Environmental Risk Assessment of Land-Based Abalone Aquaculture in South Australia

FRDC Project No. 2003/223
Innovative solutions for aquaculture planning and management – Project 5, Environmental audit of marine aquaculture developments in South Australia.

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1 Executive Summary

The value of abalone aquaculture production in South Australia has risen from $856,000 in 1998/99 to just under $2 million ($1,901,000) in 2001/02. Currently, there are nine abalone farms in South Australia; six in Louth Bay, two in Smith Bay on Kangaroo Island and one in Streaky Bay. Of the six abalone species known to inhabit South Australian waters, two are farmed commercially; these are the blacklip abalone, *Haliotis rubra* (in small quantities) and the greenlip abalone *H. laevigata*. Many farms are still experimenting with methods and equipment in order to find the conditions to maximise production and minimise costs. With the industry looking for maximum production in the near future, Ecologically Sustainable Development (ESD) is a vital factor for ensuring long-term viability. To further promote, expand, and ensure ESD of the abalone aquaculture industry there is an urgent need to assess the potential risks of associated environmental impacts. This report documents the discussions and comments from a Risk Assessment Workshop conducted in Adelaide on 26th November 2003 and an Industry Workshop held in Port Lincoln on 22nd April 2004 to assess the potential risks associated with the land-based abalone aquaculture industry in South Australia. This report also includes a brief literature review of the ‘priority’ issues that were considered to be of a moderate or higher risk. On the basis of this literature review, the risk rankings of the priority issues were re-evaluated by the authors.

The risk assessment workshop was conducted using the National ESD Reporting Framework for Australian Fisheries, including a supplement designed to customise the framework for aquaculture. Four of the eight generic component trees outlined in the framework were addressed in the workshop: Tree 1, Biological/Environmental effects of the whole industry; Tree 2, Effect of the industry on the catchment/region; Tree 3, Effects of individual facilities, and part of Tree 8, Impacts of the environment on the industry. Each of the trees was modified so that it was specific for the abalone aquaculture industry. Each issue was discussed in terms of current knowledge and management and assigned a ranking in terms of the level of risk associated with it. The risk ranking was determined using the risk analysis tool outlined in the ESD framework, which was based on the Australian Standard for Risk Management (AS/NZS 4360 1999). To assign a level of risk to an issue, two factors must be determined – the potential consequence arising from a particular activity, and the likelihood that this consequence will occur. The combination of the level of consequence and the likelihood of this consequence produces an estimate of the risk. The risk ranking given is intended to reflect what the participants considered to be likely over the next 5 years.

Sixty two of the 78 issues discussed (excluding Tree 8) were given a negligible or low ranking. The remaining 16 issues were given a moderate or moderate to high risk ranking. No issues were rated as an extreme risk. After reviewing the literature, most of the 16 priority issues identified during the workshops were changed to a low ranking, with the exception of a few issues receiving a low to moderate or moderate final ranking.

Currently, there are no research programs underway addressing the potential environmental impacts of abalone aquaculture, although PIRSA Aquaculture are in the process of developing protocols to address issues related to disease. The most important research needs are related to determining the effects of nutrient discharges on the environment, although the results of the 2003 licence-based environmental monitoring programs should be assessed before the exact needs are determined. Other lower priority areas of research include:

- Effects of abalone farms on aggregation of birds.
- Potential for disease transmission from cultured stock to wild stock.
- The effects of settlement ponds on water quality.
- Seasonal variations in quality and quantity of nutrient and solid discharges.

Tighter management and/or reporting protocols may also be useful to reduce or better assess the consequences of several issues:

- Development of best practise construction protocols to minimise terrestrial impacts, including restoration of surrounding areas after construction.
- Protocols to maximise chances of site rehabilitation after production ceases.
- Reporting of chemical use (type, amount, duration of use, discharge rates during use) as part of the environmental monitoring program (EMP) process.

2 Introduction

A small but well established land-based abalone aquaculture industry currently exists in South Australia. As with all aquaculture operations, there is potential for negative environmental impacts from the land-based abalone industry. While it is generally agreed that the environmental impacts of the land-based abalone aquaculture industry are likely to be less than those from some other forms of aquaculture (e.g. sea-cage finfish farming), there is still concern from some members of the public and some government/non-government organisations about possible detrimental impacts to the environment. In addition, the ecologically sustainable development (ESD) of the land-based abalone aquaculture industry is vital for ensuring its long-term viability. In order to address environmental concerns and to continue working towards ESD, there is an urgent need to assess the potential environmental risks associated with land-based abalone aquaculture in South Australia.

The present report provides a summary of the outcomes (and subsequent follow-up work) from an environmental risk assessment workshop that was held during late 2003 to assess and prioritise the environmental issues associated with land-based abalone aquaculture in South Australia. The main aims of this report are to: (1) document outcomes from the workshop (and an associated industry meeting held at a later date), (2) provide a brief literature review of the issues that were considered to represent a moderate or high risk to the environment, and (3) provide modified risk rankings based on the outcomes of the literature review and stakeholder comments. The report is one in a series of 3 risk assessment reports that collectively address objective 2 of FRDC Project No. 2003/223 “Environmental audit of marine aquaculture developments in South Australia”. The “audit” project has four objectives:

1. Review the current environmental status of marine aquaculture in South Australia by assessing the level and adequacy of existing information collection protocols in relation to environmental impacts.
2. Assess and prioritise the actual and potential environmental impacts of marine aquaculture in South Australia using a formal risk assessment framework.
3. Investigate identified high priority environmental impact issues through targeted field based R&D, including the development and evaluation of methodologies and sustainability indicators.
4. Develop aquaculture sector-based optimal environmental monitoring programs, including identifying the parameters to be measured (environmental as well as farm management), the spatial and temporal frequency of monitoring required, and select critical decision points against which ESD performance can be measured.

2.1 Land-based abalone aquaculture

2.1.1 History

Abalone farming was first developed in Japan over 50 years ago in response to a decline in the abundance of wild stocks as a result of over-exploitation (Hone and Fleming 1997). Since that time a number of other countries have developed abalone aquaculture including a variety of Asian and South American countries, the United States of America, South Africa, and Australia. Aquaculture of abalone in South Australia began in the late 1980's near Port Lincoln and has grown significantly since then. In 1998/99 the value of the industry was $856,000, however in 2001/02, its value had grown to just under $2 million ($1,901,000) (Knight *et al.* 2003). All six abalone species known to inhabit South Australian waters are now held in land-based farms. Although the vast majority of the abalone farmed commercially consists of greenlip abalone *(Haliotis laevigata)*, there is some blacklip abalone (*Haliotis rubra*) produced and Roe's abalone (*H. roei*), staircase abalone (*H. scalaris*), whirling abalone (*H. cyclobates*) and brownlip abalone (*H. conicopora*) are all held on various farms (Deveney, pers. com)

2.1.2 Present

There are currently nine land-based abalone farms in South Australia; six in Louth Bay near Port Lincoln, two in Smith Bay on Kangaroo Island and one in Streaky Bay on the West Coast of Eyre Peninsula (Figure 1). While the techniques for growing abalone in South Australia are broadly similar between farms, specific details vary greatly from one farm to the next. Many farms are still experimenting with methods and equipment in order to find conditions that maximise production and minimise costs (PIRSA Aquaculture 2000).

The first step in land-based abalone aquaculture involves the collection of broodstock (sexually mature adult abalone). In South Australia, broodstock are generally collected by professional divers in areas known to produce abalone suitable for spawning. *Haliotis rubra* broodstock are collected in late winter to late spring, while *H. laevigata* are collected in early spring to mid-summer (PIRSA Aquaculture 2000). Once the abalone have been transported to a hatchery, the females and males are identified by gonad colour (females are green whereas males are pale yellow-grey) and separated into different tanks. The abalone broodstock are induced to spawn by warming the water in each tank and treating it with ultraviolet light. Males generally spawn first and will continue to eject sperm for several hours while females spawn in pulses (Hone and Fleming 1997). The eggs are then mixed with the correct quantity of sperm. Once fertilised, the eggs sink to the bottom of the tank and then hatch approximately 18-24 hours later into free-swimming larvae called veligers.

The veligers are moved into settlement tanks at day 6-8 post-fertilisation where they spend approximately 8-12 months. Within the first few days in the settlement tanks they metamorphose into juveniles. The juveniles graze on settlement plates coated with microalgae until they reach a length of 10-15 mm, after which they are transferred to grow-out tanks. In most instances, the abalone are fed manufactured diets twice a week. Most abalone are harvested at the end of their third year when they are approximately 70 mm in length (or 50 g in-shell wet weight). In South

Australia, the grow-out facilities generally consist of shallow tanks housed beneath shade-cloth to stop predation and provide shelter. Seawater is continuously pumped through the tanks from the sea before being discharged back to sea, i.e., they are flow-through systems.

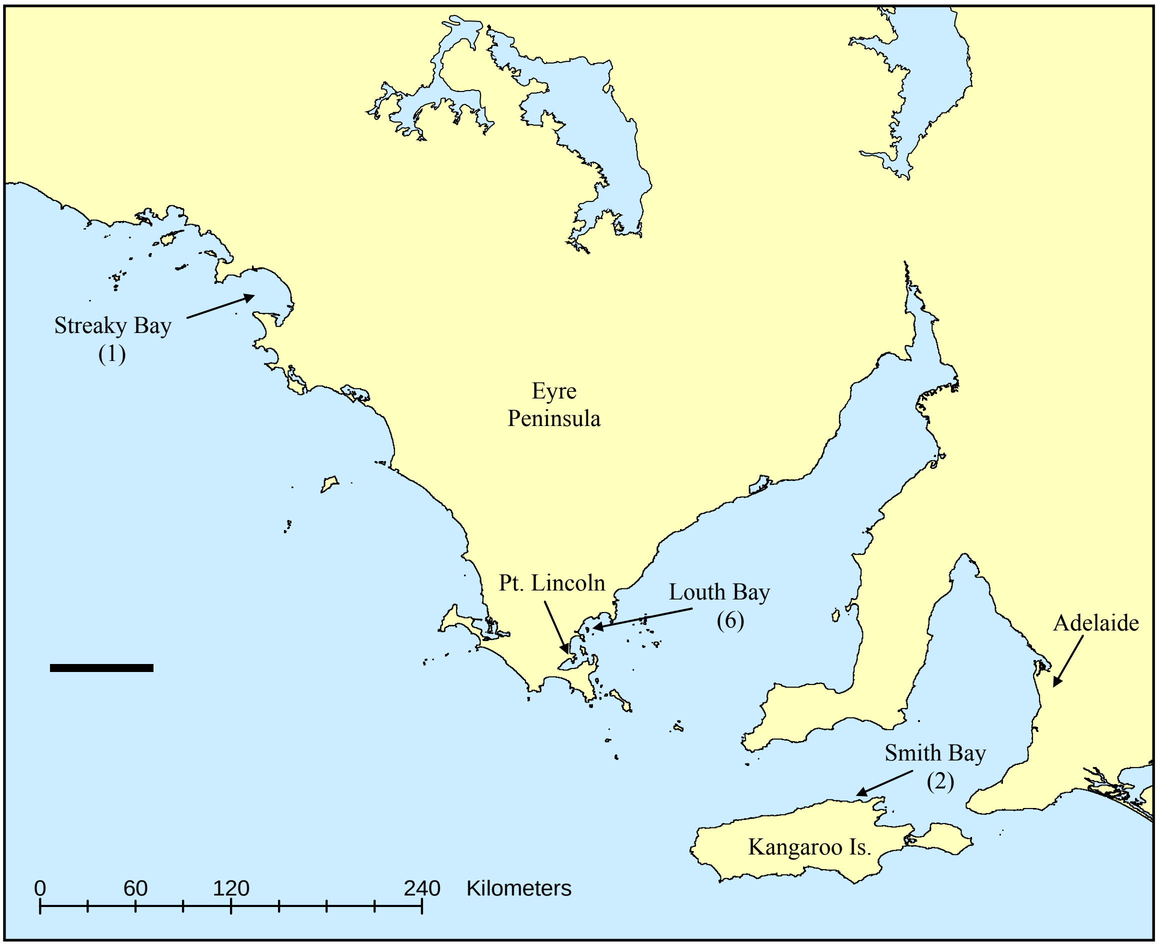

Figure 1. Map of South Australia showing the locations where land-based abalone aquaculture facilities occur. Numbers in brackets indicate the number of abalone facilities in each area in 2004.

3 Methodology

3.1 Risk Assessment Framework

In order to identify and prioritise the potential environmental issues associated with land-based abalone aquaculture in South Australia a formal risk assessment framework was used. The risk assessment was conducted using the National ESD reporting framework for Australian fisheries (Fletcher *et al*. 2002) and the aquaculture supplement (Fletcher *et al*. 2003). The reports of Fletcher *et al*. (2002, 2003) were developed to provide a framework that could be used consistently across all fishery and aquaculture sectors in Australia. The framework is based on the Australian standards for risk management (AS/NZS 4360 1999) which is used to conduct risk assessments for a wide variety of industries. This particular framework focuses on ESD outcomes by developing operational objectives and indicators to monitor and evaluate performance of management (Cheeson *et al*. 2000).

In the development of the framework, all the possible environmental, social and economic issues relating to all forms of aquaculture are identified and then grouped together in the form of eight generic component trees (see Figs. 2-5 and Appendix 2):

1. The environmental effects of the whole industry.
2. Environmental effects of the industry on the catchment/region.
3. Environmental effects of the individual facilities.
4. Impacts on the indigenous community wellbeing.
5. Impacts on community wellbeing.
6. Impacts on the national socio-economic wellbeing.
7. Governance.
8. Impact of the environment on the industry.

Each issue within a tree is assigned a risk ranking using a risk analysis tool outlined in the ESD framework, which is based on the Australian standard for risk management (AS/NZS 4360 1999). To assign a level of risk to an issue, two factors must be determined – the potential consequence arising from a particular activity, and the likelihood that this consequence will occur. The combination of consequence and likelihood produces an estimate of the risk associated with a particular issue. The main aim of the risk assessment is to determine if current management is sufficient, and therefore the current management strategies need to be considered when determining the consequence and likelihood levels. Each issue is assigned a level of consequence (from negligible to catastrophic) and likelihood (from remote to likely). In assigning a likelihood level it is important to remember that an assessment is being made of the likelihood of that consequence occurring and *not* the likelihood of that particular activity occurring. The consequence and likelihood levels are determined using the tables outlined in the framework (Tables 1 and 2). The risk value and ranking for each issue are then determined using a risk matrix (Table 3). Each risk ranking has an associated level of management response and reporting requirements (Table 4).

Table 1. The Consequence Table for use in ecological risk assessments related to aquaculture (from Fletcher et al. 2003). While this is the table used in the workshop, participants were asked to assess the situation over the next 5 years, and thus the wording should have been changed to reflect this time frame.

Level	Descriptor
Negligible (0)	Very insignificant impacts. Unlikely to be even measurable at the scale of the stock/ecosystem/community against natural background variability.
Minor (1)	Possibly detectable but minimal impact on structure/function or dynamics.
Moderate (2)	Maximum appropriate/acceptable level of impact (e.g. full assimilation rate for nutrients).
Severe (3)	This level will result in wider and longer-term impacts now occurring (e.g. increased plankton blooms).
Major (4)	Very serious impacts now occurring with relatively long time frame likely to be needed to restore to an acceptable level.
Catastrophic (5)	Widespread and permanent/irreversible damage or loss will occur – unlikely to ever be fixed (e.g. extinctions).

Table 2. Likelihood Definitions (from Fletcher *et al.* 2002).

Level	Descriptor
Remote (1)	Never heard of, but not impossible
Rare (2)	May occur in exceptional circumstances
Unlikely (3)	Uncommon, but has been known to occur elsewhere
Possible (4)	Some evidence to suggest this is possible here
Occasional (5)	May occur
Likely (6)	It is expected to occur

Table 3. Risk Matrix – numbers in cells indicate risk value, the colours/shades indicate risk rankings (from Fletcher *et al.* 2002). NB the risk level is calculated by multiplying the likelihood value by the consequence value.

		Consequence					
Likelihood		**Negligible**	**Minor**	**Moderate**	**Severe**	**Major**	**Catastrophic**
		0	1	2	3	4	5
Remote	1	0	1	2	3	4	5
Rare	2	0	2	4	6	8	10
Unlikely	3	0	3	6	9	12	15
Possible	4	0	4	8	12	16	20
Occasional	5	0	5	10	15	20	25
Likely	6	0	6	12	18	24	30

Table 4. Suggested risk rankings and outcomes (amended from Fletcher *et al.* 2002).

Risk Rankings	Risk Values	Explanation & Likely Management Response	Likely Reporting Requirements
Negligible	0	Nil	Short justification only
Low	1 – 6	No specific additional management is needed, but low level monitoring of the issue may be required. Any current management should continue, as the risk ranking is based on the current management in place.	Full justification needed
Moderate	7 – 12	Additional information may be needed or the issue may require monitoring. No immediate management is required, but the issue should be the subject of continuous improvement with the aim of achieving a low risk ranking in the future.	Full performance report
High	13 – 18	Possible increases to management activities in addition to those already being applied. Needs to be monitored and any information deficiencies should be addressed.	Full performance report
Extreme	> 19	Increases in management activities in addition to those already being applied are strongly recommended.	Full performance report

3.2 Risk Assessment Workshop

In order to successfully undertake an environmental risk assessment, all of the potential environmental issues need to be identified. Identification of all issues can only be achieved when opinions and thoughts are obtained from a number of stakeholders/stakeholder groups. Workshops have been widely recognised as one of the most efficient ways to gather all of the information required for a formal risk assessment. Consequently, an environmental risk assessment workshop was held at the South Australian Aquatic Sciences Centre on the 26th November 2003 using the National ESD Reporting Framework for Australian Fisheries (Fletcher *et al.* 2002) and the aquaculture supplement (Fletcher *et al.* 2003). A number of people were invited to participate (see Appendix 1), representing industry, government, non-government, and community groups. The workshop was convened by Dr Simon Bryars from SARDI Aquatic Sciences.

Only the four component trees that related to environmental issues (i.e., trees 1-3 and part of tree 8) were addressed in the workshop (Figures 2-5). During the workshop, each of the four generic component trees was modified to produce trees specific to land-based abalone aquaculture. This process involved either deleting or adding issues. Each issue was then discussed in terms of current knowledge and management and assigned a risk ranking based on the potential risk associated with that particular issue. Participants were asked to score the consequence and likelihood on the basis of what they expected over the next five years, not just on the current situation. Discussions leading to these rankings are summarised in Appendix 3.

The focus of the workshop was to evaluate all potential environmental risks of abalone aquaculture rather than just known risks because there is very little documented information available on this aspect for South Australia. At the time of the workshop the main species of abalone being farmed was the greenlip abalone *H. laevigata*, with one farm starting to produce very small quantities of black lip abalone, *H. rubra*, therefore the discussions focused mainly on these two species.

While the National ESD reporting framework for Australian fisheries was used to perform the risk assessment, it is not the aim of the present report to produce an ESD performance report. Rather the workshop was aimed at determining the potential environmental risks associated with land-based abalone aquaculture as a precursor to conducting field assessments of the environmental impacts and developing environmental monitoring programs. Thus, in this report, a brief literature review is given for all issues rated as moderate, high or extreme risk, but without conducting a full performance report. This literature review will help to establish priorities for the next phase of the project, i.e., field investigations. A literature review was not conducted for issues within component tree 8, as those issues do not represent an impact on the environment but more an impact on the industry itself. While these issues are important, they do not fall within the scope of this project.

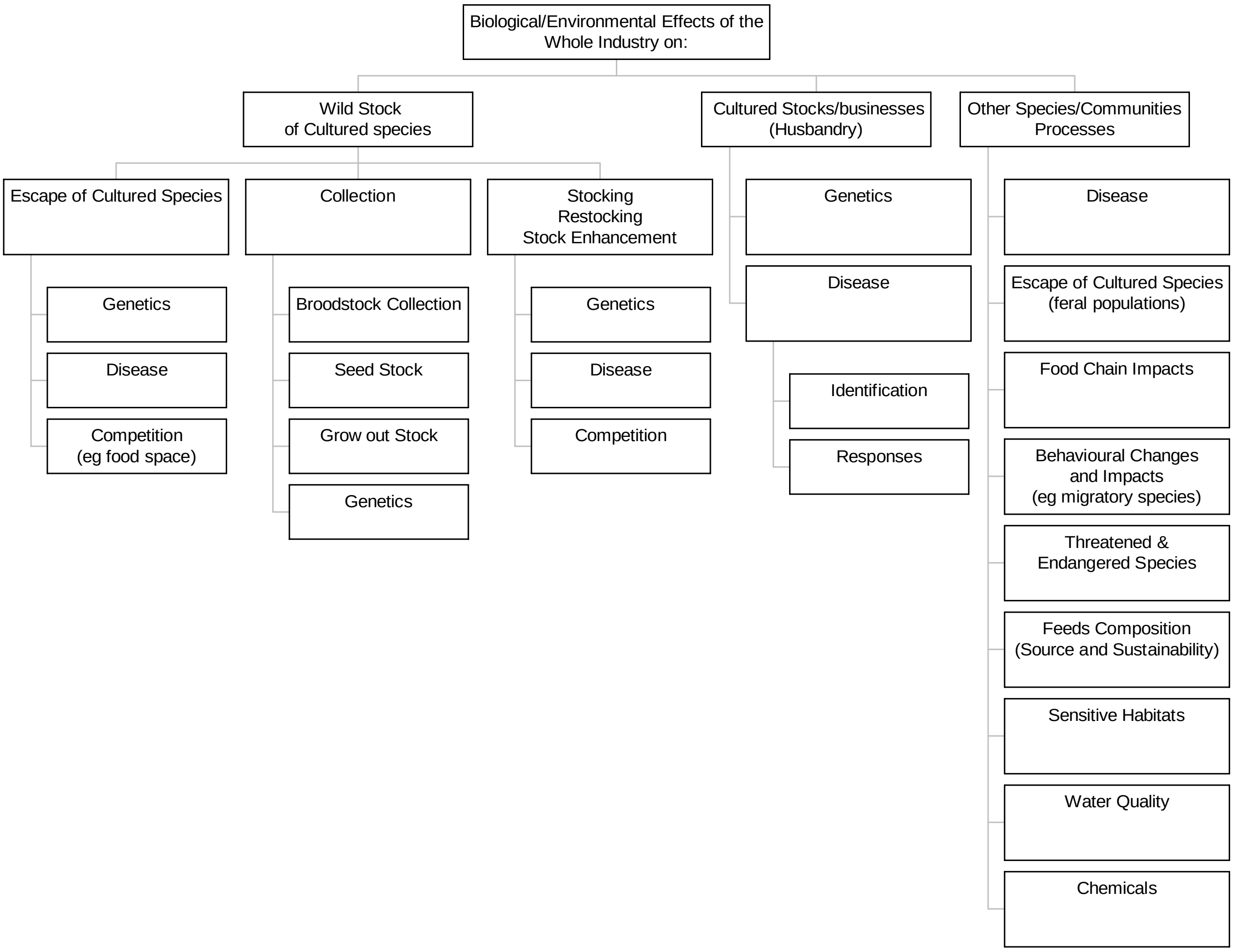

Figure 2. Component tree 1: Biological/Environmental effects of the whole land-based abalone aquaculture industry (modified from Fletcher *et al*. 2003)

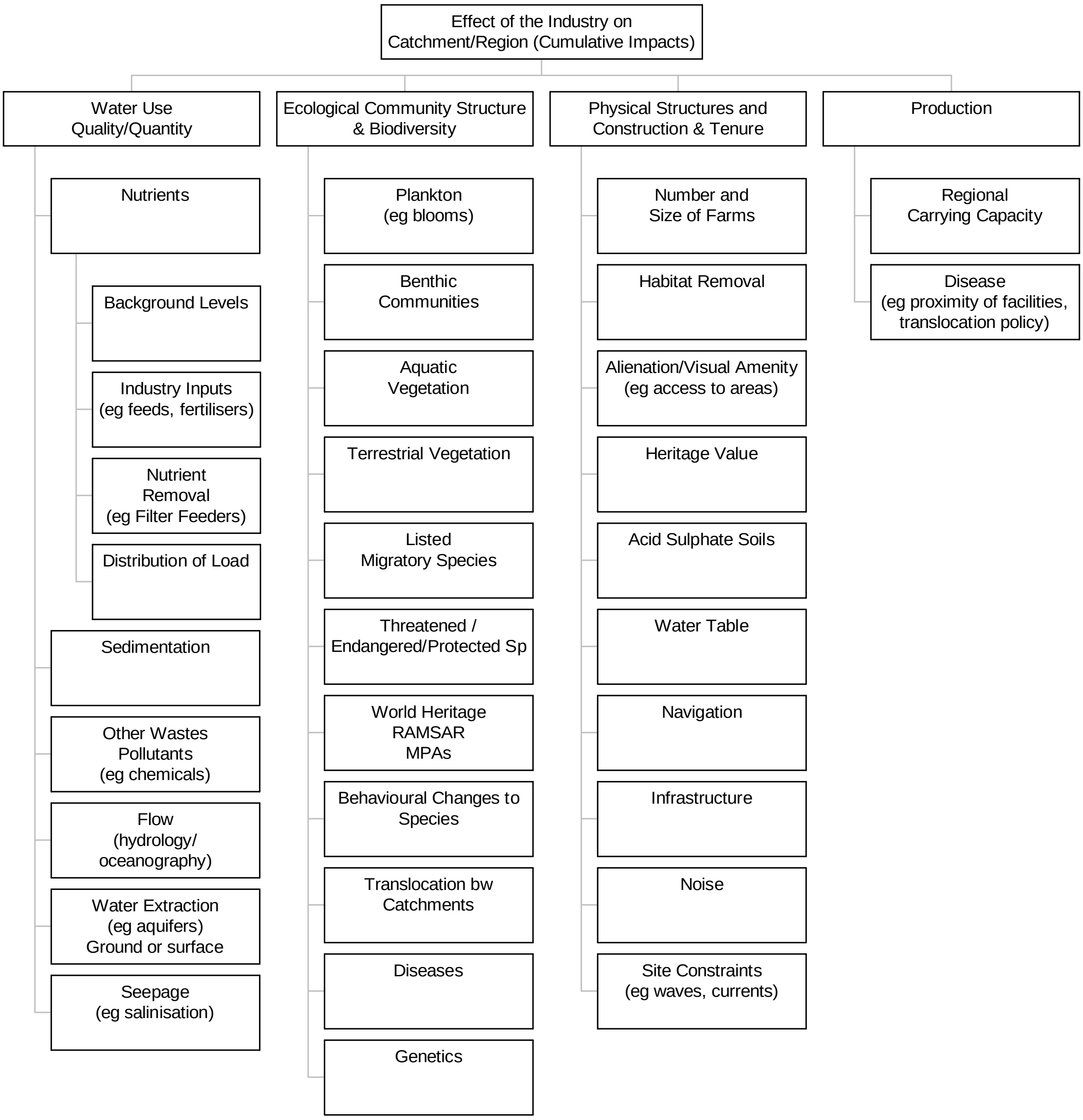

Figure 3. Component tree 2: Impact of land-based abalone aquaculture on the Catchment/Region (modified from Fletcher *et al*. 2003).

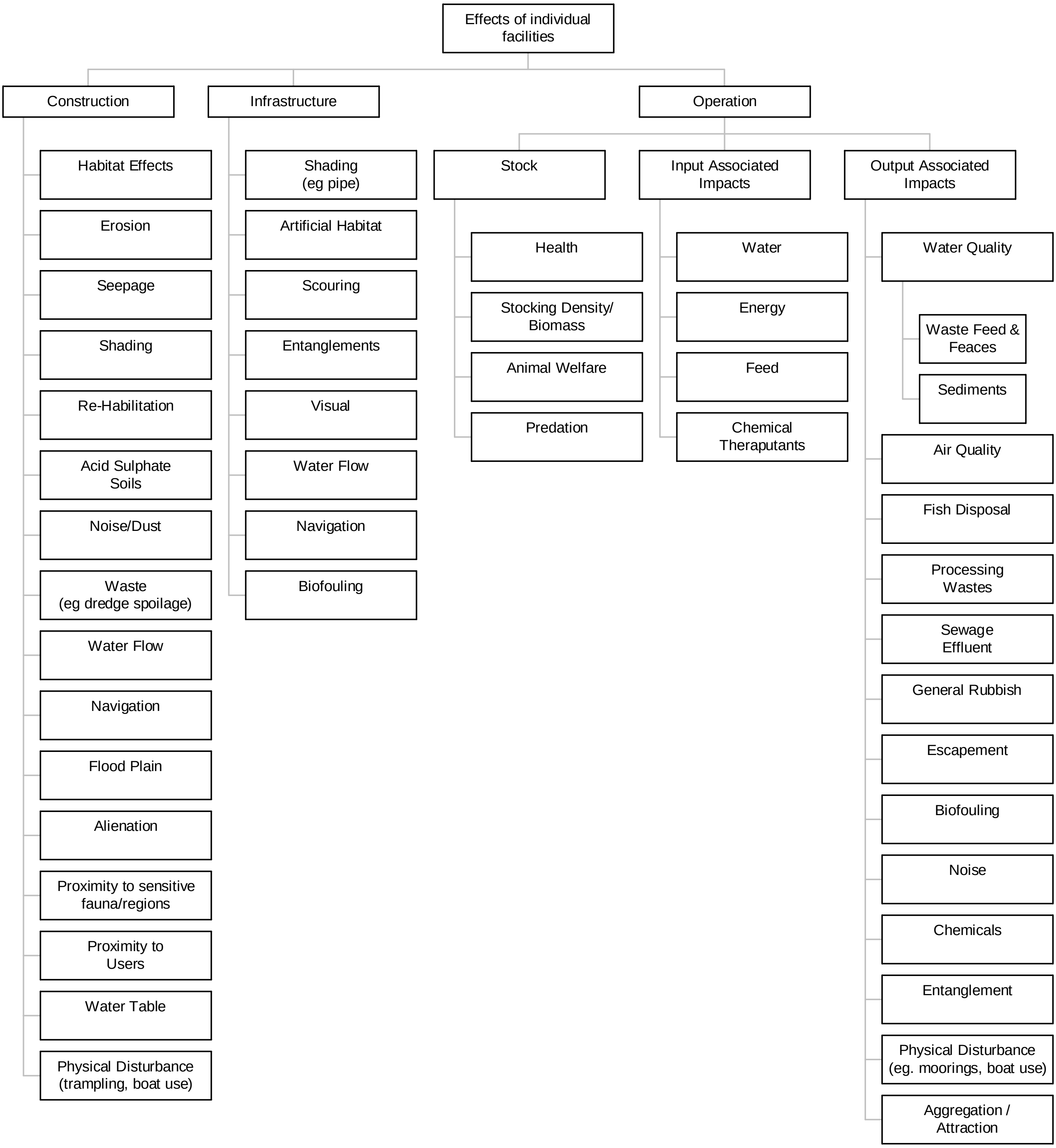

Figure 4. Component tree 3: Impacts of individual land-based abalone aquaculture Facilities on the environment (modified from Fletcher *et al*. 2003).

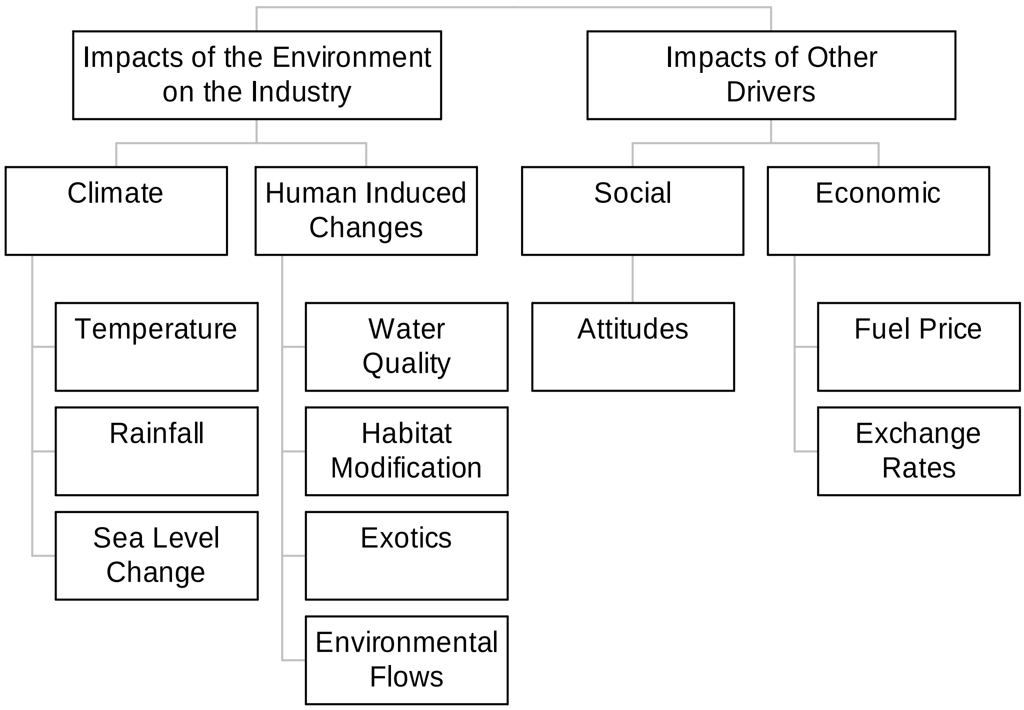

Figure 5. Component tree 8: Impacts of the environment on the land-based abalone aquaculture industry (modified from Fletcher *et al*. 2003).

Following the workshop a number of steps were undertaken to complete the risk assessment and finalise this report:

1. A summary of the minutes and outcomes of the workshop was sent out during early 2004 to attendees (and invitees who were unable to attend) for any further comments (see Appendix 3). These comments are summarised as "Additional comments" in Appendix 3. Additional comments were provided by Michael Tokley from the Abalone Industry Association of South Australia Incorporated (a group that was mistakenly overlooked in workshop invitations), Phil Czerwinski from DAARE, and Carina Cartwright and Marty Deveney from PIRSA Aquaculture.
2. Due to a lack of abalone aquaculture industry attendees at the risk assessment workshop, an additional industry workshop was held at Port Lincoln on the 22^{nd} April 2004 to obtain industry input (see Table 1b) for those issues ranked during the initial workshop as moderate or higher. These comments are summarised in the report as "Comments during industry workshop".
3. A brief literature review was conducted on all issues ranked as moderate or higher. Of particular interest for the review was any information available from South Australia, although for a number of issues, none was found. Where there was little or no information on an issue in South Australia a broader literature search was conducted to find any relevant information either in Australia or worldwide. While the suggested outcomes for the determined risk rankings in Table 4 indicate that a full performance report is required for any issue determined to be of a moderate risk or higher, such a report was beyond the scope of the present report. Furthermore, it is the responsibility of the relevant management authorities to write full performance reports.
4. The risk rankings were re-assessed by the authors based on both the comments made during the two workshops and also the results of the literature review.
5. The present report was sent out to both workshop attendees/invitees and industry meeting attendees for final comment

4 Results

Component trees 1 (whole of industry), 2 (catchment/region) and 3 (individual facilities) were discussed in the most detail during the two workshops. Only three of the 78 issues discussed were given a "moderate to high" ranking (Table 5), while none were given an extreme ranking. This is a positive outcome as a high ranking indicates a need for immediate increased management, and an extreme ranking suggests that careful consideration needs to be given to the continued existence of the industry. A further 13 issues were given a "moderate" ranking, indicating that they may require further management or research. However, management responses to moderate issues are unlikely to be immediate or drastic, and will generally involve continuous improvement over the next 5-10 years to reduce the risk to low.

15 of the 16 'priority' moderate and moderate to high ranked issues identified from Trees 1-3 during the workshops are addressed specifically in this report and fall into 4 broad groups. The first group includes issues related to escape of cultured stock and disease transmission to wild stocks (both of abalone and other species). Despite "the effects of disease transmission" issue receiving a moderate ranking, it is not discussed further as it is a risk of the industry to itself, not to the environment. The second group are issues related to habitat alteration and loss, and are mainly related to construction. Thirdly, there is a group of issues related to water quality. The final group contains a single issue on aggregation and attraction of other species.

Table 5. List of environmental issues from Component Trees 1 (Whole of Industry), 2 (Catchment/Region) and, 3 (Individual facilities) that were given a moderate or moderate to high risk ranking during the workshop. The consequence, likelihood and risk value are given. The justifications for these values for each issue are given in the summary tables for the workshop in the relevant sections of the discussion. *The authors have not allocated a risk for issues that pertain to development in general and not just aquaculture, as to do so would require a broader series of investigations.

Issue	Component tree	Consequence	Likelihood	Risk Ranking	Authors ranking
Effects of **disease** (including parasites) from the **escape of cultured species** on the wild stock of that species	Whole of Industry	3	4	12	Low
Effects of **disease** in the cultured stocks on other species	Whole of Industry	3	3	9	Low
The effects of **translocations, escapements** etc. of stock	Catchment / region	3	3	9	Low
Effects of **disease** transmission (proximity of facilities, translocation policy)	Catchment / region	3	4	12	Low
Effects of land-based abalone aquaculture on **terrestrial vegetation**	Individual facilities	3/4	6	12/18	*
Impact of construction of land-based abalone aquaculture on **erosion**	Individual facilities	2/3	4	8/12	Moderate
Rehabilitation of site	Individual facilities	3	4/5	12/15	*
Impact of construction **noise** and **dust**	Individual facilities	2	4	8	*
Impact of wastes **produced during construction**	Individual facilities	2	4	8	*
Behavioural changes and other impacts on **migratory species** (e.g. birds) due to land-based abalone aquaculture	Individual facilities	2	4	8	Low
The impact of land-based abalone aquaculture on **sensitive habitat**	Individual facilities	2	3/4	6/8	Moderate
The effect of **water quality (nutrients)** on the marine environment	Individual facilities	2	5	10	Moderate
The effect of **water quality** (**feed and faeces**) on the marine environment	Individual facilities	2	5	10	Low
The effect of **water quality** (**chemicals**) on the marine environment	Individual facilities	2	4	8	Low
Effects of **disease** (including parasites) from the **escape of cultured species** on the wild stock of that species	Individual facilities	3	4	12	Low
Impact of land-based abalone aquaculture on the **attraction/aggregation** of species	Individual facilities	2/3 1	6 6	12/18 6	Low

5 Discussion

The issues in the following sections were given a ranking of moderate or higher during the workshops. For each of these 'priority' issues, the comments and risk assessment values determined during the workshops are firstly summarised (Tables 6-20). It should be noted that the comments in these tables come directly from the workshops, or are direct quotes from subsequent written comments. As such, they do not necessarily represent SARDI's view, and no warranty is made as to their factual correctness. In the national ESD framework aquaculture guide supplement (Fletcher *et al*. 2003) a brief description of the issue to be discussed is given and this description has been included in the summary of each issue. Everyone who was invited to attend the risk assessment workshop (Appendix 1) was also invited to comment on the workshop summary and this report. Any additional comments that were made, or alternative risk values that were given have also been included in the summary table for each issue that was ranked as moderate or higher. Wherever possible the exact comments were included, however additional words and phrases have been included to improve readability and understanding.

Each workshop summary table is followed by a brief review of the current knowledge and literature that was conducted by the first author (MT). For some of the more complex issues a general overview to the issue has been included. Finally, the literature review combined with workshop summaries and additional comments for each issue are discussed in terms of the implications for the South Australian land-based abalone aquaculture industry. Unless otherwise specified, any recommendations in the tables were made in the workshops or in written submissions following it, while those in the current knowledge section come from the authors.

5.1 Escapes or disease (including parasites)

5.1.1 Overview of issues pertaining to escaped abalone:

Cultured abalone can escape land-based aquaculture production systems through the effluent system as small juveniles or in the event of a spawning event during the growing period (Hawkins and Jones 2002). It is possible that the escape of cultured abalone could lead to the transfer of diseases or parasites to wild stocks or other mollusc species. Four issues relating to the escape of cultured organisms or disease were identified in the component trees for land-based abalone aquaculture (Figures 2a-c). These issues were:

1. Genetic alteration of wild stock
2. Introduction of diseases and parasites to
    a. Wild stock
    b. Other species
3. Effects of translocation of stocks
4. Competition with the wild stock for food and space

Of these issues, 2a was given two risk values during the workshop both of which greatly depend on management policies relating to translocation of abalone in the future. Issues 2b and 3 were given a moderate risk ranking and are discussed together with issue 2a. Issues 1 and 4 were given lower risk rankings, and are not discussed further.

The major problem with investigating the occurrence of escapes may be the inability to discriminate between the wild stock and the escapees. Lee *et al*. (2002) established that stable carbon isotope analysis of abalone is a valuable tool for identifying cultured escapees from wild stock. This analysis gives an indication of the environment to which the abalone was exposed during its growth cycle. However, it is generally considered that it is unlikely that abalone larvae or cultured juvenile abalone will establish themselves in the wild and survive to spawn (Hawkins and Jones 2002, Burton and Tegner 2000). To our knowledge, there has been no research conducted in South Australia on the likelihood of cultured abalone establishing themselves in the wild or the possible ecological effects of escapees. This is probably due to the newness of the industry in South Australia, however, it is an issue which may require further research in the future if changes in the current management practices occur.

5.1.2 Effects of disease in the cultured species on the wild stock of that species, other species and the impact of translocation of stock

Table 6. Summary of comments and risk assessment values for the issue of escaped cultured species on the wild stock. Additional comments were received after the workshops. Wherever possible the exact comments were included, however additional words and phrases have been included to improve readability and understanding.

Description (Fletcher *et al*. 2003)	*What impact will the escape of cultured individuals have on the introduction of disease to wild stock? What protocols are needed at the whole of industry level to minimise the risk of disease transmission to the wild stock from the escape of cultured individuals?*
Level of impact	Whole of Industry
Comments during workshop	▪ In California there are significant issues relating to the escape of parasites. In South Australia the brood-stock are collected in local waters and therefore with current management practices in place there is not likely to be any issues relating to release of disease or parasites to wild stock. ▪ While diseases and parasites may be apparent in the natural environment and these may get a chance to thrive in aquaculture environments, workshop attendees agreed that the chance of these affecting the whole industry are negligible. ▪ In the future it is likely that stock may be translocated from other regions. There is evidence that if abalone are translocated there will be a problem in the future. ▪ Given that it is possible that management changes may take place in the next 5 years and these management changes are likely to lead to problems associated with disease and parasite transmission to the wild stock two risk values have been given. The negligible risk value relates to current management practices and the moderate value reflects the risk associated with disease transmission if management policies change and abalone can be brought in from other areas.
Comments during Abalone Industry workshop	▪ Diseases occur in the natural environment and can become apparent in aquaculture animals due to stress. However, there have been no cases of a disease outbreak and if such an event was to occur, it would be contained within the farm. *Perkinsus* spores may be transmissible, but we need more information on means of transport. ▪ It is unlikely that an infection will occur because brood-stock is collected locally. If brood-stock is imported in the future it is likely to cause a huge risk to the industry. ▪ We need to clarify what is the risk of a disease outbreak on SA Abalone? We believe there is moderate to high risk of farm stock infecting live stock, however, this is always a secondary infection not a primary infection. More information is required on the state of health of livestock. ▪ There is currently a genetics program underway that ensures farmers are selling disease free Abalone. ▪ Transport of diseases to the wild stock is highly unlikely, therefore the risk ranking of moderate was down-graded to low.
Additional comments	
PIRSA	▪ The ranking is based on the disease problem occurring in other areas and therefore poses a risk. Also, there are currently no references on the Californian disease (withering syndrome) being propagated in farms and spreading to wild populations from there. ▪ Translocation is managed under the Aquatic Animal Health Policy; a policy examining translocation is being developed. Until then, no translocation to open systems is allowed between SA metapopulations and translocation of live Abalone from interstate is out of the question. ▪ The FRDC is funding a project that will develop a translocation protocol based on thorough risk assessment and the outcomes of FRDC project 2001/201. Other projects will identify diseases which may eventually facilitate translocation between the states.
Abalone industry Association of SA Inc	▪ The withering foot disease was initially, only a local problem in California until it spread up and down the coastline, affecting what was left of the Californian Abalone fishery. Why would the current management practices relating to the collection of brood-stock from local waters mean that there is not likely to be any issues relating to

	▪ the release of disease or parasites to the wild stock? What management practices are in place? ▪ There was a case in Tasmania where a land-based operation affected nearby wild stocks when the land-based operation became highly infected by mud worms which were passed into the marine environment through the outlet pipes.			
Risk assessment values				
Organisation	**Consequence**	**Likelihood**	**Risk Value**	**Risk Ranking**
During workshop	3 0	4 0	12 0	Moderate Negligible
Industry workshop				Low
PIRSA				Low
Level of impact	Individual facilities			
Comments during workshop	▪ See comments on disease in Whole Industry section			
Comments during Abalone Industry workshop	▪ The likelihood of escapement resulting in disease is higher at farm level than for whole or catchment/region level.			
Organisation	**Consequence**	**Likelihood**	**Risk Value**	**Risk Ranking**
During workshop	3	4	12	Moderate
Industry workshop				Low

Table 7. Summary of comments and risk assessment values for the issue of disease transmission to other fauna through water or from escapes. Additional comments were received after the workshops. Wherever possible the exact comments were included, however additional words and phrases have been included to improve readability and understanding.

Description (Fletcher *et al*. 2003)	*Could diseases from the cultured species be passed on to other fauna in the area, either through water or from escapes?*			
Level of impact	Whole of Industry			
Comments during workshop	▪ To our knowledge there are no known examples in South Australia of when disease has spread from abalone to other shellfish, however it was recognised that there may be a potential for other abalone species to be affected if this was to occur.			
Comments during Abalone Industry workshop	▪ To our knowledge there is no known example where a disease has spread or could potentially spread to another shellfish apart from Abalone, however, we do believe that this is a potential issue.			
Additional comments				
PIRSA	▪ Under the aquatic Animal Health Policy farms must report unexplained mortalities, especially if they suspect a notifiable disease. The Emergency Procedures Manual and the Chapter in the State Disaster Response Plan for Aquatic Animal Disease Emergencies (currently in development) would be brought into action if a notifiable disease did occur. Risk analysis is carried out on all applications and farms that pose a significant risk are required under their license to sterilise outflow water. ▪ The statement made above regarding the development of a genetics program to ensure farmers are selling disease free abalone is misleading. The ‘family lines’ project run through the FRDC Abalone subprogram is researching better strains of abalone for aquaculture, but that research alone will not ensure that abalone are disease free. Animals produced by this project will be examined and their health status certified before they are moved. It is this certification that ensures their disease-free status, not the genetics program *per se*			
Risk assessment values				
Organisation	**Consequence**	**Likelihood**	**Risk Value**	**Risk Ranking**
During workshop	3	3	9	Moderate
Industry workshop				Low
PIRSA				Negligible

Table 8. Summary of comments and risk assessment values for the issue of escaped cultured species on the wild stock. Additional comments were received after the workshops. Wherever possible the exact comments were included, however additional words and phrases have been included to improve readability and understanding.

Description (Fletcher *et al*. 2003)	*Are there any disease issues associated with translocations, escapements, breeding programs, farming practices, etc?*			
Level of impact	Catchment/Region			
Comments during workshop	▪ The abalone farms have been operating for 10 years and within this time there have been no problems associated with disease translocation, however there have been problems overseas. Currently there is some management regimes for translocations. Management currently appears adequate. ▪ Disease could breed up in the farm and then be released. ▪ The likelihood and consequence values given to this issue indicate that it is unlikely yet would be severe if it occurred.			
Comments during Abalone Industry workshop	▪ Current management practices ensure that all abalone translocated within bays and across farms are health checked. Currently, there is no exchange of Abalone with the offshore industry and there is a ban on importing overseas stock. ▪ We need to look at individual disease agents and sum up the likelihood of an outbreak. ▪ Under current management practices the likelihood of a disease outbreak is low, but the consequences would be high.			
Additional comments				
PIRSA	▪ It is understatement that there is 'some' management of translocation. The consequences would depend on the disease, not all diseases that could take hold in a farm would have 'severe' consequences if released into the wild. The risk within the farm is low, the risk to wild stocks is negligible.			
Risk assessment values				
Organisation	**Consequence**	**Likelihood**	**Risk Value**	**Risk Ranking**
During workshop	3	4	9	Moderate
Industry workshop				Low to negligible
PIRSA				Low

Current knowledge

A review of abalone diseases conducted by Bower (2000) established that six diseases are known to be associated with mortality in various species of abalone (Table 9). To date, only a few of these diseases are present in Australian waters. Further investigations by Bower (2003) established that new infectious diseases of abalone have been encountered during the culturing process in various parts of the world. For example, high mortalities were experienced in New Zealand due to a novel haplosporidian, in southern California due to the agent 'Rickettsiales-like prokaryote' of withering syndrome, in California due to the exotic sabellid polychaete *Terebrasabella heterouncinata* and in Australia due to *Vibrio* (discussed below). Even though there has been no specific risk analysis conducted in SA on the likelihood or consequences of escapes from abalone farms, it is possible that the escape of cultured abalone in South Australia could lead to the transfer of diseases or parasites to wild stocks or other mollusc species. This could potentially have significant consequences for the environment.

Table 9. Summary of diseases reported from abalone prior to 2000 (Bower 2000).

Category	Disease/Parasite	Known distribution
1. Causes severe disease and mortality	*Vibrio fluvialia* 2/pustule disease	Vicinity of Dalian, China
	Labyrinthuloides haliotidis	British Columbia, Canada
	Perkinsus olseni	South Australia
	Sabellid polychate	California, USA: Baja California, Mexico, southern Africa
	Withering foot syndrome	California, UA
	Amyotrophia	Western Japan
2. Parasites of lesser concern	Ciliates	Global-specific studies from southern Africa
	Margolisiella haliotis	California, USA
	Echinocephalus pseudouncinatus	Southern California, USA: Gulf of California, Mexico
	Trematide parasitism	Global
3. Detrimental under adverse conditions	Ubiquitous opportunistic organisms	Global
	Shell-boring organisms	Global

There are two possible avenues by which the culture of abalone could introduce pathogens to wild abalone stocks:

1. There is the risk that non-endemic, pathogenic organisms may be introduced into an area by translocation of abalone from other areas. This is currently not allowed, and would likely need rigorous protocols such as disease testing and quarantine to minimise the risk of importing new diseases if allowed in the future.

2. The possibility of an increase in endemic disease in wild stocks due to the proximity of cultured animals. Due to higher animal density and subsequent stress of a culture situation, levels of disease causing organisms can increase. A culture environment may therefore act as a reservoir of pathogens that could increase the level of pathogens in the wild. The risk of disease transmission between cultured and wild stocks may be minimised by sound biosecurity and management practices.

Three areas of concern to the land-based abalone aquaculture industry in South Australia are the protozoan, *Perkinsus olseni*, shell infestations of polychaete mudworms and *Vibrio*.

Perkinsus

Perkinsus is a genus of protozoan parasites that have been implicated in the mortality of molluscs worldwide, including commercial oysters in North America and clams in Portugal, and has been detected in clams in Queensland (Lester *et al.* 1990; Goggin and Lester 1995). In South Australia, *Perkinsus olseni* has been known to infect both greenlip abalone (*Haliotis laevigata*) and blacklip abalone (*Haliotis rubra*) (O'Donoghue *et al.* 1991), causing mortalities in both cultured and wild stocks. *P. olseni* proliferates in abalone tissue and in some animals can produce pustules (spherical brown abscesses) up to 8 mm in diameter in the foot and mantle as a result of a chronic infection. These contain a gaseous creamy-brown deposit, reducing the market value (Bower, *et al.* 2000). Pustules do not appear in acute cases, including animals that die in outbreaks. For example, abalone that were infected by *Perkinsus* in NSW during a recent die-back event did not exhibit pustules (Deveney, pers. com). Transmission of the parasite occurs through the release of zoospores from the pustules or decaying mollusc tissue. While in South Australia *P. olseni* has been implicated in the mortalities of greenlip and blacklip abalone, other species of molluscs can be infected. In a study by Goggin and Lester (1995) seven additional species were found to be infected. These include two other species of abalone, *H. cyclobates* and *H. scalaris*, and five bivalves, *Chlamys bifrons* (scallop), *Barbatis pistachia* (ark shell), *Katelysia rhytipora* (cockle), *Cleidothaerus* sp. (false oyster) and *Pinna bicolour* (razorfish) (Goggin and Lester 1995).

In South Australia there are two locations that are known to have persistent, high levels of infection of *P. olseni*. These are Neptune Island, Thorny Passage (south of Port Lincoln) and the bottom, eastern tip of Yorke Peninsula (O'Donoghue et al. 1991; Goggin and Lester 1995). The distribution appears to be relatively stable (Goggin and Lester 1995). More recent investigations (Lester *et al*. 2001, in Bower 2003) using molecular detection techniques found P. *olseni* in wild *H. rubra* at Taylor Island, South Australia. The prevalence of the parasite was found to be positively correlated with both water temperature and size of abalone. It was also being 'maintained by *H. rubra* with negligible contributions from other susceptible abalone species or other molluscs' (Lester *et al*. 2001, in Bower 2003). Subsequently, Hayward *et al*. (2002) (in Bower 2003) established that the transmission of *P. olseni* among wild *H. rubra* has decreased and infections were less severe. The authors concluded that this reduction was highly likely to be attributed to lower maximum sea surface temperatures during summer (cooling of almost 3°C to below 20°C).

There is a possibility that land-based abalone facilities may facilitate the spread of this parasite. While there are no known methods of prevention or control for *P. olseni*, there are many ways in which the occurrence of *P. olseni* can be avoided or at least reduced within land-based abalone facilities. *Perkinsus* enters a culture facility through the use of wild animals infested with this parasite. In order to reduce the chance of infection at land-based abalone facilities, farmers should be aware of locations that are known to have wild abalone infested with *Perkinsus* and these should be avoided when collecting broodstock. Even if broodstock are collected from areas not known to be impacted by the parasite, the abalone should still be inspected. If an outbreak of *Perkinsus* does occur in a farm it would be managed under the PIRSA Aquaculture Emergency Procedures (Deveney, pers. com). Any broodstock that is found to be infected with the parasite, dead or moribund abalone should be removed from the tanks and correctly disposed of. This will limit the spread of the parasite, as the prezoosporangium of *Perkinsus* spp. requires several days in moribund tissue to develop (Goggin and Lester 1995). Laboratory experiments have shown that stresses such as high temperature predispose abalone to disease (Goggin and Lester 1995). As a result, it has been suggested that land-based abalone farmers may consider moving stock into cool water during the warmer months of the year (January and February) (Goggin and Lester 1995), although this is unlikely to be feasible. Also, moving abalone during periods of high water temperature is an additional stressor and is likely to increase disease transmission and translocation risks (M. Deveney, pers. com)

Mudworms

Mudworms are shell-boring polychaetes from the Spionid family. Mudworms can impact on a variety of mollusc species including oysters, abalone, scallops and mussels and have resulted in severe infestations, including mortality, in land-based aquaculture systems in Tasmania, South Australia and Chile, and in sea-based systems in West Australia and New Zealand (Lleonart 2001). Mudworms damage molluscs by boring into the surface of their shell. This is achieved by secreting a digestive substance which dissolves the calcium carbonate of the shell. When the worm contacts the mantle of the host the shellfish respond by secreting extra shell material over the worm – forming a blister. Early blisters tend to be yellow /amber in colour, however, with time, blisters may become covered in pearly nacre or alternatively become dark brown or near black in appearance. The latter occurs when considerable sediment and faecal matter deposited by the mudworm is accumulated within the blisters and the surface nacre layer does not become thick enough to mask the interior (Lleonart 2001). Severe infestation by mudworms can have a significant impact on the abalone industry. In addition to mortality, spionid infestation has been associated with reduced flesh weight, decreased growth rate and decreased shell strength (Bower 2001; Lleonart 2003).

There are a number of mudworm species that have the potential to impact on abalone stocks in Australia. These include *Polydora hoplura*, *P. armata*, *P. websteri*, *P. haswelli*, *P. woodwicki*, *Boccardia knoxi*, *B. proboscidea* and *B. chilensis* (Lleonart 2001). Species identified in South Australian abalone include *Polydora armata*, *P. hoplura* and *P. notialis* (Blake and Kudenov 1978 in Lleonart 2001). While mudworm infestations have not resulted in significant abalone mortalities in South Australian waters, in Tasmania outbreaks of mudworm species have severely impacted abalone culture faculties (Llenoart *et al.* 2003). The two species responsible for the mortality events are *Boccardia knoxi* and *Polydora hoplura* (Lleonart *et al*. 2003). Mortality events associated with spionid infestations have occurred since 1995, and at one site a mortality of more than 95% occurred, involving the loss of more than 30,000 individuals. The severity of spionid infestations in Tasmania is concerning to the South Australian land-based abalone industry, especially considering that management policies may change in the near future to permit the translocation of abalone from other states. Although these changes have not been implemented, they do pose some level of risk to the industry. Furthermore if infected abalone are brought into South Australia for use by restaurants, vigilance will be needed to ensure that seawater coming into contact with abalone, or their discarded shells, is not disposed into the marine environment.

Vibrio

Vibriosis is an opportunistic disease that can impact on all bivalve molluscs and is known to affect abalone species in China, Japan, Australia, and France. The bacteria that causes the disease is a member of the *Vibrio* group and can occur in all seawater where the above mentioned molluscan species exist. Vibrio bacteria can enter abalone aquaculture systems in three ways: the seawater source, the broodstock and algal food stocks. It can be controlled by proper hygienic procedures, hence it is termed a 'management disease' (Elston 1990). A disease outbreak may indicate that proper procedures are not being followed. Infected abalone can be identified by blister like lesions on the foot accompanied by high mortalities (Li *et al*. 1998). The lesions comprise of an intense haemocytic infiltration and the connective tissue and muscle fibres in the centre of the lesions are usually necrotic. The lesions on the surface of the abalone then extend into the tissue as the disease progresses. In advanced stages, the centre of the lesion contains haemocytes and bacteria only.

There are many different strains and species of *Vibrio* that have impacted on abalone industries around the globe and may have the potential to impact on Australian stocks. Some of these species or stains include, *V. alginolyticus, V. parahemolyticus*, *V. proteolyticus, V. campbelli, V. natriegens, V. harveyi, V. carchariae, V. gallicus sp. nov.,* and *V. halioticoli.* (Lizarraga-Partida *et al.* 1998; Lee *et al*. 2001; Nicolas *et al.* 2002; Tanaka *et al*. 2003; Sawabe *et al.* 2004). Cultured abalone (*H. rubra, H laevigata* and their hybrids) in Tasmania, Australia have experienced disease outbreaks and mortalities as a result of two species of *Vibrio* (*V. harveyi* and *V. splendidus* 1) and Flavobacterium-like bacteria. Stress factors such as high temperatures, grading trauma, anaesthetics, and gradual increase in salinity in the recirculation system have mostly precipitated the diseases (Handlinger *et al*. 2001, Handlinger *et al*. 2002, In Bower 2003). Antibiotics did not prove to be a successful method for treating the disease. Vibriosis has previously occurred at some South Australian abalone farms. It usually occurred during the summer months when the abalone were stressed due to inflated temperatures. Antibiotics are usually administered for 7-10 days to treat infected animals (EPA 2001). Again, this issue is a concern to the SA abalone industry, especially considering that management policies may change in the near future to permit the translocation of abalone from other states. If this is occurs, new species of *Vibrio* could be introduced into the state and may cause major problems for the industry, unless adequate precautions are taken to prevent such introductions.

We can lower the risk of disease introduction simply by not allowing the translocation of broodstock to South Australia from other areas. However, as the industry continues to expand there could be increased pressure to translocate stock. If this is inevitable then preventative measures such as a screening process prior to entering South Australia, would be useful. More research on potential disease problems is also likely to be required and most importantly policies must be implemented to ensure that translocated stock are free of diseases not known in SA. It should be noted that any change in translocation policy with regard to interstate movements would only occur after a suitable risk assessment has been carried out and risk mitigation procedures instituted. As a result there would be a translocation protocol that manages the risk for an appropriate level of protection, both within the state and nationally (Johnston, pers. com). Additionally, policies could dictate the use of filtration devices to reduce the numbers of abalone escaping to the wild. A current policy in Western Australia dictates the use of settlement ponds, sediment filters or fine filtration to reduce the disease risks associated with use of stock from interstate (Bower 2002).

At the present time broodstock are collected in local waters and as a result there are not likely to be any problems associated with the introduction of new diseases. However, if management practices change and permit the translocation of abalone from other States or overseas, the likelihood for disease transmission from cultured individuals to wild stock may increase. While current management practices appear to be effective, the problems with mudworms in Tasmania suggest that there is some risk of disease/parasite transmission to wild stocks in SA. We feel that this is low, but if management changes to allow for translocations the risk associated with disease transmission will almost certainly increase. In such an event the risk should be reassessed and appropriate risk mitigation incorporated into any translocation protocols.

5.2 Habitat alteration/loss

5.2.1 Overview of issues pertaining to impacts on habitat

Seven issues relating to the impacts of construction and infrastructure on habitat were identified as a moderate risk at the Individual facility level for land-based abalone aquaculture (Figure 2c). These issues were:

1. Effects of land-based abalone aquaculture on terrestrial vegetation
2. Impact of construction of land-based abalone aquaculture facilities on erosion
3. Rehabilitation of site
4. Impact of construction noise and dust
5. Impact of wastes produced during construction
6. Behavioural changes and other impacts on migratory species (e.g. birds) due to land-based abalone aquaculture
7. The impact of land-based abalone aquaculture on sensitive habitat

5.2.2 Terrestrial vegetation

Table 10. Summary of comments and risk assessment values for the issues relating to terrestrial habitat modification or removal during construction. Wherever possible the exact comments were included, however additional words and phrases have been included to improve readability and understanding.

Description (Fletcher *et al*. 2003)	*Will any terrestrial habitat have to be removed or affected by the construction; development; expansion of the facilities? This includes the digging of any ponds, the construction of offices/labs etc. If there will be some removal, does the proposed level fit in with the total amounts allowed to be affected within this catchment?*			
Level of impact	Individual Facilities			
Comments during workshop	▪ Given that land-based abalone farms are situated on the coast it is often the case that native vegetation has to be cleared for construction or expansion of facilities. This clearance usually takes place on the land or sand dunes to make way for the outlet pipe. ▪ These impacts are very site specific and vary with the surrounding habitats (eg. farm may be built on already cleared agricultural land). ▪ In some cases restoration of the surrounding vegetation is due to take place following construction, however does not actually happen in some locations. This is a compliance issue. ▪ The issues associated with nearby vegetation need to be addressed in the planning phase of the construction. It is likely that there are widespread problems in association with other activities also in the area. ▪ In some areas the removal of vegetation from a small area can cause blowouts of other vegetation and vegetation at the front of dunes can protect the dunes from erosion. It may also be that clearance of this vegetation is resulting in fragmentation of the coastal vegetation corridor.			
Comments during Abalone Industry workshop	▪ The removal of terrestrial vegetation is considered during the license application and planning phase. Some farms have started restoring the surrounding environment by planting lots of native trees. ▪ A code of practice needs to be included in a license agreement to ensure farms are restoring the surrounding environment.			
Risk assessment values				
Organisation	**Consequence**	**Likelihood**	**Risk Value**	**Risk Ranking**
During workshop	2/3	6	12/18	Moderate to High
Industry workshop				Low to Moderate

Current knowledge

Habitat loss is currently considered one of the primary factors leading to a decrease in species richness and because of this 'land clearance' is a listed key threatening process under the *Environment Protection and Biodiversity Conservation Act 1999*. The fragmentation and destruction of natural habitats has severely threatened the survival of many native terrestrial flora and fauna (Huxel and Hastings 1999), while the destruction and removal of vegetation has resulted in sand displacement and erosion of dune systems (Brown and McLachlan 2002). The removal of vegetation for any purpose, not just for land-based abalone aquaculture, may have these consequences. As with any development on private land the consequences of removing terrestrial vegetation for the purpose of abalone aquaculture are considered during the license application and planning phase. Revegetation programs have also been established following the construction of some facilities. As this issue is a general problem with all forms of coastal development, it needs to be dealt with through local government planning processes and so is not considered further in this report.

However, the industry have acknowledged that a code of practice relating to restoration of the surrounding environment after completion of construction would be a useful way forward. Such a code should pay particular attention to the types of vegetation that should be used, to ensure that inappropriate species are not used.

5.2.3 Erosion

Table 11. Summary of comments and risk assessment values for the issues relating to erosion during construction. Wherever possible the exact comments were included, however additional words and phrases have been included to improve readability and understanding.

Description (Fletcher *et al*. 2003)	*Will construction cause any short or long-term erosion problems for the region?*			
Level of impact	Individual Facilities			
Comments during workshop	▪ Erosion is a consequence of construction in the longer term. While some in the workshop mentioned that they were unaware of any erosion as a result of abalone farms others said they were.			
Comments during Abalone Industry workshop	▪ There is evidence of erosion around some pipelines situated on the beach and intertidal, however, this is facility specific. If the pipelines are installed properly in the first instance, erosion should not occur. We follow development guidelines that are attached to our license agreement to ensure that the pipelines do not move. At some farms the pipelines are visible during low tide, which has social consequences. There are also photographs taken during different tides of a pipeline, showing a lack of erosion.			
Risk assessment values				
Organisation	**Consequence**	**Likelihood**	**Risk Value**	**Risk Ranking**
During workshop	2/3	8	8/12	Moderate
Industry workshop				Moderate

Current knowledge

The role played by dune vegetation in the control of erosion and stabilisation of dunes (Buckley 1996) has been threatened by human activities. The destruction of natural vegetation on dunes is one of the major causes of sand drift and erosion (Brown and McLachlan 2002). Construction activities for any purpose, not just land-based abalone aquaculture, may cause erosion. Revegetating the area following construction is the most effective means of controlling erosion. As little as 4% vegetation cover can reduce soil loss by 15% compared to the bare ground (Fryrear 1995). Effective revegetation programs have been achieved through regeneration of existing vegetation or by establishing suitable vegetation (Handa and Jefferies 2000). Native plants have proven to be better at establishing in disturbed sites because populations are adapted to local environments (Olukoye *et al*. 2003). As with terrestrial habitat modification, this is a general issue for all coastal development, and is not discussed further here.

Erosion around pipelines is an issue that is directly related to some forms of aquaculture, such as the land-based abalone aquaculture industry. There is some suggestion that erosion has occurred around pipelines in the intertidal areas, and there is at least some potential for this to spread, especially during periods of storm activity. Careful consideration needs to be given to the location of the pipelines in future developments to minimise the risk. Given that it appears that erosion has occurred at some facilities, the moderate risk is probably appropriate.

5.2.4 Rehabilitation of site

Table 12. Summary of comments and risk assessment values for the issues relating to rehabilitation if production is ended. Wherever possible the exact comments were included, however additional words and phrases have been included to improve readability and understanding.

Description (Fletcher *et al*. 2003)	What systems have been planned to rehabilitate the site if production is ended?			
Level of impact	Individual Facilities			
Comments during workshop	▪ Planning arrangements outline that rehabilitation must occur (both after construction and if a site is vacated), however this may not always be done. Currently there are no routine compliance checks. ▪ To overcome this problem one workshop participant suggested that a bond should be allocated to rehabilitation if a bankruptcy occurs. ▪ There is also the concern that if rehabilitation does occur that it will not be done correctly and inappropriate vegetation will be used. ▪ Without rehabilitation there is a risk of longer-term damage of the coastal zone with erosion resulting in blowouts.			
Comments during Abalone industry workshop	▪ Given that farmers have approval to clear vegetation on private land in the first instance, it is inappropriate to discuss rehabilitation; it is a compliance issue. However, rehabilitation is part of their lease contract and some farms have rehabilitated the land after construction.			
Risk assessment values				
Organisation	**Consequence**	**Likelihood**	**Risk Value**	**Risk Ranking**
During workshop	3	4/5	12/15	Moderate to High
Industry workshop				Low

Current knowledge

The development of a land-based aquaculture facility can lead to environmental degradation and the formation of an eyesore if the area is not rehabilitated. Again, this is a problem with any type of development and abalone aquaculture should not be singled out for particular attention. The development of a code of practice for environmental restoration as per 6.2.1 would help ensure any restoration is appropriate

5.2.5 Noise and dust

Table 13. Summary of comments and risk assessment values for the issues relating to noise/dust during construction. Wherever possible the exact comments were included, however additional words and phrases have been included to improve readability and understanding.

Description (Fletcher *et al*. 2003)	Will construction of the facilities result in an unacceptable increase in noise and dust to surrounding areas?			
Level of impact	Individual Facilities			
Comments during workshop	▪ This issue will vary greatly with site. The complaints that are received are generally short lived and the ranking that has been given to this issue is likely to be the worst case scenario.			
Comments during Abalone Industry workshop	▪ Contractors involved in the construction of the facilities have to comply with their construction guidelines, so our construction noise would be no different to any other development.			
Risk assessment values				
Organisation	**Consequence**	**Likelihood**	**Risk Value**	**Risk Ranking**
During workshop	2	4	8	Moderate
Industry workshop				Low

Current knowledge

As with other developments, construction of an abalone aquaculture facility can result in increased levels of noise and dust. The nature of the facilities suggest that these problems would be at the low end of the scale relative to other coastal developments, and that the associated risk is probably low. Again, this needs to be dealt with as part of the planning process and abalone aquaculture should not be singled out for particular attention.

5.2.6 Wastes

Table 14. Summary of comments and risk assessment values for the issues relating to waste (e.g. dredge soil) during construction. Wherever possible the exact comments were included, however additional words and phrases have been included to improve readability and understanding.

<table>
<tr><td>Description
(Fletcher et al. 2003)</td><td colspan="4">Will there be a waste produced from construction? If so, what disposal mechanisms have been planned to deal with this waste (eg. dredge spoil) from the construction of the facilities?</td></tr>
<tr><td>Level of impact</td><td colspan="4">Individual Facilities</td></tr>
<tr><td>Comments during workshop</td><td colspan="4">▪ Land-based abalone farms may produce wastes from construction, excavation and digging ponds. Construction is also often ongoing with changes to farm infrastructure.
▪ Stormwater could have a severe impact on surrounding areas especially considering that a number of farms change systems regularly and are therefore in a continuous state of construction.
▪ Furthermore the stormwater may be contaminated from dirt and concrete.</td></tr>
<tr><td>Comments during Abalone Industry workshop</td><td colspan="4">▪ During the construction phase of farms, the site is considered as a normal construction site and waste is taken to a land-based dumping facility (we do not dump waste into the water). Stormwater is collected from roof surfaces and stored in rain water tanks and the residual is absorbed into the soil</td></tr>
<tr><td colspan="5">Risk assessment values</td></tr>
<tr><td>Organisation</td><td>Consequence</td><td>Likelihood</td><td>Risk Value</td><td>Risk Ranking</td></tr>
<tr><td>During workshop</td><td>2</td><td>4</td><td>8</td><td>Moderate</td></tr>
<tr><td>Industry workshop</td><td></td><td></td><td></td><td>Low</td></tr>
</table>

Current knowledge

Dredge spoil has been shown to have detrimental effects on both marine and mangrove systems (Cheshire *et al.* 2002, Gordon1988). Consequently, compliance regulations prohibit the disposal of spoil in the marine environment. Waste produced during construction of abalone farms is disposed of at a licensed land-based dumping facility. Therefore, this issue will not require further scientific research.

Conversion of natural landscapes to impervious surfaces (roads, drives, sidewalks, parking lots and roofs) removes the land's natural filtration capability, allows for increased concentration of pollutants at the land's surface and provides a means of rapid conveyance of pollutants to waterways (Mallin *et al*. 2001). Land-based abalone facilities, however, are generally situated on large allotments and have a relative small area of impervious surface. Stormwater that is not collected by rainwater tanks is absorbed directly into soil surrounding the facility. Any such development should be sympathetic towards drainage issues and again these should be dealt with in the planning process.

5.2.7 Behavioural changes and other impacts on migratory species (e.g. birds)

Table 15. Summary of comments and risk assessment values for the issues relating to behavioural change/impacts on migratory species. Wherever possible the exact comments were included, however additional words and phrases have been included to improve readability and understanding.

Description (Fletcher *et al*. 2003)	*Will the infrastructure of the facilities cause changes to behaviour of other species in the area?*			
Level of impact	Individual Facilities			
Comments during workshop	▪ Birds utilising the coastal vegetation as corridors may be impacted by changes in coastal vegetation. Coastal vegetation may be an issue, and changes in behaviour of migratory birds may result from this. This is dependent on the existence of any other existing vegetation and the degree of fragmentation. Wading birds may also be impacted but to a lesser extent. ▪ Seagulls are known to exhibit changes in behaviour (this is addressed in Operation Associated Impacts (this tree) under the aggregation/attraction component). ▪ This issue is site specific and should be addressed in the planning phase of development.			
Comments during Abalone Industry workshop	▪ Impacts on migratory birds are considered during the planning phase and we do not believe we are impacting on nesting grounds. ▪ Birds (e.g. ducks and seagulls) are attracted to farms because of Abalone food and general activity, but not in quantities that they become a pest. However, they may have congregated in the same area before the farm was constructed.			
Risk assessment values				
Organisation	**Consequence**	**Likelihood**	**Risk Value**	**Risk Ranking**
During workshop	2	4	8	Moderate
Industry workshop				Low

Current knowledge

Habitat loss is one of many factors affecting sea and migratory bird populations (Thompson and Hamer 2000; Goss-Custard *et al*. 1995). Reduction in the area, or change in the quality of, feeding areas and population density has resulted in starvation and death of migratory birds (Goss-Custard *et al*. 1995). Disruption to migratory corridors has also been shown to significantly decrease the abundance and species richness of bird assemblages (Haig *et al*. 1997; Galarza and Telleria 2003). Consequently, the removal of coastal vegetation for any terrestrially based activity, not just land-based abalone aquaculture, may change the behaviour of migratory birds. As discussed in the workshop, this is dependent on the existence of any other vegetation and the degree of fragmentation. Currently, no research has documented the effect of abalone farms on migratory birds. However, migratory birds listed in the *Environment Protection and Biodiversity Conservation Act 1999* are addressed in the planning phase of development. As abalone facilities are very unlikely to have a unique impact on migratory species, this issue is not considered further here.

5.2.7 Sensitive habitat

Table 16. Summary of comments and risk assessment values for the issues relating to sensitive habitat. Wherever possible the exact comments were included, however additional words and phrases have been included to improve readability and understanding.

Description (Fletcher *et al*. 2003)	*Will the infrastructure of the facilities impact on sensitive habitats? Should certain habitats be avoided?*			
Level of impact	Individual Facilities			
Comments during workshop	▪ This issue is addressed under "habitat effects" in construction, but there are slightly different issues for the operation of the farms on sensitive habitats. ▪ Saltmarsh habitats are vulnerable to land-based farm discharge, and although this is uncommon it has been known to occur eg. Arno Bay. ▪ There is also a possibility of seagrass scouring around the pipe.			
Comments during Abalone industry workshop	▪ We do not believe we are situated on any sensitive habitat because our sites were approved during the planning phase. We also do not discharge any water on salt marsh; all discharge is piped out to sea.			
Organisation	**Consequence**	**Likelihood**	**Risk Value**	**Risk Ranking**
During workshop	2	3/4	6/8	Low to Moderate
Industry workshop				Low

Current knowledge

Comments from industry representatives suggested that this issue is addressed during the planning phase of development. However, documentation of marine environmental information related to the application process has been limited in the past.

It was suggested at the workshop that salt marsh habitats are vulnerable to land-based farm discharge. Salt marshes have several ecological values, including a high rate of primary productivity; provision of habitats for many marine species, they assist in flood and erosion control; lessen the effects of stormwater surges; and improve water quality by filtering pollutants, excess nutrients, and disease-causing microorganisms (Vernberg 1993). Brown *et al.* (1999) showed that some salt marsh plants can act as biofilters to remove nutrients from aquaculture waste water. The plant-soil system (tested in plant pots) removed almost 100% of nutrients (e.g. nitrogen and phosphorous) contained in the effluent. The results also suggest that constant flushing of seawater may lead to plant damage (e.g. reduced nutrient uptake and growth). Even though the results do not represent all salt marsh species, they suggest a need for further research on the effect of aquaculture effluent on natural salt marsh habitats. Thus, given the sensitive nature of salt marsh habitats, discharge of wastewater into these habitats should not be allowed unless it can be demonstrated that such discharge will not have an effect.

There is also the possibility of seagrass scouring around inlet and outlet pipes. It is widely agreed that seagrass beds are sensitive habitats and are subject to widespread loss as a result of direct human impacts (e.g. Duarte 2002; Short and Wyllie-Echeverria 1996). Destruction and fragmentation of seagrass habitat has not only had severe consequences for marine flora and fauna (Hemminga and Duarte 2000), but has resulted in erosion problems because seagrass dampens water movement and binds the sediment (Duarte 2002). Extreme examples can be seen along the

Adelaide metropolitan coast (Fotheringham 2002) and at Beachport (Seddon *et al*. 2003), where seagrass loss has caused major coastal erosion problems. While only a very small area of seabed is directly affected by the placement of inlet/outlet pipes, once erosion starts there is a possibility that the area of influence will expand greatly with the formation of a blowout. Such an event is more likely in areas exposed to substantial wave action than in sheltered waters. If such erosion starts to occur, rapid action to stabilise the area may be needed to prevent expansion. It is thus suggested that facilities with pipes over seagrass report on the presence of any erosion (and possibly present a photographic record) as a part of their annual environmental monitoring.

Provided adequate consideration is given to the location of facilities in the relation to sensitive habitats in the planning process, this issue should not be cause for concern. However, there is a suggestion that there have been problems in the past, particularly in relation to a former abalone farm at Arno Bay that reportedly discharged water into a saltmarsh causing habitat damage. There are also potential concerns related to seagrass loss if inlet/outlet pipes are located in seagrass meadows. While it appears that there are no current problems, we would suggest this risk remain low-moderate to ensure sufficient attention is paid to potential problems during the planning phase for future developments as the issue has seemingly not always been addressed sufficiently in the past.

5.3. Water quality

5.3.1 Overview of issues pertaining to water quality

Four issues related to water quality were identified for land-based abalone aquaculture at the Individual Facility level (Figure 3) these being:

1. Nutrients
2. Epiphytes and macroalgae
3. Feed and Faeces
4. Chemicals

Of these issues, 1, 3 and 4 were given a moderate risk ranking at the individual facility level, however, these risks may depend on the presence and effectiveness of settlement ponds. These issues were considered to be a low risk at the catchment/region level due to the relatively low inputs at this scale. Due to a large amount of overlap in the literature regarding issues 1 and 3, they have been combined for this discussion. As a result of uncertainty regarding settlement ponds, an additional section has been added in order to gain a better understanding of their use in aquaculture operations.

5.3.2 Nutrients

Table 17. Summary of comments and risk assessment values for the issues relating to water quality (nutrients). Wherever possible the exact comments were included, however additional words and phrases have been included to improve readability and understanding.

Description (Fletcher *et al*. 2003)	*Is the quality of the water released back into the environment affected? If yes, is the quality of the output within the required levels for the catchment?*			
Level of impact	Individual Facilities			
Comments during workshop	▪ The water quality discharged from abalone farms is likely to depend a lot on the presence or absence of settlement ponds, however more information is needed on this matter. We need to know how the presence of ponds increases water quality and how the design of the ponds changes water quality. ▪ Water quality is also likely to be affected by the stocking density of the abalone, shape of the ponds, feed conversion ratio, feeding rate, etc. ▪ Water quality has been separated into 4 additional components; nutrients, sediments, waste feed & faeces and chemicals.			
Comments during Abalone Industry workshop	▪ There is no difference in water quality outputs between farms that have ponds and those that do not. Suspended solids do not settle out and it doesn't appear to be accumulating at the output, probably due to wave action. Water quality levels are within the Australian Water Quality Guidelines, so if we are already within the standards, why do we need ponds? The predicted size of ponds would be huge due to the volume of water pumped from farms daily. The ponds would continually accumulate faeces and nitrogen and as a result there would be problems associated with smell and the removal of sludge. ▪ *Ulva* can be found growing along the intertidal at points of discharge, perhaps stripping nutrients from the discharged water.			
Risk assessment values				
Organisation	**Consequence**	**Likelihood**	**Risk Value**	**Risk Ranking**
During workshop	2	5	10	Moderate
Industry workshop				Low

Table 18. Summary of comments and risk assessment values for the issues relating to feed and faeces. Wherever possible the exact comments were included, however additional words and phrases have been included to improve readability and understanding

Description (Fletcher *et al*. 2003)	*Does the outfall water include levels of waste feed or faeces? Is this within agreed limits?*			
Level of impact	Individual Facilities			
Comments during workshop	▪ Same as above (Water Quality Nutrients - Environment)			
Comments during Abalone Industry workshop	▪ The outfall water does include feed and faeces, however, the consequences aren't high because the waste is absorbed by grazing animals in the outfall			
Risk assessment values				
Organisation	**Consequence**	**Likelihood**	**Risk Value**	**Risk Ranking**
During workshop	2	5	10	Moderate
Industry workshop				Negligible

Current knowledge

Nutrient rich waste water from aquaculture facilities is increasingly becoming a concern due to eutrophication of coastal waters (Ziemmann et al. 1992). In July and August of 2001, the Environmental Protection Authority conducted a series of site inspections at land-based abalone facilities in the Port Lincoln area. They revealed that most farm discharges showed some evidence of eutrophication either in discharge channels at the shoreline or in the ocean around the discharge point (Environmental Protection Authority 2001). Although nutrient concentrations varied substantially from farm to farm, excess nutrients enter the environment as dissolved phosphorus, nitrogen, ammonia, faeces and uneaten feed. Feed derived wastes are the main source of potentially polluting waste discharged in farm effluent. It has been documented that feed derived wastes from intensive aquaculture facilities can cause negative impacts when released into the environment (Ackefors and Enell 1990). These wastes include components that are dissolved, such as phosphorus and nitrogen based nutrients, or are in a solid phase as suspended solids (Porter *et al*. 1987; Knom and Neori 1989).

Although licensees are required to submit an annual environmental monitoring report that includes information on water quality (including nitrogen, ammonia and phosphorus), at the time of a literature review of environmental information related to the industry no such reports could be found for the land-based abalone sector in license files examined or in PIRSA Aquaculture's recently established EMP filing system (Bryars 2004). Since that time, one report has been submitted to PIRSA Aquaculture. The report outlines that all the water quality parameters measured were well within the recommended EPA water quality guidelines. Also, a report by Maguire (1998) on nitrogen budgets stated that 'to date no detectable increases in soluble nitrogen have been detected adjacent to land-based abalone farms in South Australia'.

It should be noted that PIRSA Aquaculture is expecting a series of Environmental Monitoring Reports for 2003 by June 2004. PIRSA Aquaculture has spent some time improving the system of reporting by outlining specifically what is required and making the reporting system more accessible. When submitted, these reports should provide a clearer indication of the nutrient loading from each farm.

Feed derived wastes, especially solids, from intensive aquaculture operations have the potential to degrade the aquatic environment (Ackefors and Enell 1990). A review conducted by Crisp and Bergheium (2000) on solids management and removal, however, found that suspended solids (SS), total nitrogen (TN) and total phosphorus (TP) concentrations are commonly low in aquaculture effluents. In addition, not all of these waste concentrations are bound to the particulate fraction. About 7-32% of the TN and 30-84% of the TP is in the particulate fraction (Bergheim *et al*. 1993). The remainder is transported out of the farm in dissolved form. Variations in nitrogen and phosphorus concentrations with particle size (Cripps 1995) and temperature (Foy and Rosell 1991), suggest that environmental effects associated with waste feed could be seasonal, even if feeding regimes are not.

In recent years, there have been changes in aquaculture feed and feeding technologies, resulting in substantial improvements in feed conversion ratios (FCR: feed input per unit weight gain of wet animal) and growth rates (Piedrahita 2003). As the FCR improves more of the feed is used by the abalone for growth and less is wasted, resulting in reduced inputs into the environment. Most N is excreted in the dissolved form (primarily as ammonia), and most P as particulate (Skonberg *et al*. 1997). For abalone aquaculture, a number of studies have documented that it is necessary for farms to develop correct FCR values based on their animals' consumption and growth rates. For example, Marsden and Williams (1996) and Shpigel *et al*. (1996) found that feeding rate per unit biomass is generally higher in smaller and faster growing juveniles than larger abalone. Research conducted in South Australia on *H. laevigata* showed that the best FCR was 0.93 (Coote *et al*. 1996). This was achieved by adding a P supplement ($\geq$ 0.7% total P) and low amounts of Calcium to the diet. Subsequently, Britz *et al*. (1997) and Sales and Britz (2001) found that feed consumption is a function of water temperature and body size. Abalone subjected to temperatures above 20°C showed declining growth rates, deterioration of FCR, and significant increases in mortality. It was suggested that physiological processes gradually break down above 20°C and as a result feeding should cease because it would exacerbate stress and increase ammonia excretion, resulting in decreased water quality. *H .laevigata* has an optimal temperature for growth of 18.3ºC, but a preferred temperature of 18.9ºC and a critical thermal maximum of 27.5ºC (Gilroy and Edwards 1998). The management of accurate feeding practice is therefore vital to avoid excess solid waste and improve water quality.

Intensifying abalone aquaculture production has resulted in higher stocking densities at a given site. Higher biomass may contribute to poor water quality due to an increase in the production of waste materials originating from uneaten feed and metabolic waste products. A nutrient budget ('best-guess' estimate) constructed by Maguire (1998) showed that the 150 tonnes of food per year fed to cultured abalone at one aquaculture facility contained approximately 40.5 tonnes of protein, which results in 5.37 tonnes of nitrogen (as faeces, solid waste and ammonia) entering the environment per year. If an effluent treatment system is in place, this figure can be reduced to 1.07 tonnes. If the effluent volume is 600 litres per second, this equates to 56 micrograms of N per litre of effluent which is well below the ANZECC (2000) water quality guidelines of 1000 micrograms total N per litre.

Due to the evidence of eutrophication found by the EPA in 2001, the moderate risk ranking associated with nutrient inputs is probably appropriate. It may be possible to revise this after the 2003 EMP reports are submitted, depending on their results. Solids appear to be less of a problem, and so the risk associated with waste feed/faeces is likely to be low.

5.3.3 Settlement ponds

Current knowledge

Sedimentation is "the process by which settleable suspended solids, that have a greater density or specific gravity than water, can settle out of suspension and so be separated from the main flow" (Cripps and Bergheim 2000). Settling basins can either be circular or rectangular and are designed to attain minimal turbulence and resuspension (Gregory and Zabel 1990). A 'plug flow' system enables the tanks to have three design functions, these are:

1. To effectively remove suspended solids, leaving a clear effluent
2. To collect and discharge the settled sludge
3. To provide a thickened sludge with minimal volume

Failure of any one of these functions has been shown to weaken the performance of the basin and if serious, completely destroy the process (Weber 1972 in Cripps and Bergheim 2000). By establishing the correct basin design, an adequate retention time is attained and consequently these functions will be successful. Cripps and Bergheim's (2000) review found that 30 minutes is the recommended retention time for settlement. Based on this recommendation, a typical abalone farm discharging 600 L per second would require a settlement pond of $1000m^3$ in volume.

During the workshop it was suggested that water quality discharged from abalone farms is likely to depend on the presence of settlement ponds. In South Australia, only one farm uses a settlement pond to treat their entire outflow, whereas another treats a small fraction (25%) and the remaining do not use settlement ponds at all (Daryl Evans, pers. com.). There is no evidence, however, to show whether settlement ponds are effective or not. According to a review conducted by Crisp and Bergheim (2000), sedimentation basins are an unviable technology for the treatment of solids in primary wastewater due to the high overflow rates associated with intensive aquaculture systems and, hence low residence times. High flow rates can cause short-circuiting (movement of inlet water directly to the outlet without mixing in the tank), turbulence and resuspension (scouring, by the water flow, of settled material off the bottom), which makes it difficult to collect low concentrations of waste (Henderson and Bromage, 1988). They are likely to be more efficient for secondary de-watering or thickening.

Devices at the tank outlet such as rotating microscreens have been found to be an effective alternative to primary sedimentation (Tchobanoglous and Burton 1991, in Cripps and Berghein 2000). Microscreeens hold back particles on a fine mesh, which can then be scraped to a waste collection trough. These screens have been found to be especially suitable for large flow wastewater because higher water pressure increases the separation of solids (Cripps and Berghein 2000). This concentrated waste can then be frequently removed through a separate outlet from the primary flow and led to the treatment device for further thickening. The flow rate of this primary untreated waste is far lower than untreated primary effluent. As a result, it is here where the process of sedimentation takes place. Settlement is also likely to be higher for pre-treated waste due to increasing size and settling velocity of particles (Bergheim *et al*. 1998, in Cripps and Bergheim 2000).

It also should be noted that the removal of fine solids from waste water using sedimentation is difficult (Cripps, 1995). Settlement of these particles is low, however, they do not form a large fraction of the discharged solids. A review conducted by Cripps and Bergheim (2000) on foam fractionation (flotation) found that this is a popular method for removing small particles.

Once concentrated wastes are thickened by sedimentation, there are several ways in which this 'organic waste' can be used, for example:

- Applied to agriculture land
- Composting
- Vermiculture
- Reed drying beds (Tchobanoglous and Burton 1991, in Cripps and Berheim 2000)

Sedimentation is therefore unlikely to be suitable for clarifying untreated primary wastewater, but is more appropriate for second stage treatment of pre-concentrated wastes. Given that there are a large number of factors affecting sedimentation and the complicated physical characteristics of wastewater, it is beneficial to conduct site specific analyses of settling prior to planning a settling basin for a specific application (Cripps and Bergheim, 2000). At present, licensees of land-based abalone aquaculture in Western Australia are required to install coarse filtration, sedimentation traps, settling ponds or some other mechanism to remove solids from the discharge water (Fisheries, WA 1999). More research is required on the processes involved in the establishment of sedimentation basins at abalone farms in South Australia and whether they are significantly reducing the nutrient and organic loading discharged into the surrounding environment.

5.3.4 Chemicals

Table 19. Summary of comments and risk assessment values for the issues relating to chemical usage. Additional comments were received after the workshops. Wherever possible the exact comments were included, however additional words and phrases have been included to improve readability and understanding.

<table>
<tr><td>Description
(Fletcher et al. 2003)</td><td colspan="4">Will the facilities contribute large amounts of chemicals to the area? If so, what impacts will these chemicals have? Can anything be done to minimise the volumes of chemicals used?</td></tr>
<tr><td>Level of impact</td><td colspan="4">Individual Facilities</td></tr>
<tr><td>Comments during workshop</td><td colspan="4">▪ Some of the chemicals used at abalone farms include anaesthetics and chlorine.
▪ As most of the chemicals are used in very small quantities and the dilution factor in receiving waters would be high, they are not expected to have a huge impact on the environment. If there was an impact, it is likely to be a localised impact.
▪ Chlorine is used most often and in the largest volumes. It is administered to the tanks to eliminate algal growth and left overnight to breakdown naturally.
▪ It would be beneficial to determine the rate of use for the chemicals used at abalone farms. Having said this in most cases small volumes are used and dilution factor is high limiting impact on the environment.
▪ It would also be beneficial to obtain further information on how species other than abalone in the receiving waters respond to the discharge of such chemicals (eg. anaesthetics). It is likely that different chemicals will have differing levels of impact/risk.</td></tr>
<tr><td>Comments during Abalone Industry</td><td colspan="4">▪ Chlorine is not often used to eliminate algal growth but to sterilise/disinfect hatchery tanks. We need more information on the volume of chemicals used.</td></tr>
<tr><td colspan="5">Additional comments</td></tr>
<tr><td>PIRSA</td><td colspan="4">▪ PIRSA Aquaculture is developing a medicine use policy in conjunction with the EPA. Use of any chemical or medicine requires permission from PIRSA and conditions are issued based on toxicity, release concentrations and dose.
▪ The last point regarding rate of use is already included for most substances in the Aquatic Animal Health Unit medicine/chemical use approval database.
▪ When developing datasets for Australian Pesticides and Veterinary Medicines Authority (APVMA) minor use permits and registrations, an environmental care statement, based on data of non-target species is developed. For both benzocaine and Aqui-S, these data already exist.</td></tr>
<tr><td colspan="5" align="center">Risk assessment values</td></tr>
<tr><td>Organisation</td><td>Consequence</td><td>Likelihood</td><td>Risk Value</td><td>Risk Ranking</td></tr>
<tr><td>During workshop</td><td>2</td><td>4</td><td>8</td><td>Moderate</td></tr>
<tr><td>Industry workshop</td><td></td><td></td><td></td><td>Low</td></tr>
<tr><td>PIRSA</td><td></td><td></td><td></td><td>Low</td></tr>
</table>

Current knowledge

A site inspection conducted by the EPA (2001) showed that chemical usage at abalone aquaculture facilities in the Port Lincoln area was very small. Chemicals used include the following:

- The anaesthetic *benzocaine* has a minor use permit issued for its use at abalone farms and is used periodically to remove abalone from holding units during stock movement and grading.

- *Erythromycin* is used infrequently as it is most active against gram-positive bacteria, whereas bacteria problematic for abalone are gram-negative. As a result, PIRSA Aquaculture do not issue approvals for its use in situations where gram-negative bacteria are the problematic organism.

- *Oxytetracycline* is infrequently used as an antibiotic to treat *Vibrio*.

- On the odd occasion, minute amounts of chlorine are used when the aquaculture system needs disinfecting. 'Surfactant' type chemicals are generally used for cleaning tanks (Deveney, pers. com,)

None of the farms investigated in the Port Lincoln area have diversion or containment systems in place for chemically treated wastewater (EPA 2001). However, some farms are looking at diverting chemically treated wastewater to evaporation basins in the future. Again, given the amount of water flushed through abalone aquaculture systems and a high dilution factor in receiving waters, the impact of a small amount of chemicals on the environment may be low. To more properly address this risk, future EMP's should probably require documentation of the amounts and timing of each chemical used, and average discharge rates during use. Concentrations in the discharge water, along with information on the breakdown rate of each chemical, will allow rates of accumulation in the environment to be calculated. However, it is expected that these concentrations will be very low, and hence the risk associated with the amounts of chemicals currently used is probably low. It should be noted that once farms have approval by PIRSA Aquaculture (in consultation with the EPA) for the use of a veterinary medicine, they are required to report back to PIRSA regarding the result of the treatment and other information must be supplied. In addition, discharge volumes and concentrations are compared against ecotoxicology data that PIRSA has developed in conjunction with CSIRO land and water, using local marine species.

5.4 Aggregation/attraction of species

Table 20. Summary of comments and risk assessment values for the issues relating to the aggregation/attraction of species. Wherever possible the exact comments were included, however additional words and phrases have been included to improve readability and understanding.

Description (Fletcher *et al*. 2003)	*Will the operation of the facilities attract/aggregate other species?*			
Level of impact	Individual Facilities			
Comments during workshop	▪ Seagulls do aggregate at the farms, as they are attracted to the abalone feed. It may be possible that this aggregation could interrupt breeding and feeding cycles of other bird species. ▪ Fish are attracted to the outlet pipe, and this in turn may attract birds. Not much is known about this. ▪ The top value represents the risk associated with seagull aggregation. The bottom value represent that risk associated with fish aggregation.			
Comments during Abalone Industry workshop	▪ The aggregation of seagulls is not large enough to pose a threat to the ecosystem. ▪ Ducks (seabirds such as shearwaters etc.) are attracted to some farms, however, they may have aggregated in these areas before the farms were constructed. ▪ Recreational fishers have not observed fish aggregating around outlet pipes and have experienced low catch rates in these areas.			
Risk assessment values				
Organisation	**Consequence**	**Likelihood**	**Risk Value**	**Risk Ranking**
During workshop	2/3 1	6 6	12/18 6	Moderate to High Low
Industry				Low Negligible

Current knowledge

From an industry point of view, the aggregation of seagulls around abalone farms is not large enough to significantly impact breeding or feeding of other bird species. It is possible that these birds are attracted to the structure provided by the facility or odour produced by feed. Pilchards being used as feed for the tuna aquaculture industry have been shown to attract scavenging seagulls in large numbers to these sites. These seagulls may be displacing local bird populations and some sites may also cause disturbance to migratory shorebirds (The Conservation Council of SA, website). An Honours thesis (Harrison 2003) conducted last year showed that silver gull populations at Port Lincoln have significantly increased to the point where they may cause social and environmental problems. This population inflation was largely attributed to the southern bluefin tuna industry. Silver gulls were found to be consuming 70 tonnes of tuna feed per year. Partly as a result of high quality and readily available feed at tuna farms, the number of breeding pairs has doubled from 10,200 in 2000 to 20,776 in 2003.

It may also be possible that seagulls are attracted to waste products discharged from land-based abalone aquaculture outlet pipes. Site inspections conducted by the EPA in 2001 found intact feed pellets at some farm effluent points. Gull excrement was also clearly visible on rocks near discharge points, but not visible on other rocks away from discharge points. Small fish may also be attracted to waste feed around outlet pipes, which in turn may attract gulls. If gulls continue to aggregate around discharge outlets, it may indicate that effluent treatment systems (e.g. settlement tanks) are required. Given the increasing problem with seagull numbers at Port Lincoln, it is possible that land-based abalone aquaculture may be contributing towards this issue. To date, there have not been any field investigations into the interactions of seagulls with land-based abalone farms in South Australia. However, casual observations by the authors on several site visits to Louth Bay abalone farms did not suggest seagulls were a problem, and they are certainly nowhere near the problem they are for the tuna industry. As a consequence, we consider this issue to be a low risk.

6 Conclusion

While there were some differences of opinion as to appropriate risk rankings for some issues, in general there was substantial agreement throughout the risk assessment process. Most differences revolved around whether an issue was a low or a moderate risk, with the additional comments by the abalone aquaculture industry and PIRSA Aquaculture tending to provide lower risk rankings than those provided during the initial risk assessment workshop. It was obvious throughout the initial workshop that participants struggled to determine a risk ranking for some issues due to a lack of knowledge in that area. As a result, a higher risk ranking was sometimes given to an issue based on the worst-case scenario. In addition, some issues were given a higher risk ranking based on consequences resulting from possible changes in policies or procedures that could occur in the future. Such instances are identified in the discussion, and if changes in operation do occur, then the primary risk ranking will need to be revised.

Sixty-two of the 78 issues discussed in the workshops were given a negligible or low ranking. The remaining 16 ‘priority’ issues were given a moderate or moderate to high risk ranking. No issues were ranked as an extreme risk. After reviewing the literature, most of the priority issues were changed to a low risk ranking. The only issues with a final ranking of low to moderate or moderate were impacts on sensitive habitats, erosion, and nutrients. However, all three of these issues are of concern at the individual facility level, rather than at regional or whole of industry levels. The impact on sensitive (terrestrial and marine) habitats is based on previous problems related to a farm that is no longer operational, on possible scouring of seagrass around pipes (Table 21) and on the potential for future developments to cause problems if sensitive habitats are not given adequate consideration in the planning process. The impact of erosion relates to beach erosion around pipes, which has reportedly occurred at several facilities (Table 21), while the nutrients issue is based largely on evidence of eutrophication found by the EPA in 2001 (Table 21). A number of construction related issues were also ranked as moderate during the workshop, but are not discussed here as they are not specific to aquaculture, and apply to all coastal developments. The remaining three marine-based issues addressed by the literature review were ranked as low risk (Table 21).

Currently, there are no research programs underway addressing the potential environmental impacts of abalone aquaculture, although PIRSA Aquaculture are in the process of developing protocols to address issues related to disease. The most important research needs are related to determining the effects of nutrient discharges on the environment, although the results of the 2003 EMP’s should be assessed before exact needs are determined. Other lower priority areas of research include:

- Effects of abalone farms on aggregation of birds.
- Potential for disease transmission from cultured stock to wild stock.
- The effects of settlement ponds on water quality.
- Seasonal variations in quality and quantity of nutrient and solid discharges.

Tighter management and/or reporting protocols may also be useful to reduce or better assess the consequences of several issues:

- Development of best practise construction protocols to minimise terrestrial impacts, including restoration of surrounding area after construction.
- Protocols to maximise chances of site rehabilitation after production ceases.
- Reporting of chemical use (type, amount, duration of use, discharge rates during use) as part of the EMP process.

Table 21. Final risk rankings for the 'priority' marine-based environmental issues identified from the risk assessment and industry workshops.

Issue	Final risk ranking	Specific reasons
The impact of land-based abalone aquaculture on sensitive habitats	Low to Moderate	▪ There are potential concerns related to seagrass loss if inlet/outlet pipes are located in seagrass meadows. ▪ This issue does not appear to be a current problem, but it is suggested that this risk remain low-moderate to ensure sufficient attention is paid to potential problems during the planning phase for future developments as the issue has seemingly not always been addressed sufficiently in the past.
The effect of water quality (nutrients) on the marine environment	Moderate	▪ A series of site inspections by the EPA revealed that most farm discharges showed some evidence of eutrophication. ▪ The moderate risk ranking reflects the need for further information, however, this may change after the 2003 EMP reports are submitted, depending on their results.
The impact of land-based abalone aquaculture on erosion	Moderate	▪ It appears that erosion has occurred at some facilitates around pipelines in the intertidal areas, and there is at least some potential for this to spread, especially during periods of storm activity. ▪ In order to minimise the risk in future developments, careful consideration needs to be given to the location of the pipelines.
The effects of water quality (feed and faeces) on the marine environment	Low	▪ Suspended solids are commonly low in abalone aquaculture effluent. ▪ Environmental effects associated with waste feed could be seasonal and requires further investigation. ▪ Improvements to feed conversion ratios have reduced excess solid waste. ▪ The effectiveness of settlement ponds in reducing solid waste needs further investigation.
Effects of diseases (including parasites) from the escape of cultured species on the wild stock of that species	Low	▪ At the present time broodstock are collected in local waters and as a result there are not likely to be any problems associated with the introduction of new diseases. ▪ Mudworms in Tasmania suggest that there is some risk of disease/parasite transmission to wild stocks in SA. ▪ If management practices change and permit the translocation of abalone from other states or overseas, the likelihood for disease transmission from cultured individuals to wild stock may increase. ▪ Any change in translocation policy with regard to interstate movements would only occur after a suitable risk assessment has been carried out and risk mitigation procedures instituted.
Impacts of land-based abalone aquaculture on the attraction/aggregation of species	Low	▪ From an industry point of view, the aggregation of seagulls around abalone farms is not large enough to significantly impact breeding or feeding of other bird species. ▪ Gulls have been observed aggregating around discharge outlets. If this continues, it may indicate that effluent treatment systems (e.g. settlement tanks) are required. ▪ Casual observations by the authors on several site visits to Louth Bay abalone farms did not suggest seagulls were a problem; as they are with some other aquaculture sectors.

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The authors greatly appreciate everyone who organised and participated in the Environmental Rish Assessment Workshops at SARDI Aquatic Sciences and Port Lincoln. In particular we would like to thank Carina Cartwright, Dr Micheal Deering, Ian Nightingale, Dr Rick Fletcher, Suzanne Bennett, and Daryl Evans.

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Appendix 1: Workshop attendees and invitees

Table A1.1a. List of invitees and attendees of the Land-Based Abalone Aquaculture Environmental Risk Assessment Workshop held at SARDI Aquatic Sciences on Wednesday 26th November 2003.

Name	Organisation	Attendance at the Workshop
Chris Ball	Australian Marine Conservation Society (Adelaide)	No
Simon Bryars	SARDI Aquatic Sciences	Yes
Carina Cartwright	PIRSA Aquaculture	No
Anthony Cheshire	SARDI Aquatic Sciences	No
Phil Czerwinski	Department for Administration and Information Services - Department for Aboriginal Affairs and Reconciliation	No
Micheal Deering	PIRSA Aquaculture	Yes
Serena De Jong	SARDI Aquatic Sciences	Yes
Simon Divecha	The Conservation Council of SA	No
Jon Emmett	Department of Environment and Heritage (Office for Coast and Marine)	No
Daryl Evans	South Australian Abalone Growers Association	No
Tony Flaherty	SA Marine & Coastal Community Network	No
Tara Ingerson	Environment Protection Authority	Yes
Brian Jeffries	Tuna Boat Owners Association	No
Tania Kiley	Environment Protection Authority	Yes
Stephen Madigan	PIRSA Aquaculture	Yes
Rachel Marsh	SARDI Aquatic Sciences	Yes
Sue Murray-Jones	Department of Environment and Heritage (Office for Coast and Marine)	Yes
Lorraine Rosenberg	South Australian Fishing Industry Council	No
Martin Smallridge	Seafood Council	No
Simon Stone	Environment Protection Authority Board	No
Jason Tanner	SARDI Aquatic Sciences	Yes
Noel Taylor-Moore	PIRSA Fisheries	No
Jeff Todd	Environment Protection Authority	Yes
Trevor Watts	South Australian Recreational Fishing Advisory Council	No
Kane Williams	PIRSA Aquaculture	No
Bruce Zippel	South Australian Aquaculture Council	No

Table A1.1b. List of attendees of the Land-Based Abalone Aquaculture Industry Workshop held at Pt. Lincoln on Thursday 22^{tnd} April 2004.

Name	Organisation
Simon Bryars	SARDI Aquatic Sciences
Adam Butterworth	SA Abalone Developments (SAABDEV)
Leigh Cunningham	Louth Bay Abalone
Daryl Evans	SA Abalone Growers Association
Andrew Foster	Kac Jousui Aquaculture
Bruce Green	Southern Australian Seafoods
Shane McLinden	SAM Abalone P/L
Ian Nightingale	PIRSA Aquaculture
Jason Tanner	SARDI Aquatic Sciences
Mandee Theil	SARDI Aquatic Sciences

Appendix 2: Component trees discussed in the workshop, but not reported here.

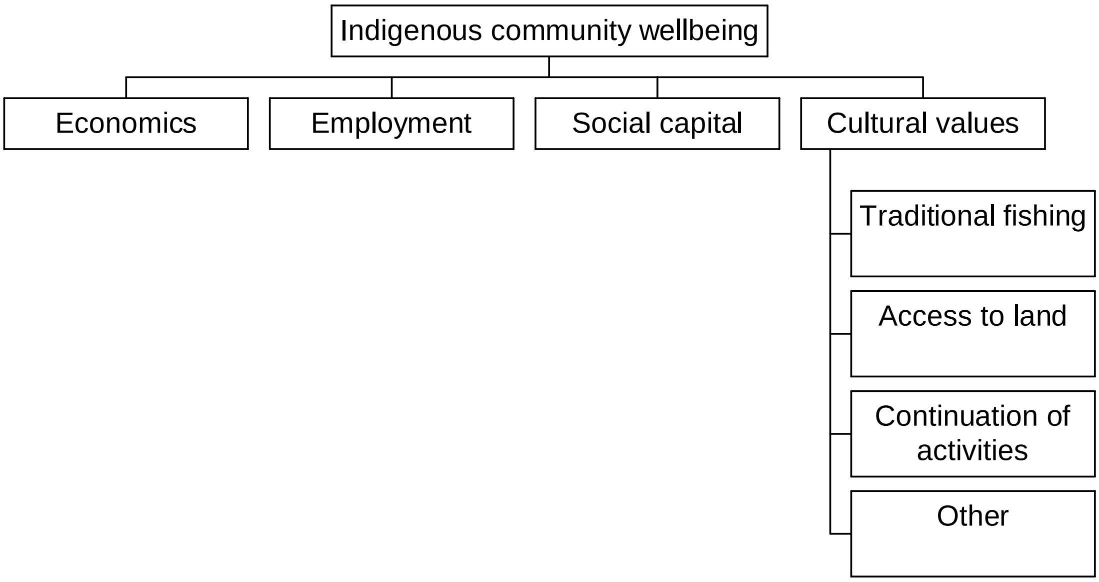

Figure A2.1a. Component Tree 4: Impacts of land-based abalone aquaculture to indigenous community wellbeing (modified from Fletcher *et al*. 2003).

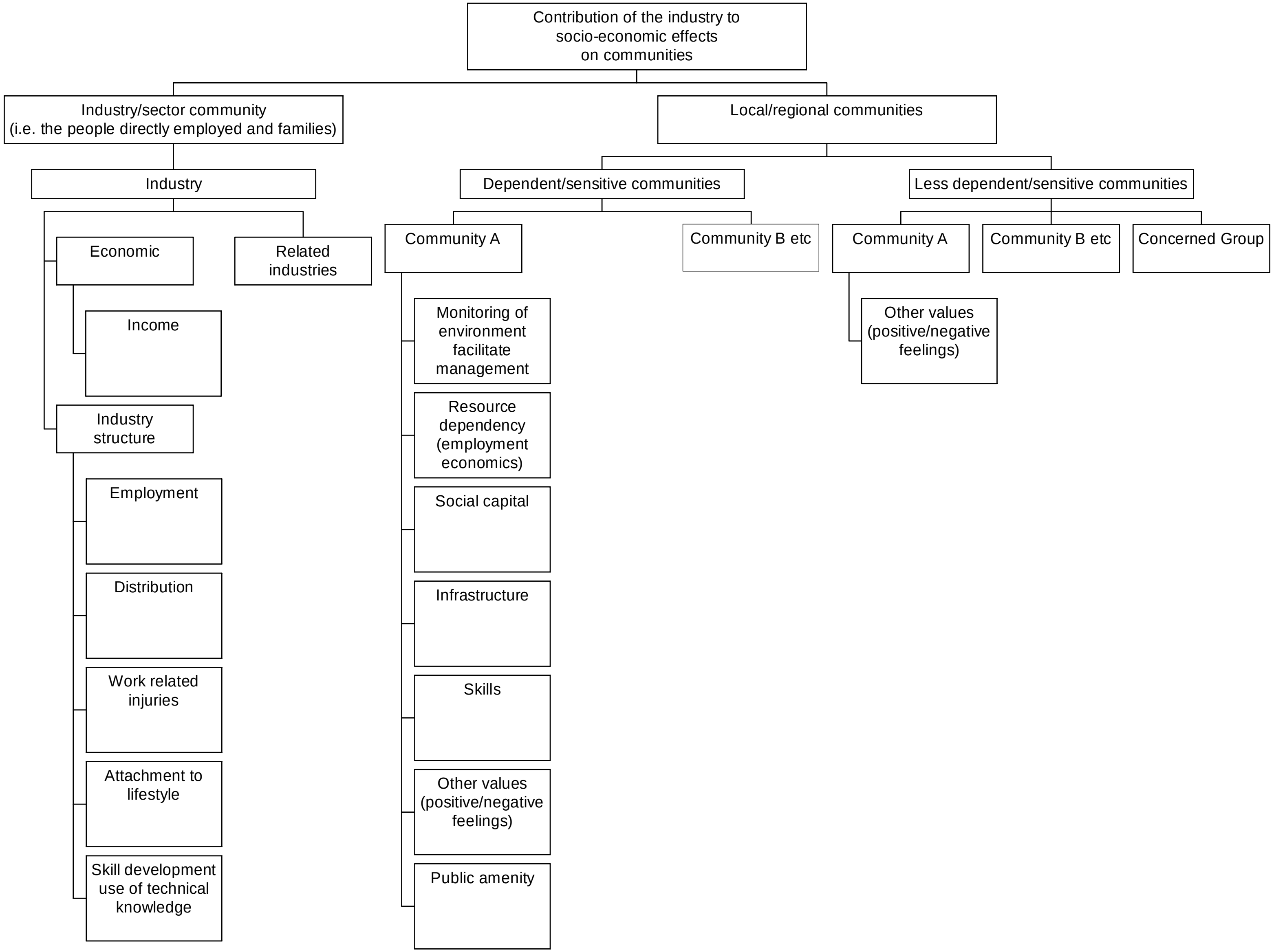

Figure A2.1b. Component Tree 5: Impacts of land-based abalone aquaculture industry to community wellbeing (modified from Fletcher *et al*. 2003).

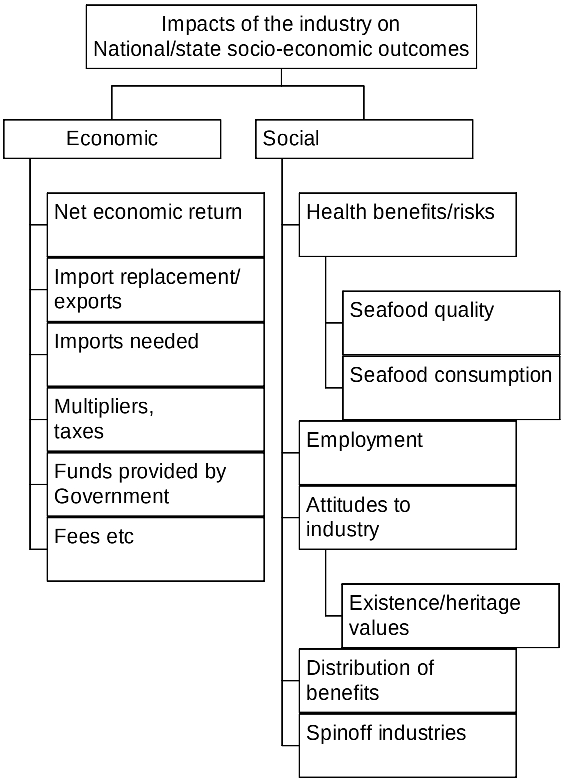

Figure A2.1c. Component Tree 6: Impacts of land-based abalone aquaculture on the National or State Socio-economic wellbeing (modified from Fletcher *et al*. 2003).

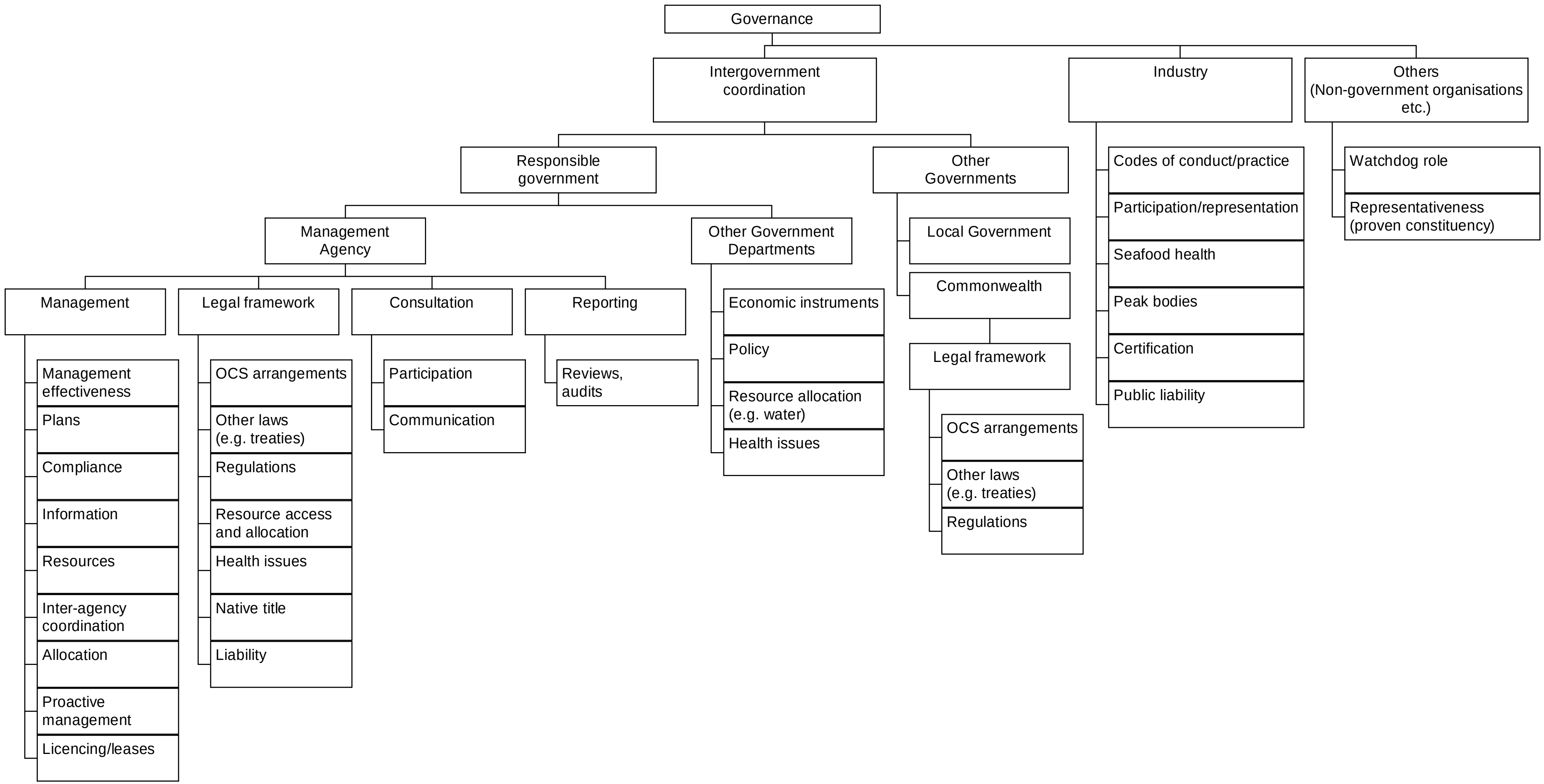

Figure A2.1d. Component Tree 7: Governance issues for land-based abalone aquaculture (modified from Fletcher *et al*. 2003).

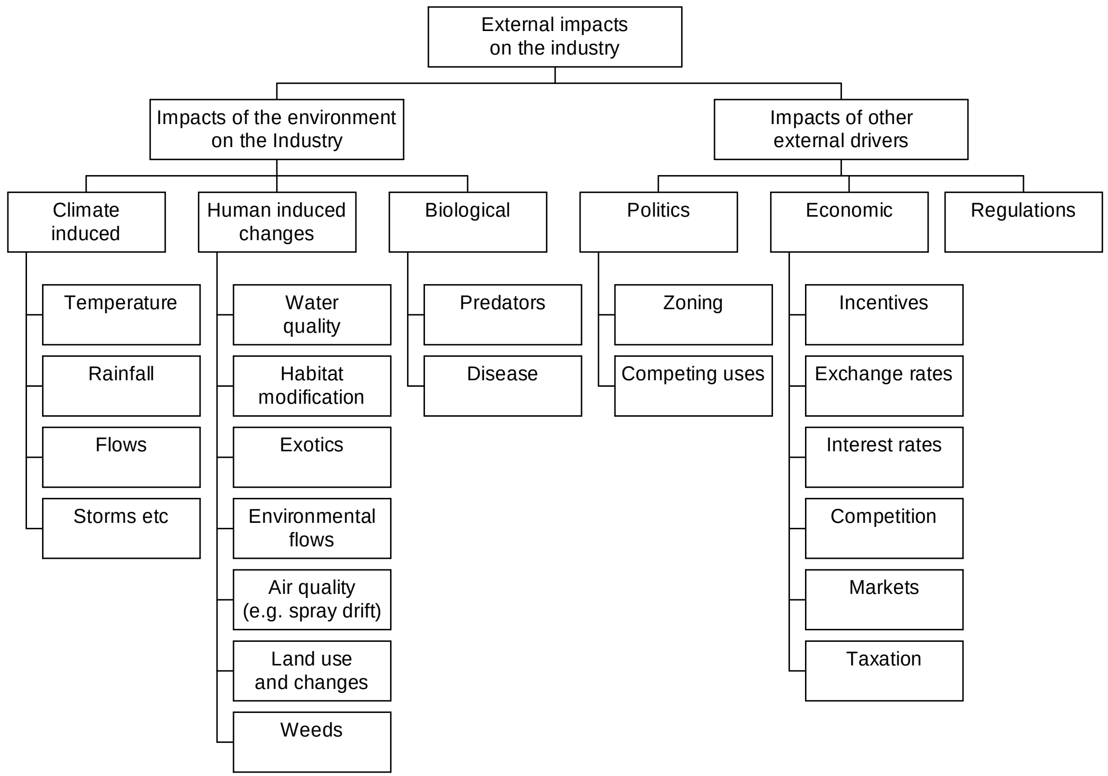

Figure A2.1e. Component Tree 8: External impacts on the land-based abalone aquaculture industry (modified from Fletcher *et al.* 2003).

Appendix 3: Summary of risk rankings for issues determined during the land-based abalone aquaculture risk assessment workshop

Table A3.1a. Risk rankings other than moderate for issues affecting the whole of the aquaculture industry (Component Tree 1). Key: C – Consequence level, L – Likelihood level, RV – Risk Value, RR – Risk Ranking. Additional comments on the summaries from the workshop were provided by Abalone Industry Association of SA Inc. Wherever possible the exact comments were included, however additional words and phrases have been included to improve readability and understanding.

Issue		C	L	RV	RR	Justification for ranking/Comments
Wild Stock						
Escape of Cultured Species	Genetics	0	-	0	Negligible	*What impact will the escape of cultured individuals have on the genetics of wild stock? What protocols (if any) are needed at the whole of industry level to minimise risk of genetic impacts on the wild stock from the escape of any cultured individuals?* ▪ While there are 4 meta-populations of abalone in South Australia, there is little gene flow between populations. As a result genetic impacts on wild stock on a "whole industry" level are negligible. ▪ Also, only first-generation abalone are grown from wild stock ie. there is no genetic modification. ▪ Any concerns relating to this issue are not likely to impact the entire population in the next 5 years and is more likely to be a regional issue. Eventually genes will be passed on to the entire population but this will take a long time.
						Additional comments: *Abalone Industry Association of SA Inc* ▪ It has been stated by land-based abalone operators that they have successfully reared fourth generation abalone that are the fastest growing male abalone that are used to fertilise eggs sourced from female wild stocks, hence there would be some level of genetic modification. In Victoria, some abalone farms have agreed to collect animals from 100 different areas in an attempt to breed "super" abalone. The risk ranking should be increased due to the potential problems that may be caused by the escape of cultured individuals.

	Competition (e.g. food and space)	0	-	0	Negligible	*Will the escape of cultured animals cause problems to the wild stock through increased competition for resources (eg food and space)?* ▪ Under current management practices the numbers of abalone escaping are negligible in comparison to those that are in the wild population, therefore impacts of the escaped abalone on the wild stock are also negligible. Particularly at a "whole industry" scale. ▪ If management practices change and allow the translocation of abalone from other regions the impacts of escapees on wild stock may change. ▪ This may be a problem if tiger abalone hybrids or 'super abs' are used. **Additional comments:** *Abalone Industry Association of SA Inc.* ▪ There are plans in place to breed "super" Abalone, therefore it should be of concern, and the ranking should reflect the potential risk of this occurring in the next 5 years or so.
Collection	Broodstock Collection	0	-	0	Negligible	*What management protocols are in place to ensure that the collection of the broodstock animals does not unduly affect the spawning stock size of the wild population?* ▪ The broodstock are generally collected within 5 km of the farms, however this can vary greatly with water temperature. In some cases they may be collected as far up as the gulfs. The time of year that broodstock are collected also varies greatly and is dependent upon success of spawning. ▪ Given that only 200 – 300 abalone are collected per farm from the wild population, there is not likely to be a very big impact on the wild stock. The numbers of broodstock collected by the abalone farmers is negligible compared to the numbers taken by commercial fishers.
	Seed Stock					*If the industry relies on seed stock, what protocols are in place to ensure these are not over harvested or unduly affect other fisheries on these species?* ▪ In South Australia seed stock are not collected therefore this issue is not relevant and has been removed from the component tree.
	Grow out Stock					*If the industry relies on collecting stock for grow out, what protocols are in place to ensure these are not over harvested or unduly affect other fisheries on these species?* ▪ This issue is not relevant and therefore has been removed from the component tree.

	Genetics	0	-	0	Negligible	*Will the collections of these individuals have any significant genetic impact on the species (most relevant if a relatively rare or endangered species is being cultivated by the industry)?* ▪ Given that only a small proportion of the wild stock are collected the impact at the "whole industry" scale is likely to be negligible. The impact of collection on the whole population is likely to be nil or very small at this scale. ▪ Limited impact on wild fishery.
Effects of Stocking, Restocking and Stock Enhancement on the wild stock of that species	Genetics	0	-	0	Negligible	*If restocking of the cultured species is an objective, what protocols have been used to ensure that this does not impact upon the genetic structure of the remnant wild stock population?* ▪ Current management policy requires that land-based abalone farmers require a permit to restock cultured individuals. ▪ Restocking trials have been conducted in the past. ▪ Restocking could be considered to take place when abalone are translocated from land –based aquaculture operations to farming in the sea in barrels. With current management in place it is unlikely that this type of restocking will have impacts associated with wild populations. ▪ If management practices change (ie. if artificial reefs are used to culture abalone) the risks on the genetic structure of the remnant wild stock may increase. However, it is likely to be more of a local issue rather than a "whole industry" issue. **Additional comments:** **Abalone Industry Association of SA Inc** ▪ What restocking trials have been conducted in the past and with what level of success or failure? ▪ What management practices are in place to eliminate the impacts associated with restocking, and are these appropriate. ▪ Apparently artificial reefs can be used to culture abalone currently. If this is the case, surely the risk ranking should reflect the potential risks on the genetic structure of the remnant wild stock.
	Disease (including parasites)	0	-	0	Negligible	*Will the release of cultured individuals increase the risk of disease introduction with the remnant stock?* ▪ See above.
	Competition (eg. food and space)	0	-	0	Negligible	*Will the stocking of individuals put the remnant wild stock at a competitive disadvantage by displacement?* ▪ See above.

Cultured Stock/businesses (Husbandry)						
Genetics		0	-	0	Negligible	*Are protocols necessary to ensure the genetic composition of captive broodstock is maintained at appropriate levels?* ▪ Under current management practices broodstock are collected from wild populations and there is no captive breeding. Consequently at the moment there are not any issues relating to changing the genetic composition of the captive broodstock. ▪ There may be some regional and local effects if there is inbreeding in a local area, but this is not likely to occur.
Disease		0	-	0	Negligible	*Are disease monitoring, surveillance and risk minimization programs needed to be applied across the whole of industry? Are programs needed to ensure that there will be identification of new diseases if they arise? What response plans have been generated to deal with a severe disease event?* ▪ There are currently no translocations between farms, but there has been in the past eg. Smith Bay stock from Louth Bay. This is subject to management arrangements ▪ There is current management of disease, identification and control. Translocations are only allowed with certification.
Disease		0	-	0	Negligible	*Could diseases from the cultured species be passed on to other fauna in the area, either through water or from escapes?* ▪ To our knowledge there are no known examples in South Australia of when disease has spread from abalone to other shellfish, however it was recognised that there may be a potential for other abalone species to be affected if this was to occur.
Other Species/Communities/Processes						
Escape of Cultured species (feral populations)						*If the species /population being cultured is not native, could they establish feral populations if they escaped?* ▪ This issue depends entirely on where the broodstock are collected from and is likely to be a regional or local issue if it was to occur.
Food Chain Impacts		0	-	0	Negligible	*If escapes occur, could these cause significant shifts in the food chain?* ▪ Given that a relatively small number of abalone are taken from the wild population, it is likely that the food chain will not be impacted.

Behavioural Changes & Impacts (eg. migratory species)		0	-	0	Negligible	*Is this type of industry (eg. structure used to house farmed individuals) likely to cause changes to behaviour of other species in the areas they are used? Is a whole of industry approach sensible (ie same types of impact likely to occur everywhere)?* ▪ There are impacts associated with the aggregations of seagulls around the farms as they are attracted to the feed, but this is a regional/local issue rather than a whole industry effect. ▪ There is a possibility that some migratory birds alter their behaviour in response to the farms but once again this is likely to be a regional issue. Similarly fish are known to aggregate at the discharge point, however this is more of a local or regional issue.
Threatened/ Endangered/ Protected Species		0	-	0	Negligible	*Is this type of industry likely to cause impacts on these categories of species? Are whole of industry approaches sensible (ie same types of impact likely to occur everywhere)?* ▪ Same as above issue, more of a regional concern.
Feeds Composition (source & sustainability)		0	-	0	Negligible	*Does the industry use feeds? If so, is the source of these feeds sustainable?* ▪ Manufactured feeds given to the cultured abalone are vegetable based (eg. soybean); as a consequence there are no foreseeable problems with sustainability.
Sensitive Habitats		0	-	0	Negligible	*Are there certain habitats that all of industry should avoid using or all of industry need to use a common approach to operate within?* ▪ The scale of farms is very small, so this is considered a local issue only and is not relevant at this scale.
Water Quality		0	-	0	Negligible	*Are there common standards for all of industry to use with regards to water quality? (e.g. to avoid poisoning customers)* ▪ The scale of farms is very small, so this is considered a local issue only and is not relevant at this scale.
Chemicals		0	-	0	Negligible	*Are there chemicals being used in the industry that require whole of industry approaches to their use?* ▪ The scale of farms is very small, so this is considered a local issue only and is not relevant at this scale.

Table A3.1b. Risk rankings other than moderate for issues affecting the Catchment/region (Component Tree 2). Key: C – Consequence level, L – Likelihood level, RV – Risk Value, RR – Risk Ranking. Additional comments on the summaries from the workshop were provided by Abalone Aquaculture Industry, PIRSA, and DAARE. Wherever possible the exact comments were included, however additional words and phrases have been included to improve readability and understanding.

Issue		C	L	RV	RR	Justification for ranking/Comments
Water use and Water Quality						
Nutrients	Background Levels	?	?		Negligible	*Are there issues associated with the background levels of nutrients in this area within incoming or receiving waters? If there is already a problem due to pre-existing industries then it is likely that no further additions will be tolerated. Similarly, if the incoming water is 'pristine', this may also affect what output levels will be allowed. These need to be identified.* ▪ Some regions where land-based abalone aquaculture is undertaken have high exchange rates with low nutrient levels. For example, Smith Bay contains low water nutrient levels, high exchange rates and no other inputs. PIRSA has 5 months of water quality data in Smith Bay, and none exceeded EPA guidelines. ▪ However, in Louth Bay water samples taken 5 years ago at a distance of 5 km and 3 km from the farm showed that the background levels exceeded EPA water quality guidelines. These already high nutrient levels mean that any addition of nutrients is likely to exceed water quality guidelines. Louth Bay also doesn't have very good exchange rates. ▪ There is a need for more information on background nutrient levels in the water and what these levels mean to the assimilative capacity in South Australian waters. Risk will vary between farms and is dependent upon background nutrient levels. The addition of nutrients from abalone aquaculture is likely to only be detectable at the farm level. ▪ A consequence and likelihood could not be assigned without further information. **Comments during industry workshop** ▪ Background levels of nutrients are within the EPA guidelines, however, some areas are more nutrient rich than others. For example at Louth bay there is much more water exchange than at Boston Bay, however, there has been no oceanographic work done to support this statement. Water quality data collected from farm outputs are equivalent to those found in an aquatic ecosystem. As a result, farm outputs have no impact on the ecosystem. ▪ Given that recent water quality data suggests that nutrient levels are not an issue, we suggest a negligible risk ranking is appropriate

	Industry Inputs	1	4	4	Low	*If the production by the facilities in the region results in a release of nutrients (either through outflow pipes or from losses in cages), a maximum/total amount allowable for the whole region may need to be set (this may need to be related to background levels).* ▪ May need to combine this and the previous issue (background nutrient levels) and then determine what the consequence is. ▪ More information is needed on the quantity of nutrients the farms actually input into the region. It is likely that if background levels are already above the assimilative capacity then the addition of further inputs may have greater consequences than in areas where there are low background nutrient levels. ▪ It is likely that it will not be possible to detect higher nutrients from farm outputs in the water at the Bay level.
					Negligible	**Industry comments:** ▪ Given that recent water quality data did not detect nutrient levels above the EPA guidelines, this issue is ranked as negligable.
	Nutrient Removal					*If the facilities produce filter feeders, their concentration may result in a reduction of nutrients in the surrounding waters, the total impact of all facilities may need to be assessed.* ▪ Abalone are not filter feeders therefore removed from the component tree.
	Distribution of load	0	-	0	Negligible	*In addition to total nutrient inputs, is there a specific issue related to where in the catchment/region these inputs should, or should not, be occurring? (eg. not next to swimming beaches; sensitive habitats)* ▪ The discharge of water should not be positioned next to reef or seagrass habitats such that they may be impacted. With current management in place this would not take place. Discharge pipes should not be placed next to sensitive habitats. ▪ At any one region there are only a few farms aggregated. Two farms together in Smith Bay, three farms together in Louth Bay.
Sedimentation		1	4	4	Low	*Can the collective amount of material released/escaping/dropping from the structures cause a problem for the catchment from sedimentation? Ie. How much of this material can there be in an area to allow for natural flushing to remove it?* ▪ The water that is discharged from the land-based abalone farms is relatively clear and free of sediments. In the past some measurements of sedimentation have been taken – results indicate that some values were found to be above the EPA guidelines (but unsure if this was due to the abalone farm). ▪ Conclusion: Sedimentation is possibly detectable at the bay level.

					Low	**Industry comments:** ▪ Any sediment that is discharged from the pipe settles out within 4-5m of the outfall. Some farms have evidence of build up at the outfall. ▪ The EPA has found sediment levels to be equivalent to background levels, thus we have no problem.
Other Wastes/Pollutants (eg. chemicals)		1	3	3	Low	*Are there any issues associated with the release of other pollutants/wastes (eg. chemicals) at a scale that need to be managed at the entire catchment/region?* ▪ Some of the chemicals that are used in land-based abalone aquaculture include chlorine, disinfectants, benzocaine (anaesthetic) and antibiotics. ▪ Only very small amounts of chemicals are used and there are only ever a few farms close together so the impact is likely to be very small. The risk value given to this issue in the workshop was said to be a cautious value or an overestimation of the true risk, but the chemicals may be detectable at the bay level.
					Low	**Industry comments:** ▪ Given that minor amounts of chemicals (e.g. chlorine is used in the hatchery at 5ppm) are used and 8 mega litres of water is released daily, it is impossible to detect chemicals used on the farm. We need more information on the longevity of the different types of chemicals we use so we can relate this to levels we use and calculate dilution factors. As a result, we can get a clear picture of which chemicals are more likely remain in the water column at detectable levels. ▪ Antibiotics have been detected but we need to know which ones are the most dangerous and why.
Flow (hydrology/ oceanography)		0	-	0	Negligible	*Could the collective impact of the facilities affect the flow of water within the embayment? (eg. too many cages close together could impede water flushing rates)* ▪ There is some modification of flow through the existence of the intake and outlet pipes, however this is more likely to be a local issue.
Water Extraction (eg aquifers)						*If freshwater is removed, does an upper limit for the catchment need to be set for all such removals?* ▪ Freshwater is not used and therefore this issue was removed from the component tree.
Seepage (eg salinisation)		0	-	0	Negligible	*If the facilities are using land-based ponds, would seepage of the water (eg saltwater) affect the surrounding water table, soil?* ▪ One farm at Smith Bay contains a sediment pond that is 100 m from the foreshore, so seepage might be an issue. However it is a local issue and therefore given a value of zero. ▪ This is not a problem when farms are on the beach because the ground water is already saline.

Ecological Community Structure & Biodiversity						
Plankton (eg. blooms)		1	3	3	Low Negligible	*If the facilities increase the nutrient load could this lead to plankton blooms and/or is there the need to monitor this region for toxic species?* ▪ It is possible that the addition of nutrients or a change in balance may initiate the development of an algae bloom. This is likely to be related to nutrients, which was given a risk value of 4 (low). ▪ There are blooms of algae in these areas anyway. **Industry comments:** ▪ Nutrient levels are not high enough to create algal blooms and if a bloom did occur it may be due to many other factors. We need to sustain these low levels of nutrients to maintain public perception of abalone aquaculture.
Benthic Communities		0	-	0	Negligible	*Could all activities result in catchment wide changes to the benthic communities such as from total levels of sedimentation (ie smothering benthic organisms), or from shading or turbidity (decreases in light intensity), or from increased nutrients and algae smothering seagrass?* ▪ More of a local issue, therefore given a value of 0.
Aquatic Vegetation		0	-	0	Negligible	*This is similar to benthic communities but allows for some differentiation – such as with intertidal vegetation, not directly under the structures etc.* ▪ More of a local issue, therefore given a value of 0.
Terrestrial Vegetation		0	-	0	Negligible	*How much terrestrial vegetation is "allowed" to be removed/affected by the construction/operation of all the facilities within the catchment.* ▪ More of a local issue, therefore given a value of 0.
Listed Migratory Species		0	-	0	Negligible	*Are there listed migratory species that frequent this area? If so, what protocols need to be employed by all facilities within the area?* ▪ More of a local issue, therefore given a value of 0.
Threatened/ Endangered/ Protected Species		0	-	0	Negligible	*Do any of these species interact with any facilities in the region? If they do, what protocols need to be employed by all facilities within the area?* ▪ More of a local issue, therefore given a value of 0.
World Heritage RAMSAR/MPAs		0	-	0	Negligible	*Are any of these types of zones present in the area? If there are, what special arrangements etc are needed to meet their requirements?* ▪ This is not a major issue at the moment as there are no MPA's in the immediate areas of the farms. In addition, given that environmental impacts in the catchment are generally considered to be fairly low, then this is not really an issue. ▪ It would be preferable not to have any farms in the middle of a MPA.

Behavioural Changes to Species		0	-	0	Negligible	*Are the facilities in the area likely to significantly alter the behaviour of individuals – either attracting them or repelling them from the area?* ▪ Seagulls are attracted to the abalone farms, however this is more of a local issue.
Translocation between Catchments						*Are there any translocation policies or protocols that need to be considered by all facilities in the region who may be importing or exporting live product/seed stock/larvae etc into or out of the region?* ▪ This component was removed from the tree and replaced by components for diseases and genetics which were felt could cover issues associated not only with translocations but also escapements, breeding programs, farming practices, etc.
						Additional comments: **PIRSA** ▪ It is understatement that there is 'some' management of translocation (see page 16 comments). The consequences would depend on the disease, not all diseases that could take hold in a farm would have 'severe' consequences if released into the wild. The risk within the farm is low, the risk to wild stocks is negligible.
						Industry comments: ▪ Current management practices ensure that all abalone translocated within bays and across farms are health checked. Currently, there is no exchange of Abalone with the offshore industry and there is a ban on importing overseas stock. ▪ We need to look at individual disease agents and sum up the likelihood of an outbreak. ▪ Under current management practices the likelihood of a disease outbreak is low, but the consequences would be high.
Genetics		1	4	4	Low	*Are there any genetics issues associated with translocations, escapements, breeding programs, farming practices, etc?* ▪ Juvenile abalone can be found aggregated around the outlet pipes of abalone farms. These aggregations are very confined and while it is possible these abalone have escaped from the farms this has not been confirmed. If these aggregations are a result of escapes it is likely that there will be a minor change in the genetic diversity of the local populations, however it is not known how far the abalone move away from the pipes and what their interactions are with wild populations. ▪ Under current management policies the abalone that are cultured are not genetically modified so the risk associated with a change in genetic diversity is fairly low. ▪ If management practices change and translocations are allowed this issue will need revisiting.

					Low to Negligible	**Industry comments:** ▪ Breeding stock is collected from the local area, so if abalone escape from farms they will be of the same species. Also, escapees are not expected to survive because they become adapted to farm conditions, which are different habitat to their natural environment. Abalone that has escaped can be found no more than 5m from the outfall. ▪ We are selecting faster growing specimens through a breeding program which may influence the wild stock if they escape. It is also highly unlikely that fertilised eggs could escape the farm and settle and survive in the natural environment. ▪ There is not a huge amount of Abalone in a bay that could be affected. Each bay has distinct genetics because Abalone do not move far; they have little dispersal from their parental reef. Follow up Brown and Murphey's study.
Physical Structures, Construction & Tenure						
Number & Size of Farms						*Are there any limitations/expectations/concerns regarding the total number of farms, the maximum size of any one farm or the total area occupied by all farms/leases within the region?* ▪ This was not considered to be an environmental issue but more of a social issue and therefore removed from the tree. Environmental issues (eg. discharge) are addressed elsewhere. ▪ At the moment there are only three farming sites with only a few farms at each of these sites. ▪ Under current management practices there are no concerns regarding a large expansion in land-based abalone aquaculture. The number of farms may increase but this process will take time.
Habitat Removal		0	-	0	Negligible	*Is there a total limit on how much habitat of one or more types that can be removed within the region for this type of industry/all industries?* ▪ At this stage there are only a small number of farms and farm numbers are not likely to significantly change in the next five years.
Alienation/Loss of Visual Amenity or Access to Area						*Are there any concerns about the total loss of area for other activities or from the impact on visual amenity? Do you need limits on the areas lost, the structures used or the level of access still possible?* ▪ This is more of a social issue although there may be some problems at Smith Bay as it is so small. This issue was removed from the component tree.
Heritage Value						*Are there any areas of heritage value that may be affected – old buildings, historical sites and places of significance?* ▪ Social issue only and therefore removed from the tree.

						Additional comments: ***DAARE*** ▪ It needs to be stated clearly that many sites of Aboriginal significance, protected from damage under the *Aboriginal Heritage Act 1988,* are found along the coastline. Therefore there is a need to consult with Aboriginal heritage committees and DAARE regarding this culturally sensitive zone. ▪ Sit is suggested that in early stages of any aquaculture planning the local Aboriginal heritage committee is consulted with, and also DAARE is contacted regarding the presence or absence of sites on the DAARE Central Archive in a specified development area.
Acid Sulphate Soils		0	-	0	Negligible	*If acid Sulphate soils are in the region, have they been mapped appropriately and what protocols are needed to ensure they are not disturbed by the construction of any facilities in this region or what areas need to be avoided?* ▪ This is a local issue, due to the small number of farms.
Water Table		0	-	0	Negligible	*What overall restrictions/problems (if any) are there for the water table. Will it impact on what and where constructions can occur and what can be extracted or discharged?* ▪ Local issue only due to the small number of farms.
Navigation		0	-	0	Negligible	*Will the collection of structures from all the facilities pose a navigation hazard or benefit for the region? Are there any requirements for all facilities to understand within this region?* ▪ Land-based abalone aquaculture does not pose as a problem for navigation. Buoys are positioned where the outlet pipes are located, however the number of farms is very low in each region.
Infrastructure						*What constraints will there be from current infrastructure (eg. roads, power, etc), what benefits will there be from the need to construct these items?* ▪ Non-environmental issue so removed from the component tree.
Site Constraints (eg waves, current etc)						*Does the region have particular constraints (eg wave height, strength) that make it suitable or unsuitable for the facilities proposed?* ▪ Non-environmental issue so removed from the component tree.
Noise		1	4	4	Low	*Do the facilities produce significant noise levels?* ▪ There is some potential for noise pollution at Smith Bay – small regions with two farms and two generators.
						Industry comments: ▪ Farms are situated on big holdings and comply with EPA decibel guidelines, therefore the risk ranking should be down graded to negligible. There is also no residential housing in close proximity to farms.

Production						
Regional Carrying Capacity		0	-	0	Negligible	*Is there likely to be a maximum level of stocking (particularly for filter feeders) within the catchment /region – to avoid stunting of growth, increased disease risk, etc?* ▪ Not relevant for abalone farms. ▪ The difference between assimilative capacity and carrying capacity needs to be clarified.

Table A3.1c. Risk rankings other than moderate for issues impacting at the Individual Facility level (Component Tree 3). Key: C – Consequence level, L – Likelihood level, RV – Risk Value, RR – Risk Ranking. Additional comments on the summaries from the workshop were provided by Abalone Aquaculture Industry, and PIRSA. Wherever possible the exact comments were included, however additional words and phrases have been included to improve readability and understanding.

Issue		C	L	RV	RR	Justification for ranking/Comments
Construction						
Habitat Effects	Marine	1	6	6	Low	*Will any marine habitat have to be removed or affected by the construction; development; expansion of the facilities? This includes the construction of cages and also other infrastructure. If there will be some removal, does the proposed level fit in with the total amounts allowed to be affected within this catchment?* ▪ Marine impacts associated with construction or expansion of the abalone farms are not as great as terrestrial impacts. Pipes only occupy a very small area of the seafloor.
					Low	**Industry comments:** ▪ Construction is likely to have a small impact on the marine environment, but the consequences would be low.
Seepage		3	1	3	Low	*Will the type of construction allow seepage of materials, eg. saltwater from ponds into neighbouring areas?* ▪ All sediment ponds are lined with the exception of one at Kangaroo Island. Current development requirements mean that all future sediment ponds must be lined. Applications that have proposed non-lined sediment ponds are no longer approved. ▪ Under current management the risk is low but there are many unknowns. It is very site specific.
					Low	**Industry comments:** ▪ The only topic mentioned here was salt water seepage.
Shading						*Will the construction of the facilities result in shading of some areas (eg. seagrass from cages/racks etc)?* ▪ This issue is not relevant and therefore removed from the component tree.
Acid Sulphate Solis		?	?	?		*Is the area prone to acid sulphate soils? If it is, what processors will be used to ensure that this does not get activated on this site?* ▪ This issue is very much site specific and therefore it is very hard to allocate a risk value to it. It is also an issue that should be picked up during the application stage of a proposal. ▪ Acid sulphate soils have been mapped but not at a small enough scale that can be related to specific farms.

Water Flow						*Will the construction of the facilities interrupt water flow within the region? (may need to refer to whole of catchment)* ▪ There is not enough rain in South Australia to warrant further consideration of this issue therefore it was removed from the component tree.
Navigation						*Will the structures pose a navigational hazard or benefit? (may need to refer to whole of catchment)* ▪ Vessels may be used to install the intake pipe but this is not considered a real issue and therefore removed from the component tree.
Flood Plain						*Will construction impact upon the flood plain?* ▪ Not applicable to coastal abalone farms in South Australia and therefore removed from component tree.
Alienation						*Will the construction of the facilities alienate other groups (eg. indigenous, recreational and commercial) from using an areas that they previously had access to?* ▪ Not an environmental issue and therefore removed form the component tree.
Proximity to Sensitive Faunal Regions		?	?	?		*Is the proposed facility close to an area where there are sensitive fauna or other regions of particular value?* ▪ Planning issue and totally site specific, therefore a risk value was not given to this issue.
Proximity to Users						*How close is the facility to markets?* ▪ This is an economic issue and therefore was removed from the component tree.
Water Table						*Will the construction of the facility have an impact on the water table (other than associated with ASS – may need to refer to whole of catchment)?* ▪ No impact with the water table, therefore removed from the component tree.
Physical Disturbance (trampling, boat use)						*Will construction of the proposed facility impact on the surrounding environment through physical disturbance (eg. trampling, boat use)?* ▪ Not relevant with land-based abalone farms and therefore removed from the component tree.
Infrastructure						
Shading (eg. pipe)		0	-	0	Negligible	*Will the infrastructure of the facilities result in the shading of some areas?* ▪ This issue is not that relevant with this type of aquaculture, except with regards to the outlet pipe. The outlet pipe is likely to affect a very small area and impacts are not likely to be long term. ▪ There are regulations about shading as a result of pipelines. Shading is likely to occur on one side of the pipe but not affect a very big area.

Artificial Habitat		0	-	0	Negligible	*Will the infrastructure of the facilities act as an artificial habitat?* ▪ The pipe is likely to act as an artificial habitat, but it does not pose as a threat. Artificial habitat could be seen as beneficial in areas with no reef habitat. The surface area of pipes is very minor. ▪ Farmers have been known to clean the girds at the outlet end of the pipe to remove any biofouling organisms.
Scouring (eg. Pipe)		1	4	4	Low	*Will the infrastructure of the facilities result in scouring of some areas?* ▪ At times there can be underwater erosion or scouring at the beach where the pipe comes out of the water and this is likely to have a very minimal impact. There may also be some underwater scouring due to water movement around the pipes. Again the total surface area of the pipes is very small.
					Low	**Industry comments:** ▪ There has been no evidence of scouring as a result of pipes on the beach, however, Kangaroo Island has experienced some erosion under pipes. This erosion could just be natural fluctuations in sand movement.
Entanglements						*Could the infrastructure result in entanglements of whales or other large/protected species?* ▪ Not relevant for land-based abalone aquaculture and therefore removed from the component tree.
Visual						*Do the facilities need to meet any visual impact limitations?* ▪ Social issue and therefore removed from the component tree.
Water Flow						*Will the infrastructure of the facilities interrupt water flow?* ▪ This relates to fresh water and is irrelevant to land-based abalone farms and therefore removed from the component tree.
Navigation		0	-	0	Negligible	*Will the infrastructure of the facilities pose a navigational hazard or benefit?* ▪ Marker buoys are positioned at the outlet pipes but the area of coverage is very minor.
Coastal Processes		1	4	4	Low	*Could infrastructure of the facilities impact upon coastal processes?* ▪ May include issues like sand movement. This should be managed in the planning phase of development.
					Low	**Industry comments:** ▪ Refer to comments above on scouring.

Threatened Species		3	1/2	3/6	Low Negligible	*Could the infrastructure of the facilities impact upon local threatened or endangered species?* ▪ This is very much a site specific issue and a list of those species that are endangered, protected or vulnerable within a given area is needed. In some areas the impact of abalone aquaculture on threatened species could be severe, but under current management is remote to rare. This issue should be addressed at the planning stage. **Industry comments:** ▪ We have no knowledge of any farm interfering with a threatened species. This is considered during the planning phase.
Biofouling		0	-	0	Negligible	*Could the infrastructure promote biofouling? Is biofouling removed from structures used in the facility?* ▪ The impacts associated with biofouling is likely to be negligible. There will be some biofouling on the pipes however this is likely to have a very small biomass.
Operation						
Stock	Health					*Is health surveillance monitoring system needed? (may need to refer to whole of industry)* ▪ Not an environmental issue (more a farm management issue) and therefore removed from the component tree.
	Stocking Density	?	?	?		*Is there a sensible limit to the stocking density (or biomass level) of individuals within the facility that affects growth/survival etc?* ▪ If stocking densities are too high there would be a risk associated increased disease.
	Animal Welfare					*Is there any relevant animal welfare legislation that needs to be incorporated into the husbandry techniques used within the facility? (may need to refer to whole of industry)* ▪ Removed from the component tree.
	Predation					*Are predators (eg. birds, seals, sharks) a problem around this facility? If these predators are protected species this may result in different actions being necessary.* ▪ Removed from the component tree.
Input Associated Impacts	Water					*Does the operation of the facilities use significant amounts of fresh water?* ▪ Facilities do not rely on freshwater and therefore this issue is irrelevant and has been removed from the component tree.
	Air					*Does the operation produce greenhouse gases, other air pollutants, smells?* ▪ This component has been moved to Output Associated Impacts.

	Energy					*What is the energy consumption for the facility and what is the energy efficiency rating?* ▪ This issue was considered irrelevant at the scale of farm operations and therefore was removed from component tree.
	Feed					*What risks are there associated with the input of feed?* ▪ Unsure of the meaning of this issue and how it could be related to abalone farming and therefore it has been removed from component tree.
	Chemicals/ Theraputants					*Will the facilities contribute large amounts of chemicals to the area? If so, what impacts will these chemicals have? Can anything be done to minimise the volumes of chemicals used?* ▪ Chemicals as an environmental issue is covered by Output Associated Impacts and has been removed from this branch of the component tree.
	Water Quality: Nutrients - Epiphytes & Macroalgae	1	5	5	Low	*Is the outfall causing increased epiphytes on seagrass and/or abundance of macroalgae?* ▪ With increases in nutrients it is possible that epiphytes will grow on nearby seagrass communities. Macroalgae (such as ulva) may also grow in the general area on the sediments. Ulva growth along the shoreline has been observed at some outlets. More information is required on the impacts of epiphytes on seagrass. Industry comments: ▪ Nutrient levels are within the water quality criteria and there is no evidence of seagrass deteriation in the area.
	Water Quality: Sediments	?	?	?		*Does the operation result in the sedimentation of solids? If yes, refer to appropriate levels for the catchment.* ▪ Same as above (Water Quality Nutrients - *Environment) but not able to give a risk value with the present state of knowledge.* **Additional comments***:* PIRSA ▪ PIRSA Aquaculture is developing a medicine use policy in conjunction with the EPA. Use of any chemical or medicine requires permission from PIRSA and conditions are issued based on toxicity, release concentrations and dose. The last point regarding rate of use is already included for most substances in the Aquatic Animal Health Unit medicine/chemical use approval database. **Industry comments:** ▪ Chlorine is not often used to eliminate algal growth but to sterilise/disinfect hatchery tanks. We need more information on the volume of chemicals used.
	Air Quality	0	-	0	Negligible	*Does the operation produce greenhouse gases, other air pollutants, smells?* ▪ The component has been moved from Input Associated Impacts to where it is now. ▪ Generators will produce some emissions.

	Fish Disposal	1	5	5	Low	*Do any deaths of individuals of the cultured species occur? Are there processes to dispose of these?* ▪ The PIRSA licence conditions outline that dead abalone must be disposed of correctly, however it is suspected that this may not always be the case. This may be a problem if large volumes of dead abalone are disposed of incorrectly.
					Low	**Industry comments:** ▪ We are not allowed to dump dead abalone into the sea, however, our license agreement changes year to year - once we had to remove dead fish from the site. What are the guidelines for disposing of dead fish?
	Processing Wastes	1	5	5	Low	*Is there any processing of product done on the facility? What happens to the waste?* ▪ Some of the processing is done on the site and some of the same issues arise that were brought up in the previous issue. This may be a potential problem if large amounts of processing occur at a given time.
	Sewage Effluent	0	-	0	Negligible	*Does the facility have appropriate sewage treatment?* ▪ Issues relating to human sewage are picked up in the planning phase of development. It is likely that septic tanks are used.
	General Rubbish	1	5	5	Low	*Are there protocols for the management of general rubbish within the facility?* ▪ Under current management regulations fines (or loss of licence) can occur if general rubbish is not disposed of correctly. Although these fines are in place the scale of the fines has not been set. It is a licence condition to dispose of rubbish correctly. ▪ An EPA audit found that plastic and feed bags were a problem at the farm.
					Low	**Industry comments:** ▪ We are aware of the problems associated with feed bags and as a result have developed a "buy back" strategy with the suppliers. We also continually strive to keep our properties tidy and free of rubbish.
	Escapement - Genetics	1	4	4	Low	*What protocols are needed at the facility level to minimise the risk of disease transmission to the wild stock from the escape of cultured individuals?* ▪ See comments on Genetics in Component Trees 1 and 2. ▪ The risk of escapement altering the genetics of wild populations is higher at the local level.
					Low	**Industry comments:** ▪ See comments on Genetics in Component Trees 1 and 2. ▪ We agree that the risk of escapements altering the genetics of wild populations is higher at the bay level.
	Escapement - Ecosystem	0	-	0	Negligible	*What are the ecosystem impacts of escapement?* ▪ See comments on Food Chain Impacts in Component Tree 1.

	Biofouling	1	5	5	Low	*Is biofouling removed from the structures used in the facilities? If so, what happens to this material when it is cleaned off?* ▪ Biofouling on cages around the intake pipes can require cleaning but the amount of material cleaned is very small.
					Negligible	**Industry comments**: ▪ There is no evidence to suggest that fouling accumulates and causes problems at the intake. If fouling does occur, it is in minimal amounts and becomes dispersed easily due to wave action.
	Noise	1	4	4	Low	*Will the facilities result in an unacceptable increase in noise to surrounding areas?* ▪ Possibly an issue but farms are usually situated in remote locations. The main problem is the noise from generators and pumps.
					Negligible	**Industry comments:** ▪ Noise created by generators and pumps are rarely heard off site because they are situated in pits or surrounded by concrete.
	Entanglements					*Could the facilities result in entanglements of whales or other large/protected species?* ▪ Not relevant so removed from the component tree.
	Physical Disturbance (eg. boat use, moorings)					*Will the operation of the facilities result in physical disturbance of nearby environments?* ▪ Not relevant so removed from the component tree.

Table A3.1d. Risk rankings for the impact of the environment on the industry (Component Tree 8). Key: C – Consequence level, L – Likelihood level, RV – Risk Value, RR – Risk Ranking. Additional comments on the summaries from the workshop were provided by the Abalone Aquaculture Industry. Wherever possible the exact comments were included, however additional words and phrases have been included to improve readability and understanding.

Issue		C	L	RV	RR	Justification for ranking/Comments
Impacts of the Environment on the Industry						
Climate	Temperature	3	5	15	High	*Will alterations in the climates temperature significantly impact on the success of the industry?* ▪ The water temperature in South Australia (where farms are currently located) is close to the abalones upper temperature tolerance. If water temperatures were to increase significantly there is a potential for the whole industry to be wiped out. Mass mortalities have occurred due to higher than average temperatures in some years. ▪ There are some management strategies in place eg. changes in tank design and there is also potential to move to other areas.
					High	**Industry comments:** ▪ We agree that temperature increases are a huge risk to the industry
	Rainfall					*Will alterations in rainfall significantly impact on the success of the industry?* ▪ There is generally low rainfall in South Australia and the tanks are covered. This issue is not relevant and therefore has been removed from the component tree.
	Sea level change	3	1	3	Low	*How would sea level change impact on the industry and what are the risks associated with this?* ▪ Sea level change is not a huge threat at the moment but it is possible in the next five years. It is generally a long-term issue and while possible, is not likely to be an issue in the next five years.
Human Induced Change	Water Quality	3	4	12	Moderate	*What are the risks associated with human induced changes associated with water quality (eg. oil spills)?* ▪ The land-based abalone aquaculture is reliant upon good water quality. Algal blooms may clog filters which may be human induced and have the potential to momentarily stop production. ▪ Human induced changes in water quality (eg. as a result of an oil spill) may have severe consequences for abalone farms.
	Habitat Modification					*How would habitat modification impact on the operation of the facilities?* ▪ The abalone are not cultured in their natural environment and therefore this issue has been removed from the component tree.

	Exotics	3	5	15	High	*What are the risks associated with exotic introductions?* ▪ There is a potential for translocation (via oyster spat) of the mud-worm which comes from Tasmania. The mud-worm causes abalone mortality and is expected to reach South Australia in the future. It is likely to reach SA in 5 years time and is almost certain within the next 100 years. There are currently management protocols in place for the translocation of oyster spat. ▪ There is also concern regarding the potential for translocation of exotic species via ballast water. Ballast water introductions are likely considering that there are currently no restrictions for ballast water for interstate movement.
	Environmental Flows					*What are the risks associated with environmental flows?* ▪ Not an issue in South Australia and therefore removed from the component tree.
Impacts of other Drivers						
Social	Attitudes					Social issue and not covered in the workshop.
Economic	Fuel Price					Social issue and not covered in the workshop.
	Exchange Rates					Social issue and not covered in the workshop.