valuable commercial fisheries in all states of Australia, except Victoria and Tasmania (Dall et al. 1990; Kailola et al. 1993). They are also caught by recreational fishers in the estuaries and nearshore waters of Australia.

- Most species of Australian prawns are found in waters north of latitude 26°S, which is in the region of Exmouth Gulf on the west coast and Moreton Bay on the east coast (Kailola et al. 1993). Species that extend into southern waters include:
  - The western king prawn, *Penaeus latisculatus*, which is found in south-western Australia and South Australia;
  - The eastern king prawn *M. plebejus*, which is found only from the Swain Reefs (north of Fraser Island in Queensland) south to Port Phillip Bay in Victoria and northern Tasmania;
  - The river and school prawns, *M. macleayi* (Fraser Island to Corner Inlet in Victoria), *M. bennettae* (Rockhampton in Queensland to Gippsland Lakes in Victoria), and *M. dalli* (southwestern Australia).
Genera of the Penaeidae family represented in Australia are: *Penaeus, Parapenaeus, Metapenaeopsis, Metapenaeus, Atypopenaeus, Parapenaeopsis, Trachypenaeus*. At least 12 prawn species are commercially fished in Australia (Kailola et al. 1993) These species are:

- Black or giant tiger prawn (*Penaeus monodon*)
- Eastern king prawn (*Melicertus plebejus*)
- Red spot king prawn (*Penaeus longistylus*)
- Western king prawn (*Melicertus latissulcatus*)
- White banana prawn (*Fenneropenaeus merguiensis*)
- Red-legged banana prawn (*Fenneropenaeus indicus*)
- Brown tiger prawn (*Penaeus esculentus*)
- Grooved tiger prawn (*Penaeus semisulcatus*)
- School prawn (*Metapenaeus macleayi*)
- Blue endeavour prawn (*Metapenaeus endeavouri*)
- Red endeavour prawn (*Metapenaeus ensis*)
- Greasyback prawn (*Metapenaeus bennettae*)

Deepwater penaeid prawns (Infraorder: Penaeidea) are trawled in waters off the Australian coastline, especially on the North-West Shelf and off New South Wales at depths exceeding 200 metres. These species include the red prawn (*Aristaeomorpha foliacea*, Family: *Aristaeidae*) the giant scarlet prawn (*Plesiopenaeus edwardsianus*, Family: *Aristaeidae*), the pink striped prawn (*Aristeus virilis*, Family: *Aristaeidae*) and the royal red prawn (*Haliporoides sibogae*, Family: Solenoceridea) (Jones and Morgan 1994).

Caridean shrimp (Infraorder: Caridea) are usually of small size and, unlike penaeids (which are exclusively found in marine waters), occur in marine and freshwater environments. In Australia, good yields of several species of carids are taken from deep waters of the north-west of Western Australia. The major species caught are the red caridean shrimp (*Heterocarpus woodmasoni*, Family: *Pandalidae*) and the white caridean shrimp (*Heterocarpus sibogae*, Family: *Pandalidae*) (Jones and Morgan 1994).

Freshwater prawns (*Macrobrachium* spp., Family: *Palaemonidae*) are widespread in northern and central Australia. The largest species *Macrobrachium rosenbergii*, commonly known as the cherabin, inhabits streams across northern Australia. This species is an important aquaculture species in South-East Asia (Jones and Morgan 1994) but attempts to culture it in Australia have met with limited success.

AusVet (1999) and Kailola et al. (1993) provide further details on diagnostic features, geographical distribution, habitat type, life history, stock structure, commercial and recreational fishery and resource status for Australian prawn species.

### 2.3 Size and structure of the prawn industry

In terms of size, the Australian prawn industry is dominated by the wildcaught sector. In 1998-99, Australian prawn fishery production was $408 million and Australian prawn aquaculture production was $44 million (ABARE 1999). The Australian fishing zone covers approximately 9 million square kilometres. Commercial fishing stocks comprise approximately 300 finfish, crustacean and molluscan species. In 1998-1999 prawns accounted for 20% of the total value of Australian fisheries products and 15% ($224 million) of the value of Australian fisheries exports. Eleven Commonwealth and State fisheries are involved in prawn fishing (ABARE 1999).
In addition to wild marine fisheries production, aquaculture production has become a major national resource in recent years. Prawns are the dominant crustacean species farmed in Australia. The value of prawn aquaculture production has increased steadily since 1990.

The volume and value of prawns caught by recreational fishers in Australia is not well documented, however, four prawn species are reported to be taken mostly from estuaries (Kailola et al. 1993).

Other fishing industry-related activities include processing, preserving, storing, transporting, marketing, and selling fish or fish products. The commercial sector of the Australian fishing industry, including prawn fishing, directly employs about 20,000 people in the catching sector, a further 3,500 in processing and thousands in marketing and selling (FRDC 1996).

2.3.1 Organisation of the prawn fishery

Table 2.1 provides a summary of the critical data applying to the nation’s principal prawn fisheries. Some of the minor Commonwealth prawn fisheries, such as the SE Fishery, are not included in the table.

Table 2.1 Australian Prawn Fisheries in 1997

<table>
<thead>
<tr>
<th>Fishery</th>
<th>Area or Species</th>
<th>Boats or units</th>
<th>Volume (tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern Prawn (Commonwealth)</td>
<td>Gulf of Carpentaria, Cape York to Cape Londonderry</td>
<td>129 boats</td>
<td>8,717</td>
</tr>
<tr>
<td>Torres Strait (C’wealth)</td>
<td>Cape York Peninsula and south coast PNG</td>
<td>529 boats</td>
<td>1,624</td>
</tr>
<tr>
<td>NSW Prawn</td>
<td>Eastern king, school and royal red prawns</td>
<td>1,037 fishers</td>
<td>2,120</td>
</tr>
<tr>
<td>Qld East Coast trawl</td>
<td>Tiger, banana, red spot king, endeavour, eastern king, eastern school and greasy back prawns</td>
<td>891 boats</td>
<td>9,625</td>
</tr>
<tr>
<td>WA Shark Bay prawn</td>
<td>King, tiger and endeavour</td>
<td>27 boats</td>
<td>1,890 (est)</td>
</tr>
<tr>
<td>WA Exmouth prawn</td>
<td>King, tiger and endeavour</td>
<td>16 boats</td>
<td>1,120 (est)</td>
</tr>
<tr>
<td>WA Nickol Bay prawn</td>
<td>King, banana</td>
<td>14 boats</td>
<td>980 (est)</td>
</tr>
<tr>
<td>SA West coast prawn</td>
<td>Western king</td>
<td>3 licence holders</td>
<td>117 (est)</td>
</tr>
<tr>
<td>SA Spencer Gulf prawn</td>
<td>Western king</td>
<td>39 licence holders</td>
<td>1,521 (est)</td>
</tr>
<tr>
<td>SA Gulf St Vincent prawn</td>
<td>Western king</td>
<td>10 licence holders</td>
<td>390 (est)</td>
</tr>
</tbody>
</table>

Source: ABARE (1997)

Commonwealth Fisheries

In 1996-97 the total prawn catch of Australian Commonwealth fisheries of 10,090 tonnes was valued at $119 million (ABARE 1997). This accounts for 36% of the total prawn production in Australia. The two major Commonwealth prawn fisheries are the Northern Prawn Fishery and the Torres Strait Fishery. The South East Trawl Fishery has a significant prawn catch. These 3 fisheries are discussed below.
Northern Prawn Fishery

This is the most valuable fishery managed by the Commonwealth with an annual catch valued at $100-150 million. The 1996-97 catch reached 8,279 tonnes and was valued at $102 million (ABARE 1997). Established in 1960, the fishery extends from Cape Londonderry in Western Australia to Cape York in Queensland encompassing the Gulf of Carpentaria, the northern coast of Arnhem Land and Joseph Bonaparte Gulf.

The main catch of this multispecies fishery are prawns; white banana prawns (*F. merguiensis*) and tiger prawns (*P. semisulcatus* and *Penaeus esculentus*) accounting for 80% of the catch. Other prawn species caught include red-legged banana prawns (*F. indicus*), endeavour prawns (*M. endeavouri* and *M. ensis*) and king prawns (*M. latisulcatus* and *Penaeus longistylus*). These species have a life span of 1-2 years and can reach commercial size by 6 months of age. The preferred market size for tiger prawns is reached by 9-12 months of age (BRS (Bureau of Resource Sciences) 1997).

Torres Strait Prawn Fishery

This is a high value fishery covering four fishing regions between the tip of Cape York Peninsula and the south coast of Papua New Guinea and bordered by the Coral Sea to the east and the Arafura Sea to the west (ABARE 1993). In 1996-97 the prawn catch of 1,624 tonnes was valued at $16 million (ABARE 1997).

The main prawn fishing region lies to the east of the Warrior Reefs with a catch comprised of brown tiger prawn (*Peneaus esculentus*) and blue endeavour prawns (*M. endeavouri*). Both prawn species complete their life cycle in one year and may live for two years. Brown tiger prawn in the Torres Strait spawn year round, with variable peaks of activity. About 5% of the catch in this fishery is red spot king prawn (*Penaeus longistylus*).

South East Trawl Fishery

This is a mixed species fishery with trawl and non-trawl sectors. The trawl sector stretches from Sydney southwards around Tasmania to Kangaroo Island in South Australia. Royal red prawn (*Haliporoides sibogae*) is the major prawn species in the trawl landings. The species ranges along the entire NSW coastline in depths of 350-550m (BRS (Bureau of Resource Sciences) 1997). In 1996-97, the royal red prawn catch of 188 tonnes was valued at $568,000 (ABARE 1997).

State fisheries

Nine State fisheries are involved in prawn fishing (ABARE 1997):

- New South Wales 1
- Queensland 2
- Western Australia 3
- South Australia 3
Queensland

In 1996-97 the prawn catch of 8,270 tonnes was valued at $96 million (ABARE, 1997 #14930). Prawn fisheries in Queensland comprise distinct sectors based on prawn species and location (DPI (Department of Primary Industries) 1996).

There is a major coastal fishery for tiger prawn (P. semisulcatus and Penaeus esculentus) and endeavour prawn (Metapenaeus endeavouri and M. ensis).

Red spot king prawn (Penaeus longistylus) and blue-legged king prawns (M. latisulcatus) are caught in the Great Barrier Reef lagoon. Banana prawn (F. merguiensis) are caught in coastal waters in the vicinity of major estuaries. Eastern king prawn (M. plebejus) migrate from estuarine nursery areas to deep waters and may be caught inshore and offshore. Black (also known as giant) tiger prawn (P. monodon) are caught for use as aquaculture broodstock. Coral prawn (Metapenaeopsis spp.) are part of the bycatch in most fisheries.

Bay prawns are a mixture of small prawns, including school prawn (M. macleayi), greasy back prawn (Metapenaeus benettai), and less common species such as hardback prawn (Trachypenaeus spp.), as well as juvenile eastern king and tiger prawns. These species are caught in the inshore waters of southern Queensland particularly Moreton Bay (DPI (Department of Primary Industries) 1996).

New South Wales

In 1996-97 the prawn catch from New South Wales of 1,849 tonnes was valued at $18 million. Eastern king prawn (M. plebejus) and school prawn (M. macleayi) are the main species caught (ABARE 1997).

Western Australia

In 1996-97 prawn catch from Western Australia of 3,995 tonnes was valued at $50 million (ABARE 1997). Three State fisheries are involved in prawn fishing: Shark Bay prawn, Exmouth prawn and Nickol Bay prawn. The main prawn species caught are western king prawn (M. latisulcatus), brown tiger prawn (Penaeus esculentus), endeavour prawn (M. endeavouri) and banana prawn (F. merguiensis) (Kailola et al. 1993).

South Australia

In 1996-97 prawn catch from South Australia of 2,024 tonnes was valued at $25 million (ABARE 1997). The three State fisheries involved in prawn fishing are West Coast Prawn Fishery, Spencer Gulf Prawn Fishery and Gulf St Vincent Prawn Fishery with western king prawn (M. latisulcatus) the main species taken.

Victoria

In 1996-97 prawn catch from Victoria was 2 tonnes compared to 32 tonnes in 1994-95, and 12 tonnes in 1995-96 (ABARE 1997). The two main species taken are eastern king prawn (M. plebejus) and school prawn (M. macleayi) (Kailola et al. 1993).

2.3.2 Prawn aquaculture

The cultured prawn industry is located on the coast in Queensland, northern New South Wales and Northern Territory. In 1996-97, production exceeded 1,600 tonnes with over 80% produced by farms located in Queensland. Black tiger prawns (P. monodon) comprised 87% of the 1996-97 harvest with the balance being kuruma prawns (P. japonicus). All the kuruma
are exported live to Japan or Korea. For the past five years (since the collapse of the
Taiwanese prawn industry) Australia has been a major supplier to this market. Unfortunately,
the total market for live prawns is small and this makes the kuruma industry in Australia
highly vulnerable to any volatility in the Japanese and Korean economies.

The size of the cultured prawn industry in Australia is small by international standards, but it
is an emerging industry with potential for growth and export income generation. It has been
estimated that the value of aquaculture production could reach $1.4 billion by the year 2005
(National Strategy on Aquaculture in Australia). However, an expansion to this magnitude
would make the farmed sector almost seven times bigger than what it is today; this may take
more than 5-6 years to achieve in view of the licensing constraints that now apply to estuarine
and marine disturbance. Furthermore, the market for live prawns in Japan is currently weak.

While world production of prawns from wild fisheries has been fairly stable in recent years,
that from cultured prawns has increased dramatically from around 90,000 tonnes in 1980 to
762,000 tonnes in 1995 and now represents almost one third of global supply. Thailand
produces about one quarter of the world’s cultured prawns from 26,000 farms and 2,000
hatcheries occupying more than 80,000 hectares. It is apparent that Australian prawn
production does not yet conform to the international model, as the local tonnage of cultured
prawns is only 6% of the total production in 1996-97 in contrast to many other countries
where the bulk of production is from farms.

The management issues pertinent to the cultured prawn industry are vastly different from
those applying to the wildcaught industry. With the cultured industry, for example, there is
not the issue of protecting the natural stock from over-exploitation, or the difficulty of sharing
the available harvest among operators so that all can make a reasonable return. Indeed the
decisions taken by prawn farmers with respect to when and how to harvest impinge on no-one
but themselves. However, pond hygiene and contiguous disease risks are affected by cropping
intensity of the ponds (eg, intermittent or continuous usage).

A second major difference between cultured and wild prawns is feed source. With cultured
prawns, the feed is manufactured and is introduced to the grow-out ponds by the farmer. As
such, the feed’s ‘quality’ can be controlled to some extent by the farmer. The major qualities
the farmer will be concerned about are nutritional value and unit cost.

A third difference worth noting refers to the costs of entry into the respective sectors. In both
sectors there are natural barriers to entry. Entry to the wildcaught industry can be gained only
by purchasing an existing harvesting right. Thus, the initial capital investment by the
wildcaught operator lies largely in purchasing the rights to participate in the harvest (i.e.,
quota and licenses) and a suitable trawling boat.

The prawn farmer’s initial capital investment, by way of contrast, lies in purchase and
development of a suitable site. While it may appear there is vast scope for expansion of prawn
farming along Australia’s coastline, there will be constraints in practice (Brown et al. 1997). It
might be expected, for example, that the best (low cost) sites will be developed first and in
this event, the capital cost of entry will rise inexorably through time.

As prawn farming intensifies, the management of disease will be of major importance to the
long-term success of this industry. The potential impact of diseases is recognised as one of the
problems in prawn farming in Queensland (Donovan 1998).
Black tiger prawn aquaculture

- This is the most suitable prawn species for farming in Australia due to:
  - availability of aquaculture technology, which was established in South East Asia
  - fast growth rate relative to other prawn species
  - ability to withstand significant changes in water salinity.

Black tiger prawn farms have been operating in Australia for the past 10 years. In 1995-96, there were farms in Queensland (24 farms), New South Wales (4 farms), and the Northern Territory (2 farms). Most of the product is sold on the domestic market.

In Queensland, black tiger prawn farms are situated along the coast between Brisbane and Cooktown. Climatic conditions in Queensland allow production of one to two crops a year. Most of the farms in New South Wales are on the Clarence River in the northern part of the state. At present all spawning stock to supply the farms is wild-caught by trawlers operating in waters off Cairns. The Australian Institute of Marine Sciences is conducting research to develop techniques to produce broodstock in captivity (Brown et al. 1997).

Kuruma prawn aquaculture

The kuruma prawn occurs naturally as far south as northern Australia. Wild populations in waters off Mackay, Queensland are thought to have been introduced via ship’s ballast water (Brown et al. 1997). An increasing number of farms in Queensland and New South Wales produce this commercially prized species. Seven kuruma prawn farms operate in Queensland and 4 in New South Wales. Most Australian kuruma prawns are exported live to Japan and Korea (Brown et al. 1997).

Kuruma prawn hatcheries currently depend on wild-caught broodstock from coastal waters near Mackay; research into closed cycle farming is underway (Harrison 1997).

Other prawn species in aquaculture

Other minor farmed prawn species include the brown tiger prawn (*Penaeus esculentus*) and banana prawn (*F. merguiensis*).

2.3.3 Non-commercial prawns in Australia

In addition to commercial prawn species discussed above, many prawn species of minor or no commercial value occur throughout Australia’s marine and freshwater aquatic environment including freshwater prawns, common estuary shrimps, commensal shrimps and rock pool shrimps. The non-commercial species are likely to be important in the food chain of various aquatic animals and thus contribute to the sustainability of commercial fisheries as well as to maintaining the balance of aquatic ecosystems.

2.4 Seafood trade in Australia

Seafood is an increasingly popular food type enjoyed by nearly all Australians (ADVS (Aquaculture Development and Veterinary Services) 1999). Domestically, seafood is sold in wholesale markets situated in each State capital city. Australians consume seafood both in
their own home and whilst eating out, with the majority of non-fish seafood consumed “out of home”.

In the last 20 years, it has become apparent that many fisheries have reached, or in some cases have exceeded, their maximum sustainable yield. Kailola et al. (1993) foreshadowed little future expansion in Australia’s fisheries catch; instead they cautioned that a high proportion of fisheries were fully exploited. This stabilisation of global fisheries production has resulted in a rapid expansion in aquaculture to meet the increasing demand for seafood.

Though Australia does produce considerable quantities of seafood, significant imports are required to satisfy domestic consumption (Kailola et al. 1993). Australia imported $878 million worth of seafood in 1998-99, comprising 60% of all seafood consumed (ABARE 1999). This included 97 600 tonnes of edible fish and 34 800 tonnes of edible crustaceans and molluscs. The major sources of edible seafood were Thailand (32% of value) and New Zealand (19% of value). Domestic consumption of prawns in 1998-99 was 28 397 tonnes; Australia imported 10 108 tonnes (worth $151 million) and exported 11 995 tonnes of prawns (worth $224 million).

The popularity of seafood as staple food product, and in catered meals in the hospitality trade, sustains high levels of employment in production, processing and retail industries.

2.5 Australian crustaceans and the environment

In conducting IRAs, AQIS takes into account the importance of maintaining biodiversity in considering the effect of the introduction and establishment of diseases.

Australia has a diverse marine and freshwater crustacean fauna. Crustaceans occupy significant niches in freshwater and marine ecosystems in Australia. Therefore, the removal of a group of crustaceans from an ecosystem, eg. due to mortality, may have a serious impact on the proper functioning of that ecosystem.

Of significance in this IRA, and specifically in relation to disease agents which infect a wide range of hosts, is the large number of freshwater crayfish which are threatened with extinction. Over one quarter of Australian freshwater crayfish species are considered to be worthy of concern from a conservation viewpoint (Horwitz 1995).

2.6 Health of prawns

Throughout the world, there is much less scientific information on the diseases of prawns than on livestock and avian diseases. One reason is that it is difficult to investigate disease in aquatic animals because the marine environment is extensive and variable and because a large number of species are involved. However, information on the health status of commonly cultured species, such as several members of the family Penaeidae, tends to be more comprehensive because disease events are more likely to be recognised in aquaculture enterprises than in wild fisheries.

In many cases, the presence of a disease agent is only recognised after an outbreak of clinical disease occurs. Diagnosis is usually based on evaluation of clinical, pathological, virological, bacteriological and parasitological findings, the interpretation of which may be confounded by poor quality specimens. While technology is improving, definitive diagnostic methods are generally limited to specialised laboratories and do not lend themselves to low-cost, large-scale testing required in routine health screening programs.
Prawn health in Australia

Several sophisticated facilities exist which are used in the investigation, diagnosis and research of prawn disease and health. These facilities may be used to monitor disease episodes in farmed prawns. Other than this, there is little structured surveillance of the presence of prawn diseases in Australia.

Significant disease events affecting prawns in Australia are investigated. Because of the economic importance of prawns and the high level of human utilisation of the coastal regions of Australia, significant disease episodes affecting wild prawns are likely to be recognised. To date, such episodes have only been observed in experimental and aquaculture situations where the stocking density, environmental conditions and close monitoring of the animals may contribute to disease occurrence and its early recognition.

- Information on prawn health in Australia has been obtained from:
  - published scientific literature;
  - reports provided by the Commonwealth and State/Territory government agencies; including official notifications to regional and international organisations;
  - published and unpublished material held by Commonwealth and State/Territory government agencies, universities, industry and research organisations.

Prawn diseases/disease agents which have not been reported in Australia

- *Aerococcus viridans* var. *homari* occurs in North America and Europe
- Infectious hypodermal and haematopoietic necrosis (IHHN)\(^{14}\) occurs in Asia, the Pacific region and the Americas
- Infectious pancreatic necrosis (IPN) occurs worldwide
- Baculoviral midgut gland necrosis virus (BMNV), occurs in Japan and Korea
- Baculovirus penaei (BP), occurs in the Americas
- *Haematodinium*-like organism occurs in North America
- Microsporidiosis\(^{15}\) occurs in the Americas and Asia
- Necrotising hepatopancreatitis (NHP), occurs in the Americas
- *Parauronema* spp. occur in the U.S.A.
- REO-III, occurs in Japan, France, Hawaii, Malaysia, Mississippi, U.S.A. and Ecuador
- REO-IV, occurs in the Yellow Sea region of Asia
- Rhabdovirus of penaeid shrimp (RPS), occurs in the Americas\(^{16}\)
- *Rickettsia* spp.\(^{17}\) occur in North America and Asia
- Taura syndrome (TS) occurs in the Americas
- *Vibrio* spp.\(^{18}\) occur worldwide
- White spot syndrome (WSS), occurs in Asia and U.S.A.
- Yellowhead disease (YHD), occurs in Asia and U.S.A.

\(^{14}\) The IHHNV-like virus detected in prawns in Australia is distinct from IHHNV (Owens 1997).
\(^{15}\) Some species are exotic to Australia.
\(^{16}\) RPS is closely related to spring viraemia of carp (SVC) Loh et al., 1997
\(^{17}\) Some species are exotic to Australia
\(^{18}\) Some species are exotic to Australia
**Prawn diseases/disease agents which have been reported in Australia**

- Spawner-isolated mortality virus (SMV)
- Monodon baculovirus (MBV)
- Plebejus baculovirus (PBV)
- Bennettae baculovirus (BBV)
- Gut and nerve syndrome (GNS)
- Hepatopancreatic parovirus (HPV)
- Penaeid haemocytic rod-shaped virus (PHRV)
- Infectious hypodermal and haematopoietic necrosis -like virus (IHNNV-like)
- Lymphoidal parvo-like virus (LPV)
- Lymphoid organ virus (LOV)
- Gill-associated virus (GAV)
- Lymphoid organ vacuolization virus (LOVV)
- Parvo-like virus of *Marsupenaeus japonicus* (P-PJ)
- Baculovirus midgut gland necrosis virus-like viral infection

**Prawn diseases/disease agents which are reportable in Australia**

The mandatory reporting to authorities of the occurrence of specified ('listed') diseases provides information which assists in the prevention and management of disease outbreaks. Such information can be used in combination with official controls on the movement of live animals and, where appropriate, their products to establish disease-free areas within infected countries or zones.

Below is the Australian national list of reportable prawn diseases/disease agents:

- Baculoviral midgut gland necrosis
- Nuclear polyhedrosis baculoviroses
  - *Baculovirus penaei*
  - *Penaeus monodon*-type baculovirus
- Infectious hypodermal and haematopoietic necrosis
- Yellowhead disease virus
- White spot disease
- Taura syndrome
- Necrotising hepatopancreatitis

**Internal restrictions on movement of prawns and prawn products**

During the preparation of this document, Chief Veterinary Officers of all States and the Northern Territory were asked to provide information on prawn disease control zones and details of intra- or inter-State movement controls on prawns and prawn products within their jurisdiction. The following is a summary of their responses in relation to these issues:

**New South Wales:** All post-larvae entering NSW must test negative for MBV prior to stocking into ponds. Similarly, post-larvae produced at NSW hatcheries which were derived from spawners imported from interstate must test negative for MBV prior to stocking into ponds.
Queensland: Disease control zones have not been established within Queensland but live prawns for use in aquaculture operations must be certified free of Declared Diseases when imported from interstate. YHV, IHHNV, WSSV, BMNV and TSV are on List A of the draft Declared Diseases List and BP is on List B of the draft Declared Diseases List. It is prohibited to sell prawns as food if the prawns contain a viable Declared Disease agent.

The Northern Territory: The *Fisheries Act 1988*, administered by the Department of Primary Industries & Fisheries prohibits the importation of live prawn into the Northern Territory unless the person does so under and in accordance with a permit. There are no controls presently in place under the *Fisheries Act 1988* to control the importation of non-live prawns and prawn products into the Northern Territory.

Western Australia: There are currently no disease control zones for prawns within the State. The importation of post-larvae into the State is restricted.

Victoria: No measures were reported.

Tasmania: No measures were reported.

South Australia: No measures were reported.

Australian Capital Territory: No measures were reported.
CHAPTER 3: GENERAL CONSIDERATIONS FOR THE RISK ASSESSMENT

3.1 General discussion of scenarios

In order to construct a scenario whereby a disease agent might be introduced into and become established in a country through the importation of a commodity, factors which contribute to the probability that the disease agent will enter and become established (see Section 1.5.2 and Box 1.3) must be considered. The factors considered in this IRA in relation to the release assessment are as follows (modified from the OIE Aquatic Code).

- The probability of the disease agent being present in prawns in the waters of origin.
- The probability of the disease agent being present in the particular prawns harvested.
- The probability of infected or contaminated prawn/product passing inspection or grading.
- The probability of the disease agent surviving processing, transport or storage.
- The probability of the disease agent being present in the particular tissues imported.

The factors considered in relation to the exposure assessment include the following (modified from the OIE Aquatic Code):

- The probability of imported product entering the aquatic environment.
- The probability that susceptible hosts will contact imported product containing viable disease agents.
- The probability of the disease agent establishing in host populations in the importing country.

Some pathways occur commonly (e.g. farmed prawns will be exposed to imported prawn feeds) while others occur less commonly, rarely or exceptionally. AQIS takes into account the extremely low probability of imported product following rare or exceptional pathways in considering their quarantine significance. This is consistent with Australia’s international obligations. The SPS Agreement requires that the likelihood of disease introduction, establishment and spread which is evaluated in a risk assessment to be an ascertainable risk; it is necessary to look at the probability of particular events occurring, not just the possibility.

The probability and nature of exposure of susceptible species to imported product are important factors in assessing quarantine risk. Other factors include the likelihood of pathogens being present in the product, the titre and condition (infectivity) of such pathogens, and the circumstances that would give rise to an index case of infection and spread of that infection to spread. It should be noted that there is little data on infectious doses for crustacean pathogens due to difficulties in titrating pathogens. However, AQIS has taken into account relevant data that are available.
In this chapter, scenarios relating to the introduction, establishment and spread of exotic prawn pathogens are discussed in general. Section 3.2 examines factors relating to the source country and the commodity under consideration (non-viable whole green prawns) that constitute the release assessment. Section 3.3 explores factors relating to the exposure of susceptible species in Australia to the imported commodity, and its derivatives, that may contain infectious organisms (the exposure assessment). In Chapter 5 the factors which bear upon the probability that a disease agent will enter and become established in Australia are examined with reference to individual disease agents. The effect of specific risk management measures, such as inspection, grading and cooking, is considered in Chapter 6.

3.2 Release assessment

This section considers factors affecting the likelihood of viable pathogens occurring in prawn products imported into Australia.

For most prawn pathogens there are few data on the epizootiology of disease in wild or farmed prawns, including on the prevalence of infection; whether infection affects the spawning success rate; the probability of post-larva being infected via infected spawners; and the likelihood that infected larvae will survive to harvest. For white spot syndrome virus (WSSV), the most-studied prawn pathogen, there are only preliminary data on these aspects and only in relation to farmed prawns.

3.2.1 The probability of the disease agent being present in prawns in the waters of origin

The prevalence (and expression) of infection in aquatic animal populations may vary markedly from one country or region to another. As scientific knowledge increases, and particularly if specific scientific investigations are conducted, information on the distribution of disease and disease agents may change considerably. Prawn aquaculture has developed rapidly since the late 1970s, concomitant with the emergence of serious disease conditions which have limited development since the late 1980s. The three most serious pathogens affecting prawn aquaculture, WSSV, yellowhead virus (YHV) and Taura syndrome virus (TSV), were all detected within the last decade and spread rapidly between countries – apparently via the movement of broodstock and post-larvae.

Systems for active surveillance and monitoring in crustacean health are rare features in prawn aquaculture. The significant impact of disease on prawn aquaculture, and the development of rapid and effective diagnostic tools, has led to the implementation of screening programs by some governments and private companies. However, no country has established active surveillance and monitoring program for prawn disease. Passive systems can be effective in detecting disease and can support the implementation of response and control programs. The lack of trained personnel and appropriate facilities in some regions limits the effectiveness of passive surveillance in some countries. Active monitoring and surveillance programs are unlikely to be common in prawn aquaculture in the foreseeable future.

This IRA has been conducted on a generic basis; thus the disease status of all potential source countries is considered. Some significant disease agents have a regional distribution and the absence of a disease from a region is an important consideration in the risk assessment. Significant factors in the assessment of regional freedom include the nature and level of surveillance and monitoring, the presence of susceptible species, the history of trade in live crustaceans and the nature and intensity of prawn aquaculture.
3.2.2 The probability of the disease agent being present in the particular prawn harvested

Many factors affect the prevalence of a disease agent in a prawn population and the expression of disease in individual prawns. Information on factors that affect the prevalence of disease in harvested prawns is considered in the IRA under the general categories listed below. Information on factors affecting the prevalence of individual disease agents is considered in Chapter 5.

Species of prawn

Some disease agents infect a wide range of species, eg WSSV can infect many prawn and other crustacean species. Other disease agents have a restricted host range.

Lifecycle stage

The prevalence of infection and/or the expression of disease may vary with the lifecycle stage of the host. For example the prawn baculoviruses primarily affect larvae and early stage post-larvae (Lightner et al. 1997b). Survivors of disease outbreaks may carry persistent subclinical infection. Lifecycle factors are considered for each pathogen in chapter 5.

Origin of prawns

The origin (ie aquaculture or wild fishery) of prawns has a bearing on the expected prevalence of infection. Disease outbreaks have mostly been reported in farmed prawns. Although there are occasional reports in wild populations of disease outbreaks due to agents which are easily identified because of their obvious clinical signs, eg microsporidiosis, disease outbreaks are rarely observed in wild prawn populations. Most affected prawns are likely to be eaten by non-susceptible predators and high recruitment rates tend to mask the expression of disease.

Farmed prawns are often held at high stocking rates. High levels of water exchange were once practiced, but minimum water exchange is increasingly the practice in prawn aquaculture. Thus, the environmental conditions in prawn farms can facilitate the spread of pathogens that are transmitted horizontally. On the other hand, the health status of farmed prawns is generally monitored more closely and managed more effectively than in the case of wild prawns. Disease management, including practices such as emergency harvest, may significantly affect quarantine risk.

Aquaculture system

The production system can have a profound influence on the health status of prawns. Prawns produced in extensive systems with low stocking densities typically have a lower prevalence of disease, presumably due to less efficient transmission of pathogens.

Local dispersal of disease agent

The dispersal of disease agents may occur via several pathways. In wild prawns, disease agents are typically dispersed by the movement of live hosts, including during natural migration. Restocking programs practiced by many countries have significantly enhanced the dispersal of disease agents in wild prawn populations. The movement of broodstock to hatcheries and of larvae from hatcheries to growing ponds has also facilitated national and international spread of disease agents.
**Seasonality**

Season, or time of year, can also affect the prevalence of disease. For example, outbreaks of white spot disease occur more frequently in the monsoon season, probably due to stressors including those resulting from fluctuations in salinity and pH (Karunasagar et al. 1997; Limsuwan 1999).

### 3.2.3 The probability of infected or contaminated prawns/product passing inspection or grading

Prawns that are used for bait are not normally inspected. The processing of bait prawns is normally limited to freezing soon after harvest, and bait prawns are not usually graded for size variation or blemishes. Bait prawns are typically small (less than 15 grams weight) and may have been found unsuitable for human consumption due to small or variable size, aesthetic defects etc. For various reasons (including younger age, poor growth because of disease or other stressors, emergency harvest) small prawns (i.e. less than 15 grams) are more likely to be infected by disease agents than prawns grown to full size through a normal production cycle.

Prawns for human consumption are normally inspected by industry or government employees to verify that they are fit for human consumption. Inspectors conduct an organoleptic assessment (touch, smell, visual), which allows abnormal prawns (eg those with visible lesions or physical damage) to be identified and rejected, or diverted for further processing. Prawns that are downgraded for aesthetic reasons may be further processed, often by cooking, to ensure consumer acceptance.

Prawns for human consumption are also graded according to quality factors such as size and appearance. Prawns are typically graded to fill a particular order of specified size, weight or count. Prawns with a loose, limp cephalothorax, discolouration or visible lesions will normally be removed from the production line and discarded or directed to industrial uses (eg. bait or pet food).

Prawn processing lines may operate at high speed, allowing little time for detailed inspection. However, under normal commercial arrangements inspection and grading decisions are made at multiple points along the processing line. Employees are trained to detect prawns/product that do not meet specified criteria, which are usually simple and clear-cut (eg. no visible lesions and normal clean colour). Inspection and grading can provide for the removal of abnormal animals and thereby contribute to the reduction of quarantine risk.

Prawn processing plants in some countries are required by government to use quality assurance (QA) or systems based on hazard analysis critical control point (HACCP) to insure compliance with food quality and safety requirements. HACCP systems are based on the monitoring of key (critical control) points in the production process to verify that the system is operating within defined standards and that action is taken to detect and correct deficiencies, including in the management of ‘failed’ product. This system has largely replaced the traditional approach, which relied on inspection of the end-product for compliance with product safety and quality parameters. It provides a structured system for control of key processes, such as operational hygiene and refrigeration, that minimises problems with food safety and quality.
HACCP systems emphasise early detection and prevention of undesirable practices (such as cross-contamination between cooked and raw product) that are important to food safety and may also be relevant to quarantine risk.

Government inspection agencies normally supervise the implementation of HACCP-based food processing systems by the conduct of regular audits, based on maintainance by the operator of complete and accurate records. This may support the provision of official attesting to the importing country requirements and traceback of product, if required. However, the utility of records depends on the information that is stored. As HACCP-based inspection tends to focus on the protection of public health, much of the information collected may be of little significance from an animal quarantine perspective.

In summary, inspection and grading of non-viable prawns and prawn products would generally provide for the detection and removal from the human food chain of prawns affected by generalised disease and visible lesions associated with infectious diseases. Moreover, prawns that are rejected for aesthetic reasons (eg signs of shell disease or melanisation) would normally be rejected from the human food chain.

Prawns processed for use as bait are not inspected and prawns showing signs of unwholesome condition or disease would not normally be rejected.

3.2.4 The probability of the disease agent surviving processing, transport or storage

The factors relevant to the persistence of disease agents through processing, transport and storage include factors intrinsic to the agent (that allow it to persist in a viable form) and the actual conditions of processing, transport and storage.

Prawns for human consumption are frequently packaged whole, after sorting, washing and freezing. It is also common for the whole prawns to be cooked then frozen. Whether cooked or green (ie raw), rapid freezing is important to maintain quality and wholesomeness.

Prawns for human consumption may be further processed including by removal of the cephalothorax (heading), removal of the exoskeleton (peeling), removal of the gut (deveining), and preservation processes that may include cooking and/or freezing and chilling. Processing and preservation treatments may reduce the titre of, but not necessarily eliminate, viable pathogens, particularly bacteria and parasites, that may be present in prawns.

Although prawns for bait use are normally frozen whole without any other treatment, some bait prawns may be deheaded and stored in preservatives such as brine. These preservatives are formulated to inhibit the growth of spoilage organisms. They would be expected to reduce the time of, but not necessarily eliminate, viable pathogens that may be present.

Washing

Washing would be expected to reduce the titre of organisms located on the shell and those associated with residual visceral tissues remaining on the tail after removal of the cephalothorax. Furthermore, HACCP procedures usually specify that water used in food-processing plants contain levels of residual chlorine which would contribute to the inactivation of bacterial pathogens on product. In most developed countries, health authorities require the use of potable water in land-based food processing plants, which normally means that the water would contain a minimum residual level of 0.2 to 0.5 milligrams per litre of free
chlorine. Some pathogens, including viruses, would be unaffected by this concentration of chlorine.

**Cold storage**

Prawns are normally transported and stored in a frozen state. Prawn products prepared for human consumption include whole green prawns, green prawn tails with the shell on or off, cooked whole prawns, and crumbed prawn tails. Under commercial conditions, prawns are typically frozen at a temperature lower than −18°C or chilled at a temperature of 0°C to 7°C (ADVS 1999). Unfrozen product must reach the consumer within a few days. Most prawn product imported into Australia is frozen due to product quality, marketing and cost factors.

Chilling and freezing generally reduce the rate of inactivation of microorganisms (ADVS 1999); however, storage at freezing temperature kills many food-borne pathogenic protozoa, cestodes and nematodes (Kim 1997). Furthermore, most viruses persist at chill temperatures for hours to days and are quite stable at freezing temperatures (ADVS 1999), while bacteria that are pathogenic or potentially pathogenic to aquatic species are inactivated to some degree by chilled or frozen storage (ADVS 1999). Laboratories commonly freeze prawn samples in order to ensure the preservation of viruses. Under laboratory conditions maximum preservation of viral infectivity is achieved when samples are held at very low temperatures (−70°C or lower).

A freeze–thaw cycle would be expected to decrease the titre of some agents such as YHV (T Flegel pers. comm.). Other pathogens, such as IHHNV, can persist and maintain infectivity in frozen prawns for extended periods.

**Heating**

Whole prawns, prawn tails, or halved prawn tails are typically cooked for one to several minutes in boiling water or steam, and then rapidly cooled in an ice slurry or freezer. The thermal centre of the products may not attain the cooking temperature throughout cooking, depending on the size of the prawn/tails, and density of tissue. Therefore, some pathogens at the centre of the product may not be inactivated. However, peripheral tissue, particularly that adjacent to the cuticle, would attain the cooking temperature for most of the cooking process. Most prawn pathogens would be inactivated at typical cooking temperatures. Some organisms (eg. paroviruses) are relatively resistant to inactivation by thermal treatment, but even in the case of more resistant pathogens, a significant proportion of the population could be inactivated by cooking.

**Multiplication during storage**

In considering the effect of storage on microorganisms in or on food, it is important to note that viruses, metazoans and most protozoal pathogens do not multiply in the tissues of a dead host.

Prawns rapidly deteriorate if they suffer temperature abuse or are stored chilled for extended periods. Such prawns develop volatile spoilage compounds and would be unacceptable for

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human consumption. The quarantine significance of bacterial replication in prawn products is unclear, as commensal organisms and environmental bacteria are likely to multiply much more rapidly and would effectively overgrow any aquatic pathogens present in the tissues. However, the proliferation of infective agents, such as *Vibrio* spp., under certain conditions during processing, storage and transport of the product is an important element that must be considered.

### 3.2.5 The probability of the disease agent being present in the particular tissues imported

Infectious agents display characteristic tissue preferences that are largely determined by the mode of infection and pathogenic characteristics of the agent in a particular host species. The nature and distribution of host cellular receptors largely determine the tissue tropisms of viruses and other intracellular agents. Some agents are highly specific, while others use cell surface receptors that occur on many tissues of the body (or at many lifecycle stages of the host).

The cephalothorax is heavily cuticularised and contains the large cuticularised foregut and several important immune system organs such as the haematopoietic nodules, the lymphoid organ and the heart (which contains phagocytic cells). Prawns have a semi-closed vascular system which means that the organs within the cephalothorax lie within the haemocoel and are bathed in haemolymph. The abdomen is cuticularised and contains mostly muscle and few organs other than the endodermal midgut and the relatively short, cuticularised hindgut.

The titre of pathogens which have a predilection for endodermal enteric tissues, such as baculoviruses (*Penaeus monodon*-type baculovirus, *Baculovirus penaei* and baculoviral midgut gland necrosis virus), and the subcutis, such as TSV, WSSV and YHV, will be significantly reduced with removal of the cephalothorax. Furthermore, viruses which cause systemic infections may persist for a longer period in prawn tails as they are less prone to enzymatic degradation compared to head-on prawns. Removal of the shell would be expected to reduce the titre of organisms that are preferentially located on it or in the sub-cuticular tissues. Pathogens that are preferentially located in muscular tissues (such as microsporidians) would not be significantly reduced in titre as a consequence of shell removal or heading.

Infection by many pathogens may result in a bacteraemia or viraemia thus the pathogen will be present at high titre throughout the body. In such cases, the removal of haemolymph-rich organs would reduce the load of pathogens present, but a significant proportion would remain in somatic muscle.

Prawns affected by generalised disease are usually visibly abnormal, showing signs such as discoloration, cuticular lesions, a loose cephalothorax, reddening or darkening due to chromatophore expansion, and epibiotic fouling. These signs would be detected during inspection and grading, and the prawns excluded from human consumption.

In subclinically infected or chronically infected recovered prawns, pathogenic organisms would not occur at high titre throughout the body; rather they would be concentrated in particular tissues, such as the lymphoid organ (eg. TSV and YHV).
3.2.6 Conclusions

Many factors will influence the likelihood that prawn product imported into Australia will be infected with disease agents of quarantine concern. For many agents limited epizootiological information is available. Notwithstanding these information gaps, some conclusions can be drawn.

As some disease agents have a limited geographical distribution, importation from regions free of the disease would have a negligible risk. However, the confidence that can be placed on knowledge of the distribution of disease agents is limited by the level of surveillance and monitoring for disease in source populations. Monitoring and surveillance for prawn diseases is not well developed.

Many factors can influence the probability of a particular prawn being infected by a disease agent. Factors include the species of prawn, the method of its production and the size of the prawn.

Inspection and grading of prawns may also influence the likelihood of an individual imported prawn having an infection. Bait prawns are not generally inspected. Prawns for human consumption are inspected and graded. Prawns with visible lesions and blemishes, including those resulting from infection, will be rejected. Although prawns are inspected at a high speed, normal procedures include inspection at several points along the processing line and most prawns with detectable lesions or blemishes will be rejected. Infected prawns that are free or lesions or have subtle lesions are likely to pass inspection and grading.

Processing including washing and value adding will also reduce risk through the physical removal of disease agents. Cooking of prawns will significantly reduce the titre of any disease agents that may be present. Prawns are usually stored and transported in a frozen form. Freezing and thawing will reduce the titre of most disease agents present to a greater or lesser extent depending on the agent and the physical conditions, however once in a frozen state the titre of pathogens is relatively stable.

In Chapter 5 the relevant factors identified above and other pertinent information will be considered for each disease agent in determining the unrestricted risk estimate for the importation of whole green prawns.

3.3 Exposure assessment

This section discusses the quarantine risks presented by the exposure of Australian prawns and other species to imported prawn products. The exposure of susceptible prawns to imported product (and infectious organisms that such product may contain) is a major determinant of quarantine risk. In considering the quarantine significance of the various pathways of exposure, AQIS takes into account the probability of certain types of prawns following the ‘human consumption’ or ‘bait’ pathway and other relevant factors. Figure 3.1 is a diagram of the disposition and use of imported prawns and the relevance to quarantine risk.
Figure 3.1 Important pathways followed by imported prawn product.
3.3.1 Probability of imported product entering the aquatic environment

In this section, the use and disposal of imported prawn products is considered in terms of their probability of entry into the aquatic environment. There are many pathways by which such products, and any disease agents they contain, can enter the aquatic environment. Pathways that are direct and have a high probability of completion contribute very substantially to the total likelihood of exposure occurring, eg the use of prawns as fishing bait (including prawns for human consumption diverted to fishing bait) and prawn feeds. Some pathways may be associated with the accumulation of biologically significant numbers of disease agents in the aquatic environment, eg commercial processing of imported prawns in Australia, and thus contribute significantly to risk.

Other pathways have a much lower probability of completion, as they are not common or involve indirect exposure to the aquatic environment. Human consumption is the most common purpose for which prawns are imported. Prawn products imported for human consumption will generally be consumed, in a cooked form, by people in households, hotels, restaurants or institutions. Most exotic prawn pathogens are unlikely to survive food processing, passage through the human gastrointestinal tract, sewerage treatment processes and solid waste disposal processes, and are therefore unlikely to reach the aquatic environment. Imported prawn product could be discarded as food scraps into the aquatic environment but this is likely to occur infrequently. Susceptible prawns/crustaceans would be very unlikely to become infected because the food scraps would be rapidly diluted in water and they would be unlikely to contain pathogens in infective form and at high titre (as most would be cooked). Moreover, discarded scraps (whether they contained infective pathogens or not) would be more likely to be consumed by non-susceptible than susceptible species.

Only those pathways that will substantially contribute to the total risk will be considered further.

**Prawns as fishing bait**

Not surprisingly prawns imported into Australia for use as fishing bait have a high probability of entering the aquatic environment. Recreational fishers throughout Australia commonly use prawns as fish bait or berley when fishing. ADVS (1999) noted:

> It is also evident that ... prawns ... are favoured bait used in very significant quantities by recreational fishers

and:

> ... cooked or uncooked prawns and prawn heads or shells left over after the preparation of food for humans are highly valued by many anglers as an attractive berley additive.

In Australia bait prawns have a commercial value that is comparable to similar sized prawns for human consumption. There may be considerable redirection of product intended for human consumption into the fish bait market. ADVS (1999) stated:
There is considerable scope for the redirection of prawns intended primarily for the human consumption market onto the bait market, and vice versa. The major motivations driving this redirection of prawns from one end-use to another are price, quality, demand and relative availability. Imported and domestic frozen or fresh frozen or fresh prawns intended specifically for human consumption are frequently purchased by fishers seeking larger, higher quality or, on occasion, cheaper products than those offered by bait suppliers. In addition, commercial fishers, co-operatives and wholesalers regularly redirect smaller or less uniform-sized prawns toward the bait market, which often tends to have a more stable pricing structure than the seafood sector. The practice of redirecting prawns intended for human consumption into the bait market was clearly identified during the case study investigating prawn products in the Moreton Bay region. It is evident that market forces identify prawns (along with squid and octopi) as one of the most dynamic of all aquatic products in terms of their ability to be quickly and readily switched from one end-use to another by players at any stage in the process; from harvester or farmer to consumer.

AQIS inquiries revealed that most green prawns used for bait purposes have an individual weight of 5 to 10 grams; prawns of 10 to 15 grams are also used as bait. Prawns greater than 15 grams are rarely used as fishing bait. Prawns that have been emergency harvested are typically smaller and likely to fall into these weight ranges. Together with their variability in size, they are less valuable and there is a high likelihood that a significant proportion of emergency harvested prawns entering Australia may be diverted to bait use.

In November 1996 AQIS imposed interim restrictions on the entry of whole green prawns not fit for human consumption to address concerns raised by the National Task Force on the Imported Fish and Fish Products about the risks potentially associated with the use of imported prawns as fishing bait. Previously there were no restrictions on the entry of green prawns irrespective of intended end-use.

Imports of prawns steadily increased in the period between 1992-93 and 1998-99 (Table 3.1). The imposition in November 1996 of interim restrictions on the use of imported prawns for bait had no obvious effect on this trend suggesting that only a small proportion of imported prawns were used for bait. However, AQIS acknowledges that some prawns imported after November 1996 for human consumption may have been diverted to the bait trade. Almost all fresh, chilled or frozen prawn imports are from the Asia-Pacific region, with approximately 60% from Thailand. The Thai submission to the technical issues paper stated that most Thai prawns exported to Australia were cooked (80%), with whole green prawns (7%), headless shell-on prawns (0.3%) and prawn meat (11.7%) making up the remainder.

Table 3.1 Australian imports of fresh, chilled or frozen prawns (in tonnes) from 1992-93 to 1998-99 (includes cooked)

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<tr>
<td>1992-93</td>
<td>6 681</td>
<td>7 480</td>
<td>8 439</td>
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<td>8 287</td>
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Bait prawns are usually transported and retailed in a frozen state, though they are thawed before use. Bait prawns frequently suffer temperature abuse immediately before use as storage facilities may not be available and product at ambient temperature is favoured for bait use.
The use of prawn scraps as berley is another issue that must be considered. Prawns are almost always eaten cooked (ADVS 1999). Prawns are usually cooked whole, and the cephalothorax and shell are removed prior to consumption of tail meat (abdominal muscle). The pathogens of prawns are generally susceptible to inactivation by heating, thus cooking would be expected to inactivate most pathogens of quarantine concern, including viruses, bacteria, protozoa and metazoa. Therefore, cooking prior to use of scraps as berley would significantly reduce the titre of pathogens that are present.

The cephalothorax and, less frequently, the exoskeleton (shell) of the prawn may be removed prior to cooking. Raw heads from imported prawns that are used by anglers for bait or berley purposes are expected to be from large prawns that have been successfully grown in aquaculture. Temperature abuse and enzymatic degradation are expected to adversely affect titres. Such prawns have a much lower probability of being infected or having a high titre of pathogens.

There is a high probability that imported prawns used as bait will enter the aquatic environment. There is a moderate likelihood that small whole green prawns, including those from emergency harvest, that enter Australia for human consumption will be diverted to bait use. There is a very low probability that raw prawn scraps will be used as berley.

**Prawn feeds**

Obviously there is a high probability that prawn feeds will enter the aquatic environment. Historically prawn feeds have contained prawn or other crustacean meal. Approximately 80% of pelleted prawn feed used in the Australian prawn aquaculture industry is imported (AquaTactics 1999). Australia imported 4930 tonnes of prawn feed in 1997/98. Prawn feeds typically contain from 35-45% protein; the exact level of protein is varied according to the species and age of prawn to be fed. The protein component of prawn feeds may be of animal or plant origin. AquaTactics (1999) stated that the industry normally uses a level of 6-10% crustacean meal in prawn feed. AquaTactics stated:

> Crustacean meals that are used in the production of prawn feeds are predominantly produced from penaeid species. Also involved in the production of these crustacean meals is the metapenaeid species. The choice of species is somewhat arbitrary and is dependent on what is available geographically and or economically. In areas where the processing of prawns for human consumption is undertaken then the waste stream (heads and shells) are often used in the production of crustacean meals destined for incorporation into prawn feeds.

There are several different types of prawn feed; each type has been developed to meet the specific nutritional requirements of the different prawn lifestages. Feeds used in hatcheries (micro-encapsulated, suspension and flake) are less price sensitive than the feeds used in the ‘grow-out’ stage (typically pelleted feeds). Consequently, higher cost ingredients are typically incorporated in hatchery feeds. These higher cost ingredients include crustacean meals produced from cold deep-water species that are rich in carotenoids. It is unusual for hatchery feeds to contain crustacean meal which include *P. monodon* (AquaTactics 1999).

Prawn feeds for use in the ‘grow-out’ stage are price sensitive and therefore contain cheaper ingredients. Prawn head meal is commonly used as a cheap crustacean meal. The prawn heads for the meal may be obtained relatively cheaply as a by-product from prawn processing plants. In areas where prawn aquaculture predominates, the prawn head meal may be derived entirely from farmed prawns. There are anecdotal reports that prawns from emergency
harvests are used in the production of prawn head meal. Meals derived from other crustacean species may be incorporated in ‘grow-out feeds’ on economic grounds due to price fluctuations from supply and demand relationships. Prawn head meal production involves prolonged drying periods often at high temperatures (up to 140°C) (Figure 3.2). The prolonged period for which the prawn heads are dried would ensure that core temperatures would be equivalent to the drying temperature for a significant proportion of that period. Though core temperatures reached during sun drying may not be as high as for the other drying methods, the prawn heads are dried for considerably longer (up to 2 days).

Charoen Pokphand (CP), Thailand’s largest prawn feed producer, no longer includes crustacean meals in prawn feed used domestically. However, on request from international clients CP will include prawn head meal and/or other crustacean meals in prawn feeds (Edgerton and Owens 2000). Other manufacturers may or may not incorporate crustacean meals in their prawn feed. No Australian aquaculture feed producers were identified as using prawn ingredients in commercially manufactured prawn feeds during the AquaTactics (1999) survey or in AQIS’s own inquiries.

AquaTactics (AquaTactics 1999) stated:

The methods used for the production of prawn feeds do not vary greatly between major prawn producing countries. Commercial prawn feeds are almost identical in form irrespective of the country of origin. As would be expected for the production of similar products the use of similar techniques and equipment has been standardised.

The two most common methods for producing prawn feeds are steam pellet pressing and steam extrusion. As the names suggest, both processes subject the ingredients to high temperatures. In steam pellet pressing, ingredients are conditioned at around 90°C for up to 90 seconds, pass through the pellet die at 100°C and into a drier for up to 40 minutes at 90°C (AquaTactics 1999; Edgerton and Owens 2000). The extrusion process is essentially the same except that the ingredients pass through an extrusion barrel and die at 90-140°C for 4-15 seconds instead of the pellet press die. There are several other methods for producing prawn feeds but these are rarely used in commercial production.

The temperatures and pressures that prawn feed reaches during manufacture will significantly reduce the titre of any disease agents that are present. The extent of reduction will vary with the specific manufacturing process used. Australia has imported prawn feed with the requirement that it be heated to 85°C for 15 minutes or 80°C for 20 minutes, and there is no evidence that this practice has resulted in the introduction of disease.

As prawn farms are in tropical or subtropical regions, ambient temperature and humidity will adversely affect product quality if storage facilities are not adequate. Following production prawn feeds are generally stored in cool rooms to maintain quality.

The conduct of the feed manufacturing premises will affect the likelihood of disease agents being present in feed. In poorly controlled premises production standards may not be maintained and/or product may be contaminated following manufacture.

Hardy (1991) detailed the approach to hazard analysis and critical control point (HACCP) programs which may be applied to aquaculture feed milling, and stated that many aquaculture feed mills had in place many of the identified steps. However, AQIS understands that formal HACCP programs may not be instituted in all prawn feed mills.

Prawn feeds clearly have a direct exposure route to farmed prawns. The likelihood of establishment of exotic prawn diseases due to the use of prawn feeds in aquaculture depends on, inter alia, the raw materials used to make the meal and the treatment to which the meal is subjected. For feed processed at high temperatures for a significant period, the likelihood
would be extremely low. Well-managed feed mills would present a lower risk than poorly managed mills.

**Commercial processing in Australia of imported prawns**

For economic reasons commercial processing of imported prawns in Australia is not commonly practiced. ADVS (1999) stated that:

currently there is little processing of imported prawns after arrival in Australia, therefore exotic prawn viruses are less likely to be present in commercial prawn waste.

Although the commercial processing of imported prawns in Australia is not widely practised at present, there are no regulatory controls that would stop such processing occurring.

Commercial processing of prawns would produce substantial volumes of waste effluent and solids. Historically prawn-processing plants have been situated close to water to allow fishing boats to off-load their catch directly into the plant. The siting of prawn processing plants in the vicinity of susceptible hosts, such as occur in a prawn farming area or in streams containing populations of freshwater crustaceans, would present an unacceptable disease risk unless the disposal of waste and effluent water were appropriately controlled. There is a strong suspicion that commercial processing in the Americas is associated with the introduction of disease (Lightner et al. 1997b; Lightner et al. 1998; Lightner, pers. comm.).

**Effluent water**

Depending on the nature of the operation, significant volumes of water would be used in commercial prawn processing plants. Waste-water from such plants would contain suspended pathogens and pieces of prawn tissue including organs of the cephalothorax, shell, pleopods, enteric tract, etc. High concentrations of pathogens may be present in effluent and, if discharged into natural waters with little or no treatment, biologically significant numbers of pathogens may result in the local environment. Frequent discharge of effluent containing lesser concentrations of pathogens may result in the build up of biologically significant numbers of pathogens.

The processing of effluent in the domestic sewerage system would significantly reduce, if not eliminate, the number of any prawn pathogens that may be present, even if it were limited to primary level processing. The physical conditions in the sewerage system, including the presence of chlorine and other chemicals inimical to the survival of microorganisms, and competition from other microorganisms for nutrients would be expected to limit the survival of many of the aquatic pathogens considered in this risk analysis. The dilution of effluent with wastewater from other sources would significantly decrease the concentration of any pathogens present. At a minimum the treatment and dilution of effluent in the domestic sewerage system would reduce the concentration of pathogens at discharge by several orders of magnitude.

The discharge of effluent into fresh water is usually controlled by local authorities, who normally require processing to a secondary or tertiary level to protect public health and the environment. Such processing would reduce the concentration of pathogens entering freshwater systems by several orders of magnitude. However, the siting of prawn processing

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21 For the purposes of this IRA, commercial processing is defined as the processing undertaken at a commercial premises that produces product for sale at another premises or location.
plants in the vicinity of fresh water containing significant freshwater crayfish populations would present a particular risk factor.

Prawn pathogens, such as WSSV and certain bacteria (eg some vibrios) that have a very wide host range, would have a higher likelihood of establishing in Australia. However, the considerable dilution of effluent containing imported aquatic product and the effect of physical factors on the condition and infectivity of these pathogens would reduce to an extremely low level the probability that an index case \(^{22}\) of disease would occur if effluent was appropriately treated.

Broodstock for prawn aquaculture are sourced from coastal waters off Cairns and Mackay. Therefore, the discharge of untreated effluent into these regions may pose a higher risk than such discharge into the marine waters in other areas of Australia.

**Solid waste**

The commercial processing of imported prawns in Australia would lead to the generation of significant quantities of solid wastes. The continuing entry of solid wastes from commercial processing plants into waters containing crustaceans presents a significant risk factor because of the potential for build up of disease agents in the local environment.

ADVS (1999) considered the processes used for waste disposal in Australia, including solid wastes result generated by seafood processing (eg cephalothorax, shell, pleopods). If this material is moved to properly designed and controlled sanitary landfills,\(^{23}\) the risk of pathogens entering the aquatic environment is extremely low. Solid waste derived from imported product would constitute a minuscule proportion of the solid waste processed through controlled waste disposal systems. Aquatic pathogens are unlikely to survive the environment at waste disposal sites (because of desiccation, ultraviolet radiation, low oxygen potential, daily variations in temperature and competition from other microorganisms for nutrients). In combination with dilution, such physical conditions would significantly reduce the concentration of pathogens in waste at commercial processing sites and would greatly reduce the probability of susceptible species being exposed to a significant concentration of pathogens via such pathways as uncontrolled run-off, leachate or the activities of scavenging seabirds.

For the same reasons, the probability of pathogens entering the aquatic environment via the disposal of imported prawn-derived solid waste from household and hotel and restaurant industry sources at properly designed and controlled sanitary landfills would be very low.

Some scientific reports suggest that seabirds may play a part in the dissemination of aquatic pathogens; however, the significance of this route remains unclear. Garza et al (1997) reported that seagulls (*Larus atricilla*) were shown to serve as potential vectors of TSV and that gulls and other shrimp-eating seabirds could transmit TSV to farms within their flight path. However, these authors noted that it is not known how long TSV remains in the gut contents of gulls or other seabirds and, therefore, how important these birds might be in

\(^{22}\) An index case is the first case of infection in a population previously free of the disease agent

\(^{23}\) In the context of the ADVS report, a properly designed and controlled sanitary landfill is taken to be one that is designed and constructed to contain putrescible materials, such as fish processing waste, and is managed to prevent accidental leakage to the aquatic environment and to minimise the opportunity for scavengers, including birds, to remove material from the site.
spreading this disease beyond a given region. The significance of birds in the epizootiology of prawn disease is unclear. Aquatic insects, particularly the water boatmen *Trichocorixa reticulata*, have been suggested as possible vectors of TSV (Hasson et al. 1995) as TSV in their gut contents was shown to be infectious (Lightner 1996a; Lightner and Redman 1998). Aquatic insects would only be able to move disease agents over short distances and are unlikely to play a significant role in exotic disease introduction.

The role of seabirds and other physical vectors in disseminating disease may be significant in circumstances where a high concentration and/or volume of the infectious agent is present (eg in animals dead or dying as a consequence of disease, high concentrations of infected wastes). This is the situation cited by Garza et al (1997). When disease agents are present at low titre (as could be the case with apparently healthy prawns imported for human consumption and then discarded at rubbish tips), seabirds and other mechanical vectors are much less likely to transmit disease.

If there were introduction of heavily infected wastes or continual introduction of infected wastes into a local environment, biologically significant numbers of pathogens may result and the likelihood of disease establishment would be significantly increased.

### 3.3.2 The probability that susceptible hosts will contact imported product containing viable disease agents

The probability of a susceptible species having contact with imported product, or other materials contaminated by disease agents, depends on several factors including the nature of the product, the volume of product released, the disease agent, which hosts are susceptible to infection and their distribution, environmental conditions and the level of competition from other scavengers/predators in the area. Discussion of the three pathways identified above will be continued in this section, viz prawns as fishing bait, prawn feeds and commercial processing in Australia of imported prawns.

As prawn species and freshwater crustaceans are widely distributed in fresh and marine waters in Australia, it is expected that all waters in which recreational fishing is carried out will contain crustacean species. A high proportion of prawns introduced into aquatic environments as bait or berley will be consumed by finfish species. Scavengers, such as crustaceans, must compete with predatory finfish and other scavengers (including other invertebrates, birds and marine mammals) for bait scraps and berley. Competition for scraps with non-susceptible aquatic species would reduce the likelihood of susceptible crustaceans consuming scraps containing infectious organisms.

At popular fishing spots, fishing bait, which may include imported prawns, regularly enters a relatively circumscribed body of water. This would increase to moderate the probability of susceptible species being exposed to imported product, taking into account that non-susceptible species will compete with susceptible species for the bait. The titre of viable disease agent, if present in the product, will depend on the initial titre, storage conditions, environmental conditions and length of time in the water before exposure. Many prawn viruses have a relatively short half life and the titre of viable viruses would rapidly decline to negligible levels, reducing the significance of this avenue of exposure.

With regard to prawn feeds there is a high probability that it will be exposed to and consumed by cultured prawns.
Crustaceans are generally expected to be present in the aquatic environment where any commercial processing wastes were to be discharged. Commercial processing of prawns will result in substantial volumes of waste. If untreated or ineffectively treated wastes enter the aquatic environment in a restricted area, it is likely that local crustaceans will directly contact that waste.

3.3.3 The probability of the disease agent establishing in host populations in the importing country

Factors relevant to this probability include the titre of organisms likely to be present in imported product and the capability of organisms to survive in the aquatic environment long enough for a susceptible host to be exposed to them. The issue of infectious dose must also be considered. The ability for a particular agent to infect a particular host depends on several factors including the strain of the agent, the route of infection, environmental conditions and the host.

Most of the factors affecting the level of pathogens that may be present in imported prawns and prawn products are discussed in Section 3.2. However, the concept of minimum infective dose should be discussed at this point.

ADVS (1999) noted that it could be misleading to recommend a minimum infective dose of any pathogen, and that such a recommendation would need to take into account the capability of a laboratory to determine accurately the number of cells or viruses present when they may be in a cryptic state. Moreover, infectious dose studies on crustacean viruses are further complicated by the lack of continuous crustacean cell lines for virus titration. The environmental conditions at the time of infection or release from a carrier and the health and immunological status of the recipient host animal would also have to be taken into account.

AQIS has considered relevant data that are available. For most agents, data are not available to provide a meaningful quantification of infectious dose, and it is only possible to conclude that the minimum infective dose is likely to be high or low, relative to the range of disease agents under consideration.

For most disease agents, infection is most readily transmitted via the introduction of a live, infected host into a naïve (and susceptible) population. Some agents may cause subclinical infection, so apparently normal, infected prawns (ie carriers) may still be a source of infectious organisms. However it is more likely that when new disease is introduced into a population, infected prawns will become clinically diseased and actively disseminate infectious organisms into the environment. The greater the population density of hosts susceptible to disease, the more readily disease may be transmitted and the greater the rate of morbidity in the susceptible population.

The dynamics of transmission of disease have been studied extensively in farmed livestock and birds, but there is much less information in relation to aquatic animals. Nonetheless, it is well recognised that most pathogens are transmitted (and disease is expressed) far more readily in aquaculture than in wild fisheries. Density of susceptible species is an important factor but other factors that affect the susceptibility of the host to infection (eg lifecycle stage, environmental conditions and intercurrent stress) may be equally important. Another factor is the density of predator or scavenger species refractory or less susceptible to a disease which may affect transmission of that disease agent between susceptible hosts. In natural waters it is more likely that fish and other predators will consume diseased prawns rather than other
scavengers that are susceptible to infection. If the density of prawns is high relative to fish and other predators, the probability of disease spreading in the prawn population will increase.

**Susceptibility of Australian prawns to infection**

Most reports of prawn pathogens are from species which are important in aquaculture. In the Asian region and Australia the main aquaculture species are *P. monodon* and *P. japonicus*. In the Americas the main aquaculture species are *L. stylirostris* and *L. vannamei*. Some pathogens may be host specific and infect only one or several prawn species, possibly from more than one genus. Other pathogens have a much wider host range and may infect other groups of crustaceans and even other arthropod groups (e.g. WSSV). Prawn pathogens such as WSSV that have a very wide host range would have a higher likelihood of establishing in Australia.

Prawns are r-selected species, and as such, exhibit very high fecundity levels and high mortality rates throughout their lifecycle. Instantaneous rates of natural mortality in prawns of up to 94% have been reported (Haywood and Staples 1993; Wang and Haywood 1999), and some research has suggested that natural mortality for sub-adult and adult penaeid prawns may be as high as 93% (Glaister 1993, cited in AusVet 1999). Predation is a major contributor to the high mortality rate of juvenile, sub-adult and adult prawns, with predation being the greatest cause of mortality in some prawn species (Minello et al. 1989). Penaeid prawns are eaten by a variety of predators including fish, sharks and rays. Many studies in Australia have confirmed the importance of teleost fish as predators of prawns, with prawns found very frequently in the gut of many fish species (Brewer et al. 1991; Salini et al. 1994; Brewer et al. 1995; Salini et al. 1998). One study showed that prawns made up 22% of the diet (by volume) of young barramundi (Robertson 1988). Other crustaceans, particularly brachyurans (crabs) in marine environments, are also major prey species for fishes (Salini et al. 1994). Thus, predation of prawns and other crustaceans will significantly reduce the likelihood of establishment of an exotic disease agent, irrespective of whether that individual is of a species severely affected by disease (see Figure 3.3).
Australian prawn species will, presumably, be at least as susceptible to infection as the same species found in other regions. However, environmental conditions which may favour the expression of disease in prawn populations in other regions may not be present in Australia. The effects of pathogens, for example WSSV and MBV, in prawn aquaculture throughout Asia are considered to have been exacerbated by environmental pollution and other stressors (Flegel 1997). On the other hand, the occurrence of white spot disease in prawn aquaculture in less polluted environments, such as in the USA, was associated with similarly high mortalities.

Conservative judgments have been used for the susceptibility of Australian prawns to infection with exotic pathogens in this risk analysis. When specific information on the susceptibility of an Australian species to infection is unavailable, the range of species infected overseas, their relatedness to Australian species and relevant epizootiological information about the disease agent is considered.

3.3.4 Conclusions

Most prawns imported for human consumption would be consumed (in cooked form) by people. This would generally present an extremely low probability of viable pathogens, if present, entering the aquatic environment. However, people may also dispose of such product by pathways that would result in a higher probability of pathogens, if present, entering the aquatic environment. Such pathways include the use of imported product for fishing bait and the use of scraps as berley. The ‘fishing bait’ pathway may occur with a high frequency in the case of some types of prawn products imported for human consumption. Cheaper products that have not been value added would have a higher likelihood of being diverted to bait, ie.
whole green prawns that weigh less than 15 grams, particularly if they have blemishes or are variable in size.

Prawns used as bait or berley will enter the aquatic environment. The concentration of pathogens entering the aquatic environment within prawn bait/berley would be rapidly reduced by dilution. If the bait/berley were used at a popular fishing location the probability would increase in line with the fishing pressure. The probability of disease establishment resulting from this pathway also depends on the prawn species used as bait and the number and nature of pathogens in these species, as well as local environmental factors and the population density of susceptible host species, relative to non-susceptible species, in the receiving waters. For aquatic pathogens that are highly host-specific (including many prawn pathogens) there would be a high probability of bait and berley being consumed by aquatic species that are not susceptible to infection.

Farmed prawns and their environment are directly exposed to prawn feed used in aquaculture. The likelihood of viable crustacean pathogens entering the aquatic environment in prawn feeds will depend on materials used to make the feed, ie. whether it contains crustaceans, and if so, from where, and the treatment of the crustacean meal and the prawn feed. Production of prawn feed, and/or crustacean meal used in the production of prawn feed, at high temperatures for a sufficient length of time would reduce the likelihood of disease introduction. The conduct of the feed processing plant would also be a factor.

Effluent from commercial prawn processing plants may contain a high concentration of aquatic pathogens. If such water bypassed the domestic sewerage system or were discharged into waterways without adequate treatment, aquatic pathogens could enter the aquatic environment in significant quantity.

There may be a higher concentration of pathogens at the point of discharge of untreated effluent. However, the concentration would be reduced by dilution further away from the point of discharge. Aquatic species often congregate at effluent discharge points. For aquatic pathogens that are highly host-specific (including many prawn pathogens) there would be a high probability of particulate matter containing pathogens being consumed by aquatic species that are not susceptible to infection. For aquatic pathogens that have a wider host range, the probability of susceptible species consuming pathogens would be greater, but non-susceptible species would still compete with these species for scraps and this would reduce the probability of an infection occurring.

The effect of dilution and exposure to physical conditions would reduce the concentration of pathogens entering the aquatic environment via solid waste in the commercial waste management system. Although the role of seabirds and other scavengers in moving solid waste around cannot be discounted, this would not significantly increase the probability in the risk analysis overall.

AQIS has considered other pathways and the probability of aquatic pathogens entering the aquatic environment by such routes. These pathways would be followed rarely or exceptionally. Moreover, in the light of other factors discussed, AQIS concludes that these pathways would not significantly increase the probability of disease establishment in the risk analysis overall.
3.4 Consequence assessment

This section discusses the factors considered by AQIS in assessing the significance, or impact, of the establishment of exotic disease. As outlined in Section 1.5.2, AQIS considers all relevant factors and classifies the significance of each disease according to categories that have been defined in qualitative terms (‘negligible’, ‘low’, ‘moderate’, ‘high’ or ‘catastrophic’, see Box 1.6). The significance and the probability of establishment are considered together in estimating the risk.

The key points relevant to the consequences of establishment of individual diseases are set out in Chapter 5. This section describes the general considerations relevant to this assessment.

3.4.1 Factors relevant to the impact of disease

Biological effects

In Section 1.5.2, the effect of the establishment of a disease was defined in biological terms (with reference to mortality, morbidity and the pathogenic effects of the agent) and in terms of economic or environmental impact. Most of the disease agents further considered in this risk analysis have the capacity to cause marked pathological effects in a significant proportion of hosts in a susceptible population and to cause significant economic effect.

The biological effect of disease depends on the interaction of the environment, pathogen and host. The nature of this interaction reflects factors intrinsic to the pathogen (such as virulence and infectivity), the host (such as immune competence and population density) and the environment (such as availability of habitat for susceptible hosts).

The biological effect of disease is normally evaluated in terms of morbidity and mortality. Morbidity can be evaluated in terms of reduced production, and described by parameters such as food conversion efficiency and fecundity that are relevant to the population under study. Diseases that reduce the efficiency of production without causing large increases in mortality are more likely to be significant in farmed prawns than wild-caught prawns.

The epizootiology of disease in aquatic populations is generally poorly understood. In farmed prawns, ‘normal’ or baseline values for production and mortality are often highly variable, reflecting husbandry practices, stocking rates and stress. Many economically significant diseases of farmed prawns are caused by commensal organisms that are opportunistic pathogens (ie they cause disease only when environmental or other conditions predispose prawns to infection).

It is likely that in wild prawns the effect of pathogens is also influenced by environmental factors that predispose the host population to infection and the expression of disease. The generally higher prevalence of disease and the frequent emergence of new pathogens in farmed prawns supports the view that farmed prawns are subject to more environmental stresses and higher disease transmission rates due to high population density. It will also reflect closer monitoring of production and mortality in farmed prawns (Section 3.2.1).

The underlying or ‘normal’ rate of mortality in wild populations may be statistically estimated, based on data collected in studies of population density, age/size structure and catch rates. Normally, this type of modelling becomes more accurate over time and the natural rate of mortality can be estimated with increasing accuracy. Population fluctuations can be linked quite closely to other factors, such as fishing pressure, using these sorts of data.
However, only major epizootics involving significant mortalities or grossly visible clinical signs would be detected in wild crustacean populations.

Perhaps the best known epizootic disease of wild crustaceans is crayfish plague, caused by *Aphanomyces astaci*, which has eliminated native freshwater crayfish from many river systems in Europe. Another example is microsporidians which are commonly recognised in wild crustacean populations including prawns. Whitening of the musculature, an obvious clinical sign of microsporidiosis, is frequently reported in wild crustacean populations. A prevalence of microsporidiosis up to 90% has been reported in wild populations (Viosca 1943; Miglarese and Shealy 1974). However, there is little data relating disease occurrence in wild populations of prawns to drops in fishery catches.

AusVet (1999) examined the impact of WSSV and IHHNV in wild prawn populations. For WSSV, AusVet (1999) concluded that:

> Although WSSV infection is common in several wild prawn populations in Asia, the weight of evidence suggests that the virus has not caused measurable reductions in catches.

The situation with respect to the impact of IHHNV on wild prawn populations is less clear. Lightner et al. (1992) reported the introduction in 1987 of IHHNV into aquaculture facilities on the western coast of Mexico with the importation of subclinically infected *L. vannamei* postlarvae. Since 1974, wild stocks of species susceptible to IHHNV in the Gulf of California had been monitored without a case of IHHNV infection being detected prior to 1987. Pantoja et al. (1999) showed that by 1990 IHHNV was common in wild stocks of *L. stylirostris*, and present in wild stocks of *Farfantepenaeus californiensis* and *L. vannamei*, from the Gulf of California. JSA (1997) stated:

> Beginning with the 1987-88 season, landings of blue shrimp (Saulnier et al. 2000) decreased by about 1000 tons per year for four consecutive years. Stocks began to recover only after about six years. This is the best chronological association of a disease and wild population effects currently known.

However, in a subsequent shrimp virus peer review workshop (ERG (Eastern Research Group) 1998) participants stated:

> it would be very difficult to diagnose the cause of a decline in a population of shrimp because many factors interact to cause natural population fluctuations of up to 25 percent per year.

and concluded that:

> identification of virus in the shrimp would indicate that the virus may have played a part in the change, but it would not establish a cause-and-effect relationship.

The contribution of the IHHNV introduction to the population decline remains unresolved.

There is a body of evidence emerging that prawn populations may rapidly develop tolerance or resistance to pathogens which initially cause very serious disease in aquaculture. Though this may be the case, relatively minor stress events may predispose latently infected prawns to clinical disease.
Initially yellowhead disease (YHD) and later WSD were associated with widespread epizootics in prawn aquaculture in south-east Asia in the early to mid 1990s. The prevalence of WSSV in wild prawns also reached high levels in the mid 1990s (Lo and Kou 1998). In the latter 1990s, techniques to manage serious diseases in prawn aquaculture in the region combined with improved diagnostic techniques have lessened the impact of disease. The epizootiology of WSSV in severely affected regions has also altered. Flegel (1997) stated:

The most intriguing feature of the WSBV [white spot baculovirus=WSSV] epizootic in Thailand is that many farmers now obtain good to excellent harvests (4-7 tons per hectare) in spite of finding a few specimens with gross signs of WSBV infection present in their ponds during the early stages of cultivation and then later throughout the cultivation cycle…… This contrasts with the situation at the height of the epizootic, where massive mortalities and essentially total crop losses were experienced. The shrimp [prawns] appear to have rapidly developed a kind of tolerance or resistance to the new virus within a period of 1.5 years since it first caused heavy losses.

Notably, by the end of the 1990s prawn aquaculture production for Thailand was approaching pre-WSD levels. The phenomenon of increased tolerance of prawns to initially serious pathogenic agents has now been observed by many researchers and prawn aquaculturists. That is not to say that WSD and YHD are no longer serious problems in prawn aquaculture in Asia. However, evidence would suggest that the worst of the YHD and then WSD panzootics in south-east Asia had passed by the mid to late 1990s. Consequently, the proportion of crops which are now aborted early (emergency harvested) would be lower than at the height of the epizootics.

The immune regulation of this putative tolerance or resistance is not understood, nor is the current epizootiology of WSSV in populations which are known to be infected. At this stage there are little to no data on the prevalence of infection by pathogens, such as WSSV, in ‘tolerant’ or ‘resistant’ populations or the typical level of infection (ie. titre of pathogen).

The consequences of exotic disease establishment in Australian prawn aquaculture must be assessed in relation to characteristics of the local industry that may differentiate it from foreign industries. The Australian prawn aquaculture industry is a small but growing industry. In Queensland, the main prawn aquaculture state, there are less than 50 farms which occur singly or in small groups along the approximately 2000 km long eastern coastline. The Queensland Department of Primary Industries is in the process of finalising new policy to enhance the sustainability of coastal aquaculture. This policy requires that applications for an aquaculture licence within 5 km of an existing operation undergo additional assessments to ensure that disease and environmental risks are minimised as the industry expands (Robertson 1999). Many Australian prawn farmers are now practising minimal water exchange policies due to environmental concerns. The dispersed nature of the prawn aquaculture industry in Australia, and the trend of reducing water exchange rates, may help to prevent rapid spread of prawn pathogens between grow-out sites. On the other hand, the spread of disease between farms may be exacerbated by the limited extent of structured surveillance and disease control policies in some states.

The complex interaction between host factors, environmental factors (including husbandry in farmed prawns) and agent factors makes it difficult to predict accurately the effect of the establishment of exotic disease. It has been conservatively assumed that farmed and wild prawns (including native species) in Australia would be at least as susceptible to infection as prawns of the same, or closely related, species reported as susceptible under similar conditions in other countries. In the case of pathogens shown by overseas experience to be
highly pathogenic (eg. WSV and YHV), it has been assumed that rates of morbidity and mortality in Australia would be comparable to those overseas.

**Australia’s capacity to respond to disease incursions**

Australia has a highly developed animal health system that can thoroughly investigate disease problems. Although few tests for the diagnosis of specific exotic diseases of prawns are routinely available in Australia, sophisticated laboratories can perform diagnostic testing and, if required, send samples overseas for additional testing. Reliance on overseas testing would hamper Australia’s efforts to deal with outbreaks of exotic prawn diseases.

Contingency planning for aquaculture disease emergencies is well advanced at the national level. AQUAPLAN\(^{24}\) is a national strategic aquatic animal health plan developed by Agriculture Fisheries and Forestry Australia (AFFA) in consultation with aquatic industries and State agencies with responsibility for fisheries and aquaculture. Since the inception of AQUAPLAN in 1998, significant progress has been made on preparedness and response plans to deal with aquatic animal disease emergencies.

An appropriately conservative approach has been taken in the IRA, in the light of the high cost associated with attempts to eradicate new aquatic animal diseases and the low likelihood of success. It has been assumed that diseases that have been shown by overseas experience to be difficult or impossible to eradicate once established (eg WSSV and YHV) would present similar difficulties in Australia.

Environmental conditions (including husbandry) clearly influence the expression of clinical disease and the amenability of introduced disease to prevention and control. Thus, methods used with success overseas may not be feasible or similarly effective in Australia. For the diseases that are routinely controlled overseas by husbandry measures (eg reduced stocking rate) or veterinary intervention (eg antimicrobial treatment), it has been assumed that a similar approach would be applicable in Australia.

For some diseases there are clear parallels. For example, Australian *P. monodon* nauplii are routinely washed to manage MBV in hatcheries. These same techniques are utilised in aquaculture to manage other intranuclear bacilliform viruses such as baculoviral midgut gland necrosis virus (BMNV) and BP in Asia and the Americas respectively. Thus, in the event that BMNV or BP were to become established in Australia, it is likely that these pathogens could be controlled by similar means and the consequences of establishment on farmed prawns mitigated.

There would be a need for regulatory approval of any drug that is not currently available in Australia if such drugs were to be used to control a newly established disease. Moreover, the implementation of a control strategy in aquaculture would introduce new costs and have adverse implications for product quality and image. For some pathogens the cost of implementation of measures for control or eradication would be so costly as to be unfeasible in practice.

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Economic effects

Increased morbidity and mortality cause direct economic losses due to decreased production. Indirect costs will also affect economic performance and may include the implementation of additional farm management procedures, disease screening of broodstock, treatment of water, exclusion of pests. There may also be economic effects due to increased insurance premiums, the loss of markets or a reduction of prices received for product. Additional costs may affect farms that are free of infection.

Effects of disease in prawn aquaculture

For prawns farmed in Australia the most significant inputs are normally feed, postlarvae (which are derived from wild-caught broodstock) and access to water of suitable quality and volume.

If a disease is characterised by significant pathological effects, its establishment can have an impact due to increased mortality and/or reduced growth, feed conversion efficiency or product quality. Control, prevention or eradication of the disease would add to the cost of production. Such costs may include use of diagnostic tests for postlarvae, chemicals for disinfection and extra equipment for sanitation. Significantly, farms that regularly produce two crops per year may experience ongoing decreases in production due to increased time required for proper pond drying (ARE (Alliance Resource Economics) 1999). Insurance premiums may be increased or it may be necessary to increase stocking rates to offset the effects of mortality. Costs associated with increased morbidity and mortality and with the implementation of control measures are taken into account.

The establishment of a disease can also harm economic performance indirectly (eg through reduced value of domestic or export markets for live or non-viable prawns). For example, the establishment of WSSV in a prawn farm that produces and exports live *P. japonicus* may cause the loss of domestic and export markets. Moreover, farms on the same waterway as the affected farm would be subjected to similar restrictions and costs as those of the affected farm. The total economic losses associated with loss of market access can be reduced if the disease were zoned (regionalised) and markets reopened for farms outside the affected zone. Markets might be reopened if disease were eradicated or farms in the affected zone implemented a testing program (at additional cost) to underpin certification that prawns were free from disease.

Effects of disease in wild capture fisheries

There are no clear examples of the economic effects of disease in wild prawn capture fisheries. There is no evidence that the disease agents under consideration in this IRA have adversely affected wild prawn fisheries. In section 3.4.1, the impact of WSSV and IHHNV on wild fisheries was discussed. Similar mechanism for the development of tolerance/resistance by farmed prawns to newly recognised disease agents may exist in wild prawns. Predation of clinically ill prawns may limit spread of disease agents in wild populations and favour the selection of highly tolerant/resistant strains of prawns.

Zoning or regionalisation of disease

The concept of zoning (regionalisation) is recognised in the SPS Agreement and the OIE Code. However, there are currently few restrictions on international trade in prawn product
for human consumption on account of aquatic animal disease. Thus, in practice, zoning of prawn diseases normally only applies to trade in sperm, fertilised eggs, nauplii, larvae, postlarvae, juveniles and/or broodstock. Similarly, interstate movement restrictions in Australia cover live prawns, but do not normally apply to movement of non-viable prawn products. If an exotic disease became established, Australia would use zoning to maintain access to international markets for live prawns and, if required, non-viable product. This would require additional specific regulatory measures such as movement controls, testing and certification, with attendant costs.

**Public health and perceptions of quality**

The establishment of the prawn diseases considered in this risk analysis would have no public health significance. With the exception of certain metazoan diseases, organisms that are primary pathogens of crustacean species do not cause disease in humans. However, pathogens such as WSSV and microsporidians can cause the formation of visible lesions in crustacean tissues, and affected product would be unacceptable to the consumer for reasons of quality and aesthetic appeal.

Public perception of risks, whether the risk is real or imagined, can significantly affect the markets for product for human consumption. This public reaction may occur whether the problem is effectively managed or not. The use of chemical treatments or the occurrence of lesions/blemishes on the product could also affect any price premiums paid for high-quality products. This may occur regardless of whether the effect on quality was real or perceived.

**Recreational fisheries**

Recreational fisheries present a special case, in that ‘production’ is not easily quantified. Recreational fishing for prawns is not commonly pursued in Australia and the economic value of this pastime industry is not available. Prawns are often caught with cast nets or seine nets in local estuaries for use as bait, and on occasion for human consumption.

**Ecological and environmental effects**

In considering the significance, or impact, of the establishment of disease, AQIS also takes into account effects on the environment. The establishment of a new disease could affect the survival of native species that are not farmed or otherwise commercially exploited. For example, the ecological balance of aquatic systems and the quality of the environment could be disturbed if the normal proportions of different native species were significantly altered by the selective loss of one or more particularly disease-sensitive species. The potential loss of biodiversity would be of concern to the Australian community.

A conservative approach is taken when considering the susceptibility of native species, particularly those that are endangered or threatened, to infection with exotic pathogens. In considering the consequences of establishment of an exotic disease, the establishment of any disease that is likely to result in the extinction of a species (which equates to having a serious, irreversible effect on the environment) would be classified as ‘catastrophic’. In most cases there is limited information on the effect of exotic pathogens in Australian conditions. However, in drawing conclusions on the likely impact of exotic disease on the environment, overseas data is considered on the species of prawns that are susceptible to infection, the effect of infection on those prawn populations and the influence of the physical environment on the outcome of infection.
In determining the likely effect of exotic pathogens on Australian native species, consideration is given to evidence that the pathogens could infect a wide range of species or families, including any that are related to Australian native species. In the case of pathogens that infect a narrow/specific range of hosts that are unrelated to Australian species, it is assumed that effects on native species would be negligible. However, for exotic pathogens that have a wide/non-specific host range, including prawn species that are related or similar to Australian species, it is assumed that native species would be susceptible to infection and that the establishment of disease could have consequences at least as severe as those reported overseas.
CHAPTER 4: HAZARD IDENTIFICATION

4.1 Process of classification of diseases/disease agents for consideration in the IRA

A large number of disease agents have been reported in association with prawns. The disease agents considered in this section include those identified by AQIS in the course of a comprehensive scientific review as well as the diseases nominated in the course of AQIS’s previous consultations with stakeholders.

In this section AQIS considers diseases/disease agents against several criteria to determine whether the diseases/disease agents should be given detailed evaluation in the IRA. To qualify for inclusion in the IRA, the following criteria should be satisfied:

1. The disease agent is infectious and
2(a) The disease agent is exotic to Australia or
2(b) The disease agent is present in Australia but subject to official control and
3(a) The disease agent is OIE listed and/or
3(b) The disease agent would be expected to cause significant harm in Australia.

Where definitive data relevant to categorisation are lacking, AQIS makes conservative judgements based on current scientific information and the advice of experts in relevant fields.

Box 1.2 in Section 1.5.1 gives further details of these criteria.

Table 4.1 shows the classification of prawn diseases and disease agents according to these criteria.

<table>
<thead>
<tr>
<th>Disease agent/pest</th>
<th>1 Disease agent is infectious</th>
<th>2a Agent or strain exotic to Australia</th>
<th>2b Control program in Australia</th>
<th>3a OIE-listed</th>
<th>3b Significant disease</th>
<th>Further consideration of disease agent is required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viruses</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monodon baculovirus (MBV)</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Plebejus baculovirus (PBV) (= MBV)</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Benettae Baculovirus (BBV, MsNPV)</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Baculovirus penaei (BPV)</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Baculovirus midgut gland necrosis virus (BMNV)</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>BMNV-like viral infections</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>White Spot syndrome virus (WSSV)</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

25 Queensland, WA and NSW legislation controls the movement of live aquatic animals in relation to listed diseases; MBV is included in these lists.
<table>
<thead>
<tr>
<th>Disease agent/pest</th>
<th>1 Disease agent is infectious</th>
<th>2a Agent or strain exotic to Australia</th>
<th>2b Control program in Australia</th>
<th>3a OIE-listed</th>
<th>3b Significant disease</th>
<th>Further consideration of disease agent is required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penaeid Haemocytic Rod-shaped Virus (PHRV)</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Irido-like virus</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Infectious hypodermal and haematopoietic necrosis virus (IHNV)</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Hepatopancreatic parovirus (HPV) (includes HPV-like viruses)</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Penaeus chinensis parovirus</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Lymphoidal Parvo-like Virus (LPV)</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Spawner-isolated mortality virus (SMV)</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Bay of Pirian shrimp virus</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Rhabdovirus of penaeid shrimp (RPS)</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>26</td>
</tr>
<tr>
<td>Yellowhead virus (YHV)</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Lymphoid Organ Virus (LOV)</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Gill associated virus</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Infectious Pancreatic Necrosis virus (IPNV)</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>27</td>
</tr>
<tr>
<td>Reo-III &amp;IV (including Reo-like virus and Palaemon B-cell reo-like virus)</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Lymphoid Organ vacuolization virus (LOVV)</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
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</tr>
<tr>
<td>Taura syndrome virus (TSV)</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td><strong>Bacteria</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Rickettsia-like organism from <em>Macrobrachium rosenbergi</em></td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>Penaeids</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
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<tr>
<td>Pandalid shrimp (stained prawn disease)</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
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<tr>
<td>α Proteo-bacteria sp. (necrotising hepatopancreatitis)</td>
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<td>Y</td>
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<td>Y</td>
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<td><em>Planctomycete</em> bacteria</td>
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<td><em>Vibrio</em> nereis</td>
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<td>N</td>
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<td><em>Vibrio</em> penaeicida</td>
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<td>Y</td>
<td>N</td>
<td>N</td>
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<td>Remaining <em>Vibrio</em> spp.</td>
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<td><em>Aeromonas</em> sp.</td>
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<td>N</td>
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<tr>
<td>Hepato-pancreatic brush border lysis (HBL) bacterium</td>
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<td>Y</td>
<td>N</td>
<td>N</td>
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<tr>
<td>Epicommensal bacteria (<em>Leucothrix mucor, Thiothrix sp., Flavo-bacterium sp., Cytophaga sp., Leucothrix sp.</em>)</td>
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<td>N</td>
<td>N</td>
<td>N</td>
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<td><em>Flexibacter</em> sp.</td>
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<td>N</td>
<td>N</td>
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</tr>
</tbody>
</table>

26 RPS is not associated with significant disease in prawns but is closely related to SVC (Loh et al. 1997) which is a significant pathogen of cyprinids (Wolf 1988).

27 IPNV is not associated with significant disease in prawns but causes significant disease in finfish (Wolf 1988).

28 GNS has been observed in Australia but is probably associated with a nodavirus (Dr L. Owens, personal communication).

29 Some *Vibrio* species associated with prawns are not considered to cause significant disease. Those that do cause significant disease and have been reported in Australia are also included in this table.
<table>
<thead>
<tr>
<th>Disease agent/pest</th>
<th>1 Disease agent is infectious</th>
<th>2a Agent or strain exotic to Australia</th>
<th>2b Control program in Australia</th>
<th>3a OIE-listed</th>
<th>3b Significant disease</th>
<th>Further consideration of disease agent is required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerococcus viridans var. homari (gaffkemia)</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y(^{30})</td>
<td>Y</td>
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<tr>
<td>Mycobacterium sp.</td>
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<td>Diplococcus sp.</td>
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<tr>
<td><strong>Fungi</strong></td>
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<tr>
<td>Lagendinium spp.</td>
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<td>Fusarium sp.</td>
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<td>N</td>
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<td>Sirolipidium sp. (=Haliphthoros sp.)</td>
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<td>N</td>
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<td>Cladosporium sp.</td>
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<td>Achlya sp.</td>
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<td>N</td>
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<td>Saprolegnia sp.</td>
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<td>Pythium sp.</td>
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<td>N</td>
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<tr>
<td>Akiniiella dubia</td>
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<td>N</td>
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<td>Leptomitus sp.</td>
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<td>Leptolegnia sp. (=Leptolegnia)</td>
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<td><strong>Protozoans</strong></td>
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<td>Leptomonas sp.</td>
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<td>Thalassomyces sp.</td>
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<td>Bodo-like flagellates Chrysidella sp.</td>
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<tr>
<td>Gregarines (Nematopsis sp., Cephalolobussp., Paraophidioidina sp.)</td>
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<td>N</td>
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<td>Ameson nelsoni</td>
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<td>Ameson (=Nosema) sp.</td>
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<td>Agmasoma (Thelohania) duorara</td>
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<td>N</td>
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</tr>
<tr>
<td>Agmasoma (Thelohania) penaei</td>
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<td>Y</td>
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<td>Y</td>
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<td>Thelohania butleri</td>
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<td>Thelohania gardi</td>
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<td>Thelohania octospora</td>
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<td>Pleistophora lintoni</td>
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<td>Y</td>
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<td>Pleistophora crangoni</td>
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<td>Parauronema sp.</td>
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<td>Apostome ciliates (Ascothrys spp., Synophrya sp., Gymnodinoidea sp.)</td>
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<td>N</td>
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<td>Peritrichous and loricate ciliates (Epistylis sp., Vorticella sp., Zoothamnium sp., Lagenophrys sp., Cothurnia sp.)</td>
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<td>Suctorian ciliates (Ephalota sp., Acineta sp., Terebrospira sp.)</td>
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<td>Y</td>
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<tr>
<td>Rhabdostyla sp., Ciliophora sp., Stylophora sp.</td>
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<tr>
<td>Haplosporidium sp. (=Minchinia sp.)</td>
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<td>Y</td>
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<tr>
<td><strong>Nematodes</strong></td>
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<td>Ascarophis sp.</td>
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<td>Bulbocephalus inglissi</td>
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<td>Thynnascaris sp. (=Contracaecum sp. = Hysterolaycladium)</td>
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<td>Eutetrarhynchus ruficollis</td>
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<td>Parachristianella dimegacantha</td>
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<td>Y</td>
<td>N</td>
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</tr>
</tbody>
</table>

\(^{30}\) *Aerococcus viridans var. homari* causes significant disease in lobsters.
Disease agent/pest | 1 Disease agent is infectious | 2a Agent or strain exotic to Australia | 2b Control program in Australia | 3a OIE-listed | 3b Significant disease | Further consideration of disease agent is required  
--- | --- | --- | --- | --- | --- | ---  
Polypocephalus sp. | Y | N | N | N | N | N  
Prochristianella penae | Y | N | N | N | N | N  
Tetrarhynchus rubromaculatus | Y | N | N | N | N | N  
**Trematodes** |  |  |  |  |  |  
Opeoeloides fimbriatis | Y | Y | N | N | N | N  
Opeoeloides variabilis | Y | N | N | N | N | N  
Microphallus | Y | Y | N | N | N | N  
Pseudophyllodistomum johnstoni | Y | N | N | N | N | N  
Diceratocephala sp. | Y | N | N | Y | N | N  
Microphallus brevicaeca | Y | Y | N | N | N | N  
**Turbellarians** |  |  |  |  |  |  
Kronborgia caridicola | Y | Y | N | N | N | N  
Temnocephala carpentariae | Y | N | N | N | N | N  
**Acanthocephalans** |  |  |  |  |  |  
Rhadinorhynchids | Y | N | N | N | N | N  
**Nematomorphs** |  |  |  |  |  |  
Nectonema spp. | Y | Y | N | N | N | N  
**Molluscs** |  |  |  |  |  |  
Caledoniella montrouzieri | Y | Y | N | N | N | N  
**Bopyrid isopods** |  |  |  |  |  |  
Anisarthussp. | Y | Y | N | N | N | N  
Anisorbione sp. | Y | N | N | N | N | N  
Augustogathosa sp. | Y | N | N | N | N | N  
Bopyrella sp., Bopyrinella albida | Y | N | N | N | N | N  
Cabriops orbionei | Y | N | N | N | Y | N  
Epipenaeon spp. | Y | N | N | N | Y | N  
Hemiarthus sp. | Y | Y | N | N | N | N  
Ionella maculata. | Y | Y | N | N | N | N  
Metaphrixus sp. | Y | N | N | N | N | N  
Orbine halipori | Y | N | N | N | N | N  
Parapenaeon spp. | Y | N | N | N | N | N  
Parapenaeonella lamellata | Y | N | N | N | N | N  
Probopyrus spp. | Y | N | N | N | Y | N  
Sacculina sp. | Y | N | N | N | Y | N  
**Cirripedia** |  |  |  |  |  |  
Sylon hippolytes | Y | Y | N | N | N | N  
**Algae** |  |  |  |  |  |  
Enteromorpha sp. | Y | Y | N | N | N | N
4.2 Viruses

4.2.1 Viruses which will be further considered in the IRA

**Baculoviral midgut gland necrosis virus**

Baculoviral midgut gland necrosis virus BMNV is now regarded by the ICTV (Murphy et al. 1995) as an unclassified virus. Outbreaks of BMNV in *M. japonicus* have occurred in Japan and Korea (Sano et al. 1984; Lightner 1993). Other penaeids, *Fenneropenaeus chinensis*, *P. semisulcatus* and *P. monodon*, are susceptible to BMNV. BMNV-type infections have been observed in *P. monodon* in East and South-East Asia. Mortalities in hatcheries occur in mysis through to 20 day old postlarvae (PL) and may reach up to 98% in PL9-10 (Sano et al. 1981).

Additional non-occluded bacilliform viruses, in prawn species other than *P. japonicus*, including viruses reported from Australia, have been grouped as BMNV-like viruses (Brock 1991; Lightner 1996b). The term BMN-type virus/agent is misleading as it gives the impression that these viruses are similar to BMNV when the necessary information is lacking. The term non-occluded bacilliform viruses is more correct at this point in time.

BMNV, which is distinct from BMN-like viruses, is regarded as exotic to Australia. BMNV is a significant pathogen overseas and OIE listed and as such, will be given further consideration in the IRA.

**Infectious hypodermal and hematopoietic necrosis virus (IHHNV)**

Infectious hypodermal and haematopoietic necrosis virus (IHHNV) is distributed widely in penaeids in culture facilities and in the wild in Asia and the Americas. Epizootics of disease due to IHHNV have been reported in south-east USA, Mexico, Ecuador, Peru, Brazil, Carribean, Central America, Hawaii, Guam, Tahiti, New Caledonia. The virus has been reported from Singapore, Malaysia, Thailand, Indonesia, the Philippines (Lightner 1996b) and China (Zhang and Sun 1997). Natural infections have been reported from *L. stylirostris*, *L. vannamei*, *Litopenaeus occidentalis*, *F. californiensis*, *P. monodon*, *P. semisulcatus* and *P. japonicus* (Lightner 1996b).

While IHHNV has not been reported in Australia, there is one report of an IHHNV-like virus in this country in prawns held under experimental conditions (Owens et al. 1992).

This agent will be given further consideration in the IRA, as it is (or at least, virulent strains of this virus are) exotic to Australia. Additionally, IHHNV is a significant pathogen overseas and is OIE listed.

**Infectious pancreatic necrosis virus**

Infectious pancreatic necrosis virus (IPNV) may cause severe damage to the pancreas and other internal organs of farmed and wild finfish species, including salmonids (Wolf 1989) resulting in significant mortalities. IPN is reported from Europe, the Americas and Asia. This agent has been isolated from *P. japonicus* but is of limited pathogenicity in this species (Giorgetti 1989).
This agent will be given further consideration in the IRA, as it is exotic to Australia, a significant pathogen overseas and OIE listed.

**Nucleopolyhedrovirus - Baculovirus penaei**


Epizootics of disease due to BP are characterised by sudden, high mortality rates among larvae, postlarvae and juvenile prawns.

This agent will be given further consideration in the IRA, as it is exotic to Australia, a significant pathogen overseas and OIE listed.

**Rhabdovirus of Penaeid shrimp**

Prawns infected with rhabdovirus of penaeid shrimp (RPS) show no signs of clinical disease and mortalities are not common (Lu et al. 1991), even among prawns infected experimentally (Nadala 1992). However, RPSV is closely related to spring viraemia of carp virus (SVC, *Rhabdovirus carpio*) (Lu and Loh 1994b), a pathogen exotic to Australia. SVC is an acute haemorrhagic infection causing mortalities, typically of cyprinids (Wolf 1988). SVC is listed as a notifiable disease in the OIE Aquatic Animal Code.

Since RPS is exotic to Australia, and may be closely related to SVC which is a significant pathogen, overseas; especially of cyprinids, it will be considered further in the IRA.

**Taura syndrome virus**

Since 1991, disease caused by this virus has reportedly cost the prawn culture industries of the USA and Latin America over US$1 billion (Brock et al. 1996). Taura syndrome virus (TSV) continues to cause problems throughout the Americas and is the subject of research into methods for the prevention and control of disease.

TSV affects cultured *L. vannamei, L. stylirostris, F. aztecus* and *L. setiferus* (Lightner et al. 1997a). Mortalities have been reported in cultured penaeids from Ecuador, Peru, Colombia, El Salvador, Guatemala, Brazil, Nicaragua, Hawaii, Florida, Mexico and Texas (Lightner 1996b) and recently in Taiwan (Tu et al. 1999)

This agent will be given further consideration in the IRA, as it is exotic to Australia and a significant pathogen overseas.

**White spot syndrome virus**

White spot syndrome virus (WSSV) causes disease characterised by the appearance of white spots on the carapace and a high level of mortality. The syndrome affects cultured *P. monodon, P. japonicus, P. chinensis, F. indicus, F. merguiensis* and *L. setiferus* stocks worldwide. The agent is described variously as: hypodermal and haematopoietic necrosis baculovirus (HHNBV) in China, rod-shaped nuclear virus of *P. japonicus* (RV-PJ) in Japan, China and Korea, systemic ectodermal and mesodermal baculovirus (SEMBV) in Thailand
and Bangladesh, white spot baculovirus (WSBV) in Indonesia, Vietnam, Malaysia, India, South Carolina and Texas and *P. monodon* non-occluded baculovirus (PmNOB) in Taiwan (Lightner 1996b).

White spot disease has spread throughout most prawn culture areas of the Indo-Pacific, excepting Australia and New Caledonia, and has spread to the Americas, and continues to cause significant stock losses of cultured prawns in countries affected by the virus.

This agent will be given further consideration in the IRA, as it is exotic to Australia, a significant pathogen overseas and OIE listed.

**Yellowhead virus**

Yellowhead virus (YHV) is reportedly widespread in cultured stocks of *P. monodon*. It has caused serious disease in cultured *P. monodon* in South-East Asia and India. By the third day post infection, mass mortality occurs and the entire crop is typically lost (Chantanachookin et al. 1993). YHD may have been associated with the *P. monodon* industry crash in Taiwan in 1986-1987 and also with disease epizootics in Indonesia, Malaysia, China, India and the Philippines (Lightner 1996b).

Two yellowhead-like viruses, one pathogenic (gill-associated virus, GAV) and the other benign (lymphoid organ virus, LOV) have been found in cultured *P. monodon* in Australia (Spann and Lester 1997). GAV and LOV have approximately a 1% difference over a 400 base pair PCR sequence of a highly conserved RNA polymerase gene (Dr Peter Walker, personal communication). Comparison of several genetic sequences has shown that YHV and GAV differ by 15-20% at the nucleotide level, and diagnostic probes are able to differentiate between them, suggesting that YHV and GAV/LOV are distinct viruses (Cowley et al. 1999).

YHV will be given further consideration in the IRA, as it is (or more virulent strains of the virus are) exotic to Australia, it is a significant pathogen overseas and is OIE listed.

**4.2.2 Viruses which will not be further considered in the IRA**

**Nucleopolyhedrovirus - Monodon baculovirus**

Monodon baculovirus (MBV) -type viruses are occluded baculoviruses designated *P. monodon* singular nucleopolyhedrovirus (PmSNPV) and are considered to comprise a number of distinct strains (Lightner 1996b). MBV-type baculoviruses are reported from most areas of the Indo-Pacific where penaeid prawns are cultured (Brock and Lightner 1990). These viruses have been described in *P. monodon, F. indicus, F. merguiensis, F. penicillatus, M. plebejus, P. esculentus, P. semisulcatus, P. kerathurus, L. vannamei* and *M. ensis* (Lightner 1996b).

Moderate to very heavy infections with MBV may occur in the hepatopancreas and anterior midgut. Mortalities occur primarily among postlarvae in the hatchery, although disease may also occur in juvenile and adult prawns (Johnson and Lightner 1988). Cumulative mortality among postlarvae (PL) may reach over 90%.

MBV type viruses have been reported in cultured *P. monodon* and *M. plebejus* and wild *F. merguiensis* in Australia (Lester et al. 1987; Doubrovsky et al. 1988).
Different strains of this virus are recognised. However, one of the MBV-type viruses found in Australia reacts with commercial gene probes specific for MBV suggesting that this virus is identical or very closely related to MBV overseas. An official control program has been implemented in Queensland and NSW with the objective of restricting the spread of the virus in live broodstock and postlarvae. MBV is listed under ‘other significant’ disease agents by the OIE. MBV is not exotic to Australia and will not be given further consideration in the IRA.

Other viruses

The Bay of Pirian shrimp virus, lymphoid organ vacuolization virus (LOVV), the irido-like virus, reo-III & IV (including reo-like virus), Palaemon B-cell reo-like virus and *F. chinensis* parovirus have been reported overseas in association with prawns. These agents are exotic to Australia, but they will not be given further consideration in the IRA, as they are not considered to cause significant disease and are not listed in the OIE Code (Lightner and Redman 1993; Lianchun et al. 1995; Vogt 1996; Lightner 1996b).

The following viruses or viral associated diseases have been reported to occur in prawns in Australia and are not the subject of official control. These agents will not be given further consideration in the IRA.

- Bennetetae baculovirus (BBV, MbSNPV)
- Gill associated virus (GAV)
- Gut and nerve syndrome virus
- Hepatopancreatic parvo-virus (HPV) (includes Hepatopancreatic parvo-like virus)
- Lymphoidal parvo-like virus (LPV)
- Lymphoid organ virus (LOV)
- Penaeid haemocytic rod-shaped virus (PHRV)
- Plebejus baculovirus (PBV)
- Spawner-isolated mortality virus (SMV)
- Baculovirus midgut gland necrosis virus like viral infection

4.3 Bacteria

Outbreaks of disease in prawns are often attributed to bacterial infection, as in many cases, bacteria may be readily recovered from diseased prawns. However, bacterial infection of prawns commonly occurs as a sequel to disease due to environmental, nutritional, traumatic or other factors (Lightner 1985). In order to satisfy Koch’s postulates for many of these bacterial species, massive numbers must be administered to prawns to induce disease (Lightner 1993). However, some species or strains of bacteria are associated with significant pathogy and are considered to be primary pathogens.

4.3.1 Bacteria which will be further considered

Rickettsia-like organisms

Rickettsia-like organisms (RLO) have been detected during outbreaks of disease in cultured penaeids (Chong and Loh 1984; Krol et al. 1991; Lightner et al. 1992), and in cultured (Cohen and Issar 1989) and wild-caught carideans (Bower et al. 1996). Experimentally, RLO have been shown to cause disease when inoculated into prawns (Lightner et al. 1992).

At least three different RLO or strains of RLO have been identified at different geographical locations and in different host species (Brock 1988; Brock and Lightner 1990; Lightner 1993;
Bower et al. 1996; Brock et al. 1996). The capacity of RLO to cause disease in prawns is not well established. Disease outbreaks reported in Malaysia and Indonesia involved other agents as well as RLOs (Anderson et al. 1987; Lightner et al. 1992).

The taxonomic relationship between RLOs of marine crustaceans is uncertain. Owens et al., (1992) considered that RLO could be broadly grouped, based on their tissue tropisms for hepatopancreatic cells or connective tissues. RLO infections of the connective tissues (Owens et al. 1992) and of the hepatopancreas (Edgerton and Prior 1999) has been reported in freshwater crayfish in Australia.

There is a diversity of RLOs and several RLOs have been reported in crustaceans in this country. Some RLOs are not reported in Australia and have been associated with significant disease episodes in other countries. Such RLOs will be given further consideration in the IRA.

**Alpha Proteobacteria sp.**

An alpha Proteobacterium causes the disease necrotizing hepatopancreatitis (NHP) which can result in losses approaching 95% of affected cultured penaeids (Frelier et al. 1993). This agent has not been reported in Australia. Accordingly, it will be the subject of further consideration in the IRA.

**Vibrio nereis**

*V. nereis* was associated with disease outbreaks in cultured *P. monodon* in Taiwan and significant mortality occurred following experimental infection of prawns with this agent (Chen 1992). The agent has not been reported in Australia and will, therefore, be given further consideration in the IRA.

**Vibrio penaeicida**

In Japan, *V. penaeicida* is considered to be the most important pathogen of cultured *P. japonicus* (Ishimaru et al. 1995; de la Pena et al. 1995). A highly pathogenic strain of *V. penaeicida* (AM 23) has been identified in association with Syndrome 93 from New Caledonia and continues to cause mortalities in cultured *L. stylirostris* (Le Groumellec et al. 1996; Costa et al. 1996). The agent has not been reported in Australia and will, therefore, be given further consideration in the IRA.

**Aerococcus viridans var. homari**

*A. viridans* var. *homari* is the aetiological agent of gaffkemia and considered to be the most virulent systemic bacterial pathogen affecting crustaceans. The disease affects marine lobsters (*Homarus* sp.) and some species of crabs (*Carcinus* sp., *Cancer* sp.) (Sindermann 1990; Brock and Lightner 1990). *A. viridans* var. *homari* was isolated from *F. aztecus* in North America (Liuzzo et al. 1965). The bacterium has not been reported from crustaceans in Australia. This agent will be given further consideration in the IRA.

### 4.3.2 Bacteria which will not be further considered in the IRA

**Chlamydia spp.**

These agents will not be given further consideration in the IRA as they do not cause significant disease in prawns (Lightner 1993).
Numerous disease outbreaks have been reported in association with *Vibrio* species. These disease syndromes were described variously, as vibrio disease, vibriosis, chitinolytic bacterial shell disease, etc. The role of vibrios as primary pathogens in these syndromes is uncertain. Vibrios are a ubiquitous and predominant component of the marine and prawn culture environment and comprise a major part of the normal flora of crustaceans (Lightner 1993). Infections with vibrios in prawns are generally regarded as opportunistic (Sindermann 1990), although several species and particular strains of vibrios are recognised as primary pathogens (Owens and Hall-Mendelin 1989; Lightner 1993).

A number of difficulties arise in attempting to evaluate the pathogenic potential of vibrios and categorise them accordingly. The taxonomy of vibrios found in tropical waters is particularly unclear. These vibrios often yield uncertain results in conventional tests (Dr Ian Anderson, pers comm) and cannot be easily identified to species level. For this reason, reports of disease outbreaks associated with particular species may not be reliable (Dr Ian Anderson, personal communication). Incorrect identification may occur commonly, particularly where diagnostic laboratories lack the facilities and expertise to test isolates for the purpose of speciation.

When vibrio species are clearly identified, using conventional tests, the status of the species can remain unclear as isolates may be heterogeneous, eg *V. cholerae* and *V. splendidus* (Austin et al. 1997). Species groupings may be close according to some tests but strain differences may be evident following further testing. For example, *V. parahaemolyticus* strains comprise several different phenotypes and serotypes yet may be 100% identified by gyrB gene based PCR testing (Venkkateswaran et al. 1998). Also, the isolates of *V. anguillarum* constitute a distinctive ribotype cluster but still comprises many serogroups (Austin et al. 1997).

Another difficulty is that *Vibrio* isolates grouped into a species may include numerous strains of differing virulence, for example *V. harveyi* (Liu et al. 1996). The expression of virulence may be complex and may be influenced by the host or environment. Virulence factors may be acquired and associated with genetically mobile elements, eg. plasmids or transposons (Pizzutto and Hirst 1995). If so, it would be difficult to definitively assign virulence to a particular species or strain.

Most of the vibrios reported overseas in prawns have been recovered from prawns in Australia and will not be given further consideration in the IRA. The remaining species, *V. anguillarum*, *V. campbelli*, *V. fluvialis*, *V. nereis*, *V. parahaemolyticus*, *V. penaeicida*, *V. splendidus*, *V. tubiashi* and *V. vulnificus* have not been reported in association with disease in prawns in Australia. However, as the determination of the cause of disease often does not continue beyond identification at the generic level, the above agents may yet be identified in prawns in this country.

*Vibrio anguillarum*, *V. campbelli*, *V. fluvialis*, *V. parahaemolyticus*, *V. splendidus*, *V. tubiashi* and *V. vulnificus* have been reported in association with disease in other Australian aquatic animal species (Humphrey 1995). These species will not be given further consideration in the IRA as they occur in Australia and are not subject to official control.
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Epicommensals

Fouling of gills, appendages and external surfaces may be caused by a range of microorganisms and parasites generally regarded as epicommensals or epibionts and not primary pathogens. Epicommensal bacteria include *Leucothrix mucor*, *Thiothrix* sp., *Flavobacterium* sp., *Cytophaga* sp., *Flexibacter* sp. and other *Leucothrix* sp. (Lightner 1996b). Under conditions of high organic load, these bacteria may attach to gills, interfering with respiration and leading to hypoxia and mortalities (Brock and Lightner 1990). These bacteria have been recovered from prawns in Australia (Owens et al. 1988; Paynter 1989) and are not the subject of official control. Accordingly, they will not be given further consideration in the IRA.

*Mycobacterium* spp., *Aeromonas* spp. and *Diplococcus* spp.

These disease agents are not generally associated with significant disease in prawns. They have been reported in prawns in Australia and overseas and are not the subject of official control. These agents will not be given further consideration in the IRA.

A number of bacteria have not been included in table 4.4 nor considered for further evaluation in the IRA because they are regarded as ubiquitous, eg. *Staphylococcus* spp.

4.4 Fungi

4.4.1 Fungi which will not be further considered in the IRA

None of the fungi reported from prawns are considered further in the risk analysis. In most instances this is because the fungus has been recovered from aquatic animals in Australia. In some cases, reports from other countries indicate that significant pathology is not associated with these fungal infections. In other cases, fungi are not clearly implicated as significant pathogens; where reports refer to an isolated episode of disease (Shah et al. 1977; Brock and Lightner 1990).

4.5 Protozoa

4.5.1 Protozoans which will be further considered in the IRA

Sarcomastigophora

A *Hematodinium*-like protozoan was recently, identified as the cause of a new disease that turned infected prawns opaque and the haemolymph milky. The disease seemed to be confined to wild populations of *Pandalus* species near British Columbia. Gross signs of infection were observed in up to 10% of prawn populations; subclinical infections were detected in up to 27% of prawns from these same populations (Bower et al. 1994; Bower and McGladdery 1998). In most *P. platyceros* with subclinical infections, the duration of the infection had been sufficiently long to affect gonadal development (Bower and McGladdery 1998). Infected prawns from the field did not survive in captivity. In Alaska, unconfirmed reports were of prevalences reaching 50%. Hematodinium spp. have also been observed in wild prawns in Central America and Africa (Lightner, pers. comm.). These agents do not occur in prawns in Australia, and therefore will be given further consideration in the IRA.
Microspora

Microsporidians are generally considered to be significant pathogens. Some species may cause mortalities of up to 20% in broodstock on capture (Bower 1995). These agents may also cause parasitic castration of wild-stocks and reduce the market value of prawns with heavy infections (Bower 1995). Agmasoma (=Thelohania) sp. and Ameson (=Nosema) sp. are recorded from prawns (and freshwater crayfish) in Australia. Few reports identify individual species, but Agmasoma penaei, A. octospora and Ameson nelsoni have not been reported in Australia. All are significant pathogens (Bower 1995; Humphrey 1995). Microsporidia in the genus Pleistophora have not been identified in prawns in Australia and two species (P. lintoni and P. crangoni) have been reported as significant pathogens overseas. Ameson nelsoni, Agmasoma penaei, A. octospora, Pleistophora lintoni and P. crangoni will be given further consideration in the IRA.

Ciliophora

The ciliate Parauronema sp. invades the haemocoel of protozoal, mysid and juvenile stages of the brown shrimp (F. aztecus) and was associated with mass mortality at a commercial hatchery (Couch 1978 #2320). Early stages of infection are confined to wounds. Later stages invade the haemolymph and damage various organs including the gills. Disease is found in larvae and overwintering adults and often causes 100% mortality in infected tanks (Bower and McGladdery 1998 #15610). This protozoan has not been reported in Australia and will be given further consideration in the IRA.

4.5.2 Protozoans which will not be further considered in the IRA

Sarcomastigophora

Leptomonas sp., Thalassomyces sp., Bodo-like flagellates and Chrysidella sp. have not been reported in prawns in Australia. They will not be given further consideration in the IRA as they are not considered to be pathogenic (Humphrey 1995; Lightner 1996b).

Apicomplexa

The gregarines, Nematopsis sp., Cephalolobus sp. and Paraophioidina sp., cause infections in prawns. These agents will not be given further consideration in the IRA as they are not considered to be pathogenic (Humphrey 1995 #8220). At least one species in this group has been recorded in prawns in Australia (L. Owens, personal communications).

Microspora

Indosporus spraguei and a number of ‘Thelohania’ species have been reported overseas but have not been recognised as being present in Australia. These microsporidians will not be given further consideration in the IRA as they have not been associated with significant disease.

Ciliophora

Members of this group of protozoans are not generally regarded as serious crustacean primary pathogens (Brock and Lightner 1990). Some are symbionts becoming opportunistic pathogens when environmental conditions are poor. Others are capable of infection only through
previous wounds in the cuticle. Most genera in this Phylum reported overseas are also recorded in Australia and they will not be considered further in the IRA.

**Ascetospora**

*Haplosporidium* spp. (=*Minchinia* sp.) have not been reported in Australia but are not considered to be significant pathogens overseas (Dykova et al. 1988; Lightner 1996b). These protozoans will not be given further considered in the IRA.

### 4.6 Metazoan parasites and algae

#### 4.6.1 Metazoans which will not be further considered in the IRA

Published literature on metazoans in prawns provides descriptive information on the parasites, including host species and geographic locations of infected prawns, but usually does not identify the pathogenic significance of the infestations (Owens 1987; Markham 1994). Some parasitic infestations may be significant in that the prawns may serve as intermediate hosts for trematodes, cestodes and acanthocephala that mature in finfish and warm-blooded animals (Sindermann 1990). However, the helminth parasites are generally considered to be of limited pathogenicity, except in isolated reports of heavy worm burdens in individual prawns (Meyers 1990; Sindermann 1990). For this reason the helminths (cestodes, trematodes, nematodes, annelids, turbellarians, acanthocephalans and nemerteans) are not given further consideration in the IRA.

Crustaceans are common parasites of prawns and some may be pathogenic to individual animals. Two groups can cause serious harm to prawn hosts; the rhizocephalans and the epicaridean isopods. Members of these groups of crustacean parasites may cause structural deformity, sterilization and death in some instances (Sindermann 1990). However the impact on the total population is generally considered to be insignificant (Sindermann 1990); accordingly these parasites are not given further consideration in the IRA.

Blue green algae (*Spirulina* sp., *Lyngbya* sp., *Schizothrix* spp., *Oscillatoriales*, spp. etc), diatoms and green algae have been reported in association with prawns (Lightner 1996b) Disease may be associated with these agents via the release of toxins. Many of these agents have been reported in Australia eg. *Spirulina* sp., *Oscillatoriales* spp. (Smith and Joshi 1996 #4160] and consequently these agents will not be given further consideration in the IRA.
CHAPTER 5: RISK ASSESSMENT

5.1 Methods

In Chapter 4, the disease agents that would be the subject of further consideration in the risk analysis, based on defined criteria, were identified. The criteria include the absence of the agent from Australia and features of the disease agent, including its ability to cause serious disease and its status according to the Office International des Epizooties (OIE, World Organisation for Animal Health).

5.1.1 Risk Assessment

The quarantine risk for each disease agent is assessed in detail in relation to the importation of whole green prawns in Section 5.3. The quarantine risk in relation to the importation of prawn feed is discussed in Section 5.4.

The risk assessment covers the following factors:

- Release assessment - the probability that the agent will enter Australia as a consequence of the importation of whole green prawns;
- Exposure assessment - if the disease agent entered Australia in whole green prawns, the probability of susceptible prawns (or other susceptible crustaceans) being exposed to a dose sufficient to cause infection;
- Probability of disease establishment - the combined release and exposure assessment;
- Consequence assessment - the consequences of the disease agent becoming established in Australia.

Each of the above assessments is defined and described in qualitative terms in Section 1.5.2.

5.1.2 Unrestricted Risk Estimate

The combined probability and consequences of disease establishment represent the unrestricted risk assessment (i.e. the risk if no management measures are applied). As presented in the risk evaluation matrix in Section 1.5.2, the unrestricted risk estimate either exceeds or meets the appropriate level of protection (ALOP). Risk management measures would be required (in the former case) or would not be justified (in the latter case).

The conclusions are summarised in a box at the end of the assessment for each disease agent.

5.2 Emerging pathogens

Semi-intensive and intensive prawn aquaculture is a relatively recent endeavour, even though extensive prawn aquaculture has been practiced for centuries in Asia. As has been the case for other species in culture, disease has emerged in prawn aquaculture as a serious limiting factor to its intensification. The recent development of prawn aquaculture has been characterised by panzootics of newly emerging diseases. Previously unrecognised diseases have rapidly spread through the prawn industry resulting in serious losses. There has frequently been confusion
and delay in recognising and reporting the occurrence of a new disease syndrome. The general lack of knowledge of crustacean pathology and immunology, skilled pathologists and microbiologists, and of necessary equipment and research tools (such as crustacean cell lines), have exacerbated the situation. Importantly, three of the most serious pathogens in prawn aquaculture, WSSV, YHV and TSV have been reported in the last decade.

The disease panzootics have affected all ages of prawns, though frequently juvenile or younger prawns have most commonly been affected. If prawns are of a size where they can be emergency harvested to provide some return on the crop, this has commonly been practised. Such prawns have a high likelihood of carrying very high titres of the infectious agent.

As discussed elsewhere, small (lower value) prawns are more likely to be diverted to be used as fishing bait than larger (higher value) prawns and processed prawn products which are more likely to remain in the human food chain.

The importation of small, whole green prawns presents a higher quarantine risk, in relation to emerging disease agents, than the importation of large green prawns, cooked prawns and processed prawn products.

5.3 Risk Assessments for Pathogens

5.3.1 Taura syndrome virus

The aetiology of Taura syndrome (TS) has been intensely debated and has been the subject of litigation (Hasson et al. 1999a). Preliminary evidence that TS was caused by fungicides (Lightner et al. 1995) lost credence when Hasson et al. (1995) demonstrated using Rivers’ postulates that the aetiology of TS was a virus which the authors named Taura syndrome virus (TSV).

Release assessment

Geographic distribution:

TSV has not been detected in Australia. Until recently, TSV was confined to the Americas. TSV infection has been detected by routine H&E histology, and recently confirmed by in situ hybridisation, in Belize, Brazil, Colombia, Costa Rica, Ecuador, El Salvador, Mexico, Honduras, Nicaragua, Panama, Peru and the USA (including Hawaii) (Lightner 1996b; Hasson et al. 1999a). TSV has also been reported in Taiwan presumably after importation of infected broodstock and postlarval *P. vannamei* (Tu et al. 1999). Belize is the only country that has effectively eradicated TSV in prawn aquaculture operations (Dixon and Dorado 1997). However, TSV may still be present in wild stocks of prawns or other potential carriers in Belize (Hasson et al. 1999a).

Host range:

TSV has only been reported to infect penaeid prawns, including *L. vannamei*, *L. stylirostris* (Brock et al. 1995), *L. setiferus*, *F. aztecs*, *Farfantepenaeus duorarum*, *P. chinensis* (Overstreet et al. 1997), and *L. schmitti* (Lightner 1996b). Brock (1997) stated that *P. monodon* and *P. japonicus* are “largely resistant” to TS disease. No non-penaeids have been demonstrated to host TSV infections.
Prevalence in prawns:

There are few data on prevalence of TSV. In the aquaculture of *L. vannamei*, most mortalities due to TS occur within 2 to 6 weeks of stocking growout ponds, i.e. when prawns are 0.1 to < 5 g (Lightner et al. 1995; Lotz 1997a). Though anecdotal observations from aquaculture suggested that older prawns may be less susceptible to TS, laboratory experiments showed that larger prawns (= 30 g) are susceptible to TSV infection and may be more susceptible to disease than smaller prawns (Lotz 1997a). Prawns which survive the acute phase typically become chronic carriers of TSV (Lightner et al. 1995; Overstreet et al. 1997; Lotz 1997b; Hasson et al. 1999b).

As most TS epizootics occur in small prawns, emergency harvest is not usually practised for commercial reasons. To manage TS, some farmers stock at very high density to ensure that sufficient prawns will remain after the TS outbreak for the production of a commercial crop. Another common management protocol is to stock specific pathogen-resistant prawns in areas where TSV is endemic (Lightner and Redman 1998). In both of these cases, many marketable prawns will be chronic carriers of TSV.

Lightner (1996b) stated that TSV has been documented in wild postlarvae (PLs) and adult *L. vannamei* in Ecuador, El Salvador and Mexico. However, prevalence data for TSV in wild populations are not available.

Detection and organs affected:

Symptomatology: Clinical signs of TS include anorexia, lethargy, irregular swimming behaviour, opaque musculature, reddening of appendages and general body surface (due to chromatophore expansion), and softening of the cuticle (Lightner 1995; Brock et al. 1995; Hasson et al. 1999b). In populations undergoing epizootic mortality some prawns display multifocal melanised lesions in the cuticle. This sign is typical of prawns in the transition phase to chronic TS (Lightner 1995; Hasson et al. 1999b).

Histopathology: Peracute and acute phases of infection are characterised by multifocal to diffuse necrosis in the cuticular epithelium of the body, appendages, gills, hindgut, oesophagus and stomach (Lightner 1995; Hasson et al. 1995; Hasson et al. 1999b). Subcuticular tissues and adjacent striated muscle are occasionally affected. Necrotic cells have pyknotic and karyorrhectic nuclei and cytoplasm with increased eosinophilia which results in a typical “buckshot” appearance in severely affected areas. Prawns in the transition phase of infection display multifocal melanised lesions in cuticular epithelia (which may be difficult to distinguish from shell disease), focal acute phase lesions, and developing spheroids in the lymphoid organ (Lightner 1995; Hasson et al. 1995; Hasson et al. 1999b). In the chronic phase, the melanised lesions in the cuticular epithelium are absent, and the lymphoid organ is greatly hypertrophied and contains numerous spheroids (Hasson et al. 1999b).

Electron microscopy: Brock et al. (1995) observed irregularly shaped clusters of 30 nm virus-like particles in the cytoplasm of necrotic cells. However, TSV is difficult to visualise in ultrathin sections due to its cytoplasmic location and similar size to ribosomes. Negatively stained purified TSV has a buoyant density of 1.337 g.ml\(^{-1}\), has icosahedral symmetry and a diameter of 31 to 32 nm (Hasson et al. 1995).

Bioassay with indicator prawns: Specific pathogen-free *L. vannamei* can be inoculated *per os* or intramuscularly with infected tissues or extracts from infected tissues respectively.
Genetic and immunologic assays: Gene probes for use in dot blot and in-situ hybridisation (ISH) (Mari et al. 1998) and RT-PCR (Nunan et al. 1998b) have been developed, and immunoassays are under development (Poulos et al. 1999).

Tissue tropism: TSV infects the cuticular epithelium, subcutis and occasionally adjacent striated muscle in the peracute to acute phase. In the transitional phase, TSV infects the lymphoid organ and is at lower titres in cuticular epithelium and subcutis. TSV is almost exclusively found in the lymphoid organ in the chronic phase (Hasson et al. 1999b).

**Discussion of release assessment:**

TSV is widespread in prawn aquaculture in the Americas and is endemic in many wild prawn populations. Recently TSV was introduced into Taiwan after importation of broodstock and postlarval *L. vannamei*. It has not been reported in other prawn farming regions of the world.

Serious outbreaks of TS typically occur in prawns that are well below marketable size. Infection with TSV would be common in prawns from areas affected by disease as survivors and TSV-resistant prawns are chronic carriers of TSV. TSV is confined to the lymphoid organ in chronic carriers.

In the acute phase, TSV typically infects cuticular epithelia systemically and signs of infection are non-specific. In the transition phase, prawns typically develop black lesions below the cuticle. There are no overt signs of chronic carrier status. Chronic carriers have enlarged lymphoid organs with abundant spheroids - a condition which is non-specific to TSV infection. In chronically infected prawns, the highest titres would be in the cephalothorax.

**Conclusions of release assessment:**

Taking these factors into account, the probability of TSV entering Australia as a consequence of unrestricted importation of whole green prawns from areas where TSV is endemic would be moderate.

**Exposure assessment**

**Transmission:**

TSV is transmitted horizontally *per os* (Brock et al. 1995; Overstreet et al. 1997; Lotz 1997a) and by water-borne exposure to the virus (Lotz 1997b). Lightner and Redman (1998) stated that vertical transmission was likely to occur. Garza et al. (1997) showed that TSV may be spread by laughing gulls *Larus atricilla* eating infected prawns, as TSV in faeces was infectious. Aquatic insects, particularly the water boatman *Trichocorixa reticulata*, were implicated as vectors of TSV (Hasson et al. 1995). However, it is not known whether *T. reticulata* are susceptible to infection by TSV. *L. vannamei* developed TS after injection with extracts from *T. reticulata* from ponds with TSV (Lightner 1996a), and gut contents from *T. reticulata* were positive in ISH (Lightner and Redman 1998).

**Agent stability:**

There have been few studies done to determine the stability of TSV. TSV for transmission experiments is typically stored at -80°C in prawn tissue (Hasson et al. 1995) and remains active after freezing and storage at 0°C (Brock et al. 1995).
Discussion of Exposure Assessment:

*P. monodon* and *P. japonicus* are the only prawn species present in Australia known to be susceptible to TSV infection though both have been found to be largely resistant (Brock 1997). TSV is transmitted orally and through seawater. Birds and insects have been shown to act as vectors for TSV. There are few data on the stability of TSV.

In natural conditions, susceptible prawn species must compete for food with other scavengers including fish and other crustaceans. The likelihood of prawn tissue sporadically introduced into an aquatic environment being consumed by a host susceptible to TSV is low. The regular introduction of relatively small amounts of prawn material into the aquatic environment, eg. at a popular fishing spot, would increase the likelihood to moderate. If there were regular introduction of relatively large amounts of prawn tissue into the aquatic environment, eg. release of untreated waste from commercial prawn-processing, the likelihood of prawn tissue being consumed by a host susceptible to TSV would be moderate-high.

There is little information on the infectivity of TSV for prawn species. However, it is known that TSV is effectively transmitted when a susceptible prawn consumes infected tissues.

The spread of infection between susceptible Australian prawns by cannibalism is unlikely as infected animals are more likely to be eaten by non-susceptible hosts than by susceptible prawns. The probability of infection spreading through water is extremely low under conditions of high dilution but may be significant when there is a heavy concentration and/or volume of infective material present in a highly localised or confined waterbody.

Thus, the probability of the establishment of TSV from the sporadic introduction of contaminated prawn material into the aquatic environment would be very low. The probability of the establishment of TSV from the regular introduction of relatively small amounts of contaminated prawn material into the aquatic environment, eg. bait use, would be low. This assessment is consistent with the observation that imported green prawns have historically been used for bait in Australia and there is no evidence that this has resulted in the establishment of any exotic disease of prawns. The probability of the establishment of TSV from the regular introduction of relatively large amounts of contaminated prawn tissue into the aquatic environment, eg. from commercial processing of imported product, would be moderate to high depending on the volume of waste released.

If tissue containing viable TSV is added to an aquaculture pond containing susceptible prawn species the likelihood of TSV establishment is high. However, it is highly unlikely that infected prawn tissues will be deliberately added to a prawn pond, and it is unlikely that infected imported prawn tissue would be carried to aquaculture ponds by natural means such as wild birds. TSV remains viable after passage through the gastrointestinal tract of birds. Therefore, birds may transmit TSV to prawns in aquaculture or in the wild by feeding on infected tissues and then defaecating in water-bodies containing susceptible species. During active infection of a prawn crop, TSV may be transmitted through water to other prawns in the aquaculture system. In prawn aquaculture in Australia, the release of effluent water and density of farms is strictly regulated. Therefore, dilution of effluent water from aquaculture ponds containing TSV-infected prawns would be expected to reduce the titre of TSV to the extent that this would be unlikely to initiate infection in susceptible hosts in the surrounding natural environment. Some TSV-infected prawns would occasionally escape. However, as discussed above, it is more likely that these individuals would be eaten by non-susceptible species than by susceptible prawns or other crustaceans.
Conclusions of Exposure Assessment:

Taking into account these factors, if TSV entered Australia in whole green prawns purchased by end-users for human consumption, the probability of TSV becoming established would be very low. However, regular introduction of infective material into the aquatic environment would present a higher probability; for small amounts, such as bait usage, the probability would be low; for large quantities, such as release of untreated waste from reprocessing plants, the probability would be moderate to high.

Consequences of disease establishment

The TS pandemic in cultured *P. vannamei* in South America has resulted in direct economic loss in excess of US$1 billion (Lightner 1995). Though TSV infects several penaeid species, most disease has been in *P. vannamei*; most species are not severely affected and do not develop TS in experimental conditions (Brock et al. 1995; Overstreet et al. 1997) or in aquaculture (Lightner and Redman 1998). *P. vannamei* is not present in Australia and is not imported. The Australian cultured species *P. monodon* and *P. japonicus*, appear to be largely resistant to TS (Brock 1997).

Although TSV has been found in wild stocks in the Americas (Lightner 1996b), Brock (1997) stated that no discernible impact on wild prawn populations has been detected. While some prawn species present in Australia, other than *P. monodon* and *P. japonicus*, may be susceptible to TSV, there is no reason to expect that wild populations of prawns in Australia will be affected.

Conclusions of consequence assessment:

Taking these factors into account, the consequences of TSV establishing in prawn populations in Australia is assessed as negligible.

Unrestricted risk estimation

A summary of the risk assessment is shown in Box 5.1.

---

31 Recognising that uncooked waste from product in the human consumption pathway will infrequently enter the aquatic environment through accidental or incidental introduction (eg. at picnics)
Box 5.1 Risk assessment - Taura syndrome virus

Unrestricted risk estimation
Release assessment = moderate

Exposure assessment
- Human consumption\(^{31}\) = very low
- Bait = low
- Processing = moderate to high

Probability of establishment
- Human consumption\(^{31}\) = very low
- Bait = low
- Processing = moderate

Significance of consequence = negligible.

From Figure 1.1 (risk evaluation matrix):
importation risk for TSV = acceptable (‘yes’ in Figure 1.1).

That is:
- the risk associated with the unrestricted importation of whole green prawns meets
  Australia’s ALOP; and
- risk management measures are not warranted.

5.3.2 White spot syndrome virus

White spot syndrome virus (WSSV), the causative agent for white spot disease (WSD), was first reported over a short period by groups in several countries. Consequently, the virus, or virus complex, was given many different names including white spot baculovirus (Wang et al. 1995), systemic ectodermal and mesodermal baculovirus (Wonteerasupaya et al. 1995), *Penaeus monodon* non-occluded baculovirus II (Wongteerasupaya et al. 1996), *Penaeus monodon* non-occluded baculovirus III (Chang et al. 1996), Chinese baculovirus (Nadala et al. 1998), hypodermal and haematopoietic necrosis baculovirus (Cai et al. 1995), penaeid rod-shaped DNA virus (Inouye et al. 1996), epithelium envelope baculovirus of *F. chinensis* (Sun and Zhang 1995), lymphoid cell nuclear baculovirus (Chen et al. 1996) and non-occluded shrimp virus (Zhu et al. 1998). The name white spot syndrome virus was subsequently adopted.

Release assessment

Geographic distribution:

White spot syndrome virus (WSSV) has not been detected in Australian prawns. WSSV is widespread in Asia and has been detected in Bangladesh (Cai et al. 1995), India (Karunasagar et al. 1997), Indonesia (Inouye et al. 1994), Korea (Park et al. 1998), Malaysia (Kasornchandra et al. 1998), Sri Lanka (Jory and Dixon 1999), Taiwan (Chou et al. 1995),
Thailand (Wongteerasupaya et al. 1995), Vietnam (Lightner 1996b), Philippines and Saudi Arabia (Tim Flegel, Mahidol University, pers. comm. 11/3/99). In the Western Hemisphere, WSSV has been detected in USA (Lightner 1996b), Panama (Fegan 1999), Mexico (Anonymous 1999a), Nicaragua, Guatemala and Honduras (Jory and Dixon 1999).

Host range:

Table 5.1 lists the decapod species that are known to be susceptible to infection with WSSV. Note, all decapods fed WSSV-infected tissues have become infected.

Table 5.1 Host range for WSSV

<table>
<thead>
<tr>
<th>Prawn spp.</th>
<th>Crabs</th>
<th>Other decapod spp.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Marine</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acetes sp.</td>
<td><strong>Calappa lophos</strong></td>
<td>Marine Crayfish</td>
</tr>
<tr>
<td>Alpheus brevicristatus</td>
<td><strong>Calappa philarigus</strong></td>
<td><strong>Panulirus homarus</strong></td>
</tr>
<tr>
<td>Alpheus lobidens</td>
<td><strong>Charybdis feriatus</strong></td>
<td><strong>Panulirus longipes</strong></td>
</tr>
<tr>
<td>Exopalaemon orientalis</td>
<td><strong>Charybdis granulata</strong></td>
<td><strong>Panulirus ornatus</strong></td>
</tr>
<tr>
<td>Metapenaeus monoceros</td>
<td><strong>Charybdis japonica</strong></td>
<td><strong>Panulirus penicillatus</strong></td>
</tr>
<tr>
<td>Metapenaeus ensis</td>
<td><strong>Charybdis natator</strong></td>
<td><strong>Panulirus polyphagus</strong></td>
</tr>
<tr>
<td>Palaemon serrifer</td>
<td><strong>Helice tridens</strong></td>
<td><strong>Panuliris versicolor</strong></td>
</tr>
<tr>
<td>Farfantepenaeus aztecus</td>
<td><strong>Hemigrapsus sanguineus</strong></td>
<td>Freshwater Crayfish</td>
</tr>
<tr>
<td>Fenneropenaeus chinensis</td>
<td><strong>Metapograpus sp.</strong></td>
<td><em>Astacus astacus</em></td>
</tr>
<tr>
<td>Farfantepenaeus duorarum</td>
<td><strong>Ocypride stimpsoni</strong></td>
<td><em>Cherax quadricarinatus</em></td>
</tr>
<tr>
<td>Penaeus indicus</td>
<td><strong>Petrolisthes japonicus</strong></td>
<td><em>Procambarus clarkii</em></td>
</tr>
<tr>
<td>Marsupenaeus japonicus</td>
<td><strong>Portunus pelagicus</strong></td>
<td><em>Procambarus sp.</em></td>
</tr>
<tr>
<td>Fenneropenaeus merguiensis</td>
<td><strong>Portunus sanguinolentus</strong></td>
<td><em>Orconectes puntimanus</em></td>
</tr>
<tr>
<td>Penaeus monodon</td>
<td><strong>Portunus trituberculatus</strong></td>
<td></td>
</tr>
<tr>
<td>Fenneropenaeus penicillatus</td>
<td><strong>Scylla serrata</strong></td>
<td></td>
</tr>
<tr>
<td>Penaeus semisulcatus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Litopenaeus setiferus</td>
<td><strong>Scylla tranquesebarica</strong></td>
<td></td>
</tr>
<tr>
<td>Litopenaeus vannamei</td>
<td><strong>Sesarma sp.</strong></td>
<td></td>
</tr>
<tr>
<td>Trachysalambria curvirostris</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upogebia major</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freshwater</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macrobrachium idella</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macrobrachium rosenbergii</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macrobrachium sp.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

C cultured (if non-cultured sp., then this refers to species captured in prawn aquaculture pond), W wild, E experimental infection (following per os or water-borne exposure)

Prevalence in prawns:

Little information is available on the prevalence of WSSV or WSD in prawn aquaculture. Serious outbreaks of WSD were common throughout Asia in the mid 1990s (Lightner et al. 1999) and in South America in the late 1990s. Ponds that are seriously affected by WSD may be emergency harvested if the prawns are of commercial value (Jory and Dixon 1999). In a study conducted on one farm in Thailand in 1996, Withyachumnarnkul (1999) found that all ponds in which WSSV-infected prawns were detected at some stage in the production cycle...
experienced a WSD outbreak. Approximately half of these severe outbreaks resulted in crop failure, i.e. the crop was terminated before the shrimp were big enough for commercial harvest, while 50% of crops were harvested. WSSV would be expected to occur at a high prevalence in farmed prawns from regions affected by serious outbreaks of WSD.

A recent development in the Asian region is that excellent crops of prawns may be obtained from ponds in which there are a few prawns displaying gross signs of WSSV infection (Flegel 1997). The epizootiology of WSSV through the production cycle is poorly understood and the prevalence of WSSV in “normal” crops is unknown. One batch of *P. monodon* which were infected under hatchery conditions with WSSV while embryos or very early stage larvae, and which were held in tanks for their entire lives, showed a consistently high prevalence of WSSV infection but mortalities only occurred once the prawns were 13 months old (Tsai et al. 1999).

Severe WSD outbreaks are stress induced and are more common during the monsoon season in farmed prawns (Karunasagar et al. 1997; Limsuwan 1999).

The reliance of the *P. monodon* aquaculture industry on wild-caught broodstock has provided data on the prevalence of WSSV in wild populations (Table 5.2). There are also some data on the prevalence of WSSV in other prawn species in the wild. WSSV seems to be common in wild prawns in countries where farms are affected by WSD. Some studies suggested that there is a seasonal effect on the prevalence of WSSV infection in wild prawn populations (Lo et al. 1997; Mushiake et al. 1998).

<table>
<thead>
<tr>
<th>Prawn sp.</th>
<th>Prevalence (%)*</th>
<th>Location</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>P. monodon</em></td>
<td>83.3 (n = 66)*b</td>
<td>Taiwan</td>
<td>Lo et al. (1996)</td>
</tr>
<tr>
<td></td>
<td>77.2 (n = 88)*b</td>
<td>Taiwan</td>
<td>Lo et al. (1997)</td>
</tr>
<tr>
<td><em>P. japonicus</em></td>
<td>9.2 (n = 1269)*b</td>
<td>Japan</td>
<td>Mushiake et al. (1998)</td>
</tr>
<tr>
<td></td>
<td>20.3 (n = 474)*b</td>
<td>Japan</td>
<td>Maeda et al. (1998a)</td>
</tr>
<tr>
<td></td>
<td>58.5 (n = 159)*ns</td>
<td>Taiwan</td>
<td>Lo and Kou (1998)</td>
</tr>
<tr>
<td><em>P. semisulcatus</em></td>
<td>26.7 (n = 15)*b</td>
<td>Taiwan</td>
<td>Wang et al. (1998)</td>
</tr>
<tr>
<td></td>
<td>6.3 (n = 32)*b</td>
<td>Taiwan</td>
<td>Lo et al. (1996)</td>
</tr>
<tr>
<td><em>F. penicillatus</em></td>
<td>11.1 (n = 27)*b</td>
<td>Taiwan</td>
<td>Lo et al. (1996)</td>
</tr>
<tr>
<td><em>M. ensis</em></td>
<td>33.3 (n = 30)*a</td>
<td>Taiwan</td>
<td>Wang et al. (1997b)</td>
</tr>
<tr>
<td>American spp.</td>
<td>5-10 (n = ?)</td>
<td>Panama</td>
<td>Flegel and Fegan (pers. comm.)</td>
</tr>
</tbody>
</table>

* Diagnosis was by PCR in all studies (*a* = 1-step PCR; *b* = 2-step PCR; *ns* = not specified).

Detection and organs affected:

Symptomatology: Clinical signs may include rapid onset of high mortality and the presence of white spots in the cuticle of affected crustaceans.

Histopathology: Eosinophilic to pale basophilic intranuclear inclusions are observed most commonly in epidermis, stomach and gill epithelium, connective tissue, and haemocytes. They are occasionally observed in striated muscle and neural tissue (Durand et al. 1996).
Rapid histological technique: Gills are excised, fixed in alcohol, stained with H&E and examined for intranuclear inclusions. Diagnosis can be accomplished within 3 hours (Flegel and Sriurairatana (1994)).

Electron microscopy: Rod-shaped virions, with stocky cylindrical nucleocapsids, and loosely applied trilaminar envelopes occur in thin sections of infected nuclei, or in purified homogenates of infected tissues (Durand et al. 1997).

Genetic and immunologic assays: Several groups have developed molecular genetic techniques such as gene probes for use in ISH or dot blot (Lu et al. 1995; Wongteerasupaya et al. 1996; Chang et al. 1996; Durand et al. 1996; Nunan and Lightner 1997; Chang et al. 1998) and PCR (Takahashi et al. 1996; Lo et al. 1996; Lo et al. 1996; Kimura et al. 1996; Kim et al. 1998) for detection of WSSV nucleic acid. Two-step PCR is $10^3$ to $10^4$ times more sensitive than 1-step PCR (Lo et al. 1996) and is capable of detecting from 10 to 50 copies of target DNA (Lo and Kou 1998).

Tissue tropism: WSSV most commonly infects cells of the stomach and cuticular epithelium and connective tissue, but also infects cells in the haematopoietic tissue, haemocytes, gills and striated muscle (Chang et al. 1996; Lo et al. 1997; Sahul Hameed et al. 1998). In persistent subclinical infections, the titre of WSSV is lower in all tissues and the virus may be undetectable in muscle by ISH (Tsai et al. 1999).

Lo et al. (1997) found that fewer cells were positive in wild-caught prawns than in cultured or experimentally infected prawns when tested by ISH (Lo et al. 1997). Furthermore, roughly 50% of wild-caught WSSV-infected prawns required 2-step PCR for positive diagnosis (Lo et al. 1996). This suggests that wild prawns infected with WSSV contain lower viral titres than farmed prawns.

**Discussion of release assessment:**

WSD has occurred throughout the major prawn aquaculture regions of Asia, and recently in some regions of the Americas.

When WSSV is first introduced to an area serious disease occurs. Emergency harvest of prawns from ponds in the early stage of a WSD outbreak is not uncommon, even when prawns are relatively small. Crops harvested in these circumstances would contain many prawns that are smaller than usual and many prawns with white spots on the cuticle (which could be detected during processing). Cases of serious disease which follow the entry of WSSV into new areas occurs less frequently over time, as does the practice of emergency harvest. There is evidence that WSSV infection occurs at a high prevalence in commercial prawns produced in areas that were severely affected several years before. It is expected that the titre of virus in such prawns would generally be lower than from crops affected by serious disease. However, individual infected prawns from apparently healthy crops may contain a high titre of virus.

WSSV is associated with obvious white spots in the cuticle of infected prawns; however, these lesions are not pathognomonic for WSSV infection. WSSV infects ectodermal and mesodermal tissues, and infections are most severe in epidermis and gut and gill epithelia. The highest viral titres would occur in the cephalothorax, but WSSV could also occur in abdominal tissues.
WSSV has a wide decapod host range and all prawn species are susceptible to infection.

**Conclusions of release assessment:**

Taking these factors into account, the probability of WSSV entering Australia via the unrestricted importation of whole green prawns from a crop harvested as a disease control measure would be high. The probability of WSSV entering Australia as a consequence of unrestricted importation of whole green prawns from normal crops in areas where WSSV is endemic, and where severe outbreaks are no longer common, would be moderate.

**Exposure assessment**

**Transmission:**

WSSV can be transmitted horizontally by feeding on infected tissue or via water. Postlarvae, juvenile and subadult penaeids are susceptible to WSSV infection and infections have been found in all life stages of penaeids (Chang et al. 1998a; Wang et al. 1999). In trials with penaeids, as little as one feed of 5% body weight of heavily infected tissue resulted in WSSV transmission (Wang et al. 1999). The introduction of a single dead infected prawn into a pond can cause several prawns to become infected as several prawns will feed on one prawn. Vertical transmission of WSSV within the egg may occur but has not been proven (Mohan et al. 1997).

**Agent stability:**

Studies on the heat stability of WSSV in semi-purified suspensions have showed that the virus can be inactivated within 1 minute at 60°C (Figure 5.1). WSSV in prawn tissues may be more resistant to heating due to the protective effect of proteins.

**Figure 5.1 Relationship between time and temperature for inactivation of WSSV (from Chang et al. (1998b), Nakano et al. (1998) and Maeda et al. (1998b))**

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>40</th>
<th>50</th>
<th>55(\text{I})</th>
<th>60</th>
<th>70</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>20</td>
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<tr>
<td>60</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>90</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

(Shaded area represents complete inactivation)

\(\text{I}\) Complete inactivation was not achieved until 60 minutes, the titre of infective virus was reduced by exposure for 5 and 30 minutes (Chang et al. 1998b).

In laboratories prawn viruses are typically stored frozen in tissue or in various states of purity and in media. Wang et al. (1999) propagated a Chinese isolate of WSSV which was frozen at -70°C in prawn tissue for 2 years. Wang et al. (1997a) transmitted WSSV by feeding prawns with infected prawn tissue which had been frozen at -20°C for an unspecified period. Nunan et al. (1998a) transmitted WSSV to susceptible prawns by injecting a homogenate made from
the pleopods of frozen prawn tails purchased from a supermarket in the USA. The prawn tails had white spots typical of WSD.

Purified WSSV remained viable for 30 days in sterile seawater kept in dark conditions at temperatures up to 30°C (Momoyama et al. 1998; Maeda et al. 1998b). However, under normal pond conditions WSSV is thought to be inactivated in about 3 days due to the combined effects of UV radiation and heating (Jory and Dixon 1999).

Data on the susceptibility of WSSV to various treatments are tabulated below (Table 5.3).

### Table 5.3 Various treatments that achieve total inactivation of WSSV

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaCl</td>
<td>Chang et al. (1998b) 25% for 24 hr Nakano et al. (1998) 12.5% for 24 hr Maeda et al. (1998b) 10 ppm for 30 min</td>
</tr>
<tr>
<td><strong>Chlorine</strong></td>
<td></td>
</tr>
<tr>
<td>Sodium hypochlorite</td>
<td>100 ppm for 10 min 1 mg.L⁻¹ for 10 min 10 ppm for 30 min</td>
</tr>
<tr>
<td>Benzalkonium chloride</td>
<td>75 ppm for 10 min</td>
</tr>
<tr>
<td>Trimethylammonium methylene chloride</td>
<td>25 mg.L⁻¹ for 10 min</td>
</tr>
<tr>
<td>Sodium carbonate peroxyhydrate</td>
<td>5 g.L⁻¹ for 60 min</td>
</tr>
<tr>
<td>Formalin</td>
<td>5 g.L⁻¹ for 10 min</td>
</tr>
<tr>
<td>Povidone iodine</td>
<td>100 ppm for 10 min 2.5 mg.L⁻¹ for 10 min 10 ppm for 30 min</td>
</tr>
<tr>
<td>Ethyl alcohol</td>
<td>30% for 10 min</td>
</tr>
<tr>
<td>Ozone</td>
<td>0.5 mg.ml⁻¹</td>
</tr>
<tr>
<td>UV</td>
<td>2.56 x 10² µW.cm⁻² for 3600 S (9 x 10⁵ µW.S.cm⁻²) 1 x 10² µW.cm⁻² for 100 S (1 x 10⁴ µW.S.cm⁻²)</td>
</tr>
<tr>
<td>pH</td>
<td>pH 1 &amp; 12 within 10 min pH 3 within 60 min</td>
</tr>
</tbody>
</table>

### Discussion of exposure assessment:

WSSV has a very wide host range and can infect many life stages of crustaceans. Prawns, freshwater crayfish and other crustaceans known to be susceptible to WSSV infection are common in freshwater and marine environments throughout Australia. WSSV is transmitted to susceptible hosts *per os* and through seawater. WSSV remains infectious in frozen prawn tissue for a prolonged period and in pond water for about 3 days after removal of infected prawns. WSSV is inactivated by temperatures above 50°C.

In natural conditions, susceptible crustacean species must compete for food with other scavengers including fish. The likelihood of prawn tissue sporadically introduced into an aquatic environment being consumed by a host susceptible to WSSV is low. The regular introduction of relatively small amounts of prawn material into the aquatic environment, eg. at
a popular fishing spot, would increase the likelihood to moderate. If there were regular introduction of relatively large amounts of prawn tissue into the aquatic environment, eg. release of untreated waste from commercial prawn-processing, the likelihood of prawn tissue being consumed by a host susceptible to WSSV would be moderate-high.

There is little information on the infectivity of WSSV for prawn species. However, it is known that WSSV is effectively transmitted when a susceptible prawn consumes infected tissues.

The spread of infection between susceptible Australian prawns by cannibalism is unlikely as infected animals are more likely to be eaten by non-susceptible hosts than by susceptible prawns. The probability of infection spreading through water is extremely low under conditions of high dilution but may be significant when there is a heavy concentration and/or volume of infective material present in a highly localised or confined waterbody.

Thus, the probability of the establishment of WSSV from the sporadic introduction of contaminated prawn material into the aquatic environment would be very low. The probability of the establishment of WSSV from the regular introduction of relatively small amounts of contaminated prawn material into the aquatic environment, eg. bait use, would be low. This assessment is consistent with the observation that imported green prawns have historically been used for bait in Australia and there is no evidence that this has resulted in the introduction of any exotic disease of prawns. The probability of the establishment of WSSV from the regular introduction of relatively large amounts of contaminated prawn tissue into the aquatic environment, eg. from commercial processing of imported product, would be moderate to high depending on the volume of waste released.

If tissue containing viable WSSV is added to an aquaculture pond containing susceptible prawn species the likelihood of WSSV establishment is high. However, it is highly unlikely that infected prawn tissues will be deliberately added to a prawn pond, and it is unlikely that infected imported prawn tissue would be carried to aquaculture ponds by natural means such as wild birds. During active infection of a prawn crop, WSSV may be transmitted through water to other prawns in the aquaculture system. In prawn aquaculture in Australia, the release of effluent water and density of farms is strictly regulated. Therefore, dilution of effluent water from aquaculture ponds containing WSSV-infected prawns would be expected to reduce the titre of WSSV to the extent that this would be unlikely to initiate infection in susceptible hosts in the surrounding natural environment. Some WSSV-infected crustaceans (such as crabs) would move between ponds and the surrounding environment, and some WSSV-infected prawns would occasionally escape. However, as discussed above, it is more likely that these individuals would be eaten by non-susceptible species than by susceptible prawns or other crustaceans.

**Conclusion of exposure assessment:**

Taking into account these factors, if WSSV entered Australia in whole green prawns purchased by end-users for human consumption, the probability of WSSV becoming established would be very low. However, regular introduction of infective material into the aquatic environment would present a higher probability; for small amounts, such as bait usage, the probability would be low; for large quantities, such as release of untreated waste from reprocessing plants, the probability would be moderate to high.
Consequences of disease establishment

A wide range of crustacean species that occur in Australia are susceptible to WSSV infection (see Table 5.1). Many Australian crustacean species susceptible to infection are economically and/or environmentally significant. Farmed prawns would be most severely affected by WSD, particularly in the period immediately after first establishment. When WSD first enters a region, susceptible species in aquaculture conditions, such as *P. monodon* and *P. japonicus*, can suffer 100% mortality within 3-10 days of the first signs of clinical disease (Lightner 1996b).

The establishment of WSSV in populations from which broodstock prawns are sourced for aquaculture would be expected to result in rapid dispersal of WSSV throughout prawn aquaculture via the movement of broodstock and postlarvae. Losses due to WSD could be significant over several crops. The severity of WSD outbreaks in an area tends to decrease after about 1.5 years postulated to be due mainly to development of tolerance or resistance in local prawns (Flegel 1997). This effect, combined with management activities, would result in reduced losses due to WSD after a few years. The implementation of systems to manage WSD, including increased stocking, testing and/or extra equipment, would add to the cost of prawn production.

If WSSV were to become established in wild crustacean populations in the vicinity of prawn aquaculture facilities, WSSV may be introduced to farmed populations via movements of wild crustaceans. The establishment of WSSV in a prawn hatchery could be followed by rapid spread (via postlarvae) and serious losses. The establishment of WSSV in an individual prawn farm could be followed by spread to adjacent farms, then general dispersal within a region. The initial impact on affected farms and, potentially, the entire affected region would be significant. Due to the relatively small contribution of aquaculture to prawn production in Australia and the low concentration of prawn farming in limited areas of Australia, the effect is expected to be insignificant at a national level.

North American freshwater crayfish in captivity are also highly susceptible to WSD (Richman et al. 1997; Lightner et al. 1997b; Wang et al. 1998). In Australia three *Cherax* spp. are important in semi-intensive aquaculture. *C. quadricarinatus* has been shown experimentally to be susceptible to infection with WSSV, but they do not exhibit apparent disease (Lightner, pers. comm.). The susceptibility to WSSV of other Australian freshwater crayfish species has not been determined. Most other crustacean species, and prawns in the wild, are not significantly affected. For example, *Panulirus* species and *Scylla serrata* have a low susceptibility to clinical WSD (Wang et al. 1998; Supamattaya et al. 1998; Rajendran et al. 1999).

The wide host range for WSSV suggests that many crustacean species in the wild in Australia will be susceptible to WSSV infection, particularly penaeid and parastacid species. The consequences of WSSV infection of these species is difficult to predict. The effects of WSSV infection in crustaceans are exacerbated by handling and other stressors (Lo and Kou 1998). There is no evidence that WSSV has had an impact on wild prawn fisheries. Throughout Asia there has been no decline in catch rates from wild populations with a high prevalence of WSSV (AusVet (AusVet Animal Health Services) 1999). The absence of an observable impact on wild prawn populations may be due to lower stress levels in wild prawns and lower levels of infection. Based on the absence of serious effects on wild crustacean populations overseas, the environmental effect of the introduction of WSSV is expected to be negligible.
Conclusions of consequence assessment:

Taking these factors into consideration, the consequences of WSSV establishing in crustacean populations in Australia would be moderate.

Unrestricted risk estimation

A summary of the risk assessment is shown in Box 5.2. Appropriate risk management measures are discussed in Chapter 6.

<table>
<thead>
<tr>
<th>Box 5.2</th>
<th>Risk assessment - white spot syndrome virus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unrestricted risk estimation</td>
<td></td>
</tr>
<tr>
<td>Release assessment</td>
<td></td>
</tr>
<tr>
<td>Normal crop (endemic area) = moderate</td>
<td></td>
</tr>
<tr>
<td>Emergency harvest = high</td>
<td></td>
</tr>
<tr>
<td>Exposure assessment</td>
<td></td>
</tr>
<tr>
<td>Human consumption(^{31}) = very low</td>
<td></td>
</tr>
<tr>
<td>Bait = low</td>
<td></td>
</tr>
<tr>
<td>Processing = moderate to high</td>
<td></td>
</tr>
<tr>
<td>Probability of establishment</td>
<td></td>
</tr>
<tr>
<td>Human consumption(^{31}) = very low</td>
<td></td>
</tr>
<tr>
<td>Bait = low</td>
<td></td>
</tr>
<tr>
<td>Processing = moderate to high</td>
<td></td>
</tr>
<tr>
<td>Significance of consequence = moderate.</td>
<td></td>
</tr>
</tbody>
</table>

From Figure 1.1 (risk evaluation matrix):
importation risk for WSSV = unacceptable (‘no’ in Figure 1.1).
That is:

- the risk associated with the unrestricted importation of whole green prawns does not meet Australia’s ALOP; and
- risk management measures are warranted.

5.3.3 Yellowhead virus

Yellowhead virus (YHV) was first recognised in association with epizootic mortalities in prawn aquaculture in south east Asia in the early 1990s (Anonymous 1992). However, several authors consider that YHV was associated with significant disease in the region for some time prior to being recognised (Lotz 1997b; Lightner et al. 1998). Gill-associated virus (GAV) is a morphologically similar virus which has been associated with significant mortalities in prawn aquaculture in Australia (Spann et al. 1997). Comparison of regions of the genome of GAV to YHV has revealed a 15-20% difference in nucleotide sequence (Cowley et al. 1999, Cowley pers. comm.). Hence, though closely related to YHV, GAV is a distinct virus.
**Release assessment**

**Geographic distribution:**

YHV has not been detected in Australia. YHV has been reported in Thailand (Anonymous 1992) and Sri Lanka (Anonymous 1999b) and has been presumptively diagnosed in India (Shankar and Mohan 1998). Lightner (1996b) suggested that YHV may have have been associated with epizootic disease in farmed prawns in Taiwan, China, Malaysia, Philippines and Indonesia in the late 1980s. Presumptive reports of YHV involvement in epizootics in prawn aquaculture in USA (Lightner 1996b) and South America have proven incorrect (FDC (OIE Fish Disease Commission) 1999; Jory and Dixon 1999).

**Host range:**

YHV only infects marine prawns (Table 5.4).

**Table 5.4 Host range of YHV (adapted from Flegel (1997))**

<table>
<thead>
<tr>
<th>Host</th>
<th>Diagnosis</th>
<th>Transmission to P. monodon</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penaeids</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>F. aztecus</em></td>
<td>H&amp;E</td>
<td></td>
<td>Lightner et al. (1998)</td>
</tr>
<tr>
<td><em>F. duorarum</em></td>
<td>H&amp;E</td>
<td></td>
<td>Lightner et al. (1998)</td>
</tr>
<tr>
<td><em>P. japonicus</em></td>
<td>H&amp;E</td>
<td></td>
<td>Wang et al. (1996)</td>
</tr>
<tr>
<td><em>F. merguiensis</em></td>
<td>H&amp;E</td>
<td>Yes</td>
<td>Flegel (1997)</td>
</tr>
<tr>
<td><em>P. monodon</em></td>
<td>H&amp;E</td>
<td>Yes</td>
<td>Boonyaratpalin et al. (1993)</td>
</tr>
<tr>
<td><em>L. setiferus</em></td>
<td>H&amp;E</td>
<td></td>
<td>Lightner (1996b)</td>
</tr>
<tr>
<td><em>L. stylirostris</em></td>
<td>H&amp;E</td>
<td></td>
<td>Lightner (1996b)</td>
</tr>
<tr>
<td><em>L. vannamei</em></td>
<td>H&amp;E</td>
<td></td>
<td>Lightner et al. (1998)</td>
</tr>
<tr>
<td>Other Prawns</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>M. ensis</em></td>
<td></td>
<td></td>
<td>Flegel (1997)</td>
</tr>
<tr>
<td><em>Parapenaeopsis stylifera</em></td>
<td>H&amp;E, ISH</td>
<td>Yes</td>
<td>Flegel (1997)</td>
</tr>
<tr>
<td><em>Euphasia superha</em></td>
<td></td>
<td>Yes</td>
<td>Flegel (1997)</td>
</tr>
<tr>
<td><em>Acetes</em> sp.</td>
<td></td>
<td>Yes</td>
<td>Boonyaratpalin (cited by Flegel et al. (1995))</td>
</tr>
</tbody>
</table>

C cultured (if non-cultured sp., from prawn aquaculture pond), W wild, E experimental infection (following per os or water-borne exposure), H&E – haematoxylin and eosin stain, ISH – in situ hybridisation.

Note Flegel (1997) included data from personal communications with B. Withychumnamkulk and V. Boonsaeng.

**Prevalence in prawns:**

Little information is available on the prevalence of YHV. Mortalities due to yellowhead disease (YHD) in Thailand were initially serious and widespread. However, high level mortality attributed to YHD declined within 1.5 years (although YHV continued to occur in normal crops of *P. monodon*) (Flegel 1997). The prevalence of subclinical infection with YHV and the titre of virus in subclinically infected prawns is unknown. Little is known of the prevalence of YHV in wild prawn populations. However, Flegel et al. (1995) found that the prevalence of YHV in used wild-caught *P. monodon* spawners was approximately 3%. F.
merguiensis remained healthy in ponds in which P. monodon were experiencing epizootic mortality (Chantanachookin et al. 1993).

Severe outbreaks of YHD most commonly occur in P. monodon aquaculture ponds 50-70 d after stocking, when prawns are 5-15 g (juvenile to subadult stage) (Lightner 1996b; Lotz 1997b). A pond undergoing a serious YHD outbreak may be harvested early as a disease control measure. It appears that emergency harvest of prawns affected by YHD is less common now than in previous years.

Detection and organs affected:

Symptomatology: When first described YHD was characterised by increased feeding quickly followed by high mortality, typically affecting all prawns in 3-5 d (Chantanachookin et al. 1993). Affected prawns had a yellow cephalothorax due to a yellow hepatopancreas visible through the translucent carapace. Most infections observed now are subclinical.

Histopathology: Changes are most pronounced in the lymphoid organ and include degeneration and loss of normal tubule structure with severe necrosis that is multifocal to diffuse (Chantanachookin et al. 1993). Necrotic cells with pyknotic or karyorrhectic nuclei and dense, spherical, basophilic, perinuclear inclusions occur in the lymphoid organ, haemolymph, haematopoietic tissue, gill epithelium and spongy connective tissues (Lightner 1996b). Flegel and Sriurairatana (1994) have developed a rapid processing and staining technique which can provide a definitive diagnosis for acute infection with YHV within 3 hours.

Electron microscopy: Flexuous, cylindrical virions with an envelope with knob-like projections are observed in the cytoplasm of infected cells (Boonyaratpalin et al. 1993; Chantanachookin et al. 1993), and in purified suspensions, which are best prepared from haemolymph (Wongteerasupaya et al. 1995; Nadala et al. 1997).

Cell culture technique: Lu et al. (1995a) developed a quantal assay in primary prawn cell culture for YHV.

Genetic and immunoassay techniques: RT-PCR (Wongteerasupaya et al. 1997), ISH with gene probes (Tang and Lightner 1999) and nitrocellulose-enzyme immunoassay (Lu et al. 1996) techniques have been developed for the detection of YHV.

Tissue tropism: YHV intensely infects the lymphoid organ, cuticular epithelium and gill. Epicardium, connective tissues, and glial cells in nerve tracts are also infected by YHV (Tang and Lightner 1999).

Discussion of Release Assessment:

YHV was panzootic in P. monodon farms throughout Asia possibly as early as the late 1980s. Initially clinical disease was widespread in infected countries but it soon became less common. Since the mid 1990s researchers have detected YHV in healthy P. monodon crops. YHV infects several marine prawn species, but there are few data on the prevalence in susceptible species.

When YHV is first introduced to an area serious disease occurs. Emergency harvest of prawns from ponds in the early stage of a YHD outbreak is not uncommon, even when prawns are relatively small. Crops harvested in these circumstances would contain many prawns that are
smaller than usual, many prawns may show yellowing of the cephalothorax or general signs of ill thrift such as loose cephalothorax and fouling (which could be detected during processing). Cases of serious disease which follow the entry of YHV into new areas occurs less frequently over time, as does the practice of emergency harvest. There is evidence that YHV infection occurs at a high prevalence in commercial prawns produced in areas that were severely affected several years before. It is expected that the titre of virus in such prawns would generally be lower than from crops affected by serious disease. However, individual infected prawns from apparently healthy crops may contain a high titre of virus.

YHV infects mesodermal and ectodermal tissues. Highest viral titres would be expected to occur in the cephalothorax.

Conclusions of Release Assessment:

Taking these factors into account, the probability of YHV entering Australia via the unrestricted importation of whole green prawns from a crop harvested as a disease control measure would be high. The probability of YHV entering Australia as a consequence of unrestricted importation of whole green prawns from normal crops in areas where YHV is endemic, and where severe outbreaks are no longer common, would be moderate.

Exposure assessment

Transmission:

Few published transmission trials have involved natural routes of infection. However, Flegel et al. (1995) reported on unpublished studies by National Institute for Coastal Aquaculture (NICA) and Charoen Pokphand Shrimp Culture Research Centre (CPSCRC) in Thailand. YHV can be transmitted to juvenile and subadult *P. monodon* per os and via seawater. The susceptibility of postlarvae to infection with YHV appears to be age-dependant. PL20 *P. monodon* fed YHV-infected prawn tissue died of YHD in 7-10 d PI (Khongpradit et al. 1993), but PL15 prawns treated similarly did not develop YHD. Lightner et al. (1998) transmitted YHV to juvenile prawns of species that occur in the western hemisphere by feeding infected tissues, but found that postlarvae were resistant to infection. Nash et al. (cited as a pers. comm. by Flegel et al. (1995)) used feeding trials to transmit YHV from *P. monodon* to *Palaemon styliferus*, and from *P. styliferus* back to *P. monodon*. It is possible that YHV could be transmitted vertically, but this has not been thoroughly investigated.

Agent stability:

Research at CPSCRC showed that tissue extracts containing YHV in seawater in aquaria remained infectious for greater than 72 hr (Flegel et al. 1995). The survival of YHV in prawn tissue has not been thoroughly studied. However, YHV-infected tissues or extracts are typically stored at -70°C to -80°C to maintain infectivity (Lu et al. 1995b; Direkbusarakom et al. 1998). Nunan et al. (1998a) detected infectious YHV in frozen prawns in retail outlets in the USA. Research at NICA showed that YHV extracts were inactivated at 60°C for 15 min (Flegel et al. 1995). No information on other time-temperature treatments was provided.

Discussion of Exposure Assessment:

YHV infects several prawn species which are common in marine environments throughout Australia. YHV can be transmitted *per os* and through seawater. YHV is considered to be relatively labile, based on initial difficulties in purifying the virus. YHV is unlikely to remain
viable in seawater in natural conditions for prolonged periods. Few data are available on viability of YHV in typical food products: YHV will remain viable in frozen tissue, and is expected to be relatively susceptible to inactivation by heating, though specific data on time and temperature regimens are not available.

In natural conditions, susceptible prawn species must compete for food with other scavengers including fish and other crustaceans. The likelihood of prawn tissue sporadically introduced into an aquatic environment being consumed by a host susceptible to YHV is low. The regular introduction of relatively small amounts of prawn material into the aquatic environment, eg. at a popular fishing spot, would increase the likelihood to moderate. If there were regular introduction of relatively large amounts of prawn tissue into the aquatic environment, eg. release of untreated waste from commercial prawn-processing, the likelihood of prawn tissue being consumed by a host susceptible to YHV would be moderate-high.

There is little information on the infectivity of YHV for prawn species. However, it is known that YHV is effectively transmitted when a susceptible prawn consumes infected tissues.

The spread of infection between susceptible Australian prawns by cannibalism is unlikely as infected animals are more likely to be eaten by non-susceptible hosts than by susceptible prawns. The probability of infection spreading through water is extremely low under conditions of high dilution but may be significant when there is a heavy concentration and/or volume of infective material present in a highly localised or confined waterbody.

Thus, the probability of the establishment of YHV from the sporadic introduction of contaminated prawn material into the aquatic environment would be very low. The probability of the establishment of YHV from the regular introduction of relatively small amounts of contaminated prawn material into the aquatic environment, eg. bait use, would be low. This assessment is consistent with the observation that imported green prawns have historically been used for bait in Australia and there is no evidence that this has resulted in the introduction of any exotic disease of prawns. The probability of the establishment of YHV from the regular introduction of relatively large amounts of contaminated prawn tissue into the aquatic environment, eg. from commercial processing of imported product, would be moderate to high depending on the volume of waste released.

If tissue containing viable YHV is added to an aquaculture pond containing susceptible prawn species the likelihood of YHV establishment is high. However, it is highly unlikely that infected prawn tissues will be deliberately added to a prawn pond, and it is unlikely that infected imported prawn tissue would be carried to aquaculture ponds by natural means such as wild birds. During active infection of a prawn crop, YHV may be transmitted through water to other prawns in the aquaculture system. In prawn aquaculture in Australia, the release of effluent water and density of farms is strictly regulated. Therefore, dilution of effluent water from aquaculture ponds containing YHV-infected prawns would be expected to reduce the titre of YHV to the extent that this would be unlikely to initiate infection in susceptible hosts in the surrounding natural environment. Some YHV-infected prawns would occasionally escape. However, as discussed above, it is more likely that these individuals would be eaten by non-susceptible species than by susceptible prawns.

**Conclusion of exposure assessment:**

Taking into account these factors, if YHV entered Australia in whole green prawns purchased by end-users for human consumption\(^{31}\), the probability of YHV becoming established would
be very low. However, regular introduction of infective material into the aquatic environment would present a higher probability; for small amounts, such as bait usage, the probability would be low; for large quantities, such as release of untreated waste from reprocessing plants, the probability would be moderate to high.

**Consequences of disease establishment**

Several prawn species that occur in Australia are susceptible to YHV infection (Table 5.4). These species are economically and/or environmentally significant. Farmed prawns would be most severely affected by YHD, particularly in the period immediately following establishment. When YHD first enters a region, susceptible species in aquaculture, such as *P. monodon*, can suffer 100% mortality within 3-5 d of the first signs of clinical disease (Boonyaratpalin et al. 1993).

The establishment of YHV in populations from which broodstock prawns are sourced for aquaculture would likely result in rapid dispersal of YHV throughout prawn aquaculture via the movement of broodstock and postlarvae. Losses due to YHD could be significant over several crops. The severity of YHD outbreaks in an area tends to decrease after about 1.5 years due mainly to the presumed development of tolerance or resistance in local prawns (Flegel 1997). This effect, combined with management activities, would result in reduced losses due to YHD after a few years. The implementation of systems to manage YHD, including increased stocking, testing and/or extra equipment, would add to the cost of prawn production.

If YHV were to become established in wild prawn populations in the vicinity of prawn aquaculture facilities, YHV may be introduced to farmed populations via intake of wild prawns. The establishment of YHV in an individual prawn farm could be followed by spread to adjacent farms, then general dispersal within a region. The initial impact on affected farms and, potentially, the entire affected region would be significant. Due to the relatively small contribution of aquaculture to prawn production in Australia and the low concentration of prawn farming in limited areas of Australia, the effect is expected to be insignificant at a national level.

There is no evidence that YHV has had an impact on wild prawn fisheries. Serious outbreaks of YHD in aquaculture are typically associated with stressful conditions such as high stocking density, high densities of farms with limited regulation of water cycling, and environmental degradation (Flegel et al. 1995). The absence of an observable impact on wild prawn populations may be due to lower stress levels in wild prawns. Based on the absence of serious effects on wild prawn populations overseas, the environmental effect of the introduction of YHV is expected to be negligible.

**Conclusions of consequence assessment:**

Taking these factors into consideration, the consequences of YHV establishing in prawn populations in Australia would be moderate.

**Unrestricted risk estimation**

A summary of the risk assessment is shown in Box 5.3. Appropriate risk management measures are discussed in Chapter 6.
Box 5.3  Risk assessment - yellowhead virus

Unrestricted risk estimation

Release assessment
   Normal crop (endemic area) = moderate
   Emergency harvest = high

Exposure assessment
   Human consumption\(^3\) = very low
   Bait = low
   Processing = moderate to high

Probability of establishment
   Human consumption\(^3\) = very low
   Bait = low
   Processing = moderate to high

Significance of consequence = moderate.

From Figure 1.1 (risk evaluation matrix):
importation risk for YHV = unacceptable (‘no’ in Figure 1.1).

That is:
• the risk associated with the unrestricted importation of whole green prawns does not meet
  Australia’s ALOP; and
• risk management measures are warranted.

5.3.4 Infectious hypodermal and haematopoietic necrosis virus

Infectious hypodermal haematopoietic necrosis (IHHN) is a disease of juvenile \(L.\ stylirostris\) and \(P.\ vannamei\) caused by a parvovirus, IHHNV (Bonami et al. 1990). IHHN was initially reported as an acute disease leading to high mortalities in juveniles of \(L.\ stylirostris\) (Lightner et al. 1983). Runt deformity syndrome (RDS) has been linked to chronic IHHN in \(L.\ vannamei\) (Lightner 1996b).

An IHHNV-like virus was reported from a hybrid penaeid, \(P.\ monodon\) x \(P.\ esculentus\), in Australia (Owens et al. 1992). Mortalities in these hybrids occurred when they reached 3-4 g in weight (Owens et al. 1992). The small perinuclear, cytoplasmic particles did not react with a gene probe to American IHHNV suggesting it had greater than 10% genomic difference (Owens 1997). There have been no subsequent reports of the IHHNV-like virus in Australia.

Release assessment

Geographic distribution:

IHHNV has been reported in prawn aquaculture facilities in the Americas and Asia (Lightner 1996b). Limited information is available on the distribution of IHHNV in wild prawns,
however, the virus is presumed to be enzootic in the Indo-Pacific region, Ecuador and western Panama. A survey of wild penaeids in the Gulf of California, Mexico revealed the presence of IHHNV in *L. stylirostris*, *F. californiensis* and *L. vannamei*. The virus has not been detected previously in the region (Pantoja et al. 1999). It is not known whether the IHHNV population is homogeneous or if geographically distinct virus strains exist (Lightner 1996b).

**Host range:**

Natural IHHNV infections have been reported from *L. stylirostris*, *L. vannamei*, *P. monodon*, *L. occidentalis*, *F. californiensis*, *P. semisulcatus* and *P. japonicus*. In addition, experimental infections of *L. setiferus*, *F. duorarum* and *F. aztecus* with IHHNV have been reported (Lightner 1996b). IHHNV infections have been reported to cause severe acute disease and mass mortalities only in *L. stylirostris* (Lightner 1996b). In *L. vannamei*, IHHNV causes RDS which is a typically chronic disease characterised by rostrum deformities in juveniles (Lightner 1996b). RDS-affected populations display a wide size variation with up to 50% being smaller than expected (Lightner 1996b).

The two penaeid species *F. indicus* and *F. merguiensis* are refractory to IHHNV infections (Lightner 1996b). Significant mortalities have not been reported in other susceptible penaeid species (OIE 1997a).

**Prevalence in prawns**

The occurrence of IHHNV in *P. monodon* aquaculture facilities that use only wild-caught broodstock from the region suggests that the virus is enzootic in South-East Asia where *P. monodon* is one of the natural host species of IHHNV (AusVet (AusVet Animal Health Services) 1999). IHHNV infection was reported at a low prevalence (4%) in cultured *P. monodon* in Thailand (Flegel et al. 1999). In that report, histological lesions characteristic of IHHNV infection were detected in 3 out of 80 grossly normal prawns that were tested.

In contrast, during IHHNV epizootics in *L. stylirostris* aquaculture facilities, the mortality rates typically exceed 80 to 90% indicating a high prevalence of the virus in susceptible stock (Lightner et al. 1983).

A histopathological survey of wild *L. stylirostris* from the Gulf of California in Mexico was performed at 39 sampling stations during 1990. The survey results showed IHHNV prevalence to be 46% in the upper Gulf zone and 26% in the central-lower Gulf zone (Pantoja et al. 1999).

**Detection and organs affected:**

Histopathology: IHHNV infection is definitively diagnosed by histological demonstration of Cowdry type A intranuclear inclusion bodies (CAIs) in infected cells of ectodermal and mesodermal origin (Lightner 1996b).

Molecular and immunologic techniques: The virus may also be detected using gene probes and monoclonal antibodies (Lightner 1996b; OIE 1997a). *In situ* hybridization is considered to be the most appropriate diagnostic test which can be run on biopsied appendages (Lightner 1996b).

Stress induction: Stress-induced enhancement of infection may be required to improve detection of low-grade infection. In this method, a sample of the suspect population is reared
under stressful conditions for 10 to 30 days prior to sampling (Lightner 1996b). Stress factors may include low dissolved oxygen in the water, unsuitable temperature, insufficient food supply or the presence of NH$_3$ or NO$_2$ in the water (OIE 1997a).

Bioassay: Asymptomatic carriers of IHHNV can be identified using a bioassay technique where an indicator prawn species such as juvenile *L. stylirostris* is used (Lightner 1996b). Indicator prawns show signs of IHHN within 5-20 days after injection with homogenates derived from suspected infected prawns (OIE 1997a). Cohabitation of indicator and suspect prawns or feeding suspect prawns to indicator prawns may also be used (OIE 1997a).

Tissue tropism: The virus infects all cells of ectodermal and mesodermal origin (OIE 1997a). Multiple organs may be affected including gills, nerve cord, foregut and lymphoid organ (Lightner 1996b; OIE 1997a).

**Discussion of release assessment:**

IHHNV is widely distributed in prawn aquaculture facilities in the Americas and Asia, and is enzootic in wild penaeid populations in the Indo-Pacific, Ecuador, western Panama and western Mexico. Survey data from the Gulf of California indicates that IHHNV has become established in wild populations of three penaeid species in the region where it was not present before 1987. It is unclear whether distinct geographic IHHNV strains exist.

*L. stylirostris* and *L. vannamei* are highly susceptible to IHHNV infection and disease. IHHNV causes disease and mortalities in juvenile prawns of susceptible species, but no disease symptoms are apparent in infected adult prawns.

Acute IHHN occurs in juvenile prawns, which are unlikely to be emergency-harvested, reducing the probability of severely infected stock entering the country. Because infected adults rarely show diseases signs, IHHNV-infected prawns, particularly wild-caught, may be marketed. Although IHHNV appears to be enzootic in wild prawn populations in specific geographic regions, the current distribution may change. This is based on the reported detection of IHHNV in the Gulf of California where it has not been detected previously.

**Conclusions of release assessment:**

Taking these factors into account, the probability of IHHNV entering Australia as a consequence of unrestricted importation of whole green prawns of species susceptible to severe disease (*L. stylirostris, L. vannamei*) from an area where it is endemic would be moderate. For other species from areas where it is endemic, the probability would be very low to low.

**Exposure assessment**

**Transmission:**

Horizontal transmission of IHHNV to susceptible prawns occurs as a result of feeding on infected carcasses, direct contact between prawns and indirectly through contaminated water. Vertical transmission of IHHNV is believed to occur but has not been confirmed. There is speculation that vertical transmission of IHHNV may have contributed to the spread of infection in cultured and wild prawns in Mexico (Pantoja et al. 1999).
Although *P. monodon* is susceptible to IHHNV infection, disease outbreaks in aquaculture facilities appear to require prolonged exposure to high doses of the virus as occurs during co-culture with the highly susceptible species *P. stylostris* (Lightner et al. 1983).

**Agent stability:**

IHHNV can survive storage at -5°C to -10°C but there is no information on the length of time (Bell and Lightner 1984). The effect of higher temperature on virus survival is not known.

**Discussion of exposure assessment:**

*P. monodon, P. japonicus* and *P. semisulcatus*, species which are common in Australia in the wild and/or in aquaculture, are susceptible to IHHNV infection. However, IHHNV infection of these species is typically low-grade and not associated with epizootic mortality. IHHNV maintains infectivity when infected prawns are frozen at -5°C. IHHNV would be expected to survive for prolonged periods in frozen prawn tissues. IHHNV can be transmitted to susceptible species by cannibalism and through seawater. Vertical transmission of IHHNV has been suggested but has not been proven.

In natural conditions, susceptible prawn species must compete for food with other scavengers including fish and other crustaceans. The likelihood of prawn tissue sporadically introduced into an aquatic environment being consumed by a host susceptible to IHHNV is low. The regular introduction of relatively small amounts of prawn material into the aquatic environment, eg. at a popular fishing spot, would increase the likelihood to moderate. If there were regular introduction of relatively large amounts of prawn tissue into the aquatic environment, eg. release of untreated waste from commercial prawn-processing, the likelihood of prawn tissue being consumed by a host susceptible to IHHNV would be moderate-high.

There is little information on the infectivity of IHHNV for prawn species. However, it is known that IHHNV is effectively transmitted when a susceptible prawn consumes infected tissues.

The spread of infection between susceptible Australian prawns by cannibalism is unlikely as infected animals are more likely to be eaten by non-susceptible hosts than by susceptible prawns. The probability of infection spreading through water is extremely low under conditions of high dilution but may be significant when there is a heavy concentration and/or volume of infective material present in a highly localised or confined waterbody.

Thus, the probability of the establishment of IHHNV from the sporadic introduction of contaminated prawn material into the aquatic environment would be very low. The probability of the establishment of IHHNV from the regular introduction of relatively small amounts of contaminated prawn material into the aquatic environment, eg. bait use, would be low. This assessment is consistent with the observation that imported green prawns have historically been used for bait in Australia and there is no evidence that this has resulted in the introduction of any exotic disease of prawns. The probability of the establishment of IHHNV from the regular introduction of relatively large amounts of contaminated prawn tissue into the aquatic environment, eg. from commercial processing of imported product, would be moderate to high depending on the volume of waste released.
If tissue containing viable IHHNV is added to an aquaculture pond containing susceptible prawn species the likelihood of IHHNV establishment is high. However, it is highly unlikely that infected prawn tissues will be deliberately added to a prawn pond, and it is unlikely that infected imported prawn tissue would be carried to aquaculture ponds by natural means such as wild birds. During active infection of a prawn crop, IHHNV may be transmitted through water to other prawns in the aquaculture system. In prawn aquaculture in Australia, the release of effluent water and density of farms is strictly regulated. Therefore, dilution of effluent water from aquaculture ponds containing IHHNV-infected prawns would be expected to reduce the titre of IHHNV to the extent that this would be unlikely to initiate infection in susceptible hosts in the surrounding natural environment. Some IHHNV-infected prawns would occasionally escape. However, as discussed above, it is more likely that these individuals would be eaten by non-susceptible species than by susceptible prawns.

Conclusions of exposure assessment:

Taking into account these factors, if IHHNV entered Australia in whole green prawns purchased by end-users for human consumption, the probability of IHHNV becoming established would be very low. However, regular introduction of infective material into the aquatic environment would present a higher probability; for small amounts, such as bait usage, the probability would be low; for large quantities, such as release of untreated waste from reprocessing plants, the probability would be moderate to high.

Consequences of disease establishment

Among prawn species in which natural IHHNV infections have been observed, *P. semisulcatus* is commercially fished in Australia. *P. monodon* and *P. japonicus*, also susceptible to IHHNV infection, are the major aquaculture prawn species in Australia. Acute IHHNV outbreaks have not been reported in *P. monodon*. However, IHHNV was diagnosed as the cause of death in numerous samples from an IHHNV-exposed population of *P. monodon* in a laboratory hatchery where mortalities had occurred over several months (Lightner et al. 1983).

It should be noted that although *P. monodon* and *P. japonicus* in east and south-east Asia are natural hosts of IHHNV, there is no evidence of wide-spread IHHNV epizootic mortality in these species. In fact, IHHNV is generally viewed as an insignificant pathogen in the region (Lightner et al. 1997b; Flegel et al. 1999). Eradication techniques for IHHNV are unavailable at present. The use of IHHNV-free broodstock would prevent the establishment of IHHNV in aquaculture facilities.

A report on the potential economic impact of establishment of IHHNV in Australia (ARE (Alliance Resource Economics) 1999), concluded that available evidence suggests IHHNV infection will cause very low rates of infection and nil to minor production losses in farmed *P. monodon* and *P. japonicus* under current Australian conditions. Although eradication techniques for IHHNV are unavailable at present, the use of IHHNV-free broodstock would prevent the establishment of IHHNV in aquaculture facilities.

The impact of IHHNV on wild prawn populations is not fully understood yet. High rates of IHHNV infection were associated with a marked decline, and subsequent recovery, in the wild population of *L. stylirostris* in the Gulf of California (JSA (Joint Subcommittee on Aquaculture) 1997). However, there has been no cause-and-effect relationship established between IHHNV and the decline in catch rates (ERG (Eastern Research Group) 1998). This
species, which is highly susceptible to IHHNV infection, does not occur in Australian waters. There is no evidence that IHHNV causes significant infection in aquatic animals other than prawns (AusVet (AusVet Animal Health Services) 1999). There is no evidence to suggest that IHHNV would have an effect on wild prawn populations in Australia.

Conclusions of consequence assessment:

Taking this factor into account, the consequences of IHHNV establishing in prawn populations in Australia would be negligible.

Unrestricted risk estimation

A summary of the risk assessment is shown in Box 5.4.

<table>
<thead>
<tr>
<th>Box 5.4</th>
<th>Risk assessment - infectious hypodermal and haematopoietic necrosis virus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unrestricted risk estimation</td>
<td></td>
</tr>
<tr>
<td>Release assessment</td>
<td></td>
</tr>
<tr>
<td>Species not susceptible to severe disease = low</td>
<td></td>
</tr>
<tr>
<td>Species susceptible to severe disease = moderate</td>
<td></td>
</tr>
<tr>
<td>Exposure assessment</td>
<td></td>
</tr>
<tr>
<td>Human consumption(^{31}) = very low</td>
<td></td>
</tr>
<tr>
<td>Bait = low</td>
<td></td>
</tr>
<tr>
<td>Processing = moderate to high</td>
<td></td>
</tr>
<tr>
<td>Probability of establishment</td>
<td></td>
</tr>
<tr>
<td>Human consumption(^{31}) = very low</td>
<td></td>
</tr>
<tr>
<td>Bait = low</td>
<td></td>
</tr>
<tr>
<td>Processing = low to moderate</td>
<td></td>
</tr>
<tr>
<td>Significance of consequence = negligible.</td>
<td></td>
</tr>
</tbody>
</table>

From Figure 1.1 (risk evaluation matrix):
importation risk for IHHNV = acceptable (‘yes’ in Figure 1.1).
That is:
• the risk associated with the unrestricted importation of whole green prawns does meet Australia’s ALOP; and
• risk management measures are not warranted.

5.3.5 Aquatic birnavirus, infectious pancreatic necrosis virus (IPNV)

Aquatic birnaviruses are commonly isolated from a variety of aquatic animal species (Reno 1999). Infectious pancreatic necrosis (IPN) is an acute disease of juvenile salmonids caused by an aquatic birnavirus, infectious pancreatic necrosis virus (IPNV) (Reno 1999). IPN is listed by the OIE as an “other significant disease” (OIE 1997a). Other aquatic birnaviruses have been associated with disease in various finfish species including turbot, yellowtail, eel, Japanese flounder and halibut (Reno 1999).
Aquatic birnavirus, identified as IPNV based on transmission studies in young salmonids, has been isolated from non-salmonid fish and from molluscs (McAllister 1995). Virulence of IPNV strains in salmonids range from low to high; for example, one report demonstrated that five virus isolates from clams caused mortality in brook trout ranging from 0% to 80% (McAllister 1995). However, it should be noted that many aquatic birnavirus isolates, that are serologically related to IPNV, are not pathogenic to salmonids and therefore should not be referred to as IPNV (Reno 1999).

An aquatic birnavirus has been isolated from adult, laboratory-bred *P. japonicus* undergoing high mortality (Bovo et al. 1984). Serological testing determined that the virus is antigenically related to IPNV (Bovo et al. 1984). However, there is no evidence that the isolated virus was responsible for the observed mortality in *P. japonicus* or that the virus causes IPN in salmonids. There are no reports demonstrating the ability of prawn-associated aquatic birnavirus to cause disease in salmonids or any other finfish species.

The scientific literature often refers to aquatic birnavirus as “IPNV” without evidence of its pathogenicity in salmonids. Consistent with the salmonid and non-salmonid marine finfish IRA (Kahn et al. 1999) in which IPNV was identified as an agent of quarantine concern, the term “IPNV” will only be used for virus isolates pathogenic to salmonids. Therefore, in this IRA, prawn isolates of aquatic birnavirus that are serologically related to IPNV but that have not been shown to cause disease in salmonids, will be referred to as IPNV-related aquatic birnavirus.

**Release assessment**

**Geographic distribution:**

There is no information available on the geographic distribution of aquatic birnavirus in wild or farmed prawn species. IPNV is widely distributed in salmonid farms in North and South America, Europe and Asia (Reno 1999). IPNV has not been reported from Australia although IPNV-related aquatic birnavirus has been isolated from fish species on the west coast of Tasmania (Crane et al. 1999). Experimental infections indicate that the Australian isolate is not pathogenic to salmonids (Crane et al. 1999). There are no reports of aquatic birnavirus, including IPNV, in farmed or wild prawn populations in Australia.

IPNV-related aquatic birnavirus has been isolated from 6 month-old laboratory-raised *P. japonicus* experiencing high mortality during May and June of 1983 in Italy (Bovo et al. 1984). The prawns were routinely fed on mussels, crabs and frozen fish sourced from various regions. The aquatic birnavirus may have been introduced into the prawn population through unprocessed feed of aquatic animal origin.

**Host range**

Aquatic birnavirus infects a wide range of aquatic animal species, however, there are few reports on infection of prawns. As cited above, an IPNV-related aquatic birnavirus was isolated from the prawn species *P. japonicus* (Bovo et al. 1984). An IPNV-related aquatic birnavirus isolated from scallops was experimentally transmitted to the prawn species *Pandalus borealis* and *Palaemon elegans* (Mortensen 1993). The virus was recovered from the viscera of prawns that fed on infected scallops or on their faeces, but not from control prawns (Mortensen 1993). The study did not determine if the virus had infected the prawns or if it had any effect on the prawn hosts.
Prevalence in prawns

There are no reports of aquatic birnavirus, including IPNV, infections in wild and farmed prawn species around the world. Based on the absence of reports, the occurrence of aquatic birnavirus in prawns is likely to be rare.

Detection and organs affected

Diagnosis of aquatic birnavirus is generally based on virus isolation in cell culture and confirmation of identity using serological methods. PCR is also used (Reno 1999). Experimental infection of salmonids is used to distinguish pathogenic IPNV from non-pathogenic IPNV-related aquatic birnaviruses.

Aquatic birnavirus was isolated in cell culture from pooled samples of homogenised hepatopancreas from *P. japonicus*, and from viscera of *Pandalus borealis* and *Palaemon elegans* prawns (Bovo et al. 1984; Mortensen 1993).

Discussion of release assessment

Aquatic birnaviruses, including IPNV, have not been reported in wild or farmed prawns. The only isolations of aquatic birnavirus from prawns have been from prawns held in laboratory situations. There is no evidence that aquatic birnavirus is associated with clinical disease in prawns.

Conclusion of release assessment

Taking these factors into account, the probability of aquatic birnavirus entering Australia as a consequence of unrestricted importation of whole green prawns would be negligible.

Since the probability of aquatic birnavirus entering and establishing in Australia is negligible, the consequences of establishment were not considered further.

Unrestricted risk estimate for importation of whole green prawns

A summary of the risk assessment is shown in Box 5.5.

<table>
<thead>
<tr>
<th>Box 5.5 Risk assessment – Aquatic birnavirus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unrestricted risk estimation</td>
</tr>
<tr>
<td>Probability of establishment = negligible</td>
</tr>
<tr>
<td>Significance of consequence = irrelevant</td>
</tr>
</tbody>
</table>

5.3.6 Baculovirus penaei

Baculovirus penaei-type (BP) viruses infect wild and aquacultured penaeid prawn species in the Americas and may cause significant mortality in larval and postlarval stages in commercial hatcheries (Overstreet 1994). BP outbreaks are characterised by the sudden onset of acute disease in larvae, typically causing cumulative losses up to 100% of the affected population (Lightner 1988; Lightner 1996b). Experimental studies showed that postlarvae, which survive BP infection, exhibit significantly reduced growth (Stuck and Overstreet 1994).


**Release assessment**

**Geographic distribution:**

BP is widely distributed in the Americas, ranging from the Northern Gulf of Mexico through the Caribbean to Central Brazil on the Atlantic Coast, and from Peru to Mexico on the Pacific Coast. BP has also been identified in Hawaii (Lightner 1996b). BP infections have not been reported outside these regions.

The distinct morphological characteristics of BP isolates, particularly virion size, from various geographic sources suggest that multiple strains of BP exist (Lightner 1996b). ISH using molecular probes suggests the existence of at least two regional BP-type viruses, one on the Pacific Coast and another on the Atlantic (Durand et al. 1998).

**Host range:**

BP infects many American penaeid species, however, significant mortalities have only been recorded from *L. vannamei*, *L. stylirostris*, *F. aztecus*, *F. duorarum* and *M. marginatus* (Overstreet 1994). Severe natural infections of *P. monodon* have also been observed in South America (Lightner, pers. comm.). BP outbreaks are often acute with high mortality rates mostly affecting mysis stages. The losses during outbreaks vary with the prawn species involved, the life stage of the prawn and the culture conditions. In postlarvae and juveniles, high-density culture is associated with subacute or chronic disease, but usually with low mortality (Lightner 1996b).

**Prevalence in prawns**

Based on published information, the prevalence of BP infection in wild prawn populations may vary within one region. For example, the prevalence of BP infection in *L. schmitti* and *P. notalis* sourced from Cuban waters in 1991 and 1993 was found to range from 3% to 31% (Fajer et al. 1998). The intensity of BP infections in the captured prawns was mild although highly variable among the capturing areas (Fajer et al. 1998).

In natural populations of *F. aztecus* inhabiting the Mississippi estuaries, monthly testing between 1989 and 1993 showed that natural BP infections occurred during the months of March to September (Overstreet 1994). Highest prevalence (up to 40%) occurred in May-June of each year, and it was below detectable levels for 5-9 months of the year (Overstreet 1994). It appears that under normal conditions mortalities from BP infections are uncommon in the wild, most likely because the highly susceptible life stages inhabit offshore waters distant from BP-contaminated estuaries (Overstreet 1994).

Factors influencing the outcome of BP infections are related to the virus strain, the host species and the environment (Overstreet 1994). In severely affected aquaculture facilities, BP-associated prawn mortalities may reach over 90% of the mysis stages (Lightner 1996b). In older prawns, a smaller percentage of prawns develop infections and the ability to “lose” infection increases (LeBlanc and Overstreet 1990).

**Detection and organs affected:**

Infected prawns do not show gross lesions that indicate BP infection. The hepatopancreas and the anterior midgut are the target organs in BP infections. Histological diagnosis is made by demonstrating occlusion bodies (OBs) in the nuclei of epithelial cells from these organs using
light microscopy (LM) (Lightner 1996b). The OBs can be easily observed in fresh preparations even without using histochemical stains (Overstreet et al. 1988).

In addition, the virus causes distinct cytopathological features including nuclear hypertrophy and chromatin margination (Lightner 1996b). Virions and OBs are released from disrupted nuclei into the lumen of the digestive tract. The BP genome can be detected by in situ hybridisation before OBs are visible in infected tissue (Bruce et al. 1994). For further confirmation of BP infection, TEM can be used to observe rod-shaped virus particles associated with OBs or free in the nucleus (Lightner 1996b).

**Discussion of release assessment**

BP is endemic in penaeids in the Americas where epizootics are characterised by acute disease in mysis stages. The highest prevalence of BP in susceptible prawn species occurs in early life stages. The disease causes high mortalities in farmed *L. vannamei*, *L. stylirostris*, *F. aztecus*, *F. duorarum* and *M. marginatus*. BP occurs seasonally in wild prawns.

Dead prawn larvae are not a commercially traded product. Though adults and subadults of susceptible species may be carriers of BP, titres would be considerably lower than in the early life stages. Infected prawns cannot be identified by gross inspection, however, OBs can be clearly observed by LM without the use of stains.

**Conclusions of release assessment:**

Taking these factors into account, the probability of BP entering Australia via the unrestricted importation of whole green prawns from areas where it is endemic would be low.

**Exposure assessment**

**Transmission:**
Spawners releasing virus-contaminated faeces transmit infection to eggs and newly hatched nauplii. Older prawns may become infected by ingesting waterborne virus or virus in moribund prawns and prawn carcasses (AusVet (AusVet Animal Health Services) 1997).

Control of BP in hatcheries can be achieved by washing eggs or nauplii with formalin, iodophores and clean seawater (OIE 1997a).

**Agent stability:**

BP is likely to survive freezing because of the protective nature of the polyhedral matrix of the OB (AusVet (AusVet Animal Health Services) 1997). The virus remains infectious after 7 days at 22°C in sea water and survives desiccation for up to 24 hours. Free and occluded virus is inactivated at pH 3 for 3 minutes but retains infectivity after exposure to pH 11 for 120 minutes (Leblanc and Overstreet 1991).

**Discussion of exposure assessment**

*P. monodon* is the only species present in Australia known to be susceptible to BP infection. BP is transmitted horizontally from infected spawners to eggs and nauplii, or in older prawns by ingesting waterborne virus and infected prawn carcasses. The virus remains infectious for long periods under natural conditions.
In natural conditions, susceptible prawn species must compete for food with other scavengers including fish and other crustaceans. The likelihood of prawn tissue sporadically introduced into an aquatic environment being consumed by a host susceptible to BP is low. The regular introduction of relatively small amounts of prawn material into the aquatic environment, eg. at a popular fishing spot, would increase the likelihood to moderate. If there were regular introduction of relatively large amounts of prawn tissue into the aquatic environment, eg. release of untreated waste from commercial prawn-processing, the likelihood of prawn tissue being consumed by a host susceptible to BP would be moderate-high.

There is little information on the infectivity of BP for prawn species. BP is known to be effectively transmitted when a susceptible prawn consumes infected tissues.

The spread of infection between susceptible Australian prawns by cannibalism is unlikely as infected animals are more likely to be eaten by non-susceptible hosts than by susceptible prawns. The probability of infection spreading through water is extremely low under conditions of high dilution but may be significant when there is a heavy concentration and/or volume of infective material present in a highly localised or confined waterbody.

Thus, the probability of the establishment of BP from the sporadic introduction of contaminated prawn material into the aquatic environment would be very low. The probability of the establishment of BP from the regular introduction of relatively small amounts of contaminated prawn material into the aquatic environment, eg. bait use, would be low. This assessment is consistent with the observation that imported green prawns have historically been used for bait in Australia and there is no evidence that this has resulted in the introduction of any exotic disease of prawns. The probability of the establishment of BP from the regular introduction of relatively large amounts of contaminated prawn tissue into the aquatic environment, eg. from commercial processing of imported product, would be moderate to high depending on the volume of waste released.

If tissue containing viable BP is added to an aquaculture pond containing susceptible prawn species the likelihood of BP establishment is high. However, it is highly unlikely that infected prawn tissues will be deliberately added to a prawn pond, and it is unlikely that infected imported prawn tissue would be carried to aquaculture ponds by natural means such as wild birds. During active infection of a prawn crop, BP may be transmitted through water to other prawns in the aquaculture system. In prawn aquaculture in Australia, the release of effluent water and density of farms is strictly regulated. Therefore, dilution of effluent water from aquaculture ponds containing BP-infected prawns would be expected to reduce the titre of BP to the extent that this would be unlikely to initiate infection in susceptible hosts in the surrounding natural environment. Some BP-infected prawns would occasionally escape. However, as discussed above, it is more likely that these individuals would be eaten by non-susceptible species than by susceptible prawns.

**Conclusion of exposure assessment:**

Taking this into account, if BP entered Australia in whole green prawns purchased by end-users for human consumption, the probability of BP becoming established would be very low. However, regular introduction of infective material into the aquatic environment would present a higher probability; for small amounts, such as bait usage, the probability would be low; for large quantities, such as release of untreated waste from reprocessing plants, the probability would be moderate to high.
Consequences of disease establishment

The five American penaeid species susceptible to BP-induced mortality do not occur naturally in Australian waters and are not used in aquaculture in Australia. There is little information on the susceptibility of commercially significant prawn species in Australia to BP infection; *P. monodon* are severely affected. BP infections are easily controlled in aquaculture facilities. A direct impact of BP on prawn fisheries has not been documented (Brock and Lightner 1990). However, the enhancing effect of chemical exposure on prevalence of BP in captive prawns suggests that the disease is potentially important in wild prawn populations if exposed to pollution (Couch 1978; Brock and Lightner 1990).

Although BP has been reported since 1974, there is no evidence that BP infection has caused any ecological or environmental impact where it is present (Brock and Lightner 1990). There are no reports of BP infections in aquatic species other than prawns.

Conclusions of consequence assessment:

Taking these factors into account, the consequences of BP establishing in prawn populations in Australia would be low.

Unrestricted risk estimate

A summary of the risk assessment is shown in Box 5.6.
### Box 5.6  Risk assessment - Baculovirus penaei (BP)

<table>
<thead>
<tr>
<th>Unrestricted risk estimation</th>
<th>Release assessment = low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposure assessment</td>
<td></td>
</tr>
<tr>
<td>Human consumption$^{31}$ = very low</td>
<td>Bait = low</td>
</tr>
<tr>
<td></td>
<td>Processing = moderate to high</td>
</tr>
<tr>
<td>Probability of establishment</td>
<td></td>
</tr>
<tr>
<td>Human consumption$^{31}$ = very low</td>
<td>Bait = low</td>
</tr>
<tr>
<td></td>
<td>Processing = low</td>
</tr>
<tr>
<td>Significance of consequence = low</td>
<td></td>
</tr>
</tbody>
</table>

From Figure 1.1 (risk evaluation matrix): importation risk for BP = acceptable (‘yes’ in Figure 1.1).

That is:
- the risk associated with the unrestricted importation of whole green prawns meets Australia’s ALOP; and
- risk management measures are not warranted.

#### 5.3.7 Baculoviral midgut gland necrosis virus

Baculoviral midgut gland necrosis virus (BMNV) has been reported from *P. japonicus* hatcheries in Japan and Korea (Lightner 1996b; OIE 1997a). The virus, which affects the hepatopancreas and may cause mass mortality in larvae, is listed by the OIE under ‘Other Significant Diseases’ (OIE 1997a).

BMN-like viral infections have also been reported in *P. monodon* from eastern and southeastern Asia and from Australia (Lightner 1996b). The Australian case of BMN-like viral infection was studied only in histology, and no electron microscopy was performed to visualise the virus. At the light microscopy level, cytopathology is remarkably consistent for the many non-occluded intranuclear bacilliform viruses that infect the gut of crustaceans (Edgerton 1999). Therefore, in the absence of evidence to the contrary, BMNV is considered to be exotic to Australia.

**Release assessment**

**Geographic distribution:**

Baculoviral midgut gland necrosis (BMN) has been reported in wild-caught and cultured *P. japonicus* in Japan and Korea (Lightner 1996b).
Host range:

Natural BMN-like virus infections have been observed in *P. japonicus*, *P. monodon* and *M. plebejus* (Lightner 1996b). The BMN-like virus infection of *M. plebejus* has not been verified. Histopathological studies revealed that larval *P. monodon* and *P. japonicus* develop severe lesions with BMNV infections (Momoyama and Sano 1996). *P. chinensis* and *P. semisulcatus* are susceptible to experimental infection, however, no growth retardation or significant mortality are reported as a result of such infections (Momoyama and Sano 1996).

Prevalence in prawns

BMN outbreaks were common in *P. japonicus* hatcheries in Japan in the 1970’s (Sano et al. 1981; Sano et al. 1984). In susceptible prawn species, larval and PL stages up to PL9 are most susceptible to severe infection by BMNV (Lightner 1996b). Cumulative mortality from mysis to 20 days postlarvae could reach up to 98% (Sano et al. 1981). There is no information on the prevalence of the carrier state in adult prawns. Hatchery epizootics are now successfully prevented by rinsing nauplii or fertile eggs with clean sea water and transferring them into a clean hatchery pond (Momoyama and Sano 1989).

Detection and organs affected:

The hepatopancreas is the organ most severely affected in BMNV infection. A presumptive diagnosis may be based on the cloudy hepatopancreas which can be easily observed by the naked eye in infected larvae (OIE 1997a). Wet mounts and histopathology of hepatopancreas are used for definite diagnosis of BMNV (OIE 1997a). The presence of hypertrophied nuclei in the hepatopancreas is a diagnostic feature (OIE 1997a). Demonstration by TEM of the rod-shaped enveloped virions of BMNV in nuclei may be used to confirm the diagnosis (Lightner 1996b).

Discussion of release assessment

BMNV is particularly virulent in early life stages of prawns causing high mortality. BMNV has not been reported outside Korea and Japan, although BMNV-like infections have been reported in other parts of Asia. Dead prawn larvae are not a commercially traded product. Though adults and subadults of susceptible species may be chronic carriers of BMNV, titres would be considerably lower than in the early life stages.

Conclusions of release assessment:

Taking these factors into account, the probability of BMNV entering Australia via the unrestricted importation of whole green prawns from areas where it is endemic would be very low.

Exposure assessment

Transmission:

BMNV is transmitted orally from virus-contaminated faeces (OIE 1997a). Stages of *P. japonicus* most susceptible to water-borne infection are zoea to PL4. Fertilised eggs and nauplii were refractory to BMNV infection (Momoyama and Sano 1989). In juveniles older than PL9, the virus may persist as a subclinical infection (Sano et al. 1985).
The main source of infection in the mass production of *P. japonicus* is latently-infected wild, mature females used as spawners, from which virus particles are excreted in the faeces (Momoyama 1988).

AQIS notes that eradication of BMNV infection can be achieved through washing of fertile eggs or nauplii using clean seawater and transferring them to disinfected rearing tanks (OIE 1997a). This process appears to have succeeded where it has been practiced on an industrial scale in Japan since 1985 (Momoyama and Sano 1989).

**Agent stability:**

BMNV is inactivated by heating at 60°C for 5 min (Momoyama 1989a). The virulence of BMNV in prawns frozen at -80°C had been shown to persist at the same level of infectivity for about one year (Sano et al. 1985). Some viral infectivity is likely to remain in commercially-frozen prawns stored at -18°C. BMNV free in seawater is inactivated within 4 days at 30°C, 7 days at 25 and 12 days at 20 (Momoyama 1989b).

**Discussion of exposure assessment**

*P. monodon*, *P. japonicus* and *M. plebejus* are susceptible to BMNV infection. BMNV is transmitted *per os* and through seawater. Susceptible prawns are infected by BMNV as larvae and survivors become chronic carriers. BMNV-contaminated faeces, from subclinically-infected spawners, is believed to be the main source of BMNV epizootics in aquaculture facilities. BMNV in frozen prawn tissue remains infectious for prolonged periods. BMNV can survive in seawater for several days.

In natural conditions, susceptible prawn species must compete for food with other scavengers including fish and other crustaceans. The likelihood of prawn tissue sporadically introduced into an aquatic environment being consumed by a host susceptible to BMNV is low. The regular introduction of relatively small amounts of prawn material into the aquatic environment, eg. at a popular fishing spot, would increase the likelihood to moderate. If there were regular introduction of relatively large amounts of prawn tissue into the aquatic environment, eg. release of untreated waste from commercial prawn-processing, the likelihood of prawn tissue being consumed by a host susceptible to BMNV would be moderate-high.

There is little information on the infectivity of BMNV for prawn species. However, it has been assumed that BMNV is effectively transmitted when a susceptible prawn consumes infected tissues.

The spread of infection between susceptible Australian prawns by cannibalism is unlikely as infected animals are more likely to be eaten by non-susceptible hosts than by susceptible prawns. The probability of infection spreading through water is extremely low under conditions of high dilution but may be significant when there is a heavy concentration and/or volume of infective material present in a highly localised or confined waterbody.

Thus, the probability of the establishment of BMNV from the sporadic introduction of contaminated prawn material into the aquatic environment would be very low. The probability of the establishment of BMNV from the regular introduction of relatively small amounts of contaminated prawn material into the aquatic environment, eg. bait use, would be low. This assessment is consistent with the observation that imported green prawns have historically
been used for bait in Australia and there is no evidence that this has resulted in the introduction of any exotic disease of prawns. The probability of the establishment of BMNV from the regular introduction of relatively large amounts of contaminated prawn tissue into the aquatic environment, eg. from commercial processing of imported product, would be moderate to high depending on the volume of waste released.

If tissue containing viable BMNV is added to an aquaculture pond containing susceptible prawn species the likelihood of BMNV establishment is high. However, it is highly unlikely that infected prawn tissues will be deliberately added to a prawn pond, and it is unlikely that infected imported prawn tissue would be carried to aquaculture ponds by natural means such as wild birds. During active infection of a prawn crop, BMNV may be transmitted through water to other prawns in the aquaculture system. In prawn aquaculture in Australia, the release of effluent water and density of farms is strictly regulated. Therefore, dilution of effluent water from aquaculture ponds containing BMNV-infected prawns would be expected to reduce the titre of BMNV to the extent that this would be unlikely to initiate infection in susceptible hosts in the surrounding natural environment. Some BMNV-infected prawns would occasionally escape. However, as discussed above, it is more likely that these individuals would be eaten by non-susceptible species than by susceptible prawns.

Conclusions of exposure assessment:

Taking into account these factors, if BMNV entered Australia in whole green prawns purchased by end-users for human consumption\textsuperscript{31}, the probability of BMNV becoming established would be very low. However, regular introduction of infective material into the aquatic environment would present a higher probability; for small amounts, such as bait usage, the probability would be low; for large quantities, such as release of untreated waste from reprocessing plants, the probability would be moderate to high.

Consequences of disease establishment

BMNV outbreaks had a large impact on the production of \textit{P. japonicus} larvae in Japan in the period following 1971 (Sano et al. 1981). High mortality rates affected the supply of prawns postlarvae to the grow-out farms. However, BMNV is now successfully controlled in aquaculture facilities by thorough washing of fertile eggs and nauplii.

Though BMN may cause serious losses in \textit{P. japonicus} hatcheries, the disease is easily controlled by routine hatchery procedures that are practiced in Australia to manage \textit{Penaeus monodon}-type baculovirus. Prevention of BMNV outbreaks in aquaculture facilities can be achieved by washing eggs and nauplii in clean seawater, and transferring them to disinfected tanks. Therefore, BMNV is unlikely to have a significant impact on prawn aquaculture in Australia if proper husbandry is practised consistently.

BMNV is expected to have minimal impact on the Australian marine environment. There have been no reports of BMN impacting on wild prawn populations where it is endemic.

Conclusions of consequence assessment

Taking these factors into consideration, the consequences of BMNV establishing in prawn populations in Australia would be low.
Unrestricted risk estimate

A summary of the risk assessment is shown in Box 5.7.

<table>
<thead>
<tr>
<th>Box 5.7 Risk assessment BMNV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unrestricted risk estimation</td>
</tr>
<tr>
<td>Release assessment = very low</td>
</tr>
<tr>
<td>Exposure assessment</td>
</tr>
<tr>
<td>Human consumption$^{31}$ = very low</td>
</tr>
<tr>
<td>Bait = low</td>
</tr>
<tr>
<td>Processing = moderate to high</td>
</tr>
<tr>
<td>Probability of establishment</td>
</tr>
<tr>
<td>Human consumption$^{31}$ = very low</td>
</tr>
<tr>
<td>Bait = very low</td>
</tr>
<tr>
<td>Processing = very low</td>
</tr>
<tr>
<td>Significance of consequence = low.</td>
</tr>
<tr>
<td>From Figure 1.1 (risk evaluation matrix):</td>
</tr>
<tr>
<td>importation risk for BMNV = acceptable (‘yes’ in Figure 1.1).</td>
</tr>
<tr>
<td>That is:</td>
</tr>
<tr>
<td>• the risk associated with the unrestricted importation of whole green prawns meets Australia’s ALOP; and</td>
</tr>
<tr>
<td>• risk management measures are not warranted.</td>
</tr>
</tbody>
</table>

5.3.8 Rhabdovirus of penaeid shrimp (RPS)

RPS has been isolated from penaeid prawns in Hawaii and Ecuador (Lightner 1996b). Electron microscopy of cell cultures inoculated with homogenised tissue from *L. stylirostris* and *L. vannamei* collected from 3 farms in Hawaii showed the presence virus particles with morphological characteristic of rhabdovirus (Lu et al. 1991). It should be noted that the virus was not observed directly in prawn tissue leading to some controversy about its origin.

Pathogenicity of the isolated rhabdovirus in prawns was assessed by intramuscular injection of subadult *L. stylirostris*. There was low survival of both the injected and control prawns which the authors believe to be most likely due to cannibalism. The virus was reisolated from six of the eight groups of prawn exposed to RPS, but only from the lymphoid organ (LO) (Nadala 1992).

Histopathological examination of the LO showed numerous and extremely large hyperplastic nodules with necrotic lesions. Cells in the nodules had one or more of the following changes: hypertropied nuclei, cytoplasmic vacuolation and basophilic cytoplasmic inclusions (Nadala 1992). However, Lightner (1996) (Lightner 1996b) points out that at least four known penaeid viruses, including TSV, LOVV and YHV, cause similar histopathology in the LO.
Analysis of the structural proteins of RPS suggest that it is closely related to spring viraemia of carp virus (SVCV) (Lu and Loh 1994a). RPS was not associated with clinical disease in prawns. There is speculation that prawns may be the carrier species for RPS while finfish are the principal host (Lightner 1996b). The pathogenicity of RPS for carp or other finfish has not been investigated.

RPS has not been reported in the scientific literature since these initial reports. The validity of RPS as a prawn virus remains uncertain and there is no evidence that it causes disease in finfish or other aquatic animals. The Thai submission to the AQIS Prawns and Prawn Product IRA technical issues paper asserted that RPS is a fish virus which probably arose as a contaminant in the original studies.

The lack of reports of RPS infecting prawns suggests this is a rare event. Taking this into account, the probability of RPS entering Australia as a consequence of unrestricted importation of whole green prawns would be negligible.

Because there is negligible probability of RPS entering Australia as a result of importation of whole green prawns, the probability of disease establishment would be negligible.

Because there is negligible probability of RPS entering and establishing in Australia, the consequences of establishment were not considered further.

Unrestricted risk estimation

A summary of the risk assessment is shown in Box 5.8.

<table>
<thead>
<tr>
<th>Box 5.8</th>
<th>Risk assessment - RPS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unrestricted risk estimation</strong></td>
<td></td>
</tr>
<tr>
<td>Probability of establishment = negligible.</td>
<td></td>
</tr>
<tr>
<td>Significance of consequence = irrelevant.</td>
<td></td>
</tr>
<tr>
<td>From Figure 1.1 (risk evaluation matrix):</td>
<td></td>
</tr>
<tr>
<td>importation risk for RPS = acceptable (‘yes’ in Figure 1.1).</td>
<td></td>
</tr>
<tr>
<td>That is:</td>
<td></td>
</tr>
<tr>
<td>• the risk associated with the unrestricted importation of whole green prawns does meet Australia’s ALOP; and</td>
<td></td>
</tr>
<tr>
<td>• risk management measures are not warranted for RPS.</td>
<td></td>
</tr>
</tbody>
</table>

5.3.9 Rickettsia-like organisms

The role of rickettsia-like organisms (RLO) in prawn diseases is not fully understood because these agents usually occur in association with other pathogens in diseased prawns (Brock and Lightner 1990; AusVet (AusVet Animal Health Services) 1997). Since the majority of these agents have not been isolated or characterised, their taxonomic relationships with other members of the Order Rickettsiales have not been established (Lightner 1996b).
Release assessment

Geographic distribution:

RLO infections have been reported in farmed penaeid prawns in South-East Asia (Malaysia, Indonesia and Singapore) and Mexico, as well as in wild penaeids from Hawaii (Lightner 1996b). RLO infections have not been reported in Australian penaeid prawns (AusVet (AusVet Animal Health Services) 1997).

In British Columbia the causative agent of stained prawn disease (SPD) of wild _Pandalus platyceros_ was shown to be a RLO (Bower et al. 1996).

Host range

Natural RLO infections have been reported in _P. monodon, M. marginatus, F. merguiensis_ and _L. vannamei_ (Chong and Loh 1984; Brock et al. 1986a; Anderson et al. 1987; Lightner et al. 1992). Significant mortalities were reported in farmed _P. monodon_ for several production cycles (Anderson et al. 1987). Although the RLO-infected prawns were concurrently infected with MBV and/ or systemic bacteria, the extensive tissue destruction was concordant with the presence of RLO microcolonies suggesting that RLO was primarily responsible for the mortalities (Anderson et al. 1987). Wild _F. indicus_ and _F. merguiensis_ within the ponds were unaffected. RLO infection in _F. merguiensis_ is usually limited to the hepatopancreas tubule epithelial cells (Lightner 1996b).

There has also been a report of a RLO infection in a commercial hatchery of _Macrobrachium rosenbergii_ in Brazil (Cohen and Isaar 1989). _L. stylirostris_ were infected experimentally by feeding with tissue from RLO-infected _M. marginatus_ resulting in disease and mortality (Brock et al. 1986a).

Prevalence in prawns

The prevalence of RLO infection in wild penaeid populations is largely unknown. Ten percent of wild _M. marginatus_ juveniles caught off the tidal flats of Manualua Bay (Hawaii) that had been maintained in captivity for 30 days, tested positive for the presence of RLO infection (Brock et al. 1986a). The prevalence of SPD in _Pandalus platyceros_ in British Columbia (Canada) was reported to range from 4% to 15% during 1990 and 1991 (Bower et al. 1996).

In Malaysia, RLO infections were detected in prawns from 2 out of 3 ponds sampled for testing after the farm reported recurring mortalities (Anderson et al. 1987). RLO microcolonies were observed in 80% and 66.6% of prawns from those ponds.

Detection and organs affected

RLO infect juvenile to adult prawns (AusVet (AusVet Animal Health Services) 1997). Most RLO infections are asymptomatic, however, symptoms such as stunted growth and dark colouration may be observed (Anderson et al. 1987; AusVet (AusVet Animal Health Services) 1997). Heavily infected prawns may have discoloured gills, patchy white abdominal muscle and atrophied hepatopancreas (Lightner 1996b). Discolouration of the cuticle occurs in SPD. (Bower et al. 1996).

Diagnosis is based on microscopic demonstration of RLO microcolonies in target cells (Lightner 1996b). In wet mounts the microcolonies appear as large granular cytoplasmic vacuoles. In Giemsa stained impression smears, the RLO appear as very small dark blue
microorganisms in cytoplasmic vacuoles. Steiner’s silver stain used in histological sections provides the best method for demonstrating the RLO. TEM is used to confirm the diagnosis by demonstrating characteristic intracellular, rod-shaped bacteria within the size range (0.2-0.7) x (0.8-1.6) µm (Lightner 1996b).

In terms of tissue tropism, RLOs generally infect hepatopancreatic cells or connective tissue of prawns (Brock et al. 1986b; Anderson et al. 1987). In infected epithelial cells of the hepatopancreas, RLO microcolonies replace the cytoplasm and cause cellular hypertrophy (Brock et al. 1986b). In *P. monodon*, RLO was detected in connective tissue, fixed phagocytes, antennal gland epithelium, lymphoid organ sheath cells and the hepatopancreas. Within these tissues, inflammatory lesions, granulomas and cell necrosis may occur. (Anderson et al. 1987; Lightner 1996b). In SPD, the RLO was reported to infect the fixed phagocytes and haemocytes (Bower et al. 1996).

**Discussion of release assessment**

RLOs have been detected in prawns from Hawaii, Mexico, British Columbia and South East Asia. There have been no reports of RLO infections from Australian prawns. RLO infections, which are largely asymptomatic, occur in juvenile to adult prawns. RLOs infect mainly hepatopancreatic cells or connective tissue of the host.

Several species including *P. monodon* are susceptible to RLO infection. However, RLO infections in farmed prawns are not common and can be effectively treated with medicated feeds containing oxytetracycline or other antibacterial drugs. There is a low prevalence of infection in wild prawn stocks.

**Conclusions of release assessment:**

Taking these factors into account, the probability of RLO entering Australia as a consequence of unrestricted importation of whole green prawns would be very low.

**Exposure assessment**

**Transmission**

RLOs are obligate intracellular microorganisms. Natural reservoir host(s) are likely to exist in the environment. Experimentally transmitted SPD was demonstrated in *Pandalus platyceros* (Bower et al. 1996). The disease was transmitted by feeding on infected prawns and via exposure to outflow water (screened to 1mm diameter) from a tank where SPD-infected prawns were held (Bower et al. 1996). Also, the indicator prawn species *L. stylirostris* developed severe RLO infection after being fed tissue from naturally infected *M. marginatus* (Brock et al. 1986b).

**Agent stability**

RLO in prawn tissue remained infectious after storage at -70°C and at -10°C for at least 10 days (Brock et al. 1986b; Bower et al. 1996).

**Discussion of exposure assessment**

RLO is expected to survive for prolonged periods in infected frozen prawn tissues and may be transmitted to susceptible species via contaminated water or by susceptible prawns feeding on small amounts of tissue from acutely infected prawns. Susceptible species in Australia include *P. monodon* and *F. merguiensis* which are found in coastal waters of northern Australia.
In natural conditions, susceptible prawn species must compete for food with other scavengers including fish and other crustaceans. The likelihood of prawn tissue sporadically introduced into an aquatic environment being consumed by a host susceptible to RLO is low. The regular introduction of relatively small amounts of prawn material into the aquatic environment, e.g. at a popular fishing spot, would increase the likelihood to moderate. If there were regular introduction of relatively large amounts of prawn tissue into the aquatic environment, e.g. release of untreated waste from commercial prawn-processing, the likelihood of prawn tissue being consumed by a host susceptible to RLO would be moderate-high.

There is little information on the infectivity of RLO for prawn species. However, it is known that RLO is effectively transmitted when a susceptible prawn consumes infected tissues.

The spread of infection between susceptible Australian prawns by cannibalism is unlikely as infected animals are more likely to be eaten by non-susceptible hosts than by susceptible prawns. The probability of infection spreading through water is extremely low under conditions of high dilution but may be significant when there is a heavy concentration and/or volume of infective material present in a highly localised or confined waterbody.

Thus, the probability of the establishment of RLO from the sporadic introduction of contaminated prawn material into the aquatic environment would be very low. The probability of the establishment of RLO from the regular introduction of relatively small amounts of contaminated prawn material into the aquatic environment, e.g. bait use, would be low. This assessment is consistent with the observation that imported green prawns have historically been used for bait in Australia and there is no evidence that this has resulted in the introduction of any exotic disease of prawns. The probability of the establishment of RLO from the regular introduction of relatively large amounts of contaminated prawn tissue into the aquatic environment, e.g. from commercial processing of imported product, would be moderate to high depending on the volume of waste released.

If tissue containing viable RLO is added to an aquaculture pond containing susceptible prawn species the likelihood of RLO establishment is high. However, it is highly unlikely that infected prawn tissues will be deliberately added to a prawn pond, and it is unlikely that infected imported prawn tissue would be carried to aquaculture ponds by natural means such as wild birds. During active infection of a prawn crop, RLO may be transmitted through water to other prawns in the aquaculture system. In prawn aquaculture in Australia, the release of effluent water and density of farms is strictly regulated. Therefore, dilution of effluent water from aquaculture ponds containing RLO-infected prawns would be expected to reduce the titre of RLO to the extent that this would be unlikely to initiate infection in susceptible hosts in the surrounding natural environment. Some RLO-infected prawns would occasionally escape. However, as discussed above, it is more likely that these individuals would be eaten by non-susceptible species than by susceptible prawns.

Conclusion of exposure assessment

Taking into account these factors, if RLO entered Australia in whole green prawns purchased by end-users for human consumption\textsuperscript{31}, the probability of RLO becoming established would be very low. However, regular introduction of infective material into the aquatic environment would present a higher probability; for small amounts, such as bait usage, the probability would be low; for large quantities, such as release of untreated waste from reprocessing plants, the probability would be moderate to high.
Consequence of disease establishment

In Australia, *P. monodon* is a commercially significant aquaculture species. Wild stocks of *F. merguiensis* inhabit northern coastal waters from Shark Bay in the west to the Tweed River in northern NSW (Kailola et al. 1993). As discussed above, RLO infections have been reported from aquaculture ponds of *P. monodon* and from *F. merguiensis*. There are no reports of RLO infections significantly affecting wild populations of prawns.

Poor growth and high cumulative mortality in farmed *P. monodon* in Malaysia was associated with RLO infection (Anderson et al. 1987; Lightner 1996b). Wild *F. merguiensis* and *F. indicus* co-habiting the ponds with *P. monodon* during the outbreak were unaffected.

A one year monitoring program of cultured *F. merguiensis* in Singapore identified a dual infection with RLO and parvovirus (Chong and Loh 1984). Although the infected prawns appeared grossly normal, histopathology of the hepatopancreas from some of these prawns showed that nearly 100% of the epithelial cells were infected, suggesting that the prawns were moribund (Lightner 1996b). It is not clear whether the RLO or viral infection was the major cause of tissue damage.

RLO infections may be effectively treated with medicated feeds containing oxytetracycline or other antibacterial drugs (Lightner 1996b).

There is no evidence that RLO infection in prawns have any ecological or environmental impact.

Conclusions of consequence assessment

Taking these factors into consideration, the consequence of RLO establishing in prawns populations in Australia would be low.

Unrestricted risk estimate for importation of whole green prawns

A summary of the risk assessment is shown in Box 5.9.
Box 5.9  Risk assessment – Rickettsia-like organisms

Unrestricted risk estimation
Release assessment = very low

Exposure assessment
   Human consumption\textsuperscript{31} = very low
   Bait = low
   Processing = moderate to high

Probability of establishment
   Human consumption\textsuperscript{31} = very low
   Bait = very low
   Processing = very low

Significance of consequence = low.

From Figure 1.1 (risk evaluation matrix):
importation risk for RLOs = acceptable ( ‘yes’ in Figure 1.1).

That is:
  • the risk associated with the unrestricted importation of whole green prawns does meet
    Australia’s ALOP; and
  • risk management measures are not warranted.

5.3.10 Alpha Proteobacteria

Necrotizing hepatopancreatitis (NHP) was first reported from \emph{L. vannamei} farms in southern Texas, USA (Frelier et al. 1992). The disease caused high mortalities in affected penaeid stocks (Lightner et al. 1992; Frelier et al. 1992). The aetiological agent in NHP has been identified as a Gram-negative, pleomorphic bacterium of the genus alpha Proteobacteria (Lightner et al. 1992; Frelier et al. 1993; Loy et al. 1996).

\textit{Release assessment}

\textit{Geographic distribution:}

NHP has been reported from Texas-USA, Brazil, Costa Rica, Ecuador, Panama, Peru and Venezuela (Lightner 1996b). The disease does not occur in Australian penaeids.

\textit{Host range}

NHP has been recognised in the American penaeids; \emph{L. vannamei}, \emph{F. aztecs}, \emph{L. setiferus}, \emph{L. stylirostris} and \emph{F. californiensis} (Lightner 1996b). There is no information on the susceptibility to NHP of other prawn species, including commercially important penaeids in Australia.
Prevalence in prawns

*L. vannamei* in a Texas prawn farm experienced NHP-induced growth retardation and mortalities ranging from 20% to 90% in 13 out of 30 ponds (Frelier et al. 1992). The disease was later recognised in Peru where cumulative mortalities reached 70 to 90% in *L. vannamei* and *L. stylirostris* farms (Lightner and Redman 1994). Mortality typically occurs within 50 days of stocking ponds, though stress later in the crop cycle may result in further mortality (Frelier et al. 1992; Lightner and Redman 1994).

As in Texas, elevated water temperature and increased salinity preceded the outbreaks in Peru. The most severely affected farms in Peru were those nearest the upper end of estuaries compared to those nearest the sea. Oxytetracycline added to prawn feed reduced the prevalence of NHP to less than 0.1% when administered early in the course of infection (Lightner and Redman 1994).

Detection and organs affected

Gross signs of NHP infection in prawns include markedly reduced growth, poor length to weight ratios, soft shells and flaccid bodies and black and darkened gills (Lightner and Redman 1994). As the target organ, the hepatopancreas appears markedly atrophied with a pale or soft, fluid-filled centre (Lightner 1996b).

Histological examination of the infected hepatopancreas shows necrotic epithelial cells and granulomatous lesions. The presence of massive numbers of intracellular bacteria in tubule epithelial cells can be demonstrated by using modified Steiner’s staining. TEM distinguishes two distinct morphological forms of the bacterium in infected cells; a rod shaped rickettsia-like form and a flagellated, helical form (Frelier et al. 1992; Lightner 1996b). A DIG-labelled DNA probe to the bacterium is available commercially.

Discussion of release assessment

NHP is limited in distribution to penaeids in the Americas. Disease outbreaks occur after prolonged periods of elevated water temperature and increased salinity. Infected prawns display gross signs such as markedly reduced weight to length ratio, soft shells, flaccid bodies and darkened gills. NHP has only been reported from farmed prawns.

Survivors of NHP epizootics may be chronic carriers of the alpha Proteobacteria. Outbreaks of NHP have not been reported in recent literature due to proper disease management by improved husbandry and judicious use of antibiotics.

Conclusions of release assessment

Taking these factors into account, the probability of the alpha Proteobacteria entering Australia as a consequence of unrestricted importation of whole green prawns would be extremely low.

Exposure assessment

Transmission
NHP was transmitted by intrahepatopancreatic injection of purified bacteria isolated from infected prawns (Frelier et al. 1993). Tanks used in these studies were maintained at 20-22ppt salinity and temperature of 27-29°C.

A feeding study using hepatopancreata from desiccated prawn carcasses collected from a pond with a 30% NHP rate failed to transmit the disease; however, the authors stated that the small number of prawns examined precludes interpretation of results (Frelier et al. 1993). The presence of and the viability of NHP bacteria in the desiccated hepatopancreatic tissue used in the feeding study were not confirmed. Also, water temperature in this experiment was maintained at 20°C compared to 27-29°C in the experiment discussed above.

The natural route of NHP infection is thought to occur by cohabitation through the water column and/or by cannibalism, the latter is believed to play a major role in transmission of disease (Frelier et al. 1994).

Prawns held for several weeks in a tank that previously contained NHP-infected prawns did not develop the disease suggesting that transmission may involve a reservoir host and/or the requirement for specific environmental conditions (Frelier et al. 1993). Species closely related to NHP bacterium are known to have free-living stages and this possibility can not be excluded for the NHP bacterium.

Agent stability

Experimental transmission studies showed that NHP bacteria isolated from infected prawns and frozen at -70°C maintained infectivity when used in intrahepatopancreatic challenge (Frelier et al. 1993). It is likely that NHP bacteria can survive in the hepatopancreatic tissue of whole frozen prawns.

Discussion of exposure assessment

A proteobacterium has been identified as the aetiologic agent for NHP infection, however, disease epizootics appear to be linked to increased water temperature and salinity. The disease agent is likely to survive in whole frozen prawns. The NHP alpha Proteobacteria is thought to be transmitted by cannibalism and cohabitation.

Reports on NHP alpha Proteobacteria infection are limited to farmed penaeid species in the Americas. The susceptibility of Australian prawn species to NHP is unknown; there are no reports of NHP alpha Proteobacteria infecting non-American penaeid species.

The following discussion is based on the scenario that prawn species in Australia will be susceptible to infection by NHP alpha Proteobacteria.

In natural conditions, susceptible prawn species must compete for food with other scavengers including fish and other crustaceans. The likelihood of prawn tissue sporadically introduced into an aquatic environment being consumed by a host susceptible to NHP alpha Proteobacteria is low. The regular introduction of relatively small amounts of prawn material into the aquatic environment, eg. at a popular fishing spot, would increase the likelihood to moderate. If there were regular introduction of relatively large amounts of prawn tissue into the aquatic environment, eg. release of untreated waste from commercial prawn-processing, the likelihood of prawn tissue being consumed by a host susceptible to NHP alpha Proteobacteria would be moderate-high.
There is little information on the infectivity of NHP alpha Proteobacteria for prawn species. Transmission studies suggest that environmental conditions play a role in the transmission and occurrence of disease. Nonetheless, it has been assumed NHP alpha Proteobacteria would be effectively transmitted if a susceptible prawn consumes infected tissues.

The spread of infection between susceptible Australian prawns by cannibalism is unlikely as infected animals are more likely to be eaten by non-susceptible hosts than by susceptible prawns. The probability of infection spreading through water is extremely low under conditions of high dilution but may be significant when there is a heavy concentration and/or volume of infective material present in a highly localised or confined waterbody.

Thus, the probability of the establishment of NHP alpha Proteobacteria from the sporadic introduction of contaminated prawn material into the aquatic environment would be very low. The probability of the establishment of NHP alpha Proteobacteria from the regular introduction of relatively small amounts of contaminated prawn material into the aquatic environment, eg. bait use, would be low. This assessment is consistent with the observation that imported green prawns have historically been used for bait in Australia and there is no evidence that this has resulted in the introduction of any exotic disease of prawns. The probability of the establishment of NHP alpha Proteobacteria from the regular introduction of relatively large amounts of contaminated prawn tissue into the aquatic environment, eg. from commercial processing of imported product, would be moderate to high depending on the volume of waste released.

If tissue containing viable NHP alpha Proteobacteria is added to an aquaculture pond containing susceptible prawn species the likelihood of NHP alpha Proteobacteria establishment is high. However, it is highly unlikely that infected prawn tissues will be deliberately added to a prawn pond, and it is unlikely that infected imported prawn tissue would be carried to aquaculture ponds by natural means such as wild birds. During active infection of a prawn crop, NHP alpha Proteobacteria may be transmitted through water to other prawns in the aquaculture system. In prawn aquaculture in Australia, the release of effluent water and density of farms is strictly regulated. Therefore, dilution of effluent water from aquaculture ponds containing NHP alpha Proteobacteria-infected prawns would be expected to reduce the titre of NHP alpha Proteobacteria to the extent that this would be unlikely to initiate infection in susceptible hosts in the surrounding natural environment. Some NHP alpha Proteobacteria-infected prawns would occasionally escape. However, as discussed above, it is more likely that these individuals would be eaten by non-susceptible species than by susceptible prawns.

Conclusions of exposure assessment

Taking this into account, if the NHP alpha Proteobacteria entered Australia in whole green prawns, and Australian species are not susceptible to infection, the probability of NHP alpha Proteobacteria becoming established would be negligible.

If NHP alpha Proteobacteria entered Australia in whole green prawns purchased by end-users for human consumption\textsuperscript{11}, and if prawn species in Australia are susceptible to infection, the probability of NHP alpha Proteobacteria becoming established would be very low. However, regular introduction of infective material into the aquatic environment would present a higher probability; for small amounts, such as bait usage, the probability would be low; for large quantities, such as release of untreated waste from reprocessing plants, the probability would be moderate to high.
Consequences of disease establishment

There are no reports of NHP in wild populations of commercially significant prawn species in regions where the disease has been reported. While some Australian prawn species may be susceptible to NHP, there is no reason to expect that wild populations of prawns in Australia would be affected. Based on the experience of aquaculture facilities overseas where NHP occurs uncommonly and is easily controlled by improved husbandry and oxytetracycline, it is not expected that NHP would have a major impact on Australian aquaculture. The lack of reports of any ecological and environmental effects of NHP in the regions where it occurs would suggest that such effects are unlikely to occur in Australia.

Conclusions of consequence assessment

Taking this into account, the consequences of NHP establishing in prawn populations in Australia would be low.

Unrestricted risk estimate for importation of whole green prawns

A summary of the risk assessment is shown in Box 5.10.

<table>
<thead>
<tr>
<th>Box 5.10 Risk assessment - NHP alpha Proteobacteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unrestricted risk estimation</td>
</tr>
<tr>
<td>Release assessment = extremely low</td>
</tr>
<tr>
<td>Exposure assessment</td>
</tr>
<tr>
<td>If no Australian species are susceptible = negligible</td>
</tr>
<tr>
<td>If prawn species in Australia are susceptible</td>
</tr>
<tr>
<td>Human consumption = very low</td>
</tr>
<tr>
<td>Bait = low</td>
</tr>
<tr>
<td>Reprocessing = moderate to high</td>
</tr>
<tr>
<td>Probability of establishment</td>
</tr>
<tr>
<td>If no Australian species are susceptible = negligible</td>
</tr>
<tr>
<td>If prawn species in Australia are susceptible</td>
</tr>
<tr>
<td>Human consumption = extremely low</td>
</tr>
<tr>
<td>Bait = extremely low</td>
</tr>
<tr>
<td>Reprocessing = extremely low</td>
</tr>
<tr>
<td>Significance of consequence = low</td>
</tr>
<tr>
<td>From Figure 1.1 (risk evaluation matrix):</td>
</tr>
<tr>
<td>importation risk for alpha Proteobacteria = acceptable (‘yes’ in Figure 1.1).</td>
</tr>
<tr>
<td>That is:</td>
</tr>
<tr>
<td>• the risk associated with the unrestricted importation of whole green prawns does meet Australia’s ALOP; and</td>
</tr>
<tr>
<td>• risk management measures are not warranted.</td>
</tr>
</tbody>
</table>
5.3.11 Vibrios

Bacteria of the genus *Vibrio* are ubiquitous in marine and brackish water environments in both temperate and tropical regions. Vibrios are part of the natural microbial flora of prawns and become opportunistic pathogens when natural defence mechanisms of the host are compromised. Vibriosis (*Vibrio septicaemia*) in prawns can be caused by a number of *Vibrio* spp., many of which occur in the Australian aquatic environment. The bacteria commonly establish lethal infections subsequent to primary conditions such as other infectious diseases, poor nutrition, environmental stress and wounds (Sindermann 1990; Lightner et al. 1992). However, some *Vibrio* infections may be caused by highly virulent species which behave more like primary pathogens than opportunistic invaders (Lightner et al. 1992).

The *Vibrio* species considered in this section are *V. nereis* and *V. penaeicida*. These species do not occur in Australia and have been associated with significant disease and mortality in penaeid prawns overseas (Baticados et al. 1990; Chen et al. 1992; Ishimaru et al. 1995).

**Release assessment**

**Geographic distribution:**

Prawns reared in aquaculture under stressful conditions are susceptible to vibriosis. Major epizootics caused by *Vibrio* species have been reported in the Indo-Pacific region, South America and Central America (Lightner 1996b).

Mass mortalities of cultured *P. monodon* were reported in which *Vibrio* species played an important role. The report also indicated that *V. nereis* and *V. harveyi* were the major species found in moribund prawns collected in Taiwan during the period 1988 to 1990 (Chen et al. 1992).

A distinct *Vibrio* (*Vibrio* sp. PJ, since named *V. penaeicida* sp. nov.) was isolated from diseased Japanese *P. japonicus* (De la Pena et al. 1993). This pathogen, was also detected in apparently healthy prawns and water samples obtained from aquaculture ponds in association with diseased prawns (Ishimaru et al. 1995).

In New Caledonia, the so-called “Syndrome 93” is a seasonal vibriosis caused by *V. penaeicida* which affects *L. stylirostris* juveniles and broodstock (Costa et al. 1998).

**Host range:**

Under stressful conditions, all aquaculture prawn species are susceptible to *Vibrio* infections (Lightner 1996b). Disease outbreaks due to *V. penaeicida* and *V. nereis* have been reported in *P. japonicus*, *L. stylirostris* and *P. monodon* (Chen et al. 1992; Ishimaru et al. 1995; Costa et al. 1998).

**Prevalence in prawns**

As discussed above, vibrios are part of the natural microbial flora of prawns. In general, *Vibrio* infections are managed in commercial aquaculture facilities through good husbandry practices.
Although vibrios are easily isolated from diseased prawns, they are difficult to detect in apparently healthy prawns using conventional isolation methods. Disease outbreaks have been reported in live shipments of prawns inferring high carrier rates of vibrios in apparently healthy prawns. To investigate this phenomenon, the carrier rate for *V. penaeicida* in *P. japonicus* farmed in Japan was determined (De la Pena et al. 1997). Apparently healthy *P. japonicus* prawns were subjected to transport stress to induce overt infection. The results showed 63% of the prawns died from *V. penaeicida* vibriosis during a period of 3 days post-transport in spite of their healthy appearance at the farm.

**Detection and organs affected:**

*Vibrio* infections in prawns may occur in localised cuticular lesions as in bacterial shell disease; localised infections of the gut, the hepatopancreas or wounds; or as generalised septicaemia (Lightner 1993). Heavily infected prawns appear with soft, dark shell and opaque muscle (Costa et al. 1998). Red leg disease in penaeid prawns, where expansion of chromatophores on the pereiopods and pleopods gives them red colouration, has been associated with vibrio species (Chen 1992). Vibrios can be isolated from the hearts, hemolymph or hepatopatopancreas of prawns affected by red leg disease (Wang et al. 1993).

Generally, *Vibrio* species can be detected in overtly diseased prawns due to the presence of large numbers of bacteria in the hemolymph as determined by the examination of wet-mounts or smears (Lightner 1996b). A definitive diagnosis may be made by isolating the organism from prawn tissue or hemolymph, purifying the organism on appropriate media and identifying the species using specific tests (Lightner 1996b). However as discussed above, *Vibrio* bacteria are not easily detectable in apparently healthy prawns.

Studies of vibriosis in *P. japonicus* reported that diseased postlarvae display cloudiness of the hepatopancreas while diseased juveniles display cloudiness of the muscle and brown spots in the gills and lymphoid organ (reviewed in Lightner et al. 1992; Lightner 1996b). Histological examination of affected prawns showed extensive necrosis and bacterial invasion of the lymphoid organ. Also evident were multiple nodules composed of a bacterial colony in the centre surrounded by a melanized zone, and multiple layers of haemocytes encapsulating the bacterial colony (reviewed in Lightner et al. 1992; Lightner 1996b).

The clinical signs of vibriosis in *P. monodon* include inflammation of the hepatopancreas and infected muscular tissue and the presence of a milky fluid in the intestine (Ruangpan and Kitao 1991).

**Discussion of release assessment**

*Vibrio* spp. are common in marine aquatic environments around the world and become opportunistic pathogens in compromised hosts. *V. nereis* and *V. penaeicida* have not been reported in Australia. These vibrios have been reported in association with significant disease and mortality overseas (Asia and New Caledonia). Major outbreaks in farmed *P. japonicus, L. stylirostris* and *P. monodon* have been associated with *V. penaeicida* and *V. nereis*. A high carrier rate of *V. penaeicida* in *P. japonicus* has been reported based on disease outbreaks occurring in apparently healthy prawns held under stressful conditions.

The Gram-negative, rod-shaped *Vibrio* bacteria can be easily detected in diseased prawns. Heavily infected prawns exhibit localised lesions on the cuticle and cloudy musculature.
Although vibrios are common in prawns and their aquatic environment, disease outbreaks in aquaculture have been reduced through good management practices. As a result, *V. nereis* and *V. penaeicida* in market-size prawns are likely to be at a low level.

**Conclusions of release assessment:**

Taking these factors into account, the probability of *V. nereis* and *V. penaeicida* entering Australia as a consequence of unrestricted importation of whole green prawns would be very low.

**Exposure assessment**

**Transmission:**

Vibrios can be transmitted via ingestion of contaminated food. Experimental infection of *P. japonicus* by feeding with *V. penaeicida*-contaminated feed resulted in 10-20% mortality (De la Pena et al. 1998). Transmission via the water also occurred when physically injured prawns were immersed in water contaminated with *V. penaeicida* (De la Pena et al. 1998). These observations suggest an oral route of infection as well as entry through deep wounds in the cuticle. For example, physical damage to appendages during or between molts allows opportunistic bacteria in the water to invade wounds and proliferate in the hemolymph (Paynter 1989).

**Agent stability:**

There is no specific information on the stability of *V. nereis* and *V. penaeicida*. However, the wide distribution of vibrios suggests a high degree of stability under natural conditions in the aquatic environment. One study reported the survival of *V. cholerae* in prawn tissue when stored frozen at -20°C for 36 days (Nascimento et al. 1998). The study also reported that *V. cholerae* in prawn tissue samples were inactivated when boiled for 2 min.

**Discussion of exposure assessment**

Two farmed prawn species in Australia, *P. monodon* and *P. japonicus*, are susceptible to infection by *V. nereis* and *V. penaeicida*. Transmission occurs via ingestion of contaminated food or via wounds in the cuticle. *Vibrio* bacteria are stable under environmental conditions and in storage at -20°C for 36 days but are inactivated by cooking.

In natural conditions, susceptible prawn species must compete for food with other scavengers including fish and other crustaceans. The likelihood of prawn tissue sporadically introduced into an aquatic environment being consumed by a host susceptible to *V. nereis* or *V. penaeicida* is low. The regular introduction of relatively small amounts of prawn material into the aquatic environment, eg. at a popular fishing spot, would increase the likelihood to moderate. If there were regular introduction of relatively large amounts of prawn tissue into the aquatic environment, eg. release of untreated waste from commercial prawn-processing, the likelihood of prawn tissue being consumed by a host susceptible to *V. nereis* or *V. penaeicida* would be moderate-high.

There is little information on the infectivity of *V. nereis* or *V. penaeicida* for prawn species. However, it is known that *V. nereis* or *V. penaeicida* is effectively transmitted when a susceptible prawn consumes infected tissues.
The spread of infection between susceptible Australian prawns by cannibalism is unlikely as infected animals are more likely to be eaten by non-susceptible hosts than by susceptible prawns. The probability of infection spreading through water is extremely low under conditions of high dilution but may be significant when there is a heavy concentration and/or volume of infective material present in a highly localised or confined waterbody.

Thus, the probability of the establishment of *V. nereis* or *V. penaeicida* from the sporadic introduction of contaminated prawn material into the aquatic environment would be very low. The probability of the establishment of *V. nereis* or *V. penaeicida* from the regular introduction of relatively small amounts of contaminated prawn material into the aquatic environment, eg. bait use, would be low. This assessment is consistent with the observation that imported green prawns have historically been used for bait in Australia and there is no evidence that this has resulted in the introduction of any exotic disease of prawns. The probability of the establishment of *V. nereis* or *V. penaeicida* from the regular introduction of relatively large amounts of contaminated prawn tissue into the aquatic environment, eg. from commercial processing of imported product, would be moderate to high depending on the volume of waste released.

If tissue containing viable *V. nereis* or *V. penaeicida* is added to an aquaculture pond containing susceptible prawn species the likelihood of *V. nereis* or *V. penaeicida* establishment is high. However, it is highly unlikely that infected prawn tissues will be deliberately added to a prawn pond, and it is unlikely that infected imported prawn tissue would be carried to aquaculture ponds by natural means such as wild birds. During active infection of a prawn crop, *V. nereis* or *V. penaeicida* may be transmitted through water to other prawns in the aquaculture system. In prawn aquaculture in Australia, the release of effluent water and density of farms is strictly regulated. Therefore, dilution of effluent water from aquaculture ponds containing *V. nereis* or *V. penaeicida*-infected prawns would be expected to reduce the titre of *V. nereis* or *V. penaeicida* to the extent that this would be unlikely to initiate infection in susceptible hosts in the surrounding natural environment. Some *V. nereis* or *V. penaeicida*-infected prawns would occasionally escape. However, as discussed above, it is more likely that these individuals would be eaten by non-susceptible species than by susceptible prawns or other crustaceans.

**Conclusions of exposure assessment**

Taking into account these factors, if *V. nereis* or *V. penaeicida* entered Australia in whole green prawns purchased by end-users for human consumption, the probability of *V. nereis* or *V. penaeicida* becoming established would be very low. However, regular introduction of infective material into the aquatic environment would present a higher probability; for small amounts, such as bait usage, the probability would be low; for large quantities, such as release of untreated waste from reprocessing plants, the probability would be moderate to high.

**Consequences of disease establishment**

*P. japonicus* and *P. monodon*, the major aquaculture species in Australia for local and export markets, are susceptible to infection with *V. nereis* and *V. penaeicida*. A combination of chemical and biological methods can be applied to control vibriosis in aquaculture facilities (Chen 1992; AusVet (AusVet Animal Health Services) 1997). The development of antibiotic resistance such as oxytetracycline by vibrio species is of concern (Nash et al. 1992).
\textit{P. monodon} and \textit{P. japonicus} are the two prawn species associated with disease outbreaks due to \textit{V. nereis} and \textit{V. penaeicida} infections. However, the expression of overt disease in farmed prawns due to these agents is highly correlated to stressful conditions such as overcrowding or live-shipping. In the absence of any reports that \textit{V. nereis} and \textit{V. penaeicida} has any impact on wild prawn populations in regions where it is present, it is expected that it would not have a significant impact on wild prawn populations, or have any ecological or environmental impact.

\textbf{Conclusions of consequence assessment:}

Taking these factors into consideration, the consequence of \textit{V. nereis} and \textit{V. penaeicida} establishing in prawn populations in Australia would be low.

\textit{Unrestricted risk estimate for importation of whole green prawns}

A summary of the risk assessment is shown in Box 5.11.

\begin{table}[h]
\centering
\begin{tabular}{|l|}
\hline
\textbf{Box 5.11 Risk assessment - \textit{V. nereis} and \textit{V. penaeicida}} \\
\hline
Unrestricted risk estimation \\
Release assessment = very low \\
Exposure assessment \\
\hspace{1cm} Human consumption\textsuperscript{31} = very low \\
\hspace{1cm} Bait = low \\
\hspace{1cm} Processing = moderate to high \\
Probability of establishment \\
\hspace{1cm} Human consumption\textsuperscript{31} = very low \\
\hspace{1cm} Bait = very low \\
\hspace{1cm} Processing = very low \\
Significance of consequence = low. \\
\hline
From Figure 1.1 (risk evaluation matrix):
importation risk for \textit{V. nereis} and \textit{V. penaeicida} = acceptable (‘yes’ in Figure 1.1). \\
That is:
\begin{itemize}
  \item the risk associated with the unrestricted importation of whole green prawns meets Australia’s ALOP; and
  \item risk management measures are not warranted.
\end{itemize}
\end{tabular}
\end{table}

5.3.12 \textit{Aerococcus viridans}-like organism

An \textit{A. viridans}-like organism was isolated on one occasion from a batch of 7 healthy \textit{F. aztecus} collected from the Gulf of Mexico (Liuzzo et al. 1965). \textit{Aerococcus viridans var. homari} is the causative agent for gaffkemia which has caused significant losses to the live homarid lobster trade in North America and Europe (Stewart 1980). The relatedness of the
prawn *A. viridans*-like organism to *A. viridans var. homari* was not reported. *Pandalus platyceros* could be infected with *A. viridans var. homari* by injection but not by feeding or by contact (Bell and Hoskins 1966, cited in Stewart 1980).

The lack of reports of *A. viridans*-like organism infection of prawns suggest that infection occurs rarely. Thus, the probability of *A. viridans*-like organism entering Australia as a consequence of unrestricted importation of whole green prawns would be negligible.

Because there is negligible probability of *A. viridans*-like organism entering Australia as a result of importation whole green prawns, the probability of disease establishment would also be negligible.

Because there is negligible probability of *A. viridans*-like organism entering and establishing in Australia, this agent does not require further consideration.

**Unrestricted risk estimation**

A summary of the risk assessment is shown in Box 5.12.

<table>
<thead>
<tr>
<th>Box 5.12 Risk assessment - <em>Aerococcus viridans</em>-like organism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unrestricted risk estimation</td>
</tr>
<tr>
<td>Probability of establishment = negligible.</td>
</tr>
<tr>
<td>Significance of consequence = irrelevant.</td>
</tr>
<tr>
<td>From Figure 1.1 (risk evaluation matrix):</td>
</tr>
<tr>
<td>importation risk for <em>A. viridans</em>-like sp. = acceptable ('yes' in Figure 1.1).</td>
</tr>
<tr>
<td>That is:</td>
</tr>
<tr>
<td>• the risk associated with the unrestricted importation of whole green prawns does meet Australia’s ALOP; and</td>
</tr>
<tr>
<td>• risk management measures are not warranted.</td>
</tr>
</tbody>
</table>

5.3.13 *Hematodinium*-like sp.

*Hematodinium* and *Hematodinium*-like species are well known pathogens of marine decapod crustaceans. *Hematodinium*-like spp. are known to infect prawns overseas (Meyers et al. 1994; Lightner pers. comm.; Bower et al. 1994). Two *Hematodinium* spp. have been reported to infect crabs in Australia (Hudson and Shields 1994). Shields (Shields 1994) considered that the Australian *Hematodinium* spp. were different from the one reported in prawns.

**Release assessment**

**Geographic distribution:**

The prawn *Hematodinium*-like spp. have been found on the Pacific coast of Alaska and Canada (Meyers et al. 1994; Bower et al. 1994), Central America and Africa (Lightner, pers. comm.) and has not been reported in Australia.
Host range:

Infection by Hematodinium-like sp. has been reported for Pandalus platyceros and Pandalus borealis (Meyers et al. 1994; Bower et al. 1994). Lightner (pers. comm.) found Hematodinium-like spp. in wild penaeids.

Prevalence in prawns:

Hematodinium-like spp. have been found at a prevalence of up to 50% in prawns, but most often the prevalence is less than 1% (Meyers et al. 1994). Hematodinium-like spp. infection of prawns is more common during winter. There are no known cases Hematodinium-like spp. infection in farmed prawns.

Detection and organs affected:


Discussion of release assessment:

Hematodinium-like spp. have been reported only from wild prawns from North and Central America and Africa. Hematodinium-like spp. typically are at a low prevalence in wild prawn populations. On rare occasions their prevalence may be moderate to high.

Conclusions of release assessment:

The probability of prawn Hematodinium-like spp. entering Australia as a consequence of unrestricted importation of whole green prawns from areas where they are endemic would be low.

Exposure assessment

Transmission:

Many researchers consider that transmission of Hematodinium species was most likely to be via cannibalism of infected tissues (Hudson and Shields 1994). However, Hudson and Shields (1994) were unable to transmit H. australis in crabs by feeding with infected tissues, leading these authors to suggest that other hosts may be required to transmit infection. As Hematodinium-like spp. have not been recognised in prawn aquaculture, they may have life cycle requirements which are not met in such conditions (Lightner, pers. comm.).

Agent stability:

There are no reported data on stability of the prawn Hematodinium-like spp.

Discussion of exposure assessment:

There is no available evidence, published or anecdotal, of Hematodinium-like spp. infecting prawn species present in Australia; however, the susceptibility of some Australian prawn species to the prawn Hematodinium-like spp. can not be discounted. Hematodinium-like spp.
that infect prawns are likely to have complex life cycle requirements, or are not efficiently transmitted even when susceptible hosts are at high density.

**Conclusions of exposure assessment:**

Taking these factors into account, if prawn Hematodinium-like spp. entered Australia in whole green prawns, the probability of the disease becoming established would be negligible.

**Consequences of disease establishment**

Prawn Hematodinium-like spp. have been reported only from a limited number of species. There are no reports of significant consequences from infections with Hematodinium-like sp. in wild prawns. There are no reports of farmed prawns being infected. There is no evidence to suggest that prawn Hematodinium-like spp. will affect any species in Australia.

**Conclusions of consequence assessment:**

Taking this into account, the consequences of the prawn Hematodinium-like spp. establishing in prawn populations in Australia would be negligible.

**Unrestricted risk estimation**

A summary of the risk assessment is shown in Box 5.13.

<table>
<thead>
<tr>
<th>Box 5.13</th>
<th>Risk assessment - Hematodinium-like sp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unrestricted risk estimation</td>
<td></td>
</tr>
<tr>
<td>Release assessment = low</td>
<td></td>
</tr>
<tr>
<td>Exposure assessment = negligible</td>
<td></td>
</tr>
<tr>
<td>Probability of establishment = negligible</td>
<td></td>
</tr>
<tr>
<td>Significance of consequence = negligible.</td>
<td></td>
</tr>
<tr>
<td>From Figure 1.1 (risk evaluation matrix): importation risk for Hematodinium sp. = negligible (‘yes’ in Figure 1.1).</td>
<td></td>
</tr>
<tr>
<td>That is:</td>
<td></td>
</tr>
<tr>
<td>• the risk associated with the unrestricted importation of whole green prawns meets Australia’s ALOP; and</td>
<td></td>
</tr>
<tr>
<td>• risk management measures are not warranted.</td>
<td></td>
</tr>
</tbody>
</table>

**5.3.14 Microsporidians**

The following microsporidian species were identified in the hazard identification (Chapter 4) for further consideration in the risk assessment: Ameson nelsoni, Agmasoma (Thelohania) penaei, Thelohania octospora, Pleistophora lintoni and Pleistophora crangoni.
Microsporidians will be discussed as a group as there are limited species-specific data relevant to risk assessment and because the available data are generally relevant to all prawn-infecting microsporidians.

*Release assessment*

**Geographic distribution and host range:**

<table>
<thead>
<tr>
<th>Microsporidian sp.</th>
<th>Geographic Range</th>
<th>Host Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Ameson nelsoni</em></td>
<td>USA (Atlantic coast)</td>
<td><em>Farfantepenaeus aztecs</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Penaeus duorarum</em> <em>Litopenaeus setiferus</em></td>
</tr>
<tr>
<td><em>Agmasoma (Thelohania) penaei</em></td>
<td>USA (Gulf of Mexico), Thailand (south-west Gulf of Thailand)</td>
<td><em>Penaeus duorarum</em> <em>Litopenaeus setiferus</em> <em>Penaeus monodon</em> <em>Penaeus merguiensis</em></td>
</tr>
<tr>
<td><em>Thelohania octospora</em></td>
<td>France, England, Romania (Black Sea)</td>
<td><em>Palaemon rectirostris</em> <em>Palaemon serratus</em> <em>Palaemon elegans</em></td>
</tr>
<tr>
<td><em>Pleistophora lintoni</em></td>
<td>USA (Georgia)</td>
<td><em>Palaemonetes pugio</em></td>
</tr>
<tr>
<td><em>Pleistophora crangoni</em></td>
<td>West coast USA (Oregon and Washington)</td>
<td><em>Crangon franciscorum</em> <em>Crangon nigricauda</em> <em>Crangon stylirostris</em> <em>Pandalus jordani</em></td>
</tr>
</tbody>
</table>

**Prevalence in prawns:**

Microsporidians most often occur at low prevalence in wild populations (Bower 1995). However, there have been occasional reports of very high prevalence (≥90%) in wild prawn populations (Viosca 1943; Miglarese and Shealy 1974). Significant disease due to microsporidians is rare in prawn aquaculture, but microsporidiosis is occasionally associated with serious outbreaks of disease (Lightner 1996b). Flegel et al. (1992) found *A. penaei* infection at a prevalence of up to 22.4% in *P. monodon* in aquaculture. There is seasonal variation in the prevalence of infection with many prawn-infecting microsporidians (Sprague 1970; Miglarese and Shealy 1974; Flegel et al. 1992).

**Detection and organs affected:**

Symptomatology: Severely affected prawns are lethargic and inappetant. Microsporidians cause focal to extensive opacity of striated musculature, a feature which is easily detected grossly. As conditions such as lactic acidosis may also cause opacity of musculature, other
techniques must be used to confirm the diagnosis and to identify the microsporidian species. Early infections may be subclinical.

Fresh mounts: Microsporidian spores and other lifestages may be detected in smears of affected tissues. The size of spores, and the number spores produced per sporont, are important diagnostic characters.

Genetic assays: Pasharawipas and Flegel (1994) have developed a gene probe for the detection of *A. penaei*.

Tissue tropism: *A. nelsoni, P. crangoni, P. lontoni* and *A. octospora* infect only striated muscle (Sprague 1950; Sprague 1970; Street and Sprague 1974; Breed and Olson 1977; Olson and Lannan 1984). *A. penaei* infects gonad and hepatopancreas as well as muscle (Viosca 1943; Kelly 1979).

**Discussion of release assessment:**

Microsporidiosis is a frequently recognised disease of prawns due to its obvious clinical sign of opaque musculature. Microsporidians are usually at low prevalence in wild and aquacultured prawns, although there have been occasional reports over the last century of very high prevalence of microsporidiosis in wild prawns (particularly of *A. penaei* infection). Often the species of microsporidian was not determined.

The microsporidian species under consideration are moderately host specific. These microsporidian species typically infect muscle, and *A. penaei* also infects the gonad and hepatopancreas.

**Conclusions of release assessment:**

Taking these factors into account, the probability of the microsporidians under consideration entering Australia as a consequence of unrestricted importation of whole green prawns from areas where they are endemic would be low.

**Exposure assessment**

**Transmission:**

Though decapod-infecting microsporidians have been studied for a century, the lifecycle for all species is poorly described. None of the microsporidians currently under consideration have been shown to infect prawns after cannibalism of infected tissues, suggesting that their lifecycles are complex and involve other hosts, either as “conditioners” or as true hosts. Iverson and Kelly (1976) were able to transmit *A. penaei* to prawns after the spores had passed through the gut of a fish (*Cynoscion nebulosus*). Transmission was dependant on the age of the exposed prawns, and similar attempts with other species of prawn-infecting microsporidians were unsuccessful. Pasharawipas and Flegel (1994) used gene probes to determine possible hosts for *A. penaei* and found that two fish species (*Priacanthus tayenus* and *Scatophagus argus*) were positive for the presence of the parasite. However, it is not known whether the microsporidian infected these fish or was simply transient in their gut. No further transmission trials or research has been conducted to confirm the role of finfish as “conditioning” hosts for *A. penaei*. 
Agent stability:

There are limited data on the stability of decapod-infecting microsporidians. *Ameson michaelis*, a pathogen of crabs, was partially inactivated by freezing at -22°C for up to 67 days (Overstreet and Whatley 1997). Furthermore, not all spores of *Glugea stephani*, a fish-infecting microsporidian, are inactivated by freezing (-19°C for 24 hours) or cooking (60°C for 30 minutes) (Amigó et al. 1996).

Discussion of exposure assessment:

The only microsporidian species under consideration known to infect hosts present in Australia is *A. penaei*. None of the microsporidian species under consideration are known to be transmissible via cannibalism. Given that microsporidians are well known pathogens of prawns, the lack of reports of experimental transmission suggests that the mode of transmission for these pathogens is complex. There is some evidence that fish act as “conditioning” hosts for some decapod-infecting microsporidians, but this has not been substantiated. It is likely that the microsporidians under consideration have complex lifecycles requiring additional host species. Therefore, the probability of infection becoming established as a result of crustaceans feeding on infected prawn tissues is negligible.

Microsporidian spores may not be completely inactivated by freezing or cooking, although there is a decrease in infectivity.

Conclusions of exposure assessment:

Taking into account these factors, if the microsporidian species under consideration entered Australia in whole green prawns, the probability of the disease becoming established would be extremely low.

Consequences of disease establishment

Microsporidians rarely cause significant disease in wild and cultured prawn populations. With the exception of *A. penaei*, the microsporidians under consideration are not known to infect prawn species present in Australia. *A. penaei* has been associated with mortality in aquaculture. *P. monodon* and *F. merguiensis*, species which are commercially significant in Australia, are susceptible to infection by *A. penaei*. Viosca (1943) reported a prevalence of *A. penaei* of 90% in *L. setiferus* along the Louisiana coast in 1919, and stated that the microsporidian “destroyed the reproductive organs”. However, the same author noted that the “1920 and 1921 ….shrimp [prawn] crops were the largest then known”. *A. penaei* caused mortality of up 24% in *P. monodon* aquaculture in Thailand (Flegel et al. 1992). Prawns clinically infected with microsporidians are unmarketable due to deterioration in abdominal muscle.

The ability of some microsporidians to cause parasitic castration in prawns (Viosca 1943; Breed and Olson 1977) suggests that they may have significant ecological and environmental effects. However, there have been no reports linking high prevalence of microsporidiosis in prawns with significant, long lasting ecological and environmental effects.

Conclusions of consequence assessment:

Taking these factors into account, the consequences of *A. penaei* becoming established in prawn populations in Australia would be low. The consequences of the other microsporidian
species under consideration becoming established in prawn populations in Australia would be negligible.

**Unrestricted risk estimation**

A summary of the risk assessment is shown in Box 5.14.

<table>
<thead>
<tr>
<th>Box 5.14 Risk assessment - Microsporidians</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unrestricted risk estimation</strong></td>
</tr>
<tr>
<td><strong>Release assessment</strong> = low</td>
</tr>
<tr>
<td><strong>Exposure assessment</strong> = extremely low</td>
</tr>
<tr>
<td><strong>Probability of establishment</strong> = extremely low</td>
</tr>
<tr>
<td><strong>Significance of consequence</strong> = low (<em>A. penaei</em>) – negligible (others).</td>
</tr>
<tr>
<td>From Figure 1.1 (risk evaluation matrix):</td>
</tr>
<tr>
<td>importation risk for Microsporidians = acceptable (‘yes’ in Figure 1.1).</td>
</tr>
</tbody>
</table>

That is:
- the risk associated with the unrestricted importation of whole green prawns meets Australia’s ALOP; and
- risk management measures are not warranted.

### 5.3.15 *Parauronema* sp.

In 1974, a scuticociliate identified as belonging to the genus *Parauronema* was associated with epizootic disease in *F. aztecus* in a hatchery in the Gulf of Mexico (Couch 1978; Bower et al. 1994). There are no other reports of *Parauronema* sp. infection of prawns.

Lifestages affected were protozoea, mysis and juveniles (Couch 1978). At least 2 other pathogens were present in the affected prawn population. *Parauronema* sp. were detected throughout the haemocoel and abdomen. No other prawn species have been reported as susceptible to *Parauronema* sp. infection.

The lack of reports of *Parauronema* sp. infecting prawns suggest this is a rare event. Taking this into account, the probability of *Parauronema* sp. entering Australia as a consequence of unrestricted importation of whole green prawns would be negligible.

Because there is negligible probability of *Parauronema* sp. entering Australia as a result of importation whole green prawns, and because there are no reported hosts for *Parauronema* sp. in Australia, the probability of disease establishment would be negligible.

Because there is negligible probability of *Parauronema* sp. entering and establishing in Australia, the consequences of establishment were not considered further.
Unrestricted risk estimation

A summary of the risk assessment is shown in Box 5.15.

Box 5.15 Risk assessment - *Parauronema* sp.

<table>
<thead>
<tr>
<th>Unrestricted risk estimation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability of establishment = negligible.</td>
</tr>
<tr>
<td>Significance of consequence = irrelevant.</td>
</tr>
</tbody>
</table>

From Figure 1.1 (risk evaluation matrix):

importation risk for *Parauronema* sp. = acceptable (‘yes’ in Figure 1.1).

That is:
- the risk associated with the unrestricted importation of whole green prawns meet Australia’s ALOP; and
- risk management measures are not warranted for *Parauronema* sp.

5.4 Prawn Feeds

Prawn feeds present a particular risk of introducing prawn pathogens to Australia as they have an extremely high probability of direct exposure to prawns. Imported prawn feeds comprise approximately 80% of prawn feeds used in the Australian prawn aquaculture industry. Prawn feeds can contain prawn tissues (meals), however it should be noted that some prawn feed manufacturers have ceased including crustacean material (Edgerton and Owens 2000).

Several factors will affect whether infection of prawns will result following exposure to infected prawn feed. These factors include the species of prawn involved, the level and nature of the stresses to which the prawn is subject including stocking density, which disease agents are present and the titre of the agent that is present.

Not all species of prawn have the same level of susceptibility to infection by disease agents. For agents such as WSSV, all prawn species exposed have thus far proved to be susceptible to infection. It is known that some agents, such as WSSV, YHV and vibrios, can be spread by ingestion of infected prawn tissues. The infectious dose of prawn disease agents is largely unknown, but it is likely that similar to other species that a minimum number of the infectious agent would need to be present to induce infection. The number required will vary with the particular circumstances including the environmental conditions and immune status of the host.

In aquaculture situations once prawns have been infected there is a high likelihood of the infection rapidly spreading to other prawns in the pond via the water or cannibalism if infected individuals are seriously affected or die.

There are several routes by which prawn feeds could be contaminated by prawn pathogens. An obvious route is the inclusion of prawn meals in prawn feeds. Waste from prawn
processing plants, including prawn heads, rejected prawns, or emergency harvested prawns may be used in the preparation of prawn meals. Such prawns have a significant probability of infection by prawn pathogens of quarantine concern to Australia. Prawn meals and feeds are heated during the manufacturing process. Commonly used commercial treatments would effectively inactivate pathogens of concern; however, heating processes vary.

In poorly managed feed processing plants, raw or partially cooked prawn tissues may contaminate processed feed. This may occur in several ways: the inadvertent inclusion of prawn tissues in the feed mixture; contamination of the feed after processing by raw ingredients; or malfunction of the process such that product is not treated at the specified temperatures.

The presence in feed of prawn pathogens that have a direct life cycle, ie are infectious to prawns without the need for passage through an intermediate host, would an unacceptable quarantine risk. In particular the presence of disease agents such as WSSV, YHV, and possible emerging pathogens, would be of concern. Risk management is discussed in Chapter 6.
CHAPTER 6: RISK MANAGEMENT

6.1 General principles

This chapter considers the risk management measures that will be required to address the quarantine risks associated with the importation of prawns. The risk assessment for the unrestricted importation of whole green prawns and some products (ie. prawn feed) (see Chapter 5) showed that the risk of establishment of some disease agents would not meet Australia’s appropriate level of protection (ALOP). The next step is to consider how risk management measures could be implemented to reduce the risk to a level that would meet the ALOP.

If the risk from the proposed importation of a commodity is determined to be greater than Australia’s ALOP – ie. the risk associated with the unrestricted importation is unacceptable – consideration is given to whether the implementation of risk management measures would achieve Australia’s ALOP. Such consideration of measures is consistent with the intent of the Quarantine Act and Quarantine Proclamation and Australia’s international obligations under the World Trade Organization (WTO) Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement).

The risk management measures chosen must not only meet Australia’s ALOP, but must also restrict trade as little as possible. In developing these measures, Australia must consider matters such as practicability and ease of implementation, cost of compliance, cost-effectiveness and impact on trade, subject to the overriding requirement that measures reliably achieve the ALOP. Additionally, under Article 4 of the SPS Agreement, if an exporting country or other party can objectively demonstrate that measures other than those adopted by Australia would deliver the level of protection we require, the alternative measures should be considered equivalent and therefore acceptable.

Quarantine measures for a commodity must be specified and applied in a way that does not discriminate between different exporting countries, taking into account differences in assessed risk associated with each source. Similarly, measures applied to limit risk from imported commodities must not be more restrictive than measures applied to address similar risks arising from domestic trade in commodities. Furthermore, quarantine measures imposed by Australia must not make arbitrary or unjustified distinctions in the acceptable level of quarantine risk from imported commodities (considering both the likelihood and consequences of establishment of the disease) if such distinctions restrict trade; ie. quarantine risk must be managed consistently.

Consistent with the SPS Agreement, Australia’s policy is to adopt international standards if their use will meet our ALOP. As noted in Chapter 1, the OIE recommends that countries importing dead prawns for human consumption require a health certificate which provides the health status of the prawns of origin with respect to TSV, WSSV and YHV. In the case of WSSV this requirement only applies to head-on prawns.

Section 6.1.1 describes the general measures available for managing quarantine risks. Section 6.2 describes the proposed quarantine measures to address the hazards identified in Chapter 4 as requiring risk management.
6.1.1 Available quarantine measures

Quarantine measures aim to reduce the likelihood that the importation of the product under consideration would lead to the introduction, establishment or spread of exotic disease agents in Australia. There are two principal methods of achieving this outcome:

- reducing the likelihood of disease agents entering Australia in imported product by imposing conditions on the population from which the product is sourced, and/or by treating the product to reduce the number of disease agents present; and

- reducing the likelihood that susceptible host species in Australia would be exposed to imported product or derived waste likely to transmit disease.

Measures can be applied in the country of origin before export and/or in Australia after import to modify the level of risk. Factors relevant to the identification of appropriate risk management measures are discussed in Sections 2.2 and 2.3.

6.1.2 Pre-export requirements for country of origin

Pre-export requirements aim to reduce the likelihood that prawns containing pathogens are exported to Australia and/or reduce the titre of disease agents likely to occur in such prawns. General factors affecting the prevalence of disease agents in imported product are discussed in Section 3.2. There are various measures that would reduce the likelihood of disease agents entering Australia in imported prawns. These include inspection, grading and processing practices, such as washing, removal of the cephalothorax, removal of exoskeleton (shell) and cooking.

Export certification

Exporting countries may provide statements in official certification to confirm the application of these procedures and any other conditions that the importing country may impose on the importation of the commodity.

Official certification may be used to provide assurances for those measures whose implementation cannot be readily confirmed on the basis of post-arrival examination. Certification may also be used as an alternative to more costly or trade restrictive methods, such as inspection and testing of product on arrival.

Certifying authorities must have systems in place to support the issuance of accurate, valid certification. The key elements of such systems may include:

- official programs to gather and collate information;
- systems for the inspection of product, including for approval and control of premises processing product;
- inspection/auditing services supported by competent laboratory system; and
- legislation concerning the issuance of certification, with appropriate sanctions to discourage the issuance of false statements.
Government certification is the basis of international trade in many commodities. Countries involved in international trade normally accept that government certificates are accurate and are supported by systems to ensure their accuracy. Importing countries have the right to take appropriate steps to verify that certificates and certification systems are reliable.

AQIS may conduct a specific evaluation of the competent authority(ies) of countries that do not have an established history of exporting to Australia animals/products certified as meeting Australia’s quarantine requirements. Animal Quarantine Policy Memorandum 1999/62 provides guidelines for the approval of countries to export animals and their products (including prawns) to Australia.

An exporting country may provide certification on matters relevant to quarantine risk, such as:

- the nature and source of exported product
- the health status of populations from which the prawns/product was derived
- the processing of the product
- the system of inspection and grading to which the product was subjected
- the form of the product.

**Nature and source of the exported product**

The nature and source of an imported product may affect the level of disease agents present in the product. An importing country may require official certification as to the source of a product, including the species, geographical location where it was caught or harvested and production system, eg. whether the prawns were farmed or wild caught.

**Health status of the population from which the prawns were derived**

Certification can be used to provide assurances that countries or regions are free of specified pathogens or diseases. Surveillance and monitoring underpins the provision of health certification. Prawn health surveillance and monitoring programs provide information to underpin disease status claims. They must be designed and implemented as appropriate to the target population and pathogens of interest. The exporting country is normally in the best position to have current and accurate information on prawn health, based on the scientific and technical resources of government, industry, research organisations and academia. For diseases listed by the OIE, countries provide regular annual and, as required, emergency reports of their disease status.

AQIS would normally accept information provided by an authority that AQIS recognises as having competence in matters of prawn health regarding the presence or absence of pathogens in susceptible populations of prawns. However, to assist evaluation of claims regarding the absence of specified pathogen(s) in a country or part of a country, AQIS may require the competent authority to present a scientific submission supporting its claims. The submission should include information obtained from ongoing surveillance and monitoring for the pathogen in question and details of controls to exclude the disease agent from the country or free region. AQIS would formally evaluate the submissions of exporting countries having
regard to the epidemiology of the disease agents and effectiveness of surveillance, monitoring and control measures.

In considering the effectiveness of an exporting country’s surveillance and monitoring program, an importing country should have regard to the principles, in the SPS Agreement, of equivalence and national treatment. In considering minimum requirements for disease surveillance by exporting countries, Australia cannot require that exporting countries conduct significantly more intensive surveillance to demonstrate the absence of specified diseases than that deemed sufficient to support Australia’s claims to freedom from the same diseases (all other technical issues being equal).

The emergence of new pathogens or disease syndromes has been a feature of the prawn aquaculture industry. AQIS reserves the right to modify, suspend or revoke import conditions in response to changes in the health status of an exporting country, if such changes are judged to substantially affect the quarantine risks presented by imported products.

**Processing of the product**

Procedures conducted in the course of normal processing for human consumption may also have the effect of reducing the level of risk. Public health authorities require that premises processing prawns for human consumption operate in a sanitary manner to ensure that the product is free from contamination and fit for human consumption. While this risk analysis does not address pathogens of public health significance, inspection controls for public health purposes may simultaneously serve quarantine objectives. For example, appropriate sanitary controls would reduce the likelihood of biofilms and cross contamination in processing plants thus reducing the probability of pathogens contaminating prawns exported to Australia.

Having regard to the principles in the SPS Agreement, AQIS could require plants to operate in accordance with sanitary standards equivalent to those of Australian plants processing prawns for human consumption.

Plants exporting prawns to Australia could be approved by a competent authority of the exporting country and subject to inspection and control by that competent authority to ensure the maintenance of appropriate standards. An appropriate measure would be for the competent authority of the exporting country to certify that prawns exported to Australia were processed in a plant approved and controlled by the competent authority and subjected to regular inspection to confirm the exported product meets Australia’s import requirements.

AQIS would retain the right to conduct reviews of national systems including audits of plants to confirm that acceptable sanitary standards were being maintained.

**System of inspection and grading**

Prawns for human consumption are inspected in many countries under a program approved and supervised by a competent authority which can provide certification attesting to the fitness of the product and that it meets specified conditions, including those of an importing country. Such inspection systems have the objective of ensuring that product is safe for human consumption and meets other specified requirements- they are not designed to detect the presence of disease agents. Commercial inspection and grading programs are commonly used to ensure that the product is wholesome and meets commercial specifications, which normally include correct processing and presentation, size/weight of prawns, absence of blemishes (including pathological lesions), colouration and rigidity of the prawn.
Prawns with visible lesions would normally be downgraded, diverted for further processing or discarded. Prawns with generalised lesions or evidence of ill thrift, such as presenting with “loose” cephalothoraces, would normally be rejected from human consumption. Apparently healthy prawns (including prawns with chronic infection, inapparent lesions and prawns incubating disease) would normally pass inspection. While inspection would not detect all infected prawns, it would provide for the detection of most visibly abnormal prawns, which are often associated with higher titres of disease agents. Thus, inspection and grading of prawns for human consumption could contribute to the reduction of quarantine risk.

Prawns that are visibly abnormal are likely to be discarded or diverted to other uses, which may be high risk, if they are detected in the prawn distribution chain. Consumers would be likely to discard prawns that are visibly abnormal. If discarded into the domestic sewerage or solid waste disposal system, such prawns would present a negligible likelihood of disease establishment. However, disposal of such prawns into water containing significant populations of susceptible prawns or diversion to bait use would present a higher likelihood of disease establishment. While this scenario cannot be discounted, product discarded by retailers and consumers would be more likely to enter the domestic sewerage or solid waste disposal system than the aquatic environment.

For many of the disease agents, inspection and grading for human consumption would increase the likelihood that diseased prawns are detected and would reduce the likelihood of disease agents entering Australia with imported prawns.

Inspection and grading would detect prawns that were visibly affected by disease due to infection with pathogens including WSSV, YHV, TSV, the rickettsia-like organism associated with stained prawn disease and microsporidians and systemic bacterial infections. Furthermore, as a general sign of disease in prawns is loss of rigidity, grading would remove prawns affected by diseases which do not show specific signs of infection. The efficiency of detection would vary from plant to plant. The majority of prawns with generalised infection would be reliably detected, while some prawns with low grade pathological lesions (which could contain a significant titre of pathogens) may pass inspection. Thus, inspection and grading would contribute to a reduction in disease risk overall.

Inspection and grading is a routine part of the processing of prawns for human consumption under normal commercial conditions. Accordingly, AQIS could introduce a requirement for inspection and grading of prawns exported to Australia for human consumption and this would not present a significant impediment to trade. An appropriate measure would be for the competent authority of the exporting country to certify that prawns exported to Australia had been inspected and graded and that they meet relevant conditions of importation.

Systems are not in place for the inspection and grading of bait prawns. Staff are not trained to recognise diseased prawns and the effectiveness of inspection is likely to be limited due to lack of infrastructure to conduct inspections. Depending on the source of prawns, rejection rates could be very high. Inspection and grading would be an effective risk management technique for bait prawns, but costs may be prohibitive.

**Form of the product**

In Australia the prawn meat (abdominal musculature) is generally the only part of the prawn that is consumed. Other parts of the prawn may be consumed but this is not common. The head (cephalothorax), legs (pereiopods), tail fan (telson and uropods), and abdominal shell
will generally be discarded. In the majority of cases these tissues will be cooked before disposal and thus pose little risk, but a significant volume of waste may be discarded raw. The cooking of prawns or the removal of these tissues before importation into Australia would reduce risk.

The cephalothorax represents a particular risk because of its size, approximately 40% of a prawn’s biomass. The cephalothorax of a prawn contains many of the major organs such as the gills, hepatopancreas, anterior midgut, lymphoid organ, heart, and the large cuticularised foregut, and certain pathogens localise or reach their highest titre in these tissues. Notably, in the US shrimp ecological risk assessment (ERG (Eastern Research Group) 1998) prawn heads were identified as “highly likely” to contain viruses. Thus, removal of the cephalothorax would be an appropriate risk-reduction requirement for certain disease agents.

AQIS could require the cooking of prawns or the removal of cephalothorax from prawns before importation into Australia. An appropriate measure could be for the competent authority of the exporting country to certify that prawns had been cooked or had their heads removed prior to export to Australia.

6.1.3 Management of risk after the arrival of product in Australia (post arrival risk management)

This strategy has the objective of reducing the probability of imported product or derived waste entering the aquatic environment and susceptible hosts being exposed to a dose sufficient to cause infection.

When product imported for human consumption is consumed by humans and waste product (cooked or uncooked) is discarded into the domestic sewerage or solid waste disposal systems, there is a negligible probability of disease establishment. If the product or waste is handled in a manner that increases the likelihood of it entering the aquatic environment in untreated form (eg, used as bait or berley) or when untreated waste products bypass the domestic waste disposal or sewerage systems, there may be a high probability of pathogens entering the aquatic environment. If there are significant populations of susceptible hosts in waters contaminated by pathogens, disease could become established.

Measures that may be applied to reduce the risk potentially associated with imported prawns include:

- restricting the type/presentation of product to increase the probability of it being used in a low risk manner;
- restricting the type/presentation of product to reduce the amount of waste generated after arrival in Australia;
- processing the product to reduce the likelihood of it containing infective aquatic pathogens in an infective form;
- restricting the distribution or end-use of imported product.

These measures may be applied singly or in combination (when they would be expected to have a cumulative effect on the reduction of quarantine risk).
Restrictions on product type

The attractiveness of a product for use other than for human consumption may be reduced by controls on the type or presentation of product. Prawns are often cooked whole, but may be deheaded, deshelled and deveined (removal of the enteric tract from abdomen) prior to cooking. It is increasingly the case that consumers purchase product that is ready to cook/eat with minimal or no further preparation required. Such processed, or value-added, products are typically more expensive. Accordingly, such products are much less likely to be used for aquatic animal feed or bait than whole green prawns. For pathogens which are present only in, or are at higher titres in, tissues which are discarded during the extra processing, these value-added products would present a considerably lower quarantine risk because there would be minimal waste potentially containing pathogens.

Certain categories of a product may be more attractive for uses other than for human consumption. Smaller and more variably sized, whole green prawns are most commonly used for fishing bait. These small and variably sized prawns are more likely to have been emergency harvested from aquaculture ponds, and this particular category of whole green prawns represents higher risk. AQIS discussions with bait shop proprietors and recreational fishers in Australia revealed that prawns less than 15 grams were most commonly used as bait.

There may be instances where imported whole or value-added product gets contaminated or spoiled and is no longer fit for human consumption. The possibility of such product being discarded in a ‘higher risk’ manner (eg. used as fish bait) cannot be discounted. However, retailers and consumers would be more likely to dispose of spoiled value-added prawns via the domestic solid waste disposal systems. While some risk is potentially associated with inappropriate disposal of contaminated or spoiled imported prawns, this would not significantly increase the risk associated with such prawns in total; thus the imposition of additional specific measures would not be warranted.

Restrictions on end-use

As discussed in Chapter 1, in November 1996 AQIS introduced interim measures to restrict importation of uncooked prawns not fit for human consumption, with the intention of preventing imported prawns from being used for fishing bait. In Chapter 3 it is noted that imports of prawns did not decrease after the introduction of interim measures suggesting that only a small proportion of imports were used for bait. However, AQIS acknowledges that a minor proportion of uncooked whole prawns imported for human consumption since the introduction of interim measures have been redirected to the bait trade. Significantly, the use of imported whole green prawns as bait in Australia has not been recognised as resulting in the establishment of any exotic disease. Nonetheless, this scenario provides a direct route for disease introduction and has been identified as a significant pathway in Chapter 3, in the US shrimp virus ecological risk assessment (ERG (Eastern Research Group) 1998), and in the Thai submission to the AQIS Prawns and Prawn Product IRA technical issues paper.

For some disease agents, the Australian prawn species known to be susceptible to infection have a limited distribution and restrictions on end-use should be developed with this in mind. Furthermore, the impact of exotic disease introduction in some crustacean populations would be considerably greater than it would be for other populations. For example, the population of *P. monodon* off the northern Queensland coast near Cairns and Innisfail, and the population of *M. japonicus* near Mackay in northern Queensland, are very important to the Australian
prawn aquaculture industry as sources of broodstock. Also noteworthy is the large number of freshwater crayfish species threatened with extinction, many of which have a limited distribution. Accordingly, domestic controls could be imposed on the use and distribution of product as a means of reducing risk. Restrictions on the supply of certain types of imported product to these areas would reduce the likelihood of susceptible and/or highly sensitive populations being exposed to pathogens, if present, in imported product.

To be effective, such measures would be based on internal quarantine of prawn products in relation to specified waterbodies. This would require the introduction of new controls over products that are currently free of movement restrictions. Under the Quarantine Act AQIS can restrict the use and distribution of goods that are subject to quarantine but has limited authority over the movement of goods once they are released from quarantine. Accordingly, AQIS could readily restrict the location of quarantine approved prawn processing premises. The implementation of regional controls on distribution or use may be most appropriately achieved through State or Territory government legislation, however such control of product released from quarantine would be practically difficult as Australian prawns and imported prawns may not be readily distinguishable. To meet Australia’s SPS obligations, regional controls must treat imported product similarly to indigenous products in equivalent circumstances. Any internal controls must have regard to the memorandum of understanding (MOU) between the State/Territory governments and the Commonwealth Government on SPS issues.

**Commercial processing**

For the purposes of this IRA, *commercial processing* is defined as the processing undertaken at a commercial premises that produces product for sale at another premises or location.

The commercial processing of imported prawns in Australia could generate a significant volume of solid or liquid waste at the premises’ point of discharge. For historical reasons, many prawn processing plants are located near or on waterways. Large scale discharge (deliberate or accidental) into the aquatic environment of untreated waste from imported prawns would increase the risk of establishment of pathogens, if present in imported product. Continuous long term release of untreated waste at the premises’ point of discharge could result in infective material building up to a biologically significant level in the aquatic environment. Accordingly, it may be appropriate to introduce controls over the disposal of waste from the commercial processing of imported prawns.

Several of the pathogens considered in the IRA could survive in imported green prawns. Prawn waste is attractive to scavengers, including crustaceans. Commercial and trade premises are generally required to keep putrescible wastes covered and dispose of them quickly via the domestic waste management system, to preserve environmental quality and protect public health. Wastes from prawn processing plants are putrescible and their disposal may be difficult or expensive. As such, commercial operators may be inclined to dispose of large volumes of waste in a manner that increases the probability of the waste entering the aquatic environment.

There is currently no commercial processing of imported prawns in Australia, however this could change in the future. In the case of product intended for further commercial processing, AQIS could order the goods into quarantine at a premises approved under Section 46A, or subject to a compliance agreement under Section 66B, of the Quarantine Act. In considering
whether to approve a plant for the purpose of processing imported prawn products, AQIS would take into account the following factors:

- the location and physical security of the premises;
- the nature of imported product, the intended processing and the volume and type of waste that would be produced;
- the control of scavengers and pests in and around the plant;
- the competency of the management to meet quarantine requirements;
- the availability of systems for maintenance of appropriate records of the processing of imported product and waste disposal;
- the availability of competent personnel to supervise quarantine-approved processes (such personnel would be expected to have a thorough knowledge of quarantine requirements);
- methods for the disposal of waste material, including arrangements for transport, storage, treatment and disposal, and the effectiveness of procedures in preventing the entry of imported product and derived waste into the aquatic environment; and
- the proximity of the plant to economically and environmentally significant populations of crustaceans.

Criteria for approval of premises to process imported prawns

AQIS would address applications for approval of premises on a case-by-case basis. Key considerations in deciding whether to approve an application would be as follows.

AQIS would consider the location of commercial processing plants proposed for approval relative to economically and environmentally significant populations of crustaceans. Prawn aquaculture in Australia is centred along the eastern coast of Queensland and northern New South Wales, and the Northern Territory. Broodstock for prawn aquaculture are sourced off the northern Queensland coast. Many threatened freshwater crayfish species occur in inland Tasmania and Victoria.

In considering methods for the treatment of liquid waste, AQIS would accept discharge into a municipal sewerage system providing that processing and dilution was judged to be sufficient to reduce risk to an acceptable level. AQIS would also accept treatment on site (eg. by heating, disinfection or an equivalent process) that was judged to be sufficient to reduce risk to an acceptable level. AQIS would require that solid waste was covered and access of scavengers prevented until final disposal by an AQIS-approved method, such as deep burial at an approved facility or heating.

AQIS would also require that premises approved for the further processing of imported prawns were located to allow quarantine inspectors and auditors ready access, to facilitate regular announced and unannounced inspection.
6.1.4 Conclusions

There is a variety of measures, which may be used singly or in combination, to manage risks associated with the importation of prawn products. The effectiveness of these measures in addressing the unacceptable risks will need to be assessed on a case-by-case basis for each risk.

6.2 Risk management for specific concerns

The risk assessment in Chapter 5 determined that the unrestricted risk associated with the importation of whole green prawns (because of the risk of establishment of WSSV, YHV, and other emerging pathogens) and prawn feeds would not meet Australia’s appropriate level of protection (ALOP). This section considers the risk management measures that could be applied to reduce those quarantine risks to a level that would meet Australia’s ALOP.

6.2.1 White spot syndrome virus

Risk assessment conclusions

In Chapter 5, it was concluded that for the unrestricted importation of whole green prawns the probability of the establishment of white spot syndrome virus (WSSV) would be very low for the human consumption pathway, low for the bait pathway, and moderate to high for the commercial processing pathway. The consequences of establishment would be moderate.

Thus, for WSSV, the risk associated with the unrestricted importation of whole green prawns does not meet Australia’s ALOP and the implementation of risk management measures is warranted (see Box 5.2).

Key risk factors

1. White spot disease (WSD) is a serious disease. Emergency harvest of severely affected prawn crops is often practised. The frequency of WSD epizootics in affected areas tends to decrease in the period following the first occurrence of the disease in a region.

2. Clinically affected prawns would have a high titre of WSSV in their body tissues.

3. WSSV may be present in apparently normal prawns which would be expected to contain a lower titre of WSSV than clinically diseased prawns. In apparently normal prawns infected with WSSV, most virus would be in the tissues of the cephalothorax. Titres in the muscle (tail) would be expected to be much lower.

4. The use of whole green prawns imported for human consumption as bait is not uncommon. Small, whole green prawns are more likely to be used as bait than large (higher value) prawns and processed prawn products.

5. WSSV could remain viable in prawn tissues in the aquatic environment for several days.

6. WSSV could accumulate to biologically significant numbers in the aquatic environment as a result of large scale use of imported prawns as bait within a circumscribed area or uncontrolled disposal of commercial processing waste from imported prawns.
Risk management measures

The following risk management measures could be used to reduce the risk associated with the establishment of WSSV via the importation of prawn products into Australia.

**Inspection and grading**

- to remove clinically diseased prawns.

**Size of prawns**

- requirement that whole green prawns are greater than a specified weight.

**Processing of prawns for export to Australia**

- cooking under the conditions that apply to commercial processing for human consumption;
- removal of the cephalothorax or further processing for green prawns smaller than a specified weight; and
- requirement that prawns are processed in premises under the control of a competent authority.

**Export certification**

- requirement that consignments exported to Australia are accompanied by official certification confirming the exported prawns meet Australia’s import conditions in full.

**Waste disposal**

- control over the commercial processing of imported prawns in Australia; and
- conditions relating to the form and presentation of imported prawn product to reduce the volume of waste generated in Australia and reduce the likelihood of the product being used for fishing bait.

**Inspection and grading**

Inspection and grading would provide for the detection of most prawns with clinical disease due to WSSV. Prawns with visible lesions are more likely to be discarded or diverted to alternate higher risk uses. This would substantially address risk factor 2. Inspection and grading would also provide for identification of whole green prawns of less than a specified weight. This would assist in addressing risk factor 4.

**Size of prawns**

WSD epizootics may be managed by emergency harvest if the prawns are of commercial size. WSD epizootics are more common in the early stages of the crop cycle (ie. in the first 14 weeks). A normal crop produces prawns of average weight greater than 15-20 grams. Farmed prawns of weight greater than 15 grams are unlikely to have been derived from ponds.
harvested early due to disease. They are also less likely to be used as fishing bait in comparison with small, lower value prawns.

The emergency harvest of prawns to control an outbreak of WSD presents a particular risk factor as a significant proportion of apparently healthy prawns may be expected to have high titres of WSSV in their body tissues. Furthermore, these prawns are more likely to be used for fishing bait due to their typical small size. AQIS could prevent the importation of whole green prawns under a specified weight. This would substantially address risk factors 1 and 4. It would partially address risk factors 3, 5 and 6. However, WSSV could still be present in larger prawns that enter the aquatic environment.

**Processing**

Inspection and grading would not detect covertly infected prawns. WSSV could be present systemically in covertly infected prawns, but highest titres would be present in the cephalothorax as this contains a high proportion of the susceptible tissues. Common commercial processes such as cooking and/or removal of the cephalothorax would substantially reduce the risks associated with risk factor 3.

WSSV is susceptible to heating. Therefore, cooking of prawns of all sizes under commercial conditions would substantially reduce the risks associated with importation of prawns through viral inactivation. Moreover, cooking would significantly decrease their attractiveness for higher risk uses.

Removal of the cephalothorax before importation into Australia would significantly reduce risk as the value-added head-off prawns are less attractive for use as bait, both for reasons of price and utility. Although some WSSV may remain in the tissues of the headed prawns it is unlikely that significant quantities of such product would enter the aquatic environment and lead to the establishment of infection.

Large whole green prawns which have been inspected and graded are less attractive for use as bait. Such prawns that are intended for human consumption would meet Australia’s ALOP and therefore would not require further controls if they were not to be subject to further commercial processing in Australia. The titre of WSSV in small green prawns would be significantly reduced by removal of the cephalothorax. Such value-added products would be unlikely to be used as fishing bait. These measures, commercial cooking or removal of the cephalothorax of small prawns, would be an alternative method to substantially address risk factor 4.

**Export certification**

To support the provision of certification, AQIS could also require that the prawns were processed in a premise approved by and under the control of a competent authority. An appropriate measure would be for the competent authority to certify that prawns exported to Australia were inspected, graded and processed in accordance with Australia’s conditions.

**Waste disposal**

The commercial processing of imported prawns in Australia could generate a significant volume of solid or liquid waste at the premises’ point of discharge. Continuous long-term release of untreated waste could result in the build-up of WSSV to a biologically significant level in the aquatic environment. As discussed in Section 6.1.3, AQIS could implement
controls over commercial plants processing imported prawns with regard to location, waste disposal and related matters that would partially address risk factors 5 and 6.

Highly processed prawn products for human consumption, such as prawn cutlets, peeled prawn meat, breaded prawns, are unlikely to present a significant quarantine risk as they are unlikely to be used for fishing baits or to contain significant residual titres of WSSV. Such product does not required specific quarantine risk management.

**Conclusions**

To mitigate the risks associated with the importation of whole green prawns in relation to the establishment in Australia of WSSV, it is proposed that the importation of prawns be subject to the conditions shown in Box 6.1. Specific quarantine risk management measures are not applicable to cooked prawns or highly processed green prawns.

For WSSV, the implementation of these measures singly would reduce risk but not to the extent required to meet Australia’s ALOP. Implementation of all the measures listed in Box 6.1 would meet Australia’s ALOP; importation of prawns should therefore be permitted subject to these conditions.

Exporting countries seeking to modify any of these requirements should provide a submission for consideration by AQIS. Proposals for the use of alternative risk reduction measures should include supporting scientific data that clearly explain how the alternative measures would reduce risk to meet Australia’s ALOP. AQIS will consider such applications on a case-by-case basis.

<table>
<thead>
<tr>
<th>Box 6.1 Risk management measures for white spot syndrome virus</th>
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<tr>
<td><strong>PRE-EXPORT REQUIREMENTS</strong></td>
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<tr>
<td>For uncooked prawns</td>
</tr>
<tr>
<td>• The prawns must be processed in a premises approved by and under the control of a competent authority.</td>
</tr>
<tr>
<td>• Consignments exported to Australia must be accompanied by official certification confirming that the exported prawns meet Australia’s import conditions in full.</td>
</tr>
<tr>
<td>• Prawns must be inspected and graded under the supervision of a competent authority.</td>
</tr>
<tr>
<td>• The product for export must be free from visible lesions associated with infectious disease and fit for human consumption.</td>
</tr>
<tr>
<td>• Prawns of less than a specified weight must be processed to at least remove the cephalothorax.</td>
</tr>
<tr>
<td><strong>POST-IMPORT MEASURES</strong></td>
</tr>
<tr>
<td>• If imported prawns are to be subjected to commercial processing in Australia, processing must take place in a premises approved by AQIS and under conditions specified by AQIS.</td>
</tr>
</tbody>
</table>
6.2.2 Yellowhead virus

Risk assessment conclusions

In Chapter 5, it was concluded that for the unrestricted importation of whole green prawns the probability of the establishment of yellowhead virus (YHV) would be very low for the human consumption pathway\(^{31}\), low for the bait pathway, and moderate to high for the commercial processing pathway. The consequences of establishment would be moderate.

Thus, for YHV, the risk associated with the unrestricted importation of whole green prawns does not meet Australia’s ALOP and the implementation of risk management measures is warranted (see Box 5.3).

Key risk factors

1. Yellowhead disease (YHD) is a serious disease. YHD epizootics most commonly occur in prawns of 5-15 grams and often results in emergency harvest of severely affected prawn crops. The frequency of YHD epizootics in affected areas tends to decrease in the period following the first occurrence of the disease in a region.

2. Clinically affected prawns would have a high titre of YHV in their body tissues.

3. YHV may be present in apparently normal prawns which would be expected to contain a lower titre of YHV than clinically diseased prawns. In apparently normal prawns infected with YHV, most virus would be in the tissues of the cephalothorax. Titres in the muscle (tail) would be expected to be much lower.

4. The use of whole green prawns imported for human consumption as bait is not uncommon. Small, whole green prawns are more likely to be used as bait than large (higher value) prawns and processed prawn products.

5. YHV could remain viable in prawn tissues in the aquatic environment for several days.

6. YHV could accumulate to biologically significant numbers in the aquatic environment as a result of large scale use of imported prawns as bait within a circumscribed area or uncontrolled disposal of commercial processing waste from imported prawns.

Risk management measures

The following risk management measures could be used to reduce the risk associated with the establishment of YHV via importation of prawn products into Australia.

Inspection and grading

- to remove clinically diseased prawns.

Size of prawns

- requirement that whole green prawns are greater than a specified weight.
Processing

- cooking under the conditions that apply to commercial processing for human consumption;
- removal of the cephalothorax or further processing for green prawns smaller than a specified weight; and
- requirement that prawns are processed in premises under the control of a competent authority.

Export certification

- requirement that consignments exported to Australia are accompanied by official certification confirming the exported prawns meet Australia’s import conditions in full.

Waste disposal

- control over the commercial processing of imported prawns in Australia; and
- conditions relating to the form and presentation of imported prawn product to reduce the volume of waste generated in Australia and reduce the likelihood of the product being used for fishing bait.

Inspection and grading

Inspection and grading would provide for detection of most prawns with clinical disease due to YHV. Prawns with visible lesions are more likely to be discarded or diverted to alternate higher risk uses. This would substantially address risk factor 2. Inspection and grading would also provide for identification of whole green prawns of less than a specified weight. This would assist in addressing risk factor 4.

Size of prawns

YHD epizootics may be managed by emergency harvest if the prawns are of commercial size. YHD epizootics are more common in the early stages of the crop cycle (ie. when prawns are 5-15 grams). A normal crop produces prawns of average weight greater than 15-20 grams. Farmed prawns of weight greater than 15 grams are unlikely to have been derived from ponds harvested early due to disease. They are also less likely to be used as fishing bait in comparison with small, lower value prawns.

The emergency harvest of prawns to control an outbreak of YHD presents a particular risk factor as a significant proportion of apparently healthy prawns may be expected to have high titres of YHV in their body tissues. Furthermore, these prawns are more likely to be used for fishing bait due to their typical small size. AQIS could prevent the importation of whole green prawns under a specified weight. This would substantially address risk factors 1 and 4. It would partially address risk factors 3, 5 and 6. However, YHV could be present in larger prawns that enter the aquatic environment.
Processing

Inspection and grading would not detect covertly infected prawns. YHV could be present systemically in covertly infected prawns, but highest titres would be present in the cephalothorax as this contains a high proportion of the susceptible tissues. Common commercial processes such as cooking and/or removal of the cephalothorax would substantially reduce the risks associated with risk factor 3.

YHV is susceptible to heating. Therefore, cooking of prawns of all sizes under commercial conditions would substantially reduce the risks associated with importation of prawns through viral inactivation. Moreover, cooking would significantly decrease their attractiveness for higher risk uses.

Removal of the cephalothorax before importation into Australia would significantly reduce risk as the value-added head-off prawns are less attractive for use as bait, both for reasons of price and utility. Although some YHV may remain in the tissues of the headed prawns it is unlikely that significant quantities of such product would enter the aquatic environment and lead to the establishment of infection.

Large whole green prawns which have been inspected and graded are less attractive for use as bait. Such prawns that are intended for human consumption would meet Australia’s ALOP and therefore would not require further controls if they were not to be subject to further commercial processing in Australia. The titre of YHD in small green prawns would be significantly reduced by removal of the cephalothorax. Such value-added products would be unlikely to be used as fishing bait. These measures, commercial cooking or removal of the cephalothorax of small prawns, would be an alternative method to substantially address risk factor 4.

Export certification

To support the provision of certification, AQIS could also require that the prawns were processed in a premise approved by and under the control of a competent authority. An appropriate measure would be for the competent authority to certify that prawns exported to Australia were inspected, graded and processed in accordance with Australia’s conditions.

Waste disposal

The commercial processing of imported prawns in Australia could generate a significant volume of solid or liquid waste at the premises’ point of discharge. Continuous long-term release of untreated waste could result in the build-up of YHV to a biologically significant level in the aquatic environment. As discussed in Section 6.1.3, AQIS could implement controls over commercial plants processing imported prawns with regard to location, waste disposal and related matters that would partially address risk factors 5 and 6.

Highly processed prawn products for human consumption, such as prawn cutlets, peeled prawn meat, breaded prawns, are unlikely to present a significant quarantine risk as they are unlikely to be used for fishing baits or have high residual titres of YHV. Such product should not be subject to specific quarantine risk management.
**Conclusions**

To mitigate the risks associated with the importation of whole green prawns in relation to the establishment in Australia of YHV, it is proposed that the importation of prawns be subject to the conditions shown in Box 6.3. Specific quarantine risk management measures are not applicable to cooked prawns or highly processed green prawns.

For YHV, the implementation of these measures singly would reduce risk but not to the extent required to meet Australia’s ALOP. Implementation of all the measures listed in Box 6.2 would meet Australia’s ALOP; importation of prawns will therefore be permitted subject to these conditions.

Exporting countries seeking to modify any of these requirements should provide a submission for consideration by AQIS. Proposals for the use of alternative risk reduction measures should include supportive scientific data that clearly explain how the alternative measures would reduce risk to meet Australia’s ALOP. AQIS will consider such applications on a case-by-case basis.

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**Box 6.2 Risk management measures for yellow head virus**

**PRE-EXPORT REQUIREMENTS**

For uncooked prawns

- The prawns must be processed in a premises approved by and under the control of a competent authority.
- Consignments exported to Australia must be accompanied by official certification confirming that the exported prawns meet Australia’s import conditions in full.
- Prawns must be inspected and graded under the supervision of a competent authority.
- The product for export must be free from visible lesions associated with infectious disease and fit for human consumption.
- Prawns of less than a specified weight must be processed to at least remove the cephalothorax.

**POST-IMPORT MEASURES**

- If imported prawns are to be subjected to commercial processing in Australia, processing must take place in a premises approved by AQIS and under conditions specified by AQIS.

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**6.2.3 Prawn feed**

As discussed in section 3.3.1, imported prawn feeds comprise approximately 80% of prawn feeds used in Australian prawn aquaculture. These feeds have a direct pathway to prawns stocked at high density. If viable pathogens were present in prawn feeds there could be a high likelihood of introduction and establishment of exotic disease. Thus, specific risk management is warranted.
Risk management measures

The following risk management measures would reduce the risk associated with the establishment of pathogens affecting prawns via importation of prawn feed.

Ingredients

• absence of prawn tissues in prawn feed.

Processing

• heating of all prawn tissues used in prawn feeds to inactivate prawn pathogens.

Export certification

• requirement that consignments exported to Australia are accompanied by official certification confirming the exported prawn feed meets Australia’s import conditions in full.

Ingredients

The use of materials not derived from prawns present a negligibe risk of introducing disease to prawn populations. Notably, there is a trend toward manufacturing prawn feeds without crustacean material. Prawn feed containing prawn tissue (ie. prawn meals) would require further risk management measures to meet Australia’s ALOP.

NOTE: All animal feeds entering Australia are subject to strict quarantine assessment and controls. Ingredients, other than prawn tissues, that are used in manufactured prawn feed may be the subject of other quarantine controls.

Processing

Many prawn feeds, particularly those used for growout, contain prawn meal as a source of protein. This prawn meal may contain exotic pathogens, particularly if derived from prawns harvested as a disease control measure. Common thermal (cooking) processes used to manufacture prawn meal and prawn feeds utilise relatively high temperatures for prolonged periods (see section 3.3.1). As discussed in chapter 5, prawn pathogens are generally thermolabile. Therefore, heating prawn tissues used in prawn feeds would substantially reduce the quarantine risks associated with this product. Specific data on time/temperature effects on survival of many prawn pathogens are not available. Under current quarantine policies, prawn meals and feeds must be heated to 85°C for 15 minutes or 80°C for 20 minutes. This practice has, apparently, been effective in reducing risk. In the absence of scientific evidence that these time/temperature combinations are inadequate, AQIS proposes to maintain these policies.

Failure of the manufacturing process to achieve the required time/temperature, and/or post-processing contamination of cooked prawn feeds with raw material containing pathogens could result in increased quarantine risk. The use of appropriate quality assurance arrangements or a HACCP program should be effective in preventing such adverse events.
Export certification

An appropriate measure would be for the competent authority to provide official certification confirming that:

- the prawn feed does not contain prawn tissue, or prawn tissues have been heated at the specified temperatures; and
- procedures are in place to ensure that the product is manufactured according to AQIS’s requirements and to prevent post-processing contamination with uncooked prawn tissues.

Conclusions

To mitigate the quarantine risks associated with the importation of prawn feed and meal, it is proposed that importation be subject to the conditions summarised in Box 6.3

Exporting countries seeking to modify any of these requirements should provide a submission for consideration by AQIS. Proposals for the use of alternative risk reduction measures should include supportive scientific data that clearly explain how the alternative measures would reduce risk to meet Australia’s ALOP. AQIS will consider such applications on a case-by-case basis.

Box 6.3 Risk management measures for prawn feed

PRE-EXPORT REQUIREMENTS
Official certification must accompany consignments of prawn feeds stating:
- either
  1. the prawn feed does not contain prawn tissues; or
  2. all prawn tissue used in prawn feed has been heated at 85°C for 15 minutes or 80°C for 20 minutes; and
- the prawn feed was processed in premises approved by an AQIS-approved competent authority and subject to a QA or HACCP-based program to ensure the product meets quarantine requirements.
CHAPTER 7: GENERAL CONCLUSIONS

This draft import risk analysis (IRA) report deals with the identification, assessment and management of the quarantine risks associated with the importation from all countries of non-viable prawns and prawn products (prawn products). This chapter summarises the conclusions of the draft report.

The Australian Quarantine and Inspection Service (AQIS) adopts quarantine policies that deliver the highly conservative animal and plant health safeguards required by Australian government policy in the least trade-restrictive way. Wherever appropriate, such measures are based on relevant international standards. In developing quarantine policies, the disease risks associated with importation are analysed using a structured, transparent and science-based process of IRA, described in the AQIS Import Risk Analysis Process Handbook.

An IRA provides the scientific and technical basis for quarantine policies that determine whether an import may be permitted and, if so, the conditions to be applied. Under the Quarantine Act 1908, the Director of Animal and Plant Quarantine may permit the entry of products on an unrestricted basis or subject to compliance with conditions, which are normally specified on an import permit.

In deciding whether to issue an import permit, the Director of Quarantine must consider the quarantine risk, and whether the imposition of conditions would be necessary to limit the quarantine risk to an acceptably low level consistent with Australian Government policy.

This risk analysis will provide the scientific and technical basis for the management of quarantine risk associated with the importation into Australia of prawn products. In keeping with the scope of the Quarantine Act 1908, only factors relevant to the evaluation of quarantine risk (i.e. the risk associated with the entry, establishment and spread of unwanted pests and diseases) are considered in the risk analysis.

Equivalent approaches to managing risk may be accepted, generally or on a case-by-case basis. Exporting countries seeking to use alternative risk reduction measures should provide a submission for consideration by AQIS; such proposals should include supporting scientific data that clearly explain the degree to which alternative measures would reduce risk.

7.1 Continuum of quarantine

In formulating quarantine policy, AQIS applies the principal of “continuum of quarantine” as set out in the Nairn Review of Australian Quarantine (Nairn et al. 1996) and in the Government Response to that review (DPIE (Department of Primary Industries and Energy) 1997). The Government response states:

The Nairn Report identified a need to establish a new quarantine culture in Australia; a culture of shared responsibility. Quarantine is the responsibility of everyone; the Commonwealth, States, industry and the wider community. While the Commonwealth Government clearly has a leadership role, it is impossible for the Commonwealth to do it all alone. For example, people have to be responsible for what they bring back when travelling overseas, and State Governments and industry each have an important role in developing incursion management plans, monitoring and surveying for pests and diseases and responding to outbreaks.
In the context of prawn production, industry organisations and State/Territory Governments associated with prawn aquaculture and fisheries play a key role in biosecurity. It is noteworthy that the Australian Prawn Farmers Association is currently developing an *Environmental Code of Practice for Australian Prawn Farmers*[^32] which emphasises prevention of the spread of disease within farms and regions, and the development of *Prawn Health Management Guidelines*. The prawn aquaculture community must continue to act responsibly in relation to risk factors associated with the introduction and establishment of exotic prawn disease agents (eg. in the selection of feeds for broodstock). The Queensland Department of Primary Industries (QDPI) is in the process of developing a new licensing policy aimed at improving the sustainability of coastal aquaculture. The QDPI proposed to establish a “zone of risk” of 5 kms around an existing aquaculture operation, so that additional licensing requirements would apply to applications for new licenses within the zone. The policy is to ensure the management of disease and environmental risks in association with the expansion of the industry. As discussed in Section 3.4.1, contingency planning for disease emergencies in Australia is included in the Aquavetplan being developed by Agriculture Fisheries and Forestry Australia (AFFA), in consultation with aquatic industries and State/Territory Government agencies.

### 7.2 Uncertainty in the risk analysis

The study of disease conditions in prawns is a relatively recent endeavour. In the last two decades, prawn aquaculture has expanded to meet global demand for prawn products. Research on the diseases of prawns has struggled to keep pace with this rapid expansion. Consequently there is a paucity of data on most prawn disease agents, including those that have been associated with major production losses. For example, the emergence of the white spot disease panzootic in Asia followed closely on from the yellowhead disease panzootic (Flegel 1997), so that research efforts focused on the newer emerging disease (WSD) and little basic data on the epizootiology of YHD have been reported. Moreover, for many of the disease agents considered in the IRA, and particularly those which affect species in the Americas, there are few experimental or anecdotal data on the susceptibility of Australian prawns/crustaceans to infection.

AQIS has taken a conservative approach to this analysis in light of significant data gaps. In cases where no or only one species present in Australia is known to be susceptible to infection by a disease agent, a scenario has been considered in the exposure assessment which assumes that several species in Australia will be susceptible to infection. In the consequence assessment, it is assumed that the impact of such disease agents in Australia would be similar to that in other countries. AQIS has also considered evidence that the susceptibility to disease of prawn species present in Australia is less than that of known or usual hosts for the pathogen. This is particularly relevant to the risk assessments for Taura syndrome virus and infectious hypodermal and hematopoietic necrosis virus. In any case, the risk management measures proposed for white spot syndrome virus and yellowhead virus would effectively manage risks associated with these pathogens in the unlikely event that species in Australia prove susceptible.

Draft

7.3 Outcome of the risk analysis

Australia is free of many important diseases of prawns which have retarded the development of prawn aquaculture in major prawn-producing countries. The IRA identifies the most significant pathways for the entry and establishment of disease. Those of particular importance include the use of imported raw prawn products as fishing bait or berley, the unregulated discharge of wastes from commercial prawn processing plants and the use of feeds containing prawn product by prawn aquaculturists. The IRA analyses the consequences of the establishment of disease and concludes that adverse effects would predominantly be felt in the aquaculture sector, similar to the situation reported overseas.

The draft report concludes that importation of prawn products for human consumption should continue to be permitted, subject to the adoption of risk management measures to reduce the probability of entry and establishment of specified diseases to an acceptably low level. The risk analysis concludes that the following disease agents should be the subject of specific risk management to achieve Australia’s appropriate level of protection (ALOP):

- white spot syndrome virus (WSSV) and
- yellowhead virus (YHV).

In addition, risk management should be adopted in relation to prawn feeds which present a higher risk due to the direct pathway, and risks associated with the emergence of previously unrecognised pathogens.

7.4 Measures affecting the importation of non-viable prawns and prawn products

As warranted by the analysis in Chapters 5 and 6, non-viable prawns may be imported subject to the following risk management measures:

- The prawns are cooked;

or

- The prawns are processed in a premises approved by and under the control of a competent authority;

- Consignments exported to Australia are accompanied by official certification confirming that the exported prawns meet Australia’s import conditions in full;

- Prawns are inspected and graded under the supervision of a competent authority;

- The product for export is free from visible lesions associated with infectious disease and fit for human consumption; and

- Prawns of less than a certain size are processed at least to remove the cephalothorax.

Commercial processing of imported green prawns in Australia must be conducted at a premises approved by AQIS.

In Chapter 6, AQIS concluded that for the unrestricted importation of whole green prawns, the emergence of new pathogens was a significant risk factor. The adoption of risk
management measures for WSSV and YHV would be expected to reduce risks associated with emerging pathogens to a significant extent.

As warranted by the analysis in Chapters 5 and 6, prawn feed may be imported subject to the following risk management measures:

- Consignments of prawn feeds are accompanied by official certification confirming that:

  3. the prawn feed does not contain prawn tissues; or

  4. all prawn tissue in prawn feed has been heated at 85°C for 15 minutes or 80°C for 20 minutes; and

- Prawn feed must be processed in a premises that uses a program (eg. Quality Assurance) approved and audited to the satisfaction of the certifying agency that ensures the product is manufactured to specification

7.5 Next steps in IRA process

In accordance with *The AQIS Import Risk Analysis Process Handbook*, a period of 60 days is provided for public comment on this draft IRA. At close of this period, AQIS will review comments and the risk management recommendations will be finalised. The recommendations will be submitted to the Director of Quarantine (Secretary of AFFA) for a final decision. Then AQIS will publish the final report of the IRA and proposed import conditions (if applicable). Stakeholders will be advised of the Director of Quarantine’s decision and will have the opportunity to appeal against the process used in the risk analysis.
APPENDIX 1: STAKEHOLDERS SUBMISSIONS

As part of the risk analysis process on the importation of prawn products, a technical issues paper and several consultancy reports were circulated. Several submissions, which are listed below, were received. These submissions are available on the public file in Canberra (contact officer: Warren Vant 02 6272 4436).

List of scientific submissions received by AQIS:

<table>
<thead>
<tr>
<th>Comments on Technical Issues Paper by:</th>
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<tbody>
<tr>
<td>Department of Foreign Affairs and Trade</td>
<td>18/11/98</td>
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<td>Primary Industries and Resources SA</td>
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<td>New Caledonia Government</td>
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<td>Australian Veterinary Association</td>
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<td>CSIRO Australian Animal Health Laboratory</td>
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<td>Australian Seafood Importers Association</td>
<td>26/2/99</td>
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<tr>
<td>Thailand Government</td>
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</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
</tr>
<tr>
<td>Primo Aquaculture Pty Ltd: comments on prawn feed consultancy</td>
<td>24/4/00</td>
</tr>
</tbody>
</table>

The key issues in these submissions have been identified and considered. A summary of the considerations is presented together with any action that was taken.

**Issue**

The relationship between overseas and Australian strains of viruses has not been fully analysed. Specific examples cited were: yellowhead virus (YHV) and the Australian yellowhead-like viruses gill associated virus (GAV) and lymphoid organ virus (LOV); infectious hypodermal and hematopoietic necrosis virus (IHHNV) and IHHNV-like virus in Australia; and strains of Penaeus monodon-type baculovirus (MBV).

**Comment**

Strain-related pathogenic variation is accepted for many terrestrial animal pathogens. There is limited information on the comparative analysis of prawn pathogens isolated from different geographic locations. Pathogen characteristics such as morphology (eg. virion size and shape), pathology (eg. morbidity/mortality rate, cytopathology and/or histopathology) and/or differential diagnosis with genetic or immunologic assays (eg. ISH, PCR) can provide a preliminary basis for comparing these pathogens. In cases where the information is sufficient to consider such pathogens as geographically distinct, the risk analysis takes into account the severity of disease reported overseas in assessing the importance of that pathogen. Wherever possible, comparative assessments are based on like conditions, ie. controlled laboratory transmission trials utilising standard procedures. Where there is very little data available, eg. only histopathology as in the example of baculovirus midgut gland necrosis-like virus in Australia, AQIS uses a conservative approach to assessing the risk consistent with Australia’s ALOP.
In the revised hazard identification chapter, MBV has been removed from the list of viruses to be considered in the IRA. A review of the information available on the Australian and overseas strains of this virus does not indicate that overseas strains of the virus are significantly different to those found in Australia. Movement controls for MBV in Australia relate only to live prawns and not to prawn products.

The information available on YHV and GAV/LOV indicates that their genetic sequences differ by 15-20% at the nucleotide level and diagnostic probes are able to differentiate them, suggesting that YHV and GAV/LOV are distinct strains (Cowley et al. 1999; Cowley pers. comm.).

The IHHN-like Cowdry type A inclusions in tissue sections of Australian prawns failed to hybridise with a commercial ISH gene probe for IHHNV, suggesting a 10% genomic difference (Owens 1997).

**Conclusion**

The information available about strains of disease agents is assessed on a case-by-case basis consistent with Australia’s conservative approach to risk management. The viral agents raised in the submissions were re-considered and it was determined that:

- there is no evidence that foreign MBV strains are significantly different to Australian strains, and
- genetic studies provided evidence that YHV and IHHNV should be considered as exotic to Australia.

The draft IRA reflect these conclusions.

**Issue**

Environmental factors may explain the differences in virulence between Australian and overseas viruses.

**Comment**

Factors other than a pathogen’s virulence may influence disease expression (including the severity of disease) in a prawn species, particularly those held in aquaculture. Important factors include the genetic susceptibility of the host stock and the culture conditions under which the animals are held. A common theme in papers discussing disease outbreaks in prawn aquaculture is the role of environmental factors in the severity of outbreaks. In the draft IRA, the virulence of a pathogen is determined on the basis of field and laboratory observations. AQIS acknowledges that factors such as pollution, reduction of mangrove, and high density of semi-intensive and intensive farms have exacerbated outbreaks of disease in farmed prawns overseas. AQIS has considered this issue in Section 3.4.1 and in Chapter 5.

**Conclusion**

As with the previous issue the available information is assessed on a case-by-case basis consistent with Australia’s conservative approach to risk management and where appropriate has been addressed in the draft IRA.
Draft

**Issue**

The taxonomy of disease agents should be considered at the same level (e.g. fungi were considered at the genus level, whereas viral strains were considered).

**Comment**

Although some fungi are considered to be significant pathogens in prawns, the occurrence of fungal infections in aquaculture is due to poor husbandry practices. The OIE list of crustacean diseases does not include any of the fungal disease described in prawns. The hazard identification process did not identify any exotic fungi responsible for significant disease problems that would justify further consideration in the IRA process.

The disease syndromes associated with fungi which are listed in the technical issues paper can be caused by several fungal species. For example, most cases of larval mycosis are caused by *Lagenidium* spp. (commonly *L. callinectes*) and *Siropodium* spp. Other fungi such as *Leptolegnia* may also occasionally cause the disease (Lightner 1996b). Fungal mycosis occurs ubiquitously wherever penaeid prawns are farmed.

**Conclusion**

All available information on fungi associated with prawn diseases is used when applying the hazard identification criteria in the IRA.

**Issue**

That the consultancy “Report on Description and Processing of Ingredients Used in the Manufacture of Prawn Feeds” did not reflect the current situation and contained inaccuracies.

**Comments**

To supplement the consultancy report, Dr Brett Edgerton and Dr Leigh Owens visited a Charoen Pokphand prawn feed mill in Thailand (the largest prawn feed miller in that country) to obtain additional information on the operation of prawn feed mills (Edgerton and Owens 2000). The information in Sections 3.3.1, 5.2.16 and 6.4 of the draft IRA report is therefore a synthesis of all available information, ie. the consultancy report, the submission, the case study by Drs Edgerton and Owens and additional literature sources.

**Conclusion**

All available data including the submission were considered and reflected in the draft IRA.
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABARE</td>
<td>Australian Bureau of Agricultural and Resource Economics</td>
</tr>
<tr>
<td>ADVS</td>
<td>Aquaculture Development and Veterinary Services</td>
</tr>
<tr>
<td>AFFA</td>
<td>Agriculture, Fisheries and Forestry-Australia</td>
</tr>
<tr>
<td>ALOP</td>
<td>appropriate level of protection</td>
</tr>
<tr>
<td>AQIS</td>
<td>Australian Quarantine and Inspection Service</td>
</tr>
<tr>
<td>AQUAPLAN</td>
<td>Aquatic Animal Health Plan</td>
</tr>
<tr>
<td>BMNV</td>
<td>baculoviral midgut gland necrosis virus</td>
</tr>
<tr>
<td>BP</td>
<td>Baculovirus penaei</td>
</tr>
<tr>
<td>BRS</td>
<td>Bureau of Resource Sciences</td>
</tr>
<tr>
<td>CSIRO</td>
<td>Commonwealth Scientific and Industrial Research organisation</td>
</tr>
<tr>
<td>CVO</td>
<td>Chief Veterinary Officer</td>
</tr>
<tr>
<td>DIG</td>
<td>digoxigenin</td>
</tr>
<tr>
<td>DNA</td>
<td>deoxyribonucleic acid</td>
</tr>
<tr>
<td>DPIE</td>
<td>Department of Primary Industries and Energy</td>
</tr>
<tr>
<td>EA</td>
<td>Environment Australia</td>
</tr>
<tr>
<td>FRDC</td>
<td>Fisheries Research and Development Corporation</td>
</tr>
<tr>
<td>H&amp;E</td>
<td>hematoxylin and eosin staining</td>
</tr>
<tr>
<td>HACCP</td>
<td>hazard analysis: critical control points</td>
</tr>
<tr>
<td>IB</td>
<td>inclusion body; area with altered cytochemical staining properties in the nucleus and/or cytoplasm of an infected cell</td>
</tr>
<tr>
<td>IHHNV</td>
<td>infectious hypodermal and hematopoietic necrosis virus</td>
</tr>
<tr>
<td>IPNV</td>
<td>infectious pancreatic necrosis virus</td>
</tr>
<tr>
<td>ISH</td>
<td>in situ hybridisation</td>
</tr>
<tr>
<td>IRA</td>
<td>import risk analysis</td>
</tr>
<tr>
<td>NTF</td>
<td>National Task Force on Importation of Fish and Fish Products</td>
</tr>
<tr>
<td>OB</td>
<td>occlusion body; a structure found in baculovirus-infected cells where virions are encased in a proteinaceous matter, composed predominantly of a 29-kd protein termed “polyhedrin”. Occlusion bodies are commonly referred to as polyhedra.</td>
</tr>
<tr>
<td>OIE</td>
<td>Office International des Epizooties (World Organisation for Animal Health)</td>
</tr>
<tr>
<td>PCR</td>
<td>polymerase chain reaction</td>
</tr>
<tr>
<td>PL</td>
<td>postlarva</td>
</tr>
<tr>
<td>Quarantine Act</td>
<td>Quarantine Act 1908</td>
</tr>
<tr>
<td>RAP</td>
<td>risk analysis panel</td>
</tr>
<tr>
<td>RLO</td>
<td>rickettsia-like organism</td>
</tr>
<tr>
<td>SPS Agreement</td>
<td>WTO Agreement on the Application of Sanitary and Phytosanitary Measures</td>
</tr>
<tr>
<td>TEM</td>
<td>transmission electron microscopy</td>
</tr>
<tr>
<td>TSV</td>
<td>Taura syndrome virus</td>
</tr>
<tr>
<td>WSSV</td>
<td>white spot syndrome virus</td>
</tr>
<tr>
<td>WTO</td>
<td>World Trade Organization</td>
</tr>
<tr>
<td>YHV</td>
<td>yellowhead virus</td>
</tr>
</tbody>
</table>
## Glossary of Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult prawn</td>
<td>Sexually mature prawn.</td>
</tr>
<tr>
<td>Aetiology</td>
<td>The cause of a disease or the study of such causes.</td>
</tr>
<tr>
<td>Appropriate level of protection (ALOP)</td>
<td>Annex A of the SPS Agreement states that the appropriate level of protection is the level of protection deemed appropriate by the Member establishing a sanitary or phytosanitary measure to protect human, animal or plant life or health within its territory. Note: many members refer to this concept as the ‘acceptable level of risk’.</td>
</tr>
<tr>
<td>Aquaculture</td>
<td>The growing of aquatic animals and plants in water.</td>
</tr>
<tr>
<td>Aquatic Code</td>
<td>The OIE International Aquatic Animal Health Code, 1997</td>
</tr>
<tr>
<td>Arthropod</td>
<td>Phylum of animals with jointed legs and a thickened exoskeleton (shell).</td>
</tr>
<tr>
<td>Biodiversity</td>
<td>A measure of the variety of the Earth’s animal, plant and microbial species; of genetic differences within species and of the ecosystems that support those species.</td>
</tr>
<tr>
<td>Biofilm</td>
<td>Thin film of bacteria that forms on a surface and is difficult to remove.</td>
</tr>
<tr>
<td>Carrier animal</td>
<td>An apparently healthy animal that is infected with a pathogenic agent and capable of transmitting the specific disease to another individual.</td>
</tr>
<tr>
<td>Cephalothorax</td>
<td>Body region formed by fusion of head and thorax in crustaceans. Colloquially referred to as ‘head’.</td>
</tr>
<tr>
<td>Clinical disease</td>
<td>Presence of infection with observable clinical signs in the affected host.</td>
</tr>
<tr>
<td>Clinical signs</td>
<td>Any evidence of disease observed by a clinician.</td>
</tr>
<tr>
<td>Commensal</td>
<td>A partner, usually the one that benefits, in a commensalism.</td>
</tr>
<tr>
<td>Commensalism</td>
<td>The association between two organisms of different species that live together and share nutrient resources, one species benefiting and the other being unharmed by the association.</td>
</tr>
<tr>
<td>Competent authority</td>
<td>The National Veterinary Services or other Authority of a country having the responsibility and competence for aquatic animal health measures within the country and for export certification.</td>
</tr>
<tr>
<td>Consequence assessment</td>
<td>An assessment of the adverse consequences that would result from the establishment of a disease in a previously free country.</td>
</tr>
<tr>
<td>Crustacean</td>
<td>A class of arthropod, mainly aquatic, gill-breathing animals such as crabs, lobsters and shrimps, often have a hard shell.</td>
</tr>
<tr>
<td>Deheading</td>
<td>Removal of the cephalothorax.</td>
</tr>
<tr>
<td>Emerging pathogen</td>
<td>A pathogen causally associated with a newly recognised disease characterised by high morbidity or mortality and usually rapid spread.</td>
</tr>
<tr>
<td>Endemic disease</td>
<td>A disease that is present- usually refers to a defined region or country. In lower order animals, such us crustaceans, the term enzootic is often used.</td>
</tr>
<tr>
<td>Epidemiology</td>
<td>The investigation of disease, other related events, and production in animal populations and the making of inferences from the investigation in an attempt to improve the health and productivity of the populations. In lower order animals, such us crustaceans, the term epizootiology is often used.</td>
</tr>
<tr>
<td>Epizootic</td>
<td>An occurrence of a disease in excess of its anticipated frequency.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Exotic disease</td>
<td>A disease that is not present –usually refers to a defined region or country.</td>
</tr>
<tr>
<td>Export certification</td>
<td>Official certification that accompanies goods in international trade.</td>
</tr>
<tr>
<td>Exposure assessment</td>
<td>An assessment of the probability of susceptible hosts being exposed to pathogens in a dose sufficient to cause infection.</td>
</tr>
<tr>
<td>Grading</td>
<td>A classification of product according to defined criteria.</td>
</tr>
<tr>
<td>Hazard</td>
<td>In the context of this import risk analysis, a hazard is a biological agent that may have an adverse effect.</td>
</tr>
<tr>
<td>Hazard identification</td>
<td>In the context of this import risk analysis, hazard identification is the process of identifying the biological agents which could be carried by the commodity being considered in the risk analysis.</td>
</tr>
<tr>
<td>Health surveillance and monitoring system</td>
<td>Systematic process of investigating the health status of a given population.</td>
</tr>
<tr>
<td>Host</td>
<td>Species that the pathogen of interest can infect..</td>
</tr>
<tr>
<td>Idiopathic diseases</td>
<td>Diseases, the aetiology of which has not been defined.</td>
</tr>
<tr>
<td>Import risk analysis</td>
<td>The process through which quarantine policy is developed or reviewed, incorporating risk assessment, risk management and risk communication.</td>
</tr>
<tr>
<td>Incidence</td>
<td>The number of new cases or outbreaks of a disease that occur in a population at risk in a particular geographical area within a defined period of time.</td>
</tr>
<tr>
<td>Index case</td>
<td>The first case of infection in a population previously free of the disease agent.</td>
</tr>
<tr>
<td>Juvenile prawn</td>
<td>Young prawn which is not sexually mature.</td>
</tr>
<tr>
<td>Metazoan</td>
<td>A phylum of multicellular animals with cells organised into tissues and possessing nervous tissue.</td>
</tr>
<tr>
<td>Morbidity</td>
<td>The amount of disease in a population (commonly defined in terms of incidence or prevalence).</td>
</tr>
<tr>
<td>Mortality</td>
<td>A measure of the number of deaths in a population.</td>
</tr>
<tr>
<td>Mysis</td>
<td>The third in a series of free-swimming larval stages of penaeid prawns.</td>
</tr>
<tr>
<td>Native species</td>
<td>Species that originated in Australia (ie, not introduced).</td>
</tr>
<tr>
<td>Nauplius</td>
<td>The minute, egg-shaped or pear-shaped, earliest larval form, into which many crustaceans, including penaeid prawns, hatch from the egg.</td>
</tr>
<tr>
<td>Non-viable</td>
<td>Dead; incapable of propagation.</td>
</tr>
<tr>
<td>Notifiable diseases (OIE)</td>
<td>The list of transmissible diseases that are considered to be of socio-economic and/or public health importance within countries and that are significant in the international trade of aquatic animals and aquatic animal products. Diseases notifiable to the OIE were previously known as listed diseases.</td>
</tr>
<tr>
<td>Pathogen</td>
<td>An organism that causes disease.</td>
</tr>
<tr>
<td>Pathway</td>
<td>The route by which a disease agent entering Australia may take before it infects a susceptible individual of an animal population in Australia.</td>
</tr>
<tr>
<td>Pereiopod</td>
<td>Thoracic appendage used in locomotion; syn., walking leg.</td>
</tr>
<tr>
<td>Pleopod</td>
<td>Swimming appendage of the abdomen.</td>
</tr>
<tr>
<td>Postlarva</td>
<td>Development stage of prawn marked by initial appearance of adult characters (approximately 20 days after egg hatching).</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Prawn</td>
<td>Marine and freshwater crustaceans within the families Aristeidae, Penaeidae, Solenoceridae, Palaemonidae and Pandalidae.</td>
</tr>
<tr>
<td>Prawn product</td>
<td>Non-viable prawns or parts of prawns.</td>
</tr>
<tr>
<td>Prevalence</td>
<td>The total number of cases or outbreaks of disease that are present in a population at risk, in a particular geographical area, at one specified time.</td>
</tr>
<tr>
<td>Probability</td>
<td>The likelihood of an event occurring.</td>
</tr>
<tr>
<td>Protozoan</td>
<td>A phylum of unicellular heterotrophic, generally non-photosynthetic, eukaryotes, lacking cell walls. Protozoans are often now classified with algae and other simple eukaryotes in a separate kingdom, Protista.</td>
</tr>
<tr>
<td>Protozoea</td>
<td>The second in a series of free-swimming larval stages of a penaeid prawns.</td>
</tr>
<tr>
<td>Quarantine risk</td>
<td>The combination of the likelihood the importation will lead to the introduction, establishment or spread of a disease or a pest in Australia, the likelihood that harm will result (to humans, animals, plants, the environment or economic activities) and the likely extent of any such harm.</td>
</tr>
<tr>
<td>Regionalisation</td>
<td>The recognition of a part of a country or countries having a different pest or disease status, due to epidemiological reasons or because of sanitary controls.</td>
</tr>
<tr>
<td>Release assessment</td>
<td>An assessment of the probability of viable pathogens being present in the commodity at the time of entry into a country.</td>
</tr>
<tr>
<td>Risk assessment</td>
<td>The processes of identifying and estimating the risks associated with the importation of a commodity and evaluating the consequences of taking those risks (OIE International Animal Health Code).</td>
</tr>
<tr>
<td>Risk management</td>
<td>The identification, documentation and implementation of the measures that can be applied to reduce the risks and their consequences (OIE International Animal Health Code).</td>
</tr>
<tr>
<td>Sanitary (quarantine) measure</td>
<td>Measures such as those described in chapters on risk management of these import risk analyses which are used to protect animal life or health from risks arising from pests and diseases.</td>
</tr>
<tr>
<td>Shrimp</td>
<td>See prawn.</td>
</tr>
<tr>
<td>Spawner prawn</td>
<td>Sexually mature prawn.</td>
</tr>
<tr>
<td>SPS Agreement</td>
<td>The WTO Agreement on the application of sanitary and phytosanitary measures.</td>
</tr>
<tr>
<td>Subadult prawn</td>
<td>Prawn beginning to mature sexually.</td>
</tr>
<tr>
<td>Sub-clinical disease</td>
<td>Presence of infection without observable clinical signs in the affected host.</td>
</tr>
<tr>
<td>Telson</td>
<td>The median tail of a crustacean.</td>
</tr>
<tr>
<td>Unrestricted risk estimate</td>
<td>An estimate of the risk associated with the importation of a commodity in the absence of quarantine measures.</td>
</tr>
<tr>
<td>Uropod</td>
<td>Paired lateral appendages of the tail of a crustacean which, together with the median telson, form the 'tail fan'.</td>
</tr>
<tr>
<td>Wild-caught prawns</td>
<td>Prawns that are captured in a natural environment</td>
</tr>
<tr>
<td>Zoning</td>
<td>See regionalisation.</td>
</tr>
</tbody>
</table>
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