Determining the risk that Southern Rock Lobster fishing and other recreational and commercial fishing activities act as a vector of transmission of Abalone Viral Ganglioneuritis (AVG)

Project Report

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In submitting this report, the researcher has agreed to FRDC publishing this material in its edited form.

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Acknowledgments

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Abbreviations

AbHV	Abalone Herpesvirus
AQUAVETPLAN	Australian Aquatic Veterinary Emergency
AVG	Abalone viral ganglioneuritis
COP	Code of Practice
FRDC	Fish Research and Development Council
HaHV-1	Haliotid herpesvirus-1
nm	nautical miles
OsHV-1	Oyster herpesvirus-1
PCR	polymerase chain reaction
POMS	Pacific Oyster Mortality Syndrome
RA	risk assessment
SA CZAF	South Australia central zone abalone fishery
SA SZAF	South Australia southern zone abalone fishery
SA SZRL	South Australia southern zone rock lobster
SA WZAF	South Australia western zone abalone fishery
SRL	Southern Rock Lobster
VIC CZAF	Victoria central zone abalone fishery
VIC EZAF	Victoria eastern zone abalone fishery
VIC SZRL	Victoria southern zone rock lobster
VIC WZAF	Victoria western zone abalone fishery
WOAH	World Organisation for Animal Health

Executive Summary

Background

The abalone industry is one of the most valuable wild catch fishing industries for Victoria and South Australia, though it has declined recently through disease and competition from Chinese aquaculture. It has been impacted by the devastating emerging and re-emerging disease, abalone viral ganglioneuritis (AVG), caused by the *Haliotid herpesvirus-1*. After initial outbreaks in wild and farmed populations in Victoria and Tasmania between 2005-10, the disease was not observed for more than a decade until it re-emerged in 2021 in wild populations in western Victoria. While this outbreak was rapidly controlled through movement restrictions and other biosecurity measures, the disease emerged in Port MacDonnell in South Australia's southern zone in early 2024. This southern zone was subsequently closed on the 6th March 2025.

The South Australian and Victorian Governments have both worked closely with the abalone and Southern Rock Lobster industries to develop a fit-for-purpose Code of Practice (COP) outlining the required biosecurity measures to prevent the spread of AVG. However, the biosecurity measures and movement restrictions do impact the fishing industries, and the impacted industries (wild catch abalone and Southern Rock Lobster) requested a scientific review of the risk pathways associated with the spread of AVG. FRDC funded this review and requested a provider to conduct a risk analyses.

Ausvet undertook this risk assessment, examining four possible risk pathways associated with the human-assisted spread of AVG, on behalf of the Fisheries Research and Development Corporation (FRDC).

Objectives and Scope of Review

The objective of this project was to assess the likelihood of the following operations spreading AVG to areas with a naïve/susceptible population present:

1. Southern Rock Lobster fishing (using pots and fishing vessels)
2. Recreational sector (diving and line fishing)
3. Commercial abalone fishing
4. Commercial net fishing.

The scope of this desktop project was relatively narrow and conducted as commissioned by FRDC under advice from industry. It was commissioned to focus on the risks of the four pathways spreading AVG to new areas, along with suitable risk mitigations for those four pathways. Unfortunately, the project could not include new field based or experimental scientific research to address scientific uncertainties, or assess additional pathways such as natural spread, as these were not commissioned within the project. Therefore, the risk assessments could not assess the role of these four assessed pathways relative to natural spread pathways (e.g. in water currents), though natural spread pathways may (or may not) be significant. Instead, uncertainties around unaddressed pathways were discussed and future research needs highlighted to assist future decision making and future commissioning of research.

Methodology

The methods included three components:

1. **Literature review** of the epidemiology of AVG, the possibly affected industries, the jurisdictional regulations and any existing veterinary risk assessments to understand the

risk AVG poses, and the appropriate control measures. The review sourced peer-reviewed publications, current state and federal legislation and policy and other grey literature.
2. **Stakeholder consultation** with relevant scientists, government and industry personnel identified by FRDC and through the consultation process. Questions were developed under broad categories such as “general”, “high risk fishing activities”, “biosecurity”, “compliance”, “impact” and “future research” and the specific questions asked reflected the areas of expertise of those consulted.
3. **Qualitative risk assessment and sensitivity analysis** to determine the estimated risks associated with the four risk pathways. The human-mediated steps necessary for AVG to spread from one reef system to another where described, and likelihood of each of steps occurring was estimated. A likelihood matrix was used to determine the estimated combined likelihoods for each pathway. A high consequence was assumed for transmission of AVG. Likelihood and consequence were combined to estimate risk. A sensitivity analysis, where estimated likelihoods were increased (if below high), was conducted to determine which pathways were likely to be influenced heavily by changes in parameter assumptions.

Results

The literature review and stakeholder consultations identified key research gaps regarding the epidemiology of AVG and how this relates to the transmission and spread of the disease. Based on these gaps, two scenarios were developed for the risk assessment. The scenarios were based on different sets of plausible biological assumptions.

For scenario A, we assume:

1. mucus plays no role in prolonging infectivity of HaHV-1
2. mucus is removed with the same detergents effective against other herperviruses
3. a large viral load is required for transmission to occur
4. the route of infection is via ingestion.

For scenario B, we assume:

1. mucus plays a role in prolonging infectivity of HaHV-1
2. mucus is difficult to remove and requires strong detergents and vigorous physical action to break down
3. a small viral load is required for transmission to occur
4. the route of infection is via immersion/gills.

Table 1 summarises the estimated combined likelihoods and overall estimated risk for each pathway, with the consequence set at high. If the combined likelihood in Scenario B was below high, a sensitivity analysis was conducted by increasing the combined likelihood by one level and the estimated risk was recalculated.

Table 1 Estimated combined likelihoods, and resulting risks for the four pathways

Pathway	Estimated Combined Likelihoods			Estimated Risks		
	Scenario A	**Scenario B**	**Sensitivity analysis**	**Scenario A**	**Scenario B**	**Sensitivity analysis**
SRL pathway 1[a]	Extremely low	Moderate	High	Very low	High	High
SRL pathway 2[b]	Extremely low	High	-	Very low	High	-
Recreational – Diving	Extremely low	Moderate	High	Very low	High	High
Recreational – Line	Extremely low	Very low	Low	Very low	Low	Moderate
Commercial abalone fishing	Very low	High	-	Low	High	-
Commercial abalone fishing with shucking	Very low	High	-	Low	High	-
Commercial net fishing	Extremely low	Very low	Very low	Very low	Low	Low

[a]Lobster pots are reset in the same location, [b]Lobster pots a reset in a new reef system

Implications for relevant stakeholders

The research gaps, especially around basic epidemiology of AVG (role of mucus in transmission, route of infection and viral load for transmission) led to considerable uncertainty in estimating the risks that various activities pose to AVG spread. If scenario A is true then there is generally a very low risk associated with activities, meaning few risk mitigation measures are required. If scenario B is true, then the risk of transmission associated with abalone and SRL fishing and recreational diving are high and risk mitigation measures are recommended. Thus a precautionary principle is recommended until further research occurs and resolves uncertainty. Therefore, the risk mitigation measures outlined in the South Australian and Victorian COP for the abalone and Southern Rock Lobster fisheries are relevant and should be maintained until this research occurs. Further research is required to determine where on the spectrum of scenario A and B the risks more accurately lie.

Further, any fishing activities that result in interaction with abalone habitats and potential transmission of HaHV-1 should be carefully managed. Early in an outbreak, when the extent of an outbreak is unknown, fishing should cease in declared areas (restricted and control areas), to manage transmission risks. However, after the outbreak is delimited, fishing in declared areas (i.e. the control area and those areas in the restricted area where there are no active outbreaks occurring – see Figure 1) may resume with risk mitigations. These mitigations will be around biosecurity practices and the movement of potentially contaminated abalone. Biosecurity practices required will focus on disinfection of boats and equipment before moving to uninfected areas to reduce the risk of fomite transmitted infection to new areas. That is, fishing can occur within uninfected areas within restricted areas, but boats must return to port and offload abalone (if abalone fisherman) and disinfect equipment (including drying and desiccation) before moving to clean areas (e.g. control areas, free areas and uninfected areas within the restricted area). Abalone from

infected areas should be considered potentially infected even if they appear healthy when harvested from infected areas and great care taken in marketing.

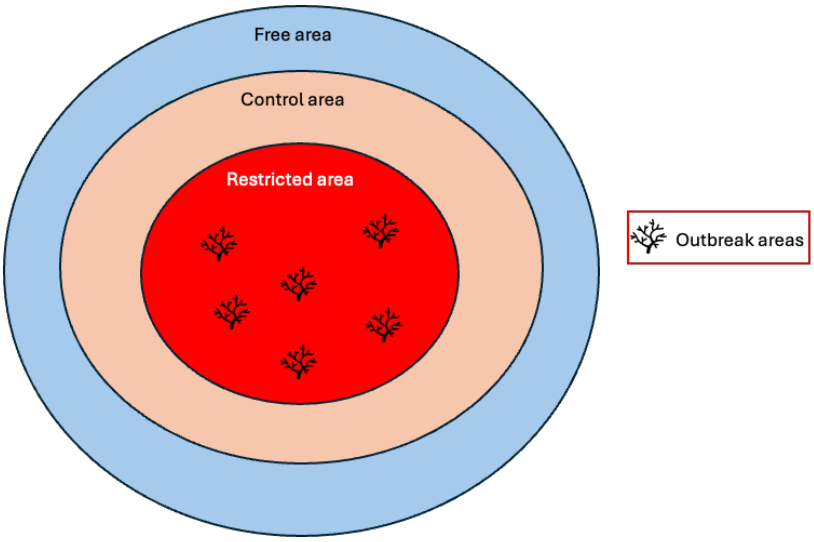


Figure 1 Schematic of the different areas that may be delimited during an outbreak response

It is important to realise this project scope did not include estimation of risks associated with natural spread (e.g. water currents, ocean upwellings etc.). This scope-stipulated-omission should be considered by stakeholders when assessing this project. If later research demonstrates that natural spread is much more significant than the four pathways considered here, then recommended risk mitigations would change. For example, imposing fishing restrictions in and around restricted and control areas would have little impact on transmission were natural spread to be significant. However, we have not assessed the evidence on natural spread or the comparative risks between this and the four pathways we assessed. We therefore cannot assess the relative importance of other spread pathways and therefore relative importance of competing risk mitigations. Research regarding the natural spread of *Ostreid herpesvirus* ranges from 10s of km to 100s of km depending on the location (Roberts et al. 2020). If this is found to be the case for HaHV-1, there may be a requirement for region specific recommendations.

As further research and data becomes available the risk assessment can be reviewed, with estimated likelihoods updated at relevant nodes to calculate new estimated risks. It is important that this occurs as new information becomes available to ensure risk mitigation advice is appropriate and contextually relevant.

Recommendations

The following areas of research have been recommended to address the research gaps and improve the accuracy of the risk assessment, and more optimal selection of risk mitigation measures:

- the role mucus plays in protecting and spreading the virus and what actions are required to break it down. Note that the CSIRO previously investigated mucus – they found that HaHV-1 could indeed be present in mucus and transmit virus to healthy abalone, but mucus did not enhance virus infectivity when in seawater. However, many important questions remain (e.g. does infected mucus assist fomite spread on equipment?).
- viral load produced during an outbreak, and subsequently required to induce transmission
- route of infection

- movement of HaHV-1 through the water column and other natural pathways[1].

The following research and activities are recommended to improve the abalone industry's preparedness for future outbreaks:

- presence of latently infected populations and natural stress events required for clinical disease, shedding and subsequent transmission to occur
- modelling of the natural spread of the virus
- clear communication of measures and recommendations for biosecurity
- cost-benefit analysis of active surveillance activities to identify latently infected populations
- workshop with researchers to determine capacity and interest for further research.

Keywords

Abalone, *Haliotidae*, Southern Rock Lobster, *Jasus edwardsii*, risk assessment, abalone viral ganglioneuritis, abalone herpesvirus, haliotid herpesvirus-1, biosecurity

[1] Hydrodynamic modelling has enabled the development of a biophysical particle tracking model for Ostreid herpesvirus 1 microvariant (OsHV-1) to determine virus spread during disease outbreaks in South Australian coastal waters. Similar models may assist in determining the natural spread of HaHV-1.

Introduction

Abalone viral ganglioneuritis (AVG), caused by *Haliotid herpesvirus-1* (HaHV-1), is an emerging and re-emerging aquatic emergency disease that impacts abalone (*Haliotidae*) fisheries and other fishing industries of Victoria, South Australia and Tasmania. Populations in New South Wales and Western Australia are still considered free of the disease. AVG initially emerged in wild and farmed abalone populations in 2005 across Victoria. Sporadic outbreaks were then seen in processing plants in Tasmania until 2010-11. Between 2010 and 2021, the disease was not observed in wild populations and was considered eradicated from farmed populations. The disease re-emerged in wild populations in the western zone of Victoria in 2021. This was followed by an outbreak in the southern zone of the South Australian abalone fishery early in 2024 (Figure 2).

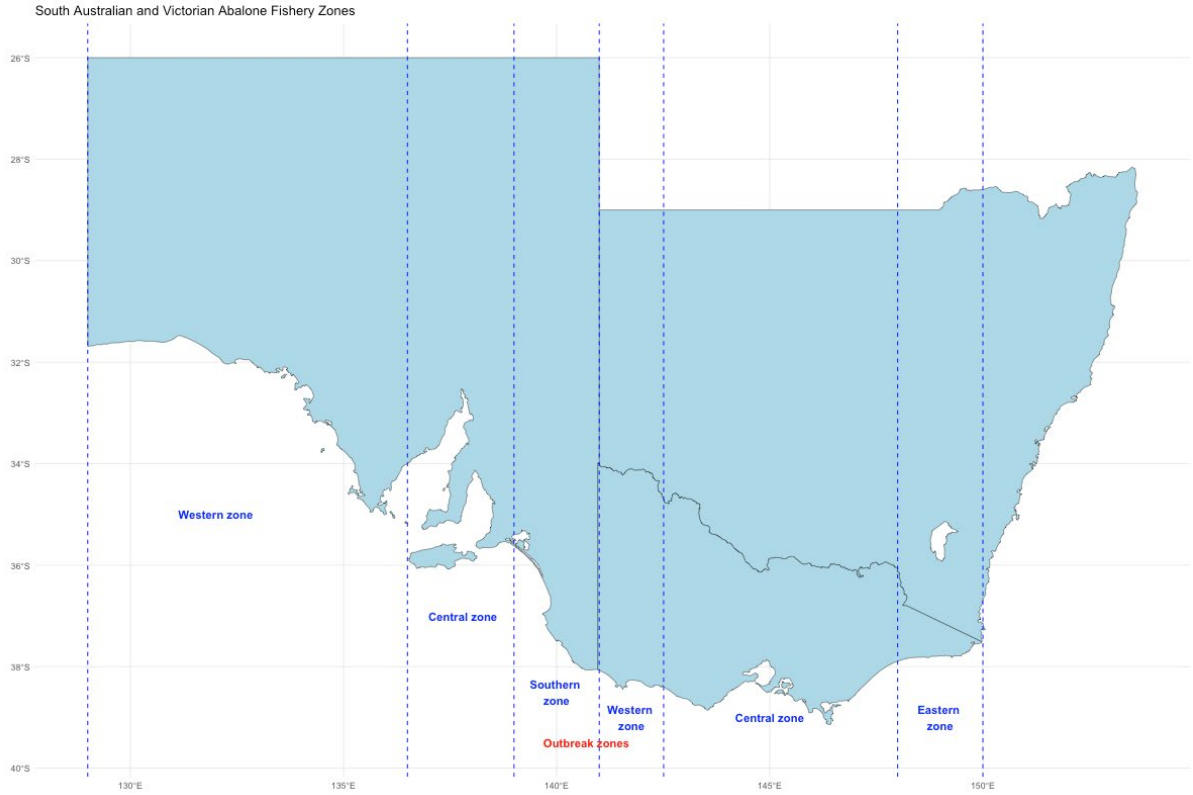


Figure 2 South Australian and Victorian abalone fishing zones

It is currently assumed that the virus is present as a latent infection in the Tasmanian and western Victorian abalone populations. Latency is a hallmark of herpesviruses. It occurs when the virus establishes a persistent infection within an immunocompetent host, remaining dormant without causing detectable symptoms or clinical disease. This dormant state can persist for extended periods until a trigger, such as stress or immunosuppression, reactivates the virus, leading to the manifestation of clinical disease (Wilkes and Kattoor 2022).

To control the movement of the infection in wild populations, South Australia and Victoria have developed codes of practice outlining recommended biosecurity measures and implemented movement restrictions. Measures have included decontamination of equipment that has had contact with the sea floor or abalone populations in suspect areas (PIRSA 2024), including washing and rinsing diving equipment with a detergent and fresh water (Bradley 2023). All gross organic material be removed from vessels at port when being removed from the water and the hull should be cleaned with fresh

water, other equipment washed with a detergent such as truckwash and rinsed with fresh water (Bradley 2023). Vessels remaining in the water should have decks, equipment and superstructures disinfected and rinsed with fresh water (Bradley 2023). However, as the abalone fishery shares waters with other fishing industries, such as the Southern Rock Lobster (*Jasus edwardsii*) fishery, these movement restrictions and biosecurity measures are impacting multiple industries. This work aimed to determine the risk of spreading AVG through the activities of abalone and other fishing industries in the region to determine if blanket movement restrictions within control zones during outbreak periods[2] should be introduced, or whether current mitigation measures can be refined through a structured risk assessment.

- Risk analyses are a systematic process used to identify hazards and analyse the risks associated with certain activities and communicate with stakeholders. They are an important decision support tool that can be used to inform animal health measures and restrictions (MacDiarmid and Pharo 2003; Bruckner et al. 2010; Horigan et al. 2023). In animal health, once the hazard of concern is identified, the risk analysis can be broken into three components; release assessment, exposure assessment and consequence assessment. Release assessment involves describing the pathways necessary for introduction of the hazard or pathogen into a population or environment and estimating the probability associated with those pathways. In the case of AVG this would be describing the steps necessary for AVG to spread from one reef system to another, and estimating the likelihood of these steps occurring.
- The exposure assessment involves describing the pathways necessary for exposure of a population to the hazard or pathogen after entry and estimating the associated likelihood. In the case of AVG, the exposure assessment may describe how infectious HaHV-1 virus that has been introduced to a new reef system could infect naïve abalone and the likelihood associated with this.
- Consequence assessment involves evaluating the consequence of entry and exposure to the hazard or pathogen, and we have assumed a high consequence for all our pathways. Consequences can be direct (such as population depletion) or indirect (such as the cost associated with a control or elimination program). Together we are focusing on the risk assessment part of risk analyses for this project.

Animal health risk assessments may be quantitative, qualitative or semi-quantitative. In quantitative risk assessments the likelihood of an outcome and the magnitude of its consequences are expressed numerically (Peeler et al. 2015). These assessments rely on adequate data being available. Quantitative risk assessments conducted with inadequate data results in outputs with wide confidence intervals that are difficult to clearly communicate to intended audiences (Peeler et al. 2015). In situations where a quantitative assessment cannot be conducted, a qualitative risk assessment is a suitable alternative, and they are faster and more intuitive. Qualitative assessments generally rely on expert judgment on the likelihood of an outcome and the magnitude of its consequences, based on the available knowledge and data. By using a systematic approach to explore biologically plausible scenarios, based on the available information, qualitative assessments can provide transparent information regarding possible risks, and areas for further research (Weiland et al. 2011). Qualitative likelihoods are expressed using non-numerical descriptors such as high, medium, low or negligible (Table 1) (Bruckner et al. 2010; Rinchen et al. 2020; DAFF 2022).

[2] An ‘outbreak’ is generally defined as sudden increase in the disease frequency related to time, place and observed population (Reintjes and Zanuzdana 2009). The accepted rule of thumb for declaring an outbreak over is when there have been no detected cases within two incubation periods from the last detected case.

Objectives

The objective of this project was to assess the likelihood of the following operations spreading AVG:

1. Southern Rock Lobster fishing (using pots and fishing vessels)
2. Recreational fishing and diving
3. Commercial abalone fishing
4. Commercial net fishing.

Method

1. Literature review

A review of available literature was conducted to investigate the epidemiology of abalone viral ganglioneuritis, and the causative agent *Haliotid herpesvirus-1* to inform the development of risk assessments for fishery activities in South Australia and Victoria.

Web of Science Core Collection (Clarivate) was used to search for peer-reviewed articles using search terms including abalone viral ganglioneuritis (AVG), *abalone herpesvirus* (AbHV), *Haliotid herpesvirus-1* (HaHV-1), epidemiology, and transmission. Further searches for grey literature, presentations, and publicly available commercial information relevant to the review were conducted on Google search. A snowball approach was also used when searching with both databases whereby peer reviewed articles and grey literature that cite selected articles were screened for inclusion. Government-associated websites were searched for documents applicable to Australia's biosecurity and disease response actions.

2. Consultations

Consultations spanned groups broadly categorised as 'fishing industry', 'aquatic biosecurity', and 'research'. This included industry representative groups from the target fisheries, jurisdictional government biosecurity staff, government and non-government-based researchers. Stakeholders represented both South Australia and Victoria.

In the first instance, The Fisheries Research and Development Corporation (FRDC) provided a list of suggested stakeholders, a small number of other stakeholders, such as researchers were identified during discussions and the literature review. A stakeholder engagement plan was developed in consultation with FRDC to guide communications. Stakeholders were contacted via email, and provided a project summary. Stakeholders that represented a group were invited to participate in group interviews, or they could nominate one-on-one interviews, if preferred. If responses were not received, follow-up emails were sent requesting participation. See Appendix 1 for the consultation list.

Consultations were semi-structured interviews. Information gaps identified through the literature review became the focus for stakeholder consultations. Questions were developed under broad categories such as "general", "high risk fishing activities", "biosecurity", "compliance", "impact" and "future research" and the specific questions asked reflected the areas of expertise of those consulted (Appendix 2). Questions were reviewed by the project team and an external expert. These questions created the basis and structure of the consultations. However, their use was not prescriptive, and the conversations and information provided was allowed to flow based on the participants engagement.

3. Mapping pathways

Scientific literature and the expert opinion generated through stakeholder consultations were used to identify plausible pathways associated with the contamination of fomites and then subsequent spread to a naïve abalone population. All pathways were developed with the assumption that an active AVG outbreak was occurring at R_1 (see Figure 3). Further, this information was used to inform the development of a scenario tree of the crucial nodes that could be applied to the different risk pathways (Figure 2). These crucial nodes along the pathways are points where contamination and subsequent exposure can occur (Peeler and Thrush 2009).

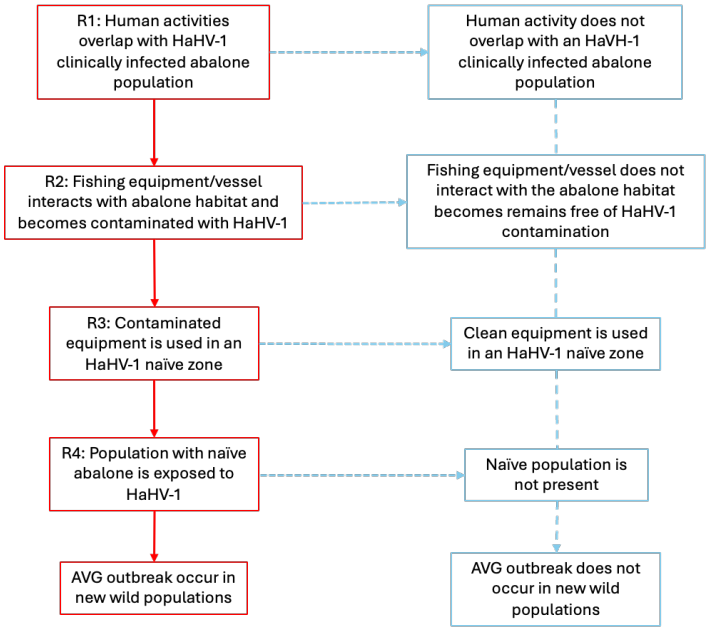


Figure 3 The scenario tree and crucial nodes for contamination and exposure of AVG

4. Qualitative risk assessment

Due to the limited data available, a qualitative risk assessment was conducted. Literature review and expert opinion from stakeholder consultation was used to estimate the qualitative likelihood for each node (Table 2). Each pathway comprised of a modified release (contamination of fomites) and exposure (introduction to new area) assessment. Each node was assigned a level of uncertainty – low, medium, high – based on the available data and consistency of expert opinions. We used a modified matrix approach to determine the overall likelihood estimate for each pathway (Figure 4) (Peeler and Thrush 2009).

The consequence of an outbreak was assessed as high based on the opinions of experts directly involved in the wild catch abalone industry. Experts indicated that abalone populations can take 10-20 years to recover to pre-outbreak quotas, leading to considerable economic loss for the industry. Local communities can suffer significant economic hardship due to decreased reinvestment and individuals leaving the area following job losses. The environmental impacts of decreasing abalone populations are also a major concern, as these animals play a crucial role in maintaining the health of reef ecosystems. Consequence and likelihood were then combined using the risk matrix to estimate the overall risk of the pathway (Figure 5).

The respective departments in South Australia and Victoria were requested to provide copies of the AVG risk assessments previously conducted.

Data were processed in R version 4.1.3 (R Core Team 2021) using the tidyverse v2.0.0 (Wickham and RStudio 2023) package. The full code is available in Appendix 3.

Table 2 Likelihood estimates and definitions used

Category	**Description** (Rinchen et al. 2020)
High	Likelihood of an event occurring is very often
Moderate	Likelihood of the event occurring is regular

Category	**Description** (Rinchen et al. 2020)
Low	Likelihood of the event occurring is occasional
Very low	Likelihood of the event occurring is rare but does occur
Extremely low	Likelihood of the event occurring is extremely rare but cannot be excluded
Negligible	Likelihood of the event occurring is so rare that it does not merit consideration

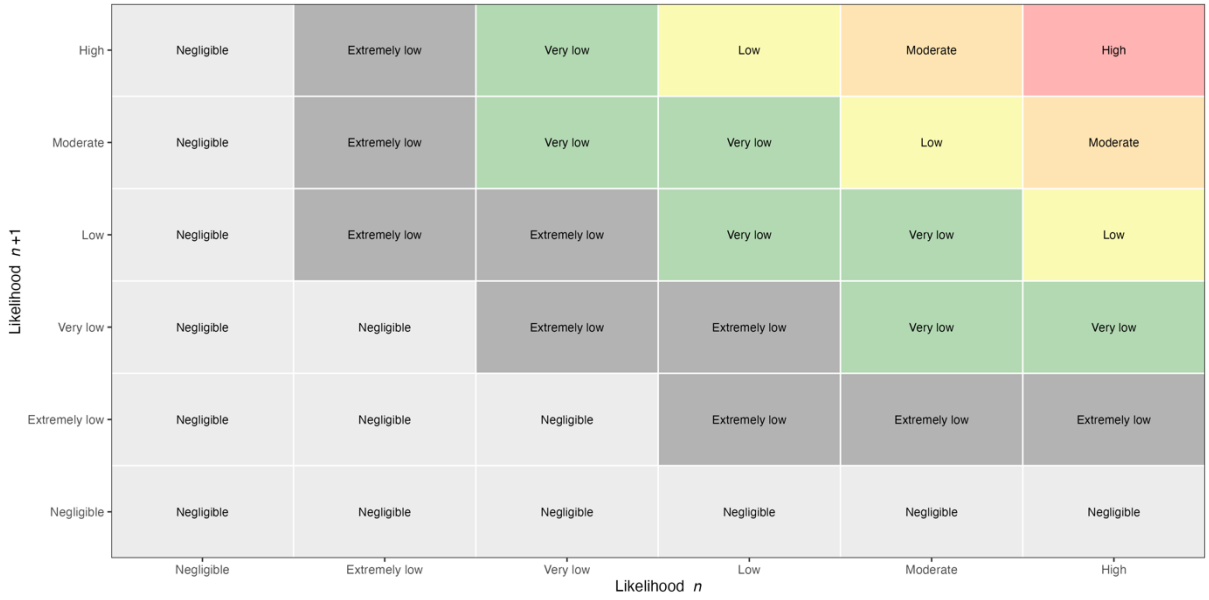


Figure 4 Modified likelihood matrix used to calculate combined likelihoods for the risk pathways (Peeler et al. 2015)

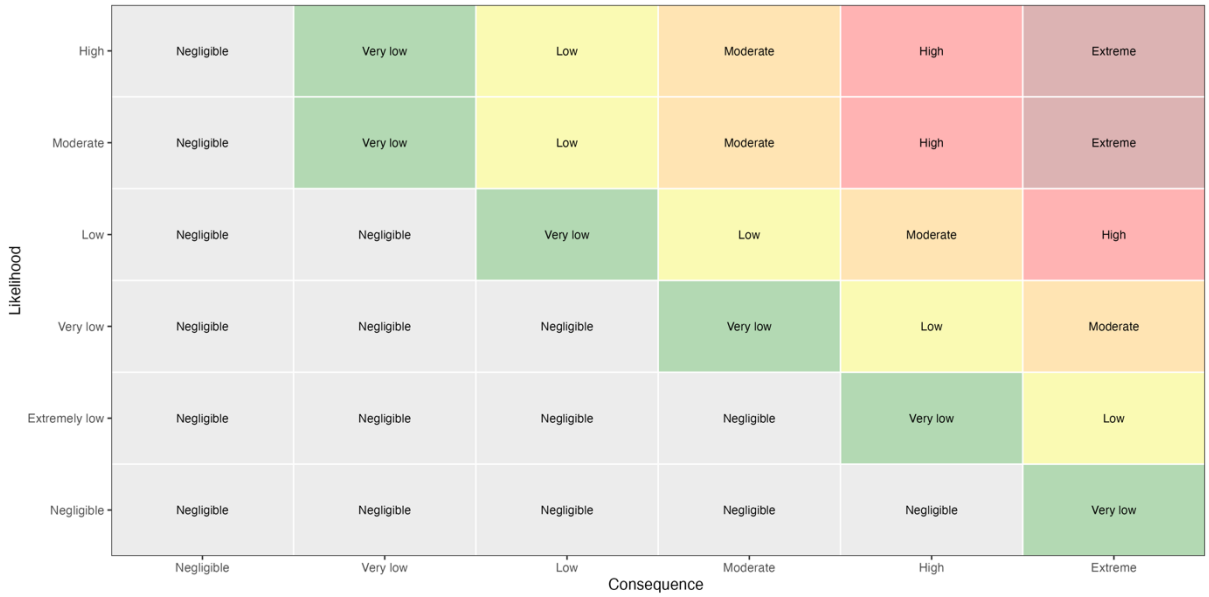


Figure 5 Overall estimated risk matrix (DAWR 2016)

Assumptions

The literature review and stakeholder consultations identified several research gaps. The gaps were associated with mucus, viral load and route of infection. As a result, we assessed the unmitigated risk

(i.e. without control measures) in two scenarios based on plausible assumptions. Whilst some research has indicated that some degree of resistance has, or can developed in previously exposed abalone populations (Holland et al. 2022; Agius et al. 2025), mortalities have continued in the 2021 Victorian outbreak despite previous outbreaks, indicating the assumption of a naïve or susceptible proportion of the population is warranted. Therefore, for both scenarios, we assume there is an active AVG outbreak and that the abalone population the disease is being introduced to has a naïve/susceptible population present.

For scenario A, we assume:

1. mucus plays no role in prolonging infectivity of HaHV-1
2. mucus is removed with the same detergents effective against herperviruses
3. a large viral load is required for clinical disease to occur
4. the route of infection is via ingestion.

For scenario B, we assume:

1. mucus plays a role in prolonging infectivity of HaHV-1
2. mucus is difficult to remove and requires strong detergents and vigorous physical action to break down
3. a small viral load is required for clinical disease to occur
4. the route of infection is via immersion/gills.

Sensitivity analysis

A sensitivity analysis was conducted to determine how sensitive the combined likelihoods are to changes in the estimated likelihood of different nodes.

The literature and information obtained from experts were assessed to identify the nodes with the highest uncertainty. These potentially influential nodes were adjusted in the sensitivity analysis to determine the impact of these changes on the overall likelihood scores. The estimated likelihood of the pre-determined nodes in scenario B were increased by one qualitative category (if below high) and the combined likelihoods were recalculated (Smith et al. 2009). These results were used to help identify the most influential uncertain nodes and therefore used to identify the key research areas required to improve the accuracy of the estimates.

Results

1. Literature review

Refer to Appendix 4 for complete literature review.

2. Consultation summary

Twenty-one stakeholders were interviewed (see Appendix 1).

Key findings are summarised below. Response to the compliance, biosecurity, cleaning and disinfection questions are provided in Appendix 5

Common ground

The neighbouring abalone fisheries of the western zone (Victoria) and southern zone (South Australia) are both small, well managed fisheries that played an active role in the development of the respective Codes of Practice.

In both states the abalone and Southern Rock Lobster (SRL) fisheries cooperate closely. Broader South Australian fisheries are concerned about impacts should AVG spread beyond the southern zone. The South Australia central and western abalone fishery zones (SA CZAF and SA WZAF) in the state overlap with many more fisheries and managing all of these in the event of a wider outbreak would be challenging.

The activities of recreational divers and line fishers are viewed as high-risk for spreading AVG. Anglers participating in line fishing may be doing this from shore, or by boat. Both line fishers and divers are more likely to move between reef systems frequently and may not be aware of their biosecurity responsibilities. This group is also linguistically and educationally diverse, making communication challenging. Recreational fishing representatives see the lack of simple and accessible information as the major barrier to mitigate the risk associated with these groups.

Divergences

Industry, government and research stakeholders from Victoria and South Australia have different opinions on the risk of SRL fishing activities spreading AVG. Victorian abalone representatives (divers and fishing authorities) see SRL fishing as a key contributor to the spread of the disease, and this is supported by industry observations from the different outbreaks in Victoria and the perceived impact the movement controls implemented have had in preventing the ongoing spread of the 2021 outbreak. However, the impact of these controls has not been independently investigated, and observations are anecdotal.

South Australian representatives generally consider the action of bringing pots to the surface with a motorised winch effective enough to reduce contaminated mucus from the equipment. Researchers and divers report detergent, such as Truck Wash, is required to effectively remove mucus. However, experts acknowledged that experimental data is lacking to confirm the opinions and reports.

Research priorities

Stakeholders were asked to outline future research priorities. The following areas were nominated:

- the actual role lobster pots play in the movement of the virus and how long HaHV-1 can remain infectious on these pots and their associated ropes

- what role does mucus play in prolonging the infectivity and spread of HaHV-1. We acknowledge CSIRO research indicated that mucus did not prolong virus survival in the water column, though virus contaminated mucus remained infectious (Corbeil et al. 2014). However, other questions remain, including the role of mucus protecting virus from desiccation and inactivation on equipment and facilitating fomite spread.
- modelling of natural movement of the virus, including speed and direction of spread
- prevalence of non-clinical HaHV-1 infection – i.e. is latency a characteristic of the virus, is it present in the wild populations and what role does that have on the spread of the virus
- the route of transmission (e.g. oral, gills, transdermal) and viral load required to induce infection and clinical disease
- what are the most cost-effective decontamination measures that can be easily implemented by all stakeholders
- what are the inciting stress events likely to be in the natural environment
- can fish contaminated with virus act as vectors (e.g. reef fish caught and used as bait elsewhere), and how long does the virus remain infective while on, or within the digestive tract of these fish.

Many stakeholders acknowledged that the areas they nominated were also referred to in needs analysis report produced from the research and development needs workshop held in December 2021 (Fox et al. 2022).

3. Mapped pathways

Ausvet was commissioned to examine the following four transmission risk pathways:

1. commercial Southern Rock Lobster fishing activities (resetting pots at the same location and resetting pots at a different location)[3]
2. recreational sector (diving and line fishing)
3. commercial wild-catch abalone fishing activities
4. net fishing (mesh and seine net)

Southern Rock Lobsters

Southern Rock Lobster fisheries in South Australia and Victoria cover the same habitat ranges as wild-catch abalone. The habitat, rocky reef systems, are shared between the two species, and fishing equipment for SRL, such as pots and rope can be placed on, or very close to reef structures, potentially becoming contaminated with HaHV-1. The actual lobsters, kept in holding wells in the floor of the vessels, the circulating water and the boat itself could also be possible fomites involved in the spread of HaHV-1.

There are two possible pathways for the spread of AVG through southern rock lobster fishing: 1) where pots are reset in the same location/ reef system, boats move to new fishing areas carrying possibly contaminated lobster to new areas, and 2) where pots are retrieved and set in new locations/ reef systems (Figure 6).

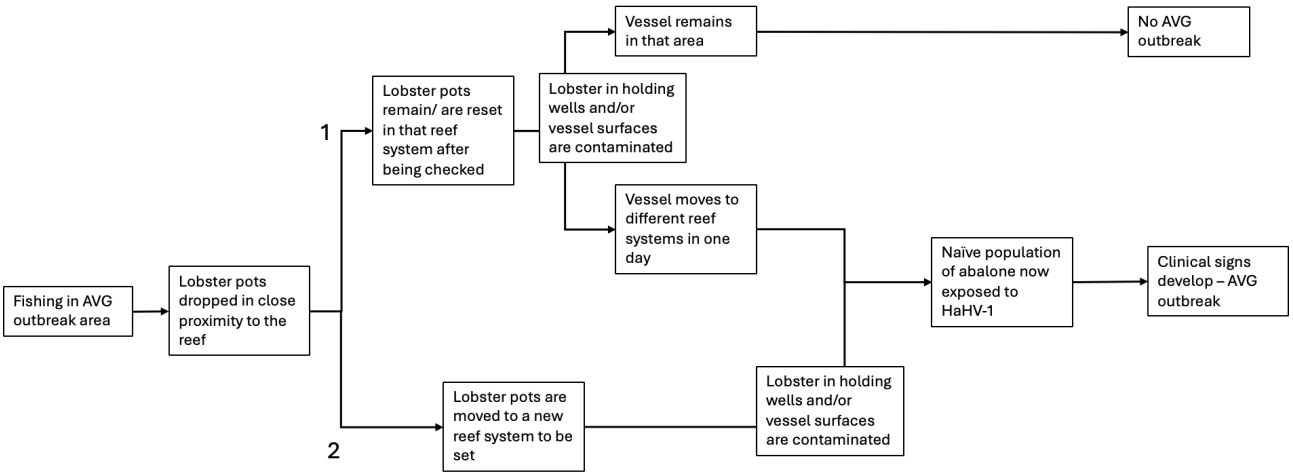


Figure 6 Risk pathways identified for the Southern Rock Lobster fishing industry

Recreational sector (diving and line fishing)

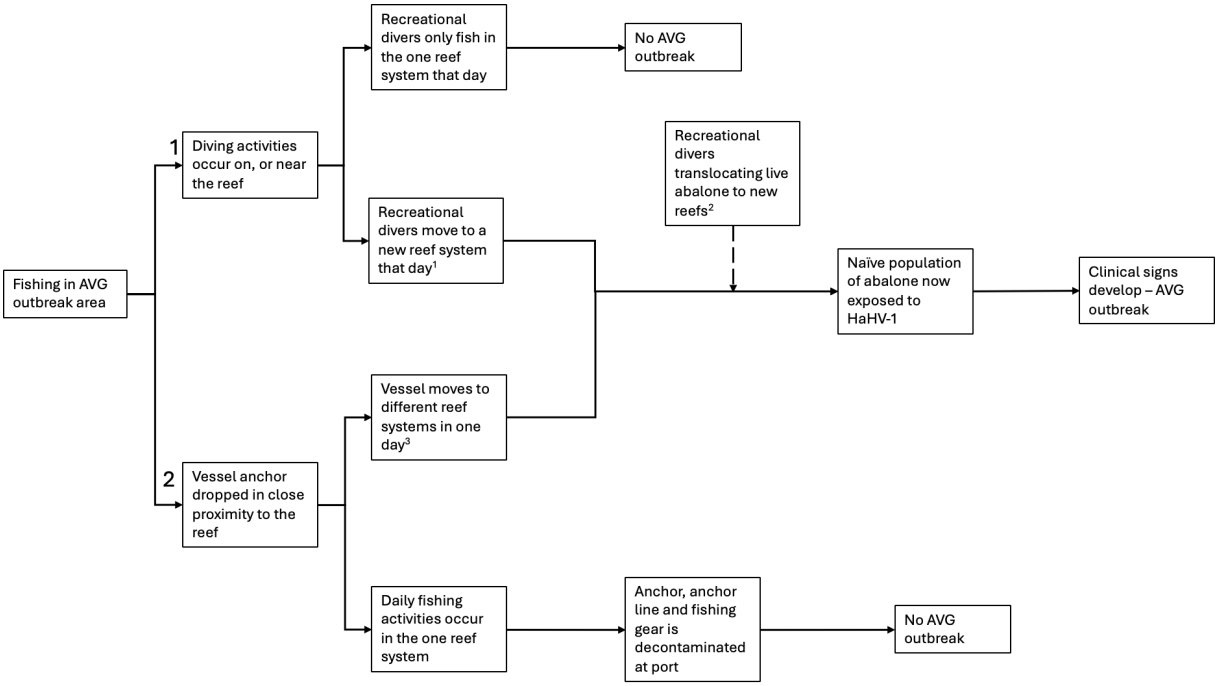
This group encompasses 1) scuba divers and fishing divers (e.g. who fish for crustaceans and abalone while diving), and 2) recreational line fishers. The pathway for line fishers will apply to those on shore or boats fishing near reef systems. Anglers targeting deep sea or open water pelagic or demersal species are not considered unless they anchor near a reef system. The basic pathways are outlined in Figure 7.

[3] Recreational lobster pot fishing is included in this pathway as recreational lobster pot fishing carries at least the same level of risk as commercial fishing (potentially more if pots are lifted manually).

Equipment used by these groups includes dive gear (wet suits, breathing apparatus), fishing equipment (bags, tools, gloves, terminal tackle, lines, live caught bait) and boating equipment (anchors, anchor chains/ ropes).

Recreational fishers are less likely to have access to biosecurity protocols, and may be more likely to disregard rules due to lack of awareness (pers. comm. Stakeholder consultation).

An additional node was introduced in the diving pathway '$R_{2.5}$ Abalone are translocated to another reef'. This node relates to the practice of 'high grading' (see footnote 2 of Figure 7).



[1]Recreational divers that may be fishing for other species may not necessarily be cognisant of the restrictions in place and may be more inclined to move between reef systems
[2]Interveiws indicated that recreational divers may "swap" abalone between reef systems if they have reached their personal catch quota but find a larger abalone while still diving – this is referred to as "high grading"
[3]Recreational anglers participating in line fishing are likely to move between reef systems, depending on the fish being caught. These individuals may also use reef fish as bait (either live or dead) at a new reef system.

Figure 7 Risk pathways identified for the recreational sector industry (diving and line fishing from shore or boat)

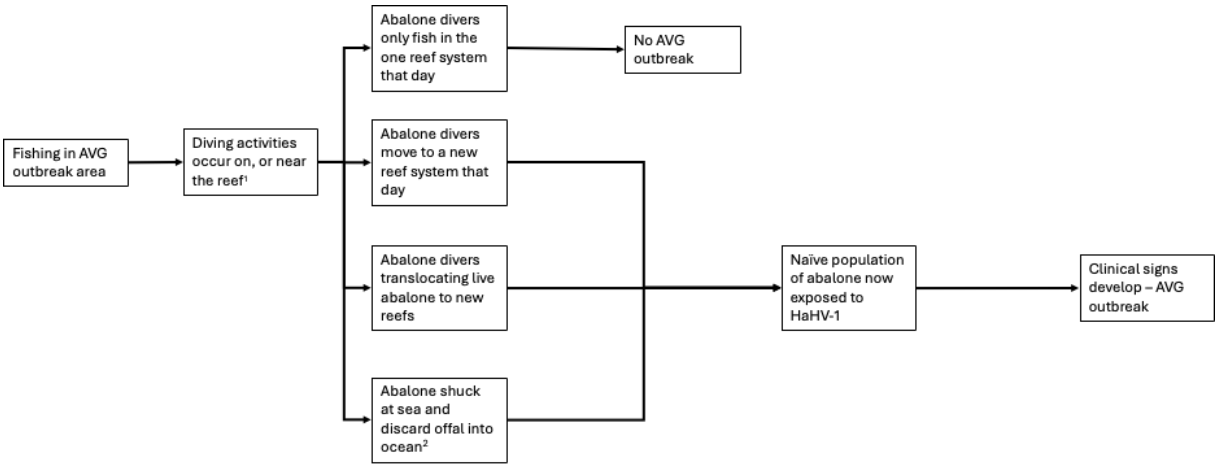
Commercial abalone fishing

This group are more likely to come into direct contact with abalone but are highly regulated and are expected to have a high level of compliance with current biosecurity regulations and recommendations; however, actual compliance is likely variable (pers. comm. Stakeholder consultation) (Figure 8). Translocation of abalone to a new reef system by commercial abalone divers was excluded from the assessment because of the highly regulated nature of the industry and the catch measurements taken during commercial dives. Experts indicated that if it were to occur it was a rare event.

In the SA CZAF and the SA WZAF commercial abalone fisherman are allowed to shuck abalone and discard the offal (gut and shell etc) at sea. This step has been included in second abalone fishing pathway. Stakeholder consultations did indicate that if the disease were to spread to these zones, this activity would be banned.

Poachers were not considered as part of the assessment due to the lack of control over the risk. This risk may also decline over time due to a potential reduction in poacher numbers. Farmed abalone

production has increased in Asia, reducing prices and making abalone less attractive for large scale/organised crime poachers (pers. comm. Stakeholder consultation). Small scale/recreational poaching may still pose a risk, but consultations indicated that this was more likely to occur in coastal/intertidal reefs and not include significant distances travelled.



[1]This includes diving and fishing gear and anchor, anchor ropes/chains
[2]This is only currently allowed in the SA CZAF and SA WZAF

Figure 8 Risk pathways identified for the commercial abalone fishing industry

Commercial net fishing

This pathway was applied to net fishing for finfish. Nets are generally set away from reef structures. However, seine and mesh nets may interact with the seabed, where sick abalone that have lost their ability to adhere to the reef can be found (pers. comm. Stakeholder consultation). This is particularly likely when nets are used within 3 nm of the shore. Sick abalone produce copious amounts of mucus that may contain viable virus (pers. comm. Stakeholder consultation), though research does indicate sea water temperatures and time do affect the infectiousness of the virus (Corbeil et al. 2014, 2012). However, we presume that a high viral load could be present on the sea floor, contaminating nets and leading to spread, as CSIRO research did indicate that even at 4C and held for several days, contaminated water still induced 50% mortality in exposed abalone (Figure 9).

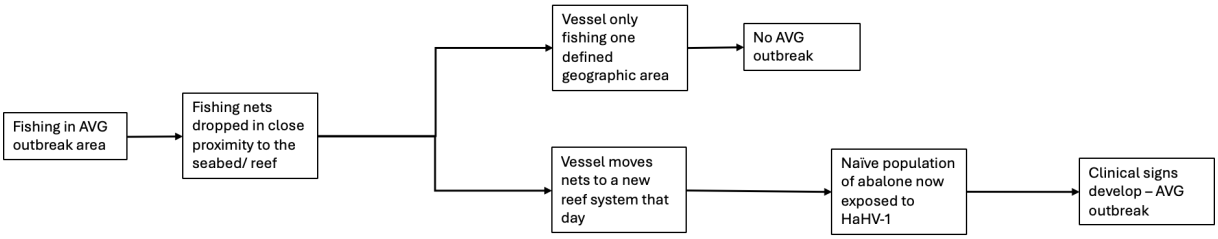


Figure 9 Risk pathways identified for the commercial net fishing industry

4. Qualitative risk assessment

The key risk question applied to each risk pathway was "*What is the likelihood the human-associated activity will lead to the spread of AVG/HaHV-1 to areas with a naïve/susceptible population present?*".

The results of all pathways are summarised in Table 3. Tables 4–10 detail the estimated likelihoods for each pathway.

Table 3 Estimated combined likelihoods for each pathway and scenario

Pathway	**Estimated Combined Likelihoods**		**Estimated Risks**	
	Scenario A	**Scenario B**	**Scenario A**	**Scenario B**
SRL pathway 1	Extremely low	Moderate	Very low	High
SRL pathway 2	Extremely low	High	Very low	High
Recreational – Diving	Extremely low	Moderate	Very low	High
Recreational – Line	Extremely low	Very low	Very low	Low
Commercial abalone fishing	Very low	High	Low	High
Commercial abalone fishing with shucking at sea	Very low	High	Low	High
Commercial net fishing	Extremely low	Very low	Very low	Low

Southern Rock Lobster

Pathway 1: Lobster pots reset in the same location

Estimated likelihoods

Table 4 Southern Rock Lobster pathway 1 qualitative risk assessment results

Node	**Likelihood**	
	Scenario A	**Scenario B**
R_1: Human activities overlap with HaHV-1 clinically infected abalone population	High	High
R_2: Equipment becomes contaminated with AVG	Low	High
R_3: Equipment contaminated with infectious HaHV-1 is used in an HaHV-1 naïve zone	Low	Moderate
R_4: Abalone become infected and clinical for AVG	Low	High
Combined likelihood	Extremely low	Moderate

R_1 Human activities overlap with HaHV-1 clinically infected abalone population

Uncertainty: Low

Likelihood: Scenario A: High*;* Scenario B: High

Justification: Southern Rock Lobster and abalone share the same habitat.

R_2 Fishing equipment/vessel interacts with abalone habitat and becomes contaminated with HaHV-1

Uncertainty: High

Likelihood: Scenario A: Low*;* Scenario B: High

Justification: Abalone are known to climb over lobster pots that are set directly on the reef (pers. comm. Stakeholder consultation). Research is absent regarding the role mucus plays in the protection and spread HaHV-1. Expert opinion on the ease with which mucus may be disrupted and removed from fomites varies. Some believed the action of pulling lobster pots out of the water would be sufficient to remove the mucus from fomites. Therefore, in scenario A, it was assumed that the action of bringing the lobster pots to the surface would remove any potential contamination. In scenario B, it was assumed that the mucus would not be removed by force when the pots are retrieved, and therefore there would be a high likelihood of pots, and any lobsters present being contaminated.

R_3 Equipment contaminated with infectious HaHV-1 is used in an HaHV-1 naïve zone

Uncertainty: High

Likelihood: Scenario A: Low*;* Scenario B: Moderate

Justification: Research is absent regarding the movement of HaHV-1 within the water column. Lobsters in holding wells, along with the seawater circulated through these wells and discharged near the surface may be contaminated. However, it is unclear how effectively the infectious virus moves vertically through the water column. Therefore, the likelihood of this contamination spreading the virus is uncertain. The likelihood estimate was set to low for Scenario A, assuming minimal vertical movement of the virus, and moderate for Scenario B, assuming some vertical movement.

R_4 Population with naïve abalone is exposed to HaHV-1

Uncertainty: High

Likelihood: Scenario A: Low*;* Scenario B: High

Justification: The likelihood of the naïve population becoming infected is dependent on the viral load produced and required to initiate infection, and route of transmission required to infect abalone which is unknown. The likelihood therefore varies between the two scenarios.

Estimated Risk

Scenario A: **Very Low**

Scenario B: **High**

Pathway 2: Lobster pots reset to a new reef system

Estimated likelihoods

Table 5 Southern Rock Lobster pathway 2 qualitative risk assessment results

Node	Likelihood	
	Scenario A	**Scenario B**
R_1: Human activities overlap with HaHV-1 clinically infected abalone population	High	High
R_2: Equipment becomes contaminated with AVG	Low	High
R_3: Equipment contaminated with infectious HaHV-1 is used in an HaHV-1 naïve zone	Low	High
R_4: Abalone become infected and clinical for AVG	Low	High
Combined likelihood	Extremely low	High

R_1 Human activities overlap with HaHV-1 clinically infected abalone population

Uncertainty: Low

Likelihood: Scenario A: High*;* Scenario B: High

Justification: As for SRL pathway 1.

R_2 Fishing equipment/vessel interacts with abalone habitat and becomes contaminated with HaHV-1

Uncertainty: High

Likelihood: Scenario A: Low*;* Scenario B: High

Justification: As for SRL pathway 1.

R_3 Equipment contaminated with infectious HaHV-1 is used in an HaHV-1 naïve zone

Uncertainty: High

Likelihood: Scenario A: Low*;* Scenario B: High

Justification: As for SRL pathway 1. However, in this pathway the lobster pots are moved to a new reef system. It is unclear as to whether the activity of setting contaminated pots would be sufficient to resuspend the virus within the water column and whether this would lead to virus being present in water column at the level that abalone are found. Therefore, the likelihood that contaminated fomites, in this case lobster pots, are used in an HaHV-1 naïve area is higher, represented in the high likelihood score for scenario B.

R_4 Population with naïve abalone is exposed to HaHV-1

Uncertainty: High

Likelihood: Scenario A: Low*;* Scenario B: High

Justification: As for SRL pathway 1.

Estimated Risk

Scenario A: **Very Low**

Scenario B: **High**

Recreational sector

Diving

Estimated likelihoods

Table 6 Recreational sector (diving) qualitative risk assessment results

Node	**Likelihood**	
	Scenario A	**Scenario B**
R_1: Human activities overlap with HaHV-1 clinically infected abalone population	High	High
R_2: Equipment becomes contaminated with AVG	Low	High
$R_{2.5}$: Abalone are translocated to another reef	Moderate	Moderate
R_3: Equipment contaminated with infectious HaHV-1 is used in an HaHV-1 naïve zone	Low	High
R_4: Abalone become infected and clinical for AVG	Low	High
Combined likelihood	Extremely low	Moderate

R_1 Human activities overlap with HaHV-1 clinically infected abalone population

Uncertainty: Low

Likelihood: Scenario A: High*;* Scenario B: High

Justification: Recreational divers, either scuba or fishing, generally focus their activities on reef systems where marine life is concentrated. Those diving for abalone or SRL will come in direct contact with abalone habitats.

R_2 Fishing equipment/vessel interacts with abalone habitat and becomes contaminated with HaHV-1

Uncertainty: Moderate

Likelihood: Scenario A: Low*;* Scenario B: High

Justification: Research is absent regarding the role mucus plays in spread of HaHV-1 and the ease of which it can be removed from fomites. There is also absent research regarding the amount of viable virus that is present in the water column during an outbreak. Therefore, the likelihood estimated for scenario A is set at low, and scenario B is set at high, to reflect the pre-defined assumptions, and uncertainty regarding the amount of virus shed.

$R_{2.5}$: Abalone are translocated to another reef

Uncertainty: Moderate

Likelihood: Scenario A: Moderate*;* Scenario B: Moderate

Justification: The total allowable catch for abalone is five per person per day. The proportion of recreational fishers that take abalone is very small (pers. comm. Stakeholder consultation; (Burnell and Hogg 2023; Victoria Department of Economic Development, Jobs, Transport and Resources 2015)). However, there are reports of "high grading", where divers exchange a previously caught smaller abalone for a larger one, so they don't exceed their five abalone limit. This may result in divers releasing smaller abalone in another reef (pers. comm. Stakeholder consultation); a practice that could introduce disease. The frequency of this practice is unknown.

R_3 Equipment contaminated with infectious HaHV-1 is used in an HaHV-1 naïve zone

Uncertainty: High

Likelihood: Scenario A: Low*;* Scenario B: High

Justification: As with R_2, divers are swimming in the direct habitat of abalone. The different likelihood estimates between the two scenarios reflect the uncertainty surrounding duration of fomite contamination.

R_4 Population with naïve abalone is exposed to HaHV-1

Uncertainty: High

Likelihood: Scenario A: Low*;* Scenario B: High

Justification: The differences in the likelihoods for the scenarios are reflective of the different assumptions used regarding the route of infection and viral load. In scenario B the introduction of contaminated fomites directly to the abalone habitat, such as when divers handle abalone or the reef may be sufficient to cause exposure of naïve animals to the virus.

Estimated Risk

Scenario A: **Very low**

Scenario B: **High**

Line fishing

Estimated likelihoods

Table 7 Recreational sector (line) qualitative risk assessment results

Node	Likelihood	
	Scenario A	**Scenario B**
R_1: Human activities overlap with HaHV-1 clinically infected abalone population	High	High
R_2: Equipment becomes contaminated with AVG	Low	Moderate
R_3: Equipment contaminated with infectious HaHV-1 is used in an HaHV-1 naïve zone	Low	Moderate
R_4: Abalone become infected and clinical for AVG	Very Low	Low
Combined likelihood	Extremely low	Very low

R_1 Human activities overlap with HaHV-1 clinically infected abalone population

Uncertainty: Low

Likelihood: Scenario A: High*;* Scenario B: High

Justification: Not all ocean-based line anglers fish over or near reef systems. For the purpose of this pathway the fishing activity is assumed to be conducted within the vicinity of reef systems.

R_2 Fishing equipment/vessel interacts with abalone habitat and becomes contaminated with HaHV-1

Uncertainty: Moderate

Likelihood: Scenario A: Low*;* Scenario B: Moderate

Justification: Equipment in this pathway includes fishing line and tackle, along with anchors and anchor ropes/ chains. In scenario A general activities, such as reeling in fishing line, casting off and recovering the anchor are sufficient to disrupt the mucus, so there is a low likelihood of contamination. This increases to moderate likelihood in scenario B. Anchors may be more likely to encounter the sea floor, or rocky reefs, and become contaminated. Further, if they are manually removed from the water (i.e. without the use of motorised winch) this action is not expected to enough to disrupt the mucus. An additional fomite to be considered in this pathway are bait fish caught on the reefs and then either used as live bait, or cut up and used at another reef system.

R_3 Equipment contaminated with infectious HaHV-1 is used in an HaHV-1 naïve zone

Uncertainty: High

Likelihood: Scenario A: Low*;* Scenario B: Moderate

Justification: Fomites such as anchors, associated ropes, tackle and caught bait fish may be reused in a new reef system on the same day. In scenario A there would be minimal contamination remaining on equipment when arriving at the new location. For scenario A, the handling or storage (e.g. container with refreshed sea water) of bait fish (live or dead) is sufficient to remove any contamination, and digestive tracts/offal are not used as bait. In scenario B the bait fish and equipment will remain contaminated, and enter the water column around the new population.

R_4 Population with naïve abalone is exposed to HaHV-1

Uncertainty: High

Likelihood: Scenario A: Very low*;* Scenario B: Low

Justification: Reef pick anchors may be dropped directly on to reef systems. These anchors have been specifically designed to reduce damage to reefs as the prongs will straighten if snagged. This design has been developed to also reduce the organic material that is brought to the surface. When reef fishing at 20+meters it is common to practice "drift fishing" where anchors are not deployed (pers. comm. Stakeholder consultation). Contaminated bait fish may be located in the water column closer to the abalone, leading to higher likelihood in scenario B.

Estimated Risk

Scenario A: **Very low**

Scenario B: **Low**

Commercial abalone fishing

Estimated likelihoods

Table 8 Commercial abalone fishing qualitative risk assessment results

Node	Likelihood	
	Scenario A	**Scenario B**
R_1: Human activities overlap with HaHV-1 clinically infected abalone population	High	High
R_2: Equipment becomes contaminated with AVG	High	High
R_3: Equipment contaminated with infectious HaHV-1 is used in an HaHV-1 naïve zone	Low	High
R_4: Abalone become infected and clinical for AVG	Moderate	High
Combined likelihood	Very low	High

R_1 Human activities overlap with HaHV-1 clinically infected abalone population

Uncertainty: Low

Likelihood: Scenario A: High*;* Scenario B: High

Justification: Abalone fishing will take place in the areas with abalone.

R_2 Fishing equipment/vessel interacts with abalone habitat and becomes contaminated with HaHV-1

Uncertainty: High

Likelihood: Scenario A: High*;* Scenario B: High

Justification: Abalone divers swim close to the reef systems and handle abalone.

R_3 Equipment contaminated with infectious HaHV-1 is used in an HaHV-1 naïve zone

Uncertainty: High

Likelihood: Scenario A: Low*;* Scenario B: High

Justification: The likelihood for this node is dependent on many variables. For example, depending on weather and ocean conditions, divers may fish at multiple reef systems in one day, and may dive on consecutive days, or conversely, they may dive once every couple of weeks and only target one reef system a day (pers. comm. Stakeholder consultation).

R_4 Population with naïve abalone is exposed to HaHV-1

Uncertainty: High

Likelihood: Scenario A: Moderate*;* Scenario B: High

Justification: As for the recreational diving pathway. However, scenario A has been classed as moderate due to the increased volume of abalone commercial divers are expected to interact with each dive.

Estimated Risk

Scenario A: **Low**

Scenario B: **High**

Commercial abalone fishing in zones where shucking at sea is permitted

Estimated likelihoods

Table 9 Commercial abalone fishing with shucking at sea qualitative risk assessment results

Node	Likelihood	
	Scenario A	Scenario B
R_1: Human activities overlap with HaHV-1 clinically infected abalone population	High	High
R_2: Equipment becomes contaminated with AVG	High	High
$R_{2.5}$: Abalone gut is shucked and discarded at sea	Moderate	High

Node	Likelihood	
	Scenario A	**Scenario B**
R_3: Equipment contaminated with infectious HaHV-1 is used in an HaHV-1 naïve zone	Low	High
R_4: Abalone become infected and clinical for AVG	Moderate	High
Combined likelihood	Very low	High

R_1 Human activities overlap with HaHV-1 clinically infected abalone population

Uncertainty: Low

Likelihood: Scenario A: High*;* Scenario B: High

Justification: As for the commercial abalone fishing pathway.

R_2 Fishing equipment/vessel interacts with abalone habitat and becomes contaminated with HaHV-1

Uncertainty: High

Likelihood: Scenario A: High*;* Scenario B: High

Justification: As for the commercial abalone fishing pathway.

$R_{2.5}$: Abalone gut is shucked and discarded at sea

Uncertainty: High

Likelihood: Scenario A: Moderate*;* Scenario B: High

Justification: Abalone gut can be discarded at sea in the SA WZAF and the SA CZAF. If abalone offal is discarded directly over reefs the contamination of the local environment would be high, especially if transmission assumptions for Scenario B are true. The likelihood is expected to be lower if transmission assumptions in Scenario A are true as a proportion of offal would be expected to be scavenged by reef fish and local currents may disperse the material.

R_3 Equipment contaminated with infectious HaHV-1 is used in an HaHV-1 naïve zone

Uncertainty: High

Likelihood: Scenario A: Low*;* Scenario B: High

Justification: As for the commercial abalone fishing pathway.

R_4 Population with naïve abalone is exposed to HaHV-1

Uncertainty: High

Likelihood: Scenario A: Moderate*;* Scenario B: High

Justification: As for the commercial abalone fishing pathway.

Estimated Risk

Scenario A: **Low**

Scenario B: **High**

Commercial net fishing

Estimated likelihoods

Table 10 Commercial net fishing qualitative risk assessment results

Node	Likelihood	
	Scenario A	**Scenario B**
R_1: Human activities overlap with HaHV-1 clinically infected abalone population	Low	Low
R_2: Equipment becomes contaminated with AVG	Moderate	Moderate
R_3: Equipment contaminated with infectious HaHV-1 is used in an HaHV-1 naïve zone	Low	Moderate
R_4: Abalone become infected and clinical for AVG	Low	Moderate
Combined likelihood	Extremely low	Very low

R_1 Human activities overlap with HaHV-1 clinically infected abalone population

Uncertainty: Low

Likelihood: Scenario A: Low*;* Scenario B: Low

Justification: Seine and mesh net fishing involve the use of weights to keep the nets submerged and are set behind boats (Australian Fisheries Management Authority 2023). Reefs can damage these submerged structures. Due to the possible damage most fishing activities that involve nets near the sea floor generally avoid reefs. Therefore, the likelihood of this activity being conducted near an abalone habitat has been set at low for both scenario A and B.

R_2 Fishing equipment/vessel interacts with abalone habitat and becomes contaminated with HaHV-1

Uncertainty: High

Likelihood: Scenario A: Moderate*;* Scenario B: Moderate

Justification: Moribund abalone are usually located on the seafloor as they lose their ability to remain adhered to the rocky reef and it is here where the mucus may be found. Fishing nets are also used on sea floors.

R_3 Contaminated equipment is used in an HaHV-1 naïve zone

Uncertainty: High

Likelihood: Scenario A: Low*;* Scenario B: Moderate

Justification: The likelihood of nets and associated equipment remaining contaminated as they move through the water between different fishing zones depends on the material, speed at which the boats trawled the nets, and whether the nets were removed from the water between fishing areas.

R_4 Population with naïve abalone is exposed to HaHV-1

Uncertainty: High

Likelihood: Scenario A: Low*;* Scenario B: Moderate

Justification: As for recreational line fishing pathway.

Estimated Risk

Scenario A: **Very low**

Scenario B: **Low**

Sensitivity analysis

Sensitivity analysis was used to determine how changes in individual node likelihoods affect the combined likelihoods of HaHV-1 transmission. Nodes R_2 and R_3, which represent the role of equipment as a fomite in viral spread, were identified as having the most uncertainty due to limited research on the role of mucus in HaHV-1 transmission.

As shown in Table 11, this analysis revealed increased combined likelihoods in three of the four pathways. Notably, the estimated risk only increased for the recreational line fishing pathway. However, the overall risk for SRL Pathway 1 and recreational diving remained high. This sensitivity to changes in nodes R_2 and R_3 highlights the need for further research to better understand the role of equipment and fomites in HaHV-1 transmission, which will improve the accuracy of risk assessments.

Table 11 Sensitivity analysis results

Pathway	Current combined likelihood (scenario B)	Combined likelihoods when R_2 and/or R_3 are increased by one category	Updated Estimated Risk
SRL Pathway 1	Moderate	High	High
Recreational sector – Diving	Moderate	High	High
Recreational sector – Line fishing	Very low	Low	Moderate
Commercial net fishing	Very low	Very low	Low

Discussion and Conclusion

Knowledge gaps in the epidemiology of AVG and HAHV-1 contribute to high uncertainty on many of the nodes assessed as part of this risk assessment. Further, SA and Vic departments were unable to share their respective AVG risk assessments. To address this, the risk assessment was conducted for two different scenarios. There is a significant difference in the overall risk associated with pathways between the two scenarios. Further, the knowledge gaps associated with the natural movement of the virus in ocean currents, including rate and distance viable virus can spread impedes the ability to consider the true impact these pathways will play on the spread of the disease, relative to other assessed pathways. It is therefore difficult to make recommendations regarding the appropriateness of current risk mitigations without knowing where on the scenario spectrum most accurately reflects the true epidemiology of AVG and HaHV-1. Given the uncertainty, a precautionary approach is recommended until further research can clarify the risks. Therefore, existing mitigation measures in the Victorian COP for abalone and Southern Rock Lobster fisheries – i.e. allow fishing in control areas but not outbreak areas along with the use of decontamination – should be maintained and applied to South Australia to ensure consistency across the jurisdictions.

Standard practice in the SA WZAF and SA CZAF permits the shucking and discarding of abalone offal at sea, but the offal must be discarded in the area the abalone are caught (pers comm. stakeholder consultation). While the disease is absent from these zones this activity poses little risk. However, if there were to be an outbreak of AVG, or reported cases moved closer to the SA CZAF this activity would be increasingly risky, especially if there was poor compliance with offal being discarded in the catch area and fisherman were discarding it in other areas. Further, there is the possibility that an outbreak could be undetected for a period of time, and be spread by this practice.

The current standard operating practices (SOPs) outlined in each COP focus on basic decontamination of vessel, diving equipment, transport vehicles, fish bins and personnel. Recommendations are to remove all visible organic material, including any residual mucus, cleaning with fresh water and detergent – physically scrubbing where indicated – and in cases where equipment has been used in a high risk setting, e.g. an active outbreak area, disinfectants should be used (Bradley 2023; PIRSA 2024). The South Australia COP includes detailed SOPs for the commercial wild catch abalone fishery, basic SOPs for commercial SRL fishery, recreational sector, abalone aquaculture and processing sectors, whereas the Victorian version does not include the commercial SRL fishery. However, the Victorian SRL fishery has its own COP, and this does include detailed recommendations regarding AVG including the explicit recommendation to use detergent. The SA COP does not explicitly recommend the use of detergents for SRL fishing equipment. This inconsistency between the two states may lead to decreased compliance, especially in those that fish across the two states. Any recommendations regarding detergents or disinfectants should ensure the specific products recommended are approved by the Australian Pesticides and Veterinary Medicine Authority. The measures outlined in the respective codes have not been regulated and are therefore not legally enforceable under the respective Biosecurity Acts. The recommendations in the COPs should be standardised so that they may become regulated and applied across all jurisdictions that may become affected by future outbreaks.

When considering the current control measures in regard to the two scenarios examined in the risk assessment (Table 12), the current recommendations of using fresh water and detergent to clean gear, leaving to air dry in sunlight, and using disinfectant if being in a high risk area should be sufficient to minimise the risk of human-assisted spread for the abalone diving fishery and recreational sector.

The SRL fishery poses potential risks due to their activities and hesitancy to use detergents or disinfectants on their pots, and the variability in the materials used for the pots (porous vs non-porous materials) – which are the primary fomite of concern. In scenario A, the basic decontamination measures would still be recommended. For scenario B, if the currently recommended risk mitigation measures, such as use of detergents or disinfectants between different areas are used, then fishing in a

control area could be permitted to continue. However, if these measures are not regulated or practiced then biosecurity practices will be insufficient to prevent human-mediated disease transmission. In this case, it would be advisable to cease any fishing activities that involved equipment coming into contact with the seafloor and reef structures while there is an active outbreak occurring – i.e. new cases in the current or new area are being reported. Where decontamination of pots and equipment is not practiced, SRL fishing activities could only continue if pots were not moved between abalone reef systems as defined by the relevant fishery authority. SRL fishing without movement between reef systems may continue as the lobster and circulated water in the holding wells are probably unlikely to contribute to the spread of the virus. SRL fishing may also be considered acceptable if the pots are set at a depth of greater than 40 m as abalone are not found at this depth.

Table 12 Assumptions used for each biologically plausible scenarios

Scenario A	**Scenario B**
mucus plays no role in prolonging infectivity of HaHV-1	mucus plays a role in prolonging infectivity of HaHV-1
mucus is removed with the same detergents effective against herperviruses	mucus is difficult to remove and requires strong detergents and vigorous physical action to break down
a large viral load is required for clinical disease to occur	a small viral load is required for clinical disease to occur
the route of infection is via ingestion.	the route of infection is via immersion/gills.

The variability in the scenarios results from alternative assumptions regarding the role mucus plays in virus survivability, the viral dose required to induce infection and the route of infection for abalone. Whilst the CSIRO has addressed some issues (for example the role of mucus protecting virus in sea water), this research did demonstrate virus contaminated sea water remains infective, even over time and at extreme temperatures (Corbeil et al. 2014). Further research in these three areas is crucial to accurately assessing risk, particularly for the SRL pathway. This research would also help to clarify if the biosecurity measures for divers (recreational or commercial) are sufficient. Recommendations for future research areas are described in more detail in the Recommendations section below.

Publicly available data on the socio-economic impact of AVG outbreaks is also limited, and it is unclear if the impact of initial outbreaks has been thoroughly investigated. Without this information, our consequence assessment may under- or over-estimate the true potential impact of an outbreak, though we assessed consequences as high.

Commercial net fishing and recreational line fishing are the only risk pathways that pose a low to very low risk to the movement of HaHV-1/AVG outbreaks to new areas for both scenarios. Line fishing was found to be sensitive to changes in the estimated likelihoods of nodes with the combined likelihood increasing to low, and risk increasing to moderate. Extension activities facilitated by the representative recreational fishing bodies may be expected to manage this risk.

The risk mitigation strategies recommended in the COPs for each state were reviewed as part of the literature review in this project (Appendix 4). There are significant knowledge gaps (discussed above) that limit our capacity to assess the appropriateness of current risk mitigation strategies – i.e. primarily, we are unable to recommend lessening the biosecurity protocols. The Victorian SRL COP advises against fishing in any outbreak areas, where the South Australian COP recommends relocating if in an outbreak area. The language in both of these could be interpreted as ambiguous and clearer, consistent messaging is advisable. Based on the available knowledge, and anecdotal reports from stakeholders we recommend that South Australia adopts the same level of biosecurity as Victoria, in terms of recommendations for the use of detergents and disinfectants for any fishing activity in high risk areas.

In the event that the control measures enacted for abalone and SRL fisheries during the 2021 Victorian AVG outbreak are determined to have been instrumental in preventing its ongoing dissemination, it is recommended that these same measures, particularly the temporary cessation of abalone and SRL fishing during outbreak delimitation, be applied in response to subsequent outbreaks. A retrospective

qualitative study of previous outbreaks and management strategies would be beneficial to investigate what management factors may have led to the spread, or limited the spread of the outbreaks. If further research indicates that ocean currents contribute significantly to the natural spread of AVG, then it may be deemed that certain biosecurity measures are not warranted.

The VIC WZAF stakeholders interviewed described the blanket movement ban implemented during the 2021 outbreak as a collaborative decision between the abalone and SRL fisheries, indicating that the abalone industry would reciprocate and comply if the SRL industry was faced with a similar situation. This was an optimal result of collaboration, which does not appear to have been achieved in the SA SZAF. However, the reasons behind this were not explored in the consultations and speculations will not be made. Understanding the barriers to collaboration is considered crucial to improving future biosecurity responses, and should be the topic of further investigation. However, the consultation process for this risk assessment was not considered to be the appropriate forum to investigate barriers to collaboration.

Further complicating the issue is the latency of the virus, and whether the abalone populations along the South Australian and Victorian coastlines are already infected. The virus is assumed to be present as a latent infection in Tasmanian wild populations with clinical disease occurring in processing facilities. Victorian authorities have declared AVG endemic (pers. comm. Stakeholder consultation), but still notifiable within seven days of suspicion/detection (Department of Energy, Environment and Climate Action 2023). There is concern from the VIC EZAF that this endemic classification will lead to stakeholders being less agreeable to control measures, especially if not regulated, and may be less inclined to report the disease if it is detected beyond the VIC WZAF. While there are examples of endemic aquatic and terrestrial diseases that are subject to control measures during outbreaks, such as epizootic haematopoietic necrosis virus (EHNV) and *Aeromonas salmonicida* – atypical strain, clear messaging around the reporting requirements and relevant control measures to minimise the spread and impact of an outbreak is critical.

Key knowledge gaps regarding the epidemiology of AVG and HaHV-1 must be addressed to ensure the abalone and SRL fisheries, along with recreational divers can work together in implementing evidence-based and practical control measures. Whilst mitigation measures can be costly, the benefits generally outweigh the costs of, and disruptions caused by AVG outbreaks. A cost-benefit analysis of control measures would be beneficial for the respective states and industries to determine the most cost-effective measures.

Until research gaps are addressed it would be prudent for the abalone industry to take a precautionary approach and enforce quarantine measures, including movement controls and/or biosecurity measures on any fishers accessing outbreak areas. Once key research gaps are addressed, policymakers can determine which assumptions used in the scenarios tested here most accurately reflect the true epidemiology of AVG and HaHV-1, facilitating design of truly evidence-based mitigation measures.

Implications

The research gaps, especially around basic epidemiology of AVG (role of mucus in transmission, route of infection and viral load for transmission) lead to considerable uncertainty in estimating the risks that various activities pose to AVG spread. If scenario A is true then there is generally a very low risk associated with activities, meaning few risk mitigation measures are required. If scenario B is true, then the risk of transmission associated with abalone and SRL fishing and recreational diving are high and risk mitigation measures are recommended. Thus a precautionary principle is recommended until further research occurs and resolves uncertainty. Therefore, the risk mitigation measures outlined in the South Australian and Victorian COP for the abalone and Southern Rock Lobster fisheries are relevant and should be maintained until this research occurs. Further research is required to determine where on the spectrum of scenario A and B the risks more accurately lie.

Further, any fishing activities that result in interaction with abalone habitats and potential transmission of HaHV-1 should be carefully managed. Early in an outbreak, when the extent of an outbreak is unknown, fishing should cease in an affected area, to manage transmission risks. However, after the outbreak is delimited, fishing in declared areas (i.e. those areas in the restricted area where there are no active outbreaks occurring and the controlled area– see Figure 1) may resume with mitigations. These mitigations will be around biosecurity practices and the movement of potentially contaminated abalone. Biosecurity practices required will focus on disinfection of boats and equipment before moving to uninfected areas to reduce the risk of fomite transmitted infection to new areas. That is, fishing can occur within a control area, but boats must return to port and offload abalone (if abalone fisherman) and disinfect equipment (including drying and desiccation) before moving to clean areas. Abalone from infected areas should be considered potentially infected even if they appear healthy when harvested from infected areas and great care taken in marketing.

It is important to realise this project scope did not include estimation of risks associated with natural spread (e.g. water currents, ocean upwellings etc.). This scope-stipulated-omission should be considered by stakeholders when assessing this project. If later research demonstrates that natural spread is much more significant than the four pathways considered here, then recommended risk mitigations would change. For example, imposing fishing restrictions in and around containment and control areas would have little impact on transmission were natural spread to be significant. However, we have not assessed the evidence on natural spread or the comparative risks between this and the four pathways we assessed. We therefore cannot assess the relative importance of other spread pathways and therefore relative importance of competing risk mitigations. Research regarding the natural spread of *Ostreid herpesvirus* ranges from 10s of km to 100s of km depending on the location (Roberts et al. 2020). If this is found to be the case for HaHV-1, there may be a requirement for region specific recommendations.

As further research and data becomes available the risk assessment can be reviewed, with estimated likelihoods updated at relevant nodes to calculate new estimated risks. It is important that this occurs as new information becomes available to ensure risk mitigation advice is appropriate and contextually relevant.

Recommendations

Non-research recommendations

Standardised Code of Practice protocols

Protocols and messages developed in the COPs of different jurisdictions should be standardised to encourage compliance from stakeholders accessing fishing zones in multiple jurisdictions. Currently the Victorian COP outlines more stringent biosecurity measures such as the explicit recommendation of using detergents on lobster pots. The standardisation of COPs will provide a useful resource if the jurisdictions or federal department decide to regulate control measures.

Restriction of all reef-based fishing activities in a control area based on compliance

Until further research is conducted to address the research gaps around the epidemiology of the disease it is recommended that jurisdictions only allow reef-based fishing activities in control areas if biosecurity measures are followed – access to reefs with active outbreaks should still be banned while the outbreak area is being delimited, and while active cases are still occurring. These measures include not moving fishing equipment to non-control areas without proper decontamination. Decontamination should include the use of fresh water, detergents and disinfectants (if there is one available to be used safely on equipment). Equipment should be allowed to dry in the sun. As compliance will play an important role in reducing the risk of spread associated with the abalone and SRL pathways, the respective jurisdictions and industries may need to invest in new technology to better monitor compliance.

Cease shucking at sea

It would be prudent for PIRSA to consider implementing a ban on this activity in the SA CZAF and SA WZAF while there is active disease transmission in the SA SZAF. The licence holders in these two zones should be consulted with prior to decisions being finalised to ensure any support structures or required infrastructure is identified early on to support the fisherman.

Future research

As previously discussed, there was a high level of uncertainty associated with numerous nodes within the pathways (Table 13). The sensitivity analysis specifically examined nodes two and three as these are associated with the role of human-mediated activities and fomites in the spread and transmission of HaHV-1 to naïve populations.

Therefore, based on the nodes with higher levels of uncertainty being associated with contamination of fomites it is recommended that this research gap is prioritised as it should provide more information on the actual role fomites play in the spread and transmission of HaHV-1. Modelling the natural spread, along with the identification of latently infected populations would also be beneficial to prioritise as this information will help assist the industry to be better prepared for future outbreak events. The associated nodes the research will contribute to are listed below.

Table 13 Uncertainty levels for each node and pathway

	SRL – Pathway 1	SRL – Pathway 2	Recreational – Diving	Recreational – Line	Commercial abalone	Commercial abalone with shucking	Net fishing
R_1: Human activities overlap with HaHV-1 clinically infected abalone population							
	Low	Low	Low	Low	Low	Low	Low
R_2: Equipment becomes contaminated with AVG							
	High	High	Moderate	Moderate	High	High	High
$R_{2.5}$			Moderate			High	
R_3: Equipment contaminated with infectious HaHV-1 is used in an HaHV-1 naïve zone							
	High	High	High	High	High	High	High
R_4: Abalone become infected and clinical for AVG							
	High	High	High	High	High	High	High

1. The role mucus plays in protecting the virus and what actions are required to break it down.

This research gap was identified in the 2021 industry research and development workshop (Fox et al. 2022). Expert opinion regarding this issue is divided with those interviewed from the research sector and Victorian fisheries holding the assumption that the mucus plays a role in the transmission of the virus and that even the action of removing lobster pots from the water with a motorised winch is not sufficient to remove infectious material. It was also suggested that detergents currently recommended, such as Truck Wash may be insufficient to disrupt the mucus matrix, even if they can inactivate the virus, or they may require a certain level of mechanical action/agitation to be effective.

Clarifying the role mucus plays in disease transmission will be crucial for determining the risk SRL fishing activities play in the spread of the disease and will ensure decontamination measures are appropriate for any fomite that becomes contaminated with mucus during an outbreak.

This research will contribute to the following nodes:

- R_2: Equipment becomes contaminated with AVG
- R_3: Equipment contaminated with infectious HaHV-1 is used in an HaHV-1 naïve zone

2. Modelling of natural spread of the virus.

In the original Victorian outbreak in 2005, AVG spread long distances along the coast. This spread was later assumed to be due to SRL fishing as the rapid introduction of movement controls in the 2021 outbreak resulted in less spread and fewer reefs becoming infected. However, a retrospective qualitative study of the 2021 outbreak is needed to confirm whether the movement restrictions were protective, or the reduction in outbreak magnitude was coincidental and due to other reasons, such as increased genetic resistance within the population. We recommend determining whether there is sufficient data to conduct simulation modelling to investigate the rate and distance of spread of AVG expected in the absence of human-mediated activities. Similar modelling has been conducted in other aquaculture industries (Aldrin et al. 2011; Scheel et al. 2007; Ding et al. 2024; Romero et al. 2022; Roberts et al. 2020). Similar research in *Ostreid Herpesvirus* found the distance of virus movement varied depending on the original location (Roberts et al. 2020). Therefore, it would be recommended that movements across different areas in each jurisdiction are studied.

This research will contribute to the following node:

- R_3: Equipment contaminated with infectious HaHV-1 is used in an HaHV-1 naïve zone

3. Presence of latently infected populations and natural stress events.

During the consultations, the question of latency within the wild abalone populations was discussed. Surveillance of the wild populations could determine the possibility of latency and, where possible, map suspected latent populations. This information, along with the identification of possible natural stress events would assist local industries in determining mitigation measures in the event of an outbreak.

This information would help other zones and industries develop management plans that are fit-for-purpose and immediately implementable. By being proactive and developing the models and relevant management plans, industries and fisheries may be adequately prepared in the event of an early incursion.

This research will contribute to the following nodes:

- R_3: Equipment contaminated with infectious HaHV-1 is used in an HaHV-1 naïve zone
- R_4: Abalone become infected and clinical for AVG

4. Viral load produced during an outbreak, and subsequently required to induce clinical infection.

The viral load produced during an outbreak or required to induce clinical infection in abalone is unclear. Further research in this area will complement any research findings regarding the role mucus plays in the spread and transmission of the disease. For example, if outbreaks produce a large volume of viable virus, and a small viral load is required to induce infection, activities occurring in an outbreak area will have a much higher likelihood of spreading the virus to new areas.

This research will contribute to the following nodes:

- R_2: Equipment becomes contaminated with AVG
- R_3: Equipment contaminated with infectious HaHV-1 is used in an HaHV-1 naïve zone
- R_4: Abalone become infected and clinical for AVG

5. Route of infection.

The primary route of infection for wild abalone is unclear. There are three possible routes: ingestion, via the gills, via immersion/ transdermal. Clarification on the primary route of infection would help determine the likelihood of exposure through the water column leading to clinical infection. This would complement any findings from the previous two research areas and allow more accurate likelihood assumptions to be made regarding the role fomites may play in the transmission of the virus.

This research will contribute to the following node:

- R_4: Abalone become infected and clinical for AVG

6. Movement of HaHV-1 by vessel waste water.

This research will be useful for determining whether vessel biowaste water, including water from holding wells with possibly contaminated lobsters may contribute to the movement of HaHV-1 to new areas. Based on expert opinion, the holding wells are supplied with sea water taken from the upper two metres of the water column, and it is into this zone that water is discharged. It could be assumed that this distance is sufficient to protect abalone population. However, it is unknown whether sediment may assist in virus movement, increasing the risk of virus reaching the depths that abalone are present.

This research will contribute to the following node:

- R_3: Equipment contaminated with infectious HaHV-1 is used in an HaHV-1 naïve zone

Further development

Clear communication of measures and recommendations for biosecurity.

Several stakeholders are concerned that fit-for-purpose information regarding restrictions and recommended mitigation measures is not readily available. This was identified as a key issue for the recreational sector where participants are highly diverse. While there are resources available, such as fisheries notices, and the COP for each state, recreational anglers and divers may not be aware of these or know where to access them.

As AVG is becoming relevant to several jurisdictions, it is recommended that the affected jurisdictions work together to ensure consistency in messaging.

Cost-benefit analysis of active surveillance activities to identify latently infected populations.

Identification of latent populations is likely to have implications for control and mitigation measures. Cost-benefit analysis of the proposed surveillance is recommended.

Workshop with researchers to determine capacity and interest for further research – coordinated approach.

As identified, there are several research gaps that limit the utility of this risk assessment. However, the findings help redefine future research areas. A workshop with relevant researchers and industry members could be convened to identify the capabilities of each group and funding available for research. This would allow for key areas to be agreed upon and prioritised. A similar workshop was conducted in 2021. However, the identified actions points were not followed through, reportedly due to reduced stakeholder availability immediately following the workshop leading to loss of momentum.

Extension and Adoption

At the completion of the project a short companion report will be developed and disseminated to industry. If there is sufficient industry interest, we will also deliver industry webinar to present the findings and a 1-2 page document for each risk pathway summarising the findings.

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Project materials developed

An industry focused companion report was developed for FRDC to circulate amongst the stakeholder groups (Appendix 6).

Pathway summaries were developed to accompany the industry companion report (Appendix 7).

Webinars are planned to be conducted for the different stakeholder groups.

Appendices

Appendix 1

Stakeholder consultation list

Stakeholder group	Organisation	Role	Name	State
Target fisheries	Abalone Council Victoria / Western Abalone Divers Association (WADA)	Chair of Abalone Council Vic, Chairman of WADA	Craig Fox	Victoria
	Southern Zone Abalone Fishery Inc	Executive Officer	Arthur Martel	South Australia
	Western Abalone Divers Association	Executive Officer	Travis Baulch	Victoria
	Eastern Zone Abalone Industry Association	Executive Officer	Helen Burvill	Victoria
	Southern Ocean Mariculture	Operations Manager	Hamish Ebery	Victoria
	Victoria Rock Lobster / Net fishing, octopus, wrasse / Seafood Industry Victoria	Chief Executive Officer	Matt Wassnig	Victoria
	SA Southern Zone Rock Lobster/ South Australian Rock Lobster Advisory Council Inc / South Eastern Professional Fishermen's Association Inc	Executive Officer	Nathan Kimber	South Australia
	SA Northern Zone Rock Lobster / South Australian Northern Zone Rock Lobster Fishermen's Association Inc / Seafood Industry SA	Executive Officer	Kyriakos Toumazos	South Australia
	Victorian Fisheries Authority and Rock Lobster Resource Assessment Group (RAG)	Fisheries managers	Ewan Flanagan	Victoria

Stakeholder group	Organisation	Role	Name	State
	VRFish	Executive Officer	Ben Scullin	Victoria
Jurisdictional government biosecurity staff	Department of Primary Industries and Regions, South Australia (PIRSA)	Aquatic animal health manager	Matt Bansemer	South Australia
	PIRSA/South Australian Research and Development Institute (SARDI)	Sub-Program Leader – Molluscan Fisheries at SARDI Aquatic Sciences	Stephen Mayfield	South Australia
	PIRSA	General Managers, Fisheries	Annabel Jones	South Australia
	Agriculture Victoria	Principle Veterinary Officer	Tracey Bradley	Victoria
	Victorian Fisheries Authority	Abalone Fishery Manager	Anthony McGrath	Victoria
Researchers	CSIRO ACDP	Team Leader for Aquatic Diagnostic Capacity	Nick Moody	Victoria
	Deakin University Geelong Campus Waurn Ponds Campus	Associate Professor in Ecology and Environmental Genetics	Craig Sherman	Victoria
	La Trobe University Melbourne Campus	Professor in Microbiology, Anatomy, Physiology & Pharmacology	Karla Helbig	Victoria
	La Trobe University Melbourne Campus	PhD Candidate under Prof Helbig	Jacinta Aguis	Victoria
	Institute for Marine and Antarctic Studies (IMAS) Hobart	Senior Research Fellow, Sustain Fisheries, Sustainable Marine Research Collaboration	Craig Mundy	Tasmania
	University of Tasmania	Research Fellow Dive Fisheries, Sustainable Marine Research Collaboration	Jaime McAllister	Tasmania

Appendix 2

Stakeholder consultation questions - Industry

Topic Area	Wild abalones	Farmed abalones	SRL	Recreational fishing
Normal fishing/processing operations	Can you describe your routine/daily fishing operations? Prior to any movement restrictions, would you travel between different fishing zones within a day or a week? What influences your selection of fishing site? How has this been impacted by the recent AVG movement restrictions? How much, if any, processing of abalone is done on the boat prior to it returning to the dock? How do you hold stock (live or processed) onboard? Do you use a flow through or static tank or well?	Can you describe your routine operations? Can you describe the processes around abalone broodstock sourcing?	Can you describe your routine/daily fishing operations and how they interact with the wild abalone industry? Prior to any movement restrictions due to the AVG outbreak, would you typically travel between different fishing zones or stay within the one? What influences your selection of fishing site? How has this been impacted by the recent AVG movement restrictions?	Can you describe the general fishing practices of recreational fishers? i.e. how frequently do they go out, key fishing locations, types of bait used, species Where do rec fishers collect most of their abalone in South Australia and Victoria? How do rec fishers typically process their abalone? Where do they do this?

Topic Area	Wild abalones	Farmed abalones	SRL	Recreational fishing
Overlap with abalone fishing industry	Do you hold a licence for any other fisheries? if so, what are they and do you use the same boat or equipment for these, and do you fish in the same zone?	Can you describe your interactions with the wild catch abalone industry? Do you hold licenses for any other fishery species?	Where do you see the overlap of the SRL industry with abalone?	Areas of abalone collection and rec fishing?
AVG high risk activities	What does the industry (or do you) see as the higher risk activities for the spread of AVG or other diseases? During your fishing operations, can you describe your interactions with the seafloor?	What does the industry see as the higher risk activities for the spread of AVG or other diseases?	What do you see as higher risk activities in your industry for potential to spread AVG?	What proportion of rec fishers would be collecting abalone? What do you see as high risk activities for potential to spread AVG?
Biosecurity	Can you describe your general biosecurity practices used during your fishing operations? Have these changed since the AVG outbreak with any new measures being implemented?	Can you please describe the general biosecurity measures that you implement on your facility? Have any new measures been introduced to reduce the risk of AVG from entering your farm? Do you have a quarantine (and screening) process if wild broodstock (any stocks?) are brought onto the facility?	What are the general biosecurity measures you use on SRL fishing vessels	Can you describe the general biosecurity measures that rec fishers would likely use on a regular basis? Do rec fishers often shuck their abalone at sea i.e. discard shell and gut into the ocean? In situ or on their way back?

Equipment	Do you typically change fishing and diving equipment between different fishing sites or do you use the same equipment for one trip and then clean at the end? What would be the Time gap between trips? Is fishing equipment cleaned between each voyage? How do you clean your diving equipment? Do you use disinfectants? If so, which ones.	Does any farm equipment ever leave the farm and is used in other sites or wild catch activities? If so, what type of equipment and what biosecurity protocols have you introduced to manage the risks?	What equipment do you use that could potentially become contaminated with AVG? i.e. direct contact with sick abalone or seafloor contact etc Do you typically change fishing and diving equipment between sites or do you use the same equipment for one trip and then clean at the end? What would be the time gap between trip? Can you describe the general cleaning practices of your equipment i.e. frequency, what types of disinfectant etc. Is equipment shared between boats or it remains on the one vessel? We understand that the microbiome present on the lobster pots plays an important role in their effectiveness for catching lobsters - before AVG was a threat what was the normal biosecurity/cleaning processes undertaken? i.e. where pots ever left to dry in the sun between use?	How would rec fishers typically clean and handle their fishing gear? Would this differ between locations?

Topic Area	Wild abalones	Farmed abalones	SRL	Recreational fishing
Waste disposal	Can you describe the disposal methods of (bio)wastes accumulated on the boat during a fishing trip i.e. abalone waste, waste water etc.	Can you describe the disposal methods of wastes accumulated at your facility i.e. abalone waste, waste water etc.	Can you describe the disposal methods of wastes accumulated on the boat during a fishing trip i.e. waste water etc.	
Personnel	Do personnel on the boat bring their own diving equipment? How is this cleaned and monitored?	Do any of your personnel also actively participate in other fishing (recreational or commercial) activities? Are there any biosecurity measures imposed on these individuals?	Are there any personnel risks that you can see for AVG i.e. bringing their own equipment on boat, reusing their own equipment as a recreational fisher?	
Cleaning and disinfection processes	What are the cleaning and disinfection protocols used on the boat? How often is this done? Are there any challenges with cleaning the vessel and equipment? What are your cleaning and treatment processes around biofouling and waste water?	Can you please describe the routine cleaning and disinfection processes undertaken at your facility, and those that would be undertaken in the event of an outbreak?	What cleaning and disinfection protocols do you use on your boats and equipment? What types of disinfectant do you use? With lobster pots - there are issues with using strong disinfectants that can affect the microbiome on the lobster pot, impacting catch rate. What do you typically use? Are regularly cleaned between use?	What are the recommended disinfectants to rec fishers to clean their equipment? Are the recommended disinfectants easily accessible to rec fishers?

Topic Area	Wild abalones	Farmed abalones	SRL	Recreational fishing
Vessel movement	Prior to any movement restrictions, would you typically travel between different fishing zones? What are the distances you would typically travel during a fishing trip? How many sites would you typically visit and what are the durations of these trips? How do vessel movements vary between the seasons?	Do your operations involve the use of vessels? Can you provide details.	Describe general SRL boat movements during a fishing trip i.e. how far would you typically travel, duration, number of sites visited, movement between zones?	Do rec fishers typically stay in one area and use a regular fishing spot or do they move around?
Movement of product - legal and illegal	Can you describe the movement of abalone once you arrive at the dock? Which processing facilities do you use? How many processing facilities do you typically take product to? Do you feel like/ suspect there are poaching activities regularly occurring in the areas you fish in? Do you feel like they are posing a risk of AVG spread?	Do you ever hold wild abalones? Do you have a processing facility on site? or are your abalone transported to an external processing facility? If they are transported, can you please describe this process, and what measures are taken to reduce the stress on abalone during transport?		What do rec fishers typically do with their abalone i.e. is this for home consumption or do they sell it? Do you think rec fishers are aware of the restrictions in place regarding movement of abalone?

Biosecurity compliance	Do wild catch divers feel like the biosecurity measures outlined in the code of practice are effective, practical, operationally relevant and followed by most members? Does the industry feel like most members are following the code of practice? Do you have any suggestions to update or improve the code and compliance?	As an industry, or a business, how well equipped are abalone farms to deal with onsite outbreaks? i.e. is the cost of depopulating and repopulating able to be managed or is it likely to wipe out a number of farms? If you had to undergo repopulation, how confident are you that infection and disease free abalone could be successfully sourced? What do you see as the greatest risks to your sector of the industry?	Do you feel the biosecurity measures outlined in the AVG and SRL codes of practice to prevent the spread of AVG are effective, realistic and practical? Do you feel like most members follow them? Who/what group/activity do you see as the biggest risk for spreading AVG in your fishery area? Are there any biosecurity measures that you feel should be implemented to help with AVG?	What are realistic biosecurity measures that will be followed by rec fishers? Have there been any workshops for rec fishers on their roles and responsibilities and how to practice good biosecurity? Are the different rec fishing representative groups confident that rec fishers are complying with biosecurity regulations? What is the process around compliance checks with rec fishers? What challenges do you face when implementing biosecurity measures? In SA, you don't need a recreational fishing license (although you need a permit for certain locations). How does this impact reinforcement with disease control measures, movement controls and cleaning of equipment etc. How is this checked, monitored? If further biosecurity restrictions were implemented for AVG, how would this impact the rec fishing community? What would be

Topic Area	Wild abalones	Farmed abalones	SRL	Recreational fishing
				some of the negative repercussions of that?
Legislation and compliance				What are the specific regulations that apply to rec fishers as a result of the AVG outbreak? Have any new regulations been adequately communicated to the rec fishing community?
Translocation of abalone	Have you ever been involved in the translocation of abalone?	Has your facility ever been involved in the translocation of farmed or wild live abalone? Does your facility sell live abalone to other states for the restaurant market?		Have there ever been any reports of rec fishers translocating abalone to new reefs?
Risk of other fishery sectors	Do you see any other fishery sectors being a disease risk to the abalone fishery? if so, which one/s and why?	Do you see any other fishery sectors being a disease risk to the wild abalone fishery? if so, which one/s and why?	What are your thoughts on the transmission of AVG and how it's spreading? What do you see as the biggest risks?	Are rec fishers likely to be targeting multiple species when diving? if so, what would they likely be?
Current and future research	What does the industry see as priority area for research concerning abalone and AVG?	What does the industry see as target areas for research concerning abalone and AVG?	What would you like to receive more information on and see research being conducted?	

Topic Area	Wild abalones	Farmed abalones	SRL	Recreational fishing
Communication			Do you feel the current communication methods are sufficient to disseminate new findings/measures to members?	What communication measures do you use to reach out to rec fishing members? Are the communication methods adequate to disseminate key biosecurity measures to recreational fishers? What is the awareness level of rec fishers to AVG, the current control measures and potential disease transmission?
Other	Do you have any other general comments on AVG or the current outbreaks that could support our risk assessment?	Do you have any other general comments on AVG or the current outbreaks that could support our risk assessment?	Do you have any other general comments on AVG or the current outbreaks that could support our risk assessment?	Do you have any other general comments on AVG or the current outbreaks that could support our risk assessment?

Stakeholder consultation questions - Government

Topic areas	South Australia Government	Victorian Government
General	Can you provide a general description of where the current AVG outbreak is at in SA and your key activities being conducted at the moment?	Can you provide a general description of where the current AVG outbreak is at in Victoria and your key activities being conducted at the moment?
Compliance	How do you monitor and reinforce the compliance of recommended biosecurity measures across the different industries as outlined in the code of practice? Is this harder with recreational fishers?	How do you monitor the compliance of recommended biosecurity measures across the different industries as outlined in the code of practice? Is this harder with recreational fishers?

Topic areas	South Australia Government	Victorian Government
Biosecurity	The code of practice discusses a number of risk assessments conducted as part of response activities - are you able to discuss these in more detail or share the reports? Have you received any industry feedback regarding the biosecurity measures recommended in the Code of Practice- does industry see these as practical measures? Does the department feel that the measures they are recommending will be adequate? It is understood that abalone fishers are allowed to process/shuck abalone on boats in the western and central zone - is this likely to change as the risk of AVG is increasing? How is bait type and usage monitored for the different fishing sectors? i.e. can't use abalone product - is this done by rec fishers?	The code of practice discusses a number of risk assessments conducted as part of response activities - are you able to discuss these in more detail or share the reports? Have you received any industry feedback regarding the biosecurity measures recommended in the Code of Practice- does industry see these as practical measures? Does the department feel that the biosecurity measures they are recommending will be adequate? It is understood that abalone fishers are not allowed to process/shuck abalone on boats in Victoria. Does this still occur and how is this monitored? How is bait type and usage monitored for the different fishing sectors? i.e. can't use abalone - is this done by rec fishers?
Compliance	Has there been any push back from different industry groups when trying to implement different biosecurity measures? which ones? what are their concerns and how do you see these best addressed?	Has there been any push back from different industry groups when trying to implement different biosecurity measures? which ones? what are their concerns and how do you see these best addressed?
Impact	What would the impact on the SA abalone industry be if the disease was to spread to the central and western zones?	Can you describe how Victoria is being impacted by the AVG outbreak, in regards to the different fishing sectors?
Research	What areas of research have been funded and are there any preliminary findings that can be shared that may contribute to the risk assessment?	What areas of research have been funded and are there any preliminary findings that can be shared that may contribute to the risk assessment?

Topic areas	South Australia Government	Victorian Government
Abalone movements	Can you describe the movement processes around wild abalone broodstock going to aquaculture farms and from farmed back to wild to help restocking of population?	Can you describe the movement processes around wild abalone broodstock going to aquaculture farms and from farmed back to wild to help restocking of population?
Compliance	Do you feel that abalone poachers are posing a threat to the control of AVG?	Do you feel that abalone poachers are posing a threat to the control of AVG?
Current and future research	What do you see as target areas for AVG research that are needed?	What do you see as target areas for AVG research that are needed?
Other	Do you have any other general comments on AVG or the current outbreaks that could support our risk assessment?	Do you have any other general comments on AVG or the current outbreaks that could support our risk assessment?

Stakeholder consultation questions - Research

Topic areas	Research
General	Can you describe your involvement in AVG research, the current outbreaks or any other relevant activities?
Epidemiology	Has your organisation been involved in any research activities to address the current knowledge gaps regarding the epidemiology of AVG - in particular, the transmission pathways? Has any recent research provided further insights into what is causing infected wild abalone to show clinical signs of AVG? e.g. insights into stressful events?

Topic areas	Research
Risk	Based on the collective knowledge available, what is the perceived risk non-abalone fishing activities pose for the spread of AVG? Is there any research available that has looked at the distance HaHV-1 can travel in the water column, or at what depth it is found? Has there been any work conducted on the development of 'pond-side' tests to diagnose AVG? if so, would these be suitable to be used at sea, or for land-based farming only? Research is being conducted into improving abalone immune response to AVG. Is this likely to be applicable only to land-based farming operations or could be used in a marine environment with wild abalone populations? Do the current biosecurity recommendations outlined in the SA and Vic Codes of Practice seem appropriate? Maybe split the question into bio-exclusion measures and bio-containment measures. What would cause you to suggest stricter, of less strict measures?
Other	Do you have any other general comments on AVG or the current outbreaks that could support our risk assessment?

Appendix 3

R code

The script used to generate the cumulative risk ratings and sensitivity analysis is available upon request.

Appendix 4

Literature review

Executive Summary

Objective and background

Abalone viral ganglioneuritis (AVG) is an emerging and re-emerging aquatic emergency disease that impacts abalone fisheries and other fishing industries of Victoria, South Australia and Tasmania. Populations in New South Wales and Western Australia are still considered free of the disease. AVG initially emerged in wild and farmed abalone populations between 2005-10 across Victoria. Sporadic outbreaks were then seen in farmed populations in Tasmania until 2010-11. The disease appeared to be dormant in the wild populations and was considered eradicated from farmed populations until an outbreak was detected in wild populations in the western zone of Victoria in 2021. This was followed by an outbreak in the southern zone of the South Australian abalone fishery early in 2024.

To control the movement of the disease in wild populations, South Australia and Victoria have developed codes of practice and implemented movement restrictions. However, as the abalone fishery shares waters with other fishing industries, such as the Southern Rock Lobster fishery, these movement restrictions are potentially negatively impacting these other fisheries. A shared responsibility framework is essential to ensure a sustainable and long-term approach can be adopted.

Methods

A literature review was conducted to understand the epidemiology of AVG and the different fishing industries in South Australia and Victoria. The search engine, Web of Science Core Collection (Clarivate), was used to search for peer-reviewed articles using search terms such as abalone viral ganglioneuritis (AVG), abalone herpesvirus (AbHV), Haliotid herpesvirus-1 (HaHV-1), epidemiology, and transmission. The Google search engine was used to further search for grey literature, presentations, and publicly available commercial information relevant to the review. Government-associated websites were searched for documents applicable to Australia's biosecurity and disease response actions. A snowball approach was also used when searching the databases.

Key findings

The literature review has identified a number of key findings. The abalone industry comprises of wild catch and aquaculture sectors. However, the market is still predominantly reliant on wild caught product. This presents a risk for disease impacts, such as mass mortalities from AVG. While populations are able to reseed and recover, this generally occurs via self-recruitment as larvae do not typically travel long distances. Populations that experience higher rates of mortalities, have greater difficulty repopulating to a sustainable level.

There are a number of overlapping fishing industries that operate in the same areas as abalone divers. Due to the target species, and methods of harvesting, it is suspected that Southern Rock Lobster (*Jasus edwardsii*) fishing (commercial and recreational pot fishers), and recreational fishers (diving and line) are likely to be industries that pose a risk of AVG spread. The codes of practice developed by South Australia and Victoria are detailed, highlighting key biosecurity practices to support the response. However, it remains unclear whether the recommendations are fit-for-purpose for all stakeholders – i.e. are detergent/disinfectant recommendations necessary for SRL or is desiccation and UV exposure sufficient – and the level of compliance that is actually achieved.

There are significant knowledge gaps regarding the epidemiology of AVG and the causative agent. These include:

- duration of infectivity

- role of latency
- risk of fomites
- role mucus plays in the spread and transmission
- point of entry
- risk of vertical transmission
- natural movement through the water column
- methods of control in wild populations
- environmental factors that will result in outbreaks in wild populations.

This lack of knowledge in the wider scientific community will increase the level of uncertainty in risk assessments. This is particularly the case for the role of fomites and the spread of the virus through the water column, as it is not well understood. This creates challenges in determining the suitability of control measures applied to other fishing activities. As AVG is caused by a herpesvirus, we have presented some literature on other aquatic herpesviruses that can provide some insight into the general epidemiology of this virus type in the marine environment.

The stakeholder consultations have provided further insight into the research gaps – key information gathered from these consultations have been included in *italics*. Hypotheses raised during stakeholder consultations will be considered 'expert opinion' when they are biologically plausible; and will be used to inform a risk assessment of nodes where there is insufficient additional data or published literature. Uncertainty estimates will reflect nodes where data and published literature is lacking and the effect of this uncertainty on the overall risk associated with each pathway will be tested through sensitivity analysis.

Conclusions

The abalone industry faces challenges from AVG and potential vector transmission from other fishing activities. Addressing these challenges requires improved biosecurity protocols, increased research into AVG, and ensuring compliance with existing regulations to protect abalone populations and sustainability of fishing industries.

The Abalone fishing industry

Abalone ecology

Abalone are reef-dwelling marine molluscs found in Australia's southern waters, with considerable industries in Tasmania, South Australia, Victoria and southern Western Australia (Table 14). Their bodies are comprised of a single shell and a muscular foot. Abalone are generally found at depths of 3-10 m (can range from 2-40 m). They follow a simple life cycle and reach sexual maturity once the shells are a specific size, depending on the species – this usually occurs around two to three years, depending on feed availability. Populations generally rely on self-recruitment as spawn and larvae do not travel far (Miyake et al., 2017). The males and females broadcast spawn, with fertilised eggs developing into larvae within 24 hours. Larvae drift in the water column for approximately one week before settling on a suitable substrate, such as a rocky reef. The larvae have poor ability to move horizontally in the water column, so do not migrate far during this period, unless they are carried on currents (Miyake et al., 2017, 2009). Reports suggest that spawning may range from 80-500 km, depending on the geographical location and species of abalone; population ranges of less than 200 m have also been found (Miyake et al., 2017). Abalone larvae are expected to remain at depths close to suitable settlement substrates while they move through the water column as they respond to chemical cues and swim downward towards these substrates (Li et al., 2006). If the substrate is suitable, the larvae then develop into 'post-larvae' that can crawl along the substrate but can no longer swim. During this phase, the larvae will feed on benthic microflora. The longer the larvae spend in the mobile phase, the lower the chance of it surviving into an adult abalone (Miyake et al., 2009). At 5-10mm they begin feeding on microalgae, and once the shell develops, they are termed spat and start feeding on algae (Jenkins, 2004). Abalone can take up to about four years to reach a marketable size and generally only grow 2-3cm per year.

Larvae may undergo short or long distance movement in water, or a combination of both. Short distance dispersal is vital for replenishment of populations and enables larvae to settle on suitable substrates in their natal reef. Long distance dispersal can support population movement to reefs that may host fewer predators and have an abundant food source. However, long-distance dispersal presents a risk for larvae settling in areas that do not have suitable substrates, such as sandy sea floors (Miyake et al., 2017). Coastal environments, such as those found between the central and southern zones of the South Australian abalone fishery may provide natural barriers to population dispersal but further research is required to better understand larval dispersal and the rate of natural spread.

Abalone populations have previously been impacted by Perkinsus (*Perkinus olseni*), a protozoan parasite. The disease is characterised by foot lesions and mass mortalities, and has occurred in the western zone fishery of South Australia. It is not thought to be present in the Victorian abalone population (PIRSA, 2021a; VFA, 2007). A 2019 ecological sustainable development risk assessment of the South Australian industry found the greenlip abalone to be sustainable in the western and central zones, and undefined in the southern zone (FRDC 2024). The blacklip abalone is depleted in the central zone, and sustainable in the southern and western zones ((FRDC 2023, PIRSA, 2021b). In Victoria, the blacklip abalone population is depleting in the central and eastern zone, and the greenlip abalone is undefined in the western and central zones (FRDC, 2023, 2024a).

The majority of abalone harvest enters the Asian export market, primarily as live product. However, it is also sold as canned, frozen, dried, or vacuum-packed product. Abalone has predominantly been sourced from wild stock, but there is a growing land-based farming sector and a small sea-ranching sector within the industry. Each of these are described in more detail below.

Table 14 Commercially harvested abalone species in Southern Australia, and populations affect by abalone viral ganglioneuritis.

State	Species harvested	Harvest method	AVG susceptible	Population affected
Western Australia	Roe's Abalone (*Haliotis roei*) Greenlip abalone (*Haliotis laevigata*) Brownlip abalone (*Haliotis conicopora*)	Wild catch, sea ranching, land-based farming	Greenlip abalone (*H. laevigata*) Brownlip abalone (*H. conicopora*)	Nil
South Australia	Greenlip abalone (*H.laevigata*) Blacklip abalone (*H. rubra*) Roe's Abalone (*H. roei*) (western zone only)	Wild catch, land based farming	Greenlip abalone (*H. laevigata*) Blacklip abalone (*H. rubra*)	Wild – southern zone populations only
Victoria	Greenlip abalone (*H.laevigata*) Blacklip abalone (*H. rubra*)	Wild catch, land based farming	Greenlip abalone (*H. laevigata*) Blacklip abalone (*H. rubra*)	Wild and farmed, restricted to the western zone
Tasmania	Greenlip abalone (*H. laevigata*) Blacklip abalone (*H. rubra*) Hybrid abalone (*Haliotis* spp.)	Wild catch, land based farming	Greenlip abalone (*H.laevigata*) Blacklip abalone (*H. rubra*) Hybrid abalone (*H.* spp.)	Wild – clinical disease only apparent once in processing facilities
New South Wales	Blacklip abalone (*H. rubra*)	Wild	Blacklip abalone (*H. rubra*)	Nil

Wild caught abalone

Divers harvest wild stock abalone in all southern states. Each state enforces regulations and management practices to ensure industry sustainability and protect wild stock population. Licences, total allowable catch limits and minimum size regulations are used to manage stocks. Wild stocks are monitored regularly, and annual quotas for the industry are determined each year through this monitoring process. In South Australia the collective share of the annual quota for commercial divers is 99.74% (PIRSA, 2024a).

The size limits ensure that only mature abalone are harvested to ensure younger stock can breed. Seasonal closures are implemented to protect the population during breeding seasons. The relevant fishing authorities regulate the equipment divers can use during harvest to ensure safety and minimise any adverse impacts on catch. Catch is then processed at licenced processing facilities, discussed in more detail in the Processing and exports section.

Victoria and South Australia have divided their abalone fisheries into different zones – in both states these geographical regions host other fisheries, discussed below. The Victorian fishery is divided into western, central, and eastern zones, with total allowable catch limits specific for each zone (Abalone Council Victoria, 2020) (Figure 10). The South Australian abalone fishery is divided into western, central, and southern zones (PIRSA, 2022a) (Figure 11). Some zones, such as the central and western zone in South Australia are shared with a more diverse range of fisheries. While the activities of the

overlapping fisheries are distinct, the shared use of similar locations may pose a biosecurity risk for aquatic diseases. The more diverse the range of fisheries present, the more challenging it will be to develop cost effective measures applicable to all fisheries.

Currently, shucking abalone by commercial operators at sea is permitted in the western and central zone in South Australia. It is illegal to shuck abalone at sea in the southern zone in South Australia and in Victorian fisheries. Shucking at sea is considered a risk factor affecting the transmission of Perkinsus, and is ostensibly also a risk factor for the spread of AVG if infected material is transported and returned disconnected abalone habitats. In Victoria and the southern zone of South Australia, the catch must be brought ashore to be processed, and waste is not allowed to re-enter the marine environment. The restrictions also ensure that authorities are able to accurately monitor quotas as removal of shells reduces the reported catch weight, potentially leading divers to exceed their allowed limits. However, poaching (the illegal collection of abalone without licences or permits) is not uncommon, but prevalence is unknown and shucking at sea is more likely to occur in these situations (Tailby and Gant, 2002).

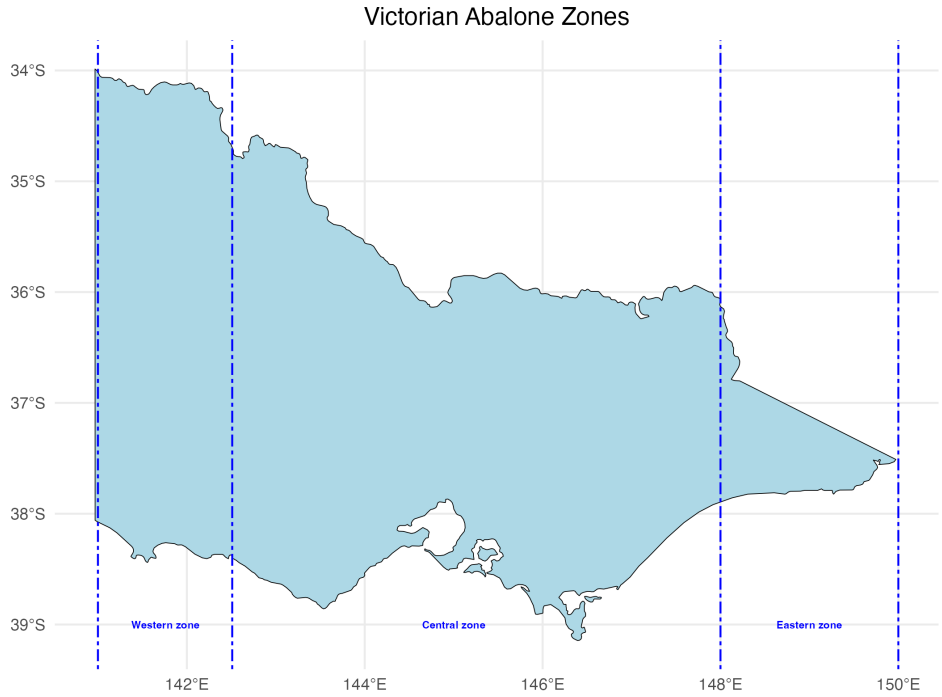

Figure 10 Abalone fishing zones in Victoria. The zones extend to 40°S (Western), 39°12'S (Central and Eastern). The 2021 outbreak occurred in the Western zone.

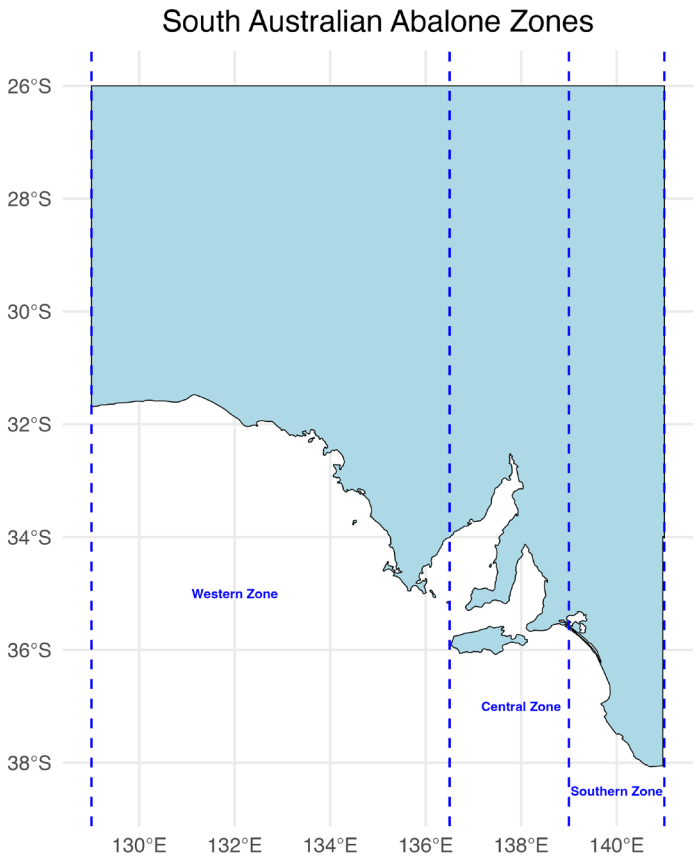

Figure 11 Abalone fishing zones of South Australia. The abalone viral ganglioneuritis control zone is located in the southern zone (PIRSA, 2022a).

Land-based abalone systems

Land-based systems are gaining popularity due to increased control over environmental factors, growth rates, and disease prevention. They are typically divided into either hatchery production or abalone grow out. The systems generally rely on broodstock being sourced from the wild. Spawning and larval rearing typically occur in smaller purpose built tanks. This is followed by a six-month grow out period in a larger tank. Abalone are then moved to a final tank for the next 18 months to 2 years until they reach marketable size. Abalone are fed a plant-based diet typically consisting of pellets and/or algae, which differ depending on stage of growth. Most of these facilities are located adjacent to coastal areas, relying on fresh seawater being pumped in and then discharged back out to sea. This may lead to environmental impacts and disease spread if not managed appropriately (Ingerson et al., 2007).

Sea-based abalone production

Sea ranching is the technique of growing farmed abalone on artificial reefs in the ocean. The artificial reef structures are populated with juvenile abalone bred in land-based farms. Supplementary feeding and predator protection are not implemented, so the survival rate can be variable. This method of abalone farming has been successful in southern Western Australia and has been trialled in South Australia and Victoria, with varying levels of success.

Processing and exports

Processing facilities are licenced by the state fishing authority where they are located and receive abalone from abalone fishing licence holders and farms. Processing involves preparing abalone for live export or drying, freezing, cooking, canning, and vacuum-packing. As processing facilities hold live abalone, they require access to clean, fresh seawater to maintain holding tanks. Australia has a reputation for supplying high-quality live products. Any disease outbreaks in processing facilities have the potential to impact this reputation severely. In many cases the sea water is circulated through the holding tanks and discharged into the ocean. If water is not treated on outflow, and outbreaks have occurred, this can pose a risk to wild populations located in the outflow bays.

In Tasmania, AVG was detected in at least six processing facilities between 2008-10. In the first detection in 2008, the disease was characterised by rapid onset of morbidity and mortality in a tank holding blacklip abalone from two different regions of Tasmania (Ellard, 2015). This initial case was characterised by a lower rate of mortality, but a higher rate of abalone becoming progressively weaker, and subsequently being rejected by the export market. A second processing facility reported mortalities in 2009. This event was characterised by increased mortalities without overt signs of disease other than rope-like mucous being present in the tanks (Ellard, 2015). In 2010-11, multiple facilities were affected, characterised by unexplained mortalities over several weeks, along with an unacceptable rate of mortalities in exported live product. All affected facilities received wild caught abalone and mixed consignments in tanks (Ellard, 2015).

Poachers may have direct involvement in the processing and export of abalone (Tailby and Gant, 2002), and anecdotal reports indicate that Asian markets receive twice as much abalone as Australian divers are legally allowed to harvest (Cook, 2023). Poachers will either develop ways to have their catch incorporated into legal catch quotas, or will set up illegal processing facilities and export through black market channels (Tailby and Gant, 2002). Legitimate processing facilities that knowingly or unknowingly receive poached abalone are likely to be at a higher risk of AVG and other disease outbreaks as the source location of these abalone are unlikely to be accurately verified.

Overlapping commercial fishing industries

The South Australian and Victorian abalone fishing zones overlap with other fishing industries, including crabs, charter fishing, marine scale fish, Prawns (*Penaeoidea* and *Caridea*), Southern Rock Lobsters, Scallops (*Pectinidae*) and small pelagic fisheries (Figure 12 and Figure 13). These industries, along with recreational fishing and diving activities can pose a risk of disease transmission between zones and into new areas if appropriate biosecurity measures are not followed as fishing gear may act as fomites, and target species may act as mechanical vectors. There is no biological vector involved in the transmission of AVG.

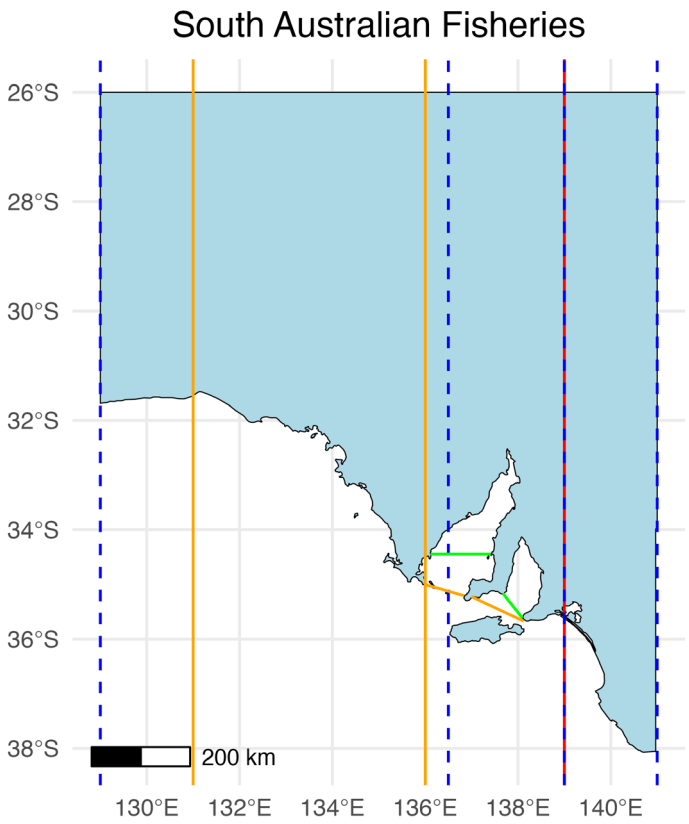

Figure 12 Fisheries in South Australian waters. The abalone fishery is between the dotted blue longitudinal lines (western, central, and southern). The prawn fishery is located north of the orange lines in the Gulf St Vincent and Spencer Gulf and between the two orange longitudinal lines. The crab fishery is primarily north of the green lines in the Gulf St Vincent and Spencer Gulf. The Southern Rock Lobster fishery is located west (northern) and east (southern) of the red longitudinal line. The scale bar is approximate.

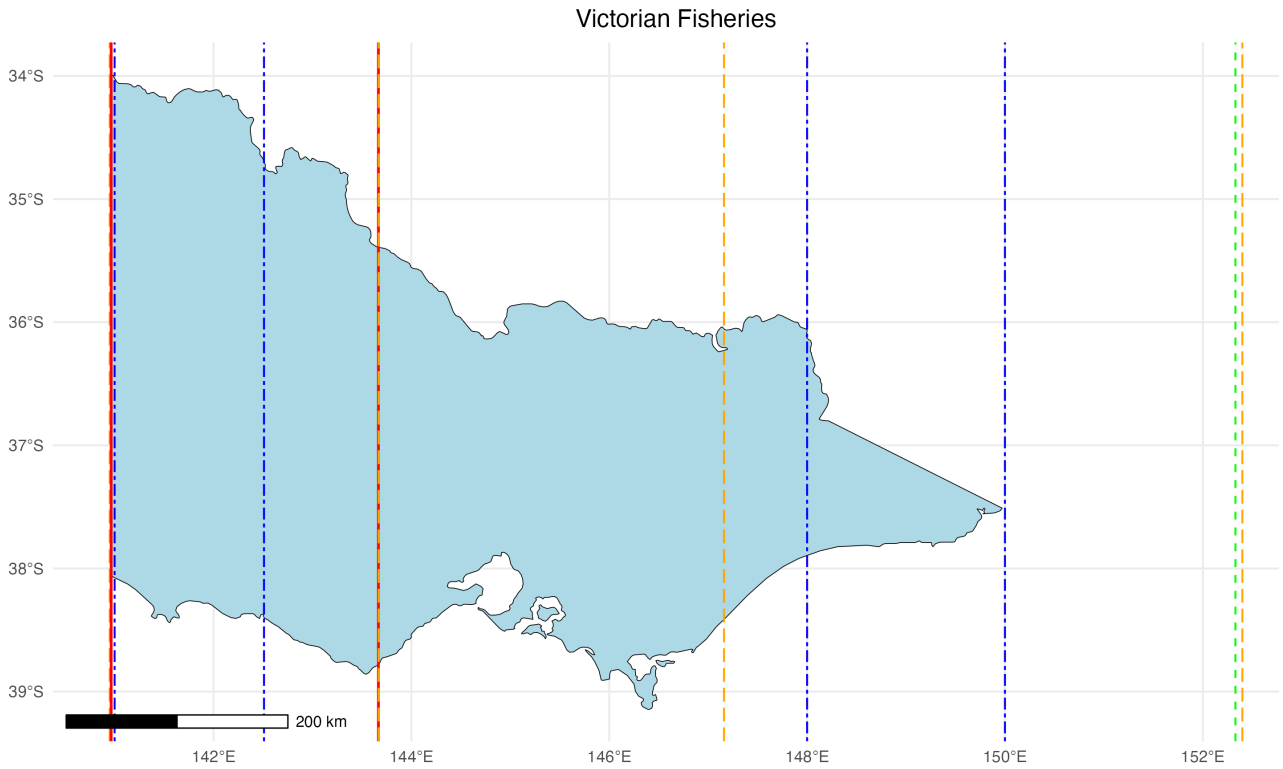

Figure 13 Fisheries present in Victorian waters. The abalone fishery is bounded by the blue longitudials (western, central and eastern zones), the Southern Rock Lobster is bounded by the green longitudinals. The western and eastern zone is divided at approximately 143°E. The crab fishery overlaps the Southern Rock Lobster in the western zone (red longitudinals). The octopus fishery is found bewteen the orange longitudinals, including 143°E. The scale bar is approximate.

Crab fishery

The crabbing industry in South Australia is predominantly blue swimmer and ocean sand crab. For both species, the catch is focused on male crabs, and they are captured using specific crab pots that are dropped from boats onto the ocean floor overnight and collected the following day. The main area of blue swimmer crabs is in the Spencer Gulf and the Gulf St Vincent (Figure 14). Both of these regions provide vital breeding habitats for fish and crustaceans, including CUTTLEFISHES (*Sepia spp.*), King George Whiting (*Sillaginodes punctatus*), Southern Garfish (*Hyporhamphus melanochir*), Western King Prawns (*Melicertus latisulcatus*), Yelloweye Mullet (*Mugilidae*) and Blue Swimmer Crabs (*Portunus armatus*) (PIRSA, 2024a). Blue swimmer crabs are commonly found on sandy or muddy substrates when not active. Since the typical habitat of blue swimmer crab lacks suitable substrate for abalone, it is unlikely that commercial crab fishing activities would significantly contribute to the spread of AVG. **However, as crabs are known to feed on animals such as abalone, they may act as a natural fomite if they feed on actively shedding abalone**. **Further, recreational divers or fishers targeting multiple species per trip may become contaminated fomites if they are present during an outbreak event, or if contaminated mucus is present**.

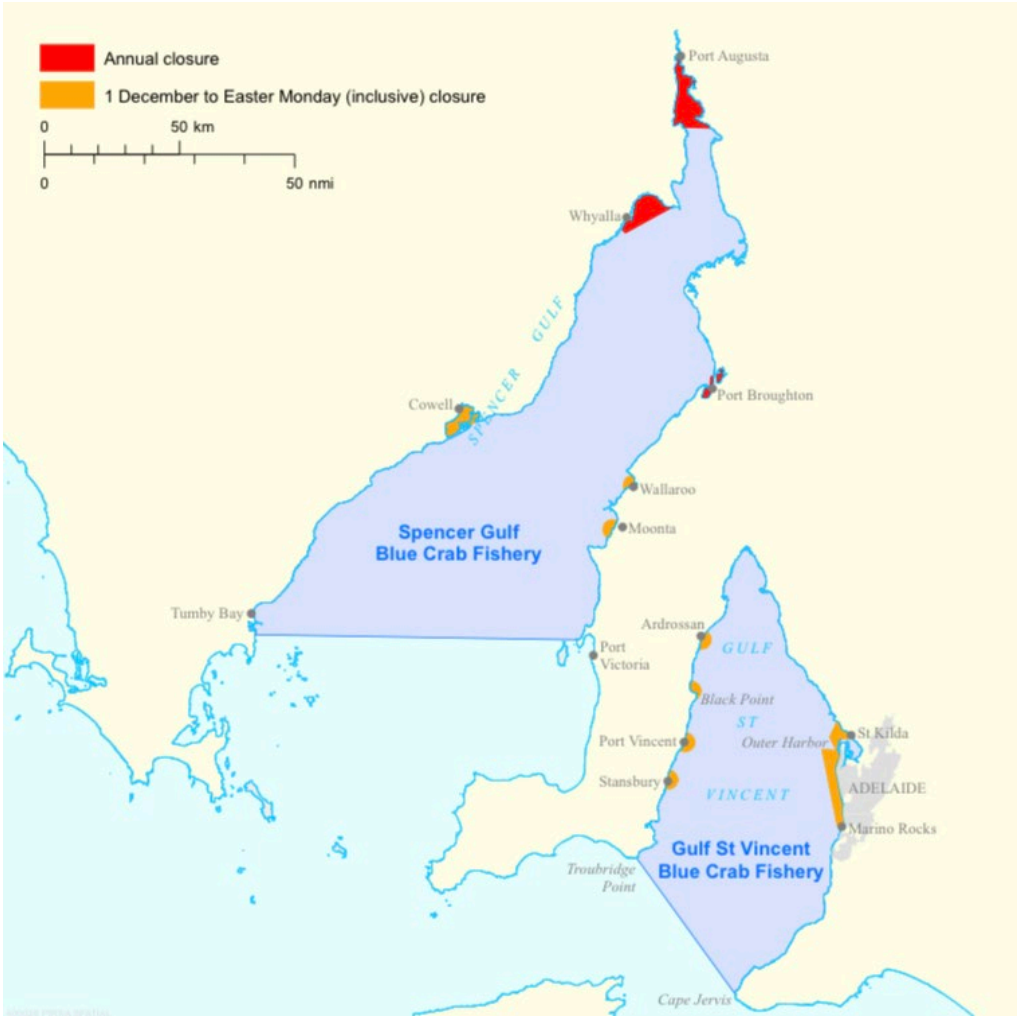

Figure 14 Blue crab fishery zones of South Australia (PIRSA, 2024a)

Southern Rock Lobster fishery

Southern Rock Lobster (SRL, *Jasus edwardsii*) is another commercially important species that overlaps with abalone habitats and fishing grounds (Figure 15 and Figure 16). In the South Australian fishery the season runs 01/10 – 31/05 in the southern zone and 01/11 – 31/05 in the northern zone (PIRSA, 2024b), and in Victoria 16/11 – 31/05 for females and 16/11 – 14/09 for males (VFA, 2024). They are typically caught using pots that are dropped to the sea floor near rocky reefs and may sometimes contact the rock edges on the descent (Casement and Svane, 1999). If this were to occur in an AVG risk area, these actions could lead to the transmission and spread of disease. **If the virus is carried through the water column with sediment, this increase in activity within the water column may result in virus resuspension and subsequent spread.** Any crustacean fishing that involves baited pots may be a transmission risk, depending on the type and source of bait used.

Recreational anglers may also dive for SRL, capturing them from rocky reefs, or using recreational lobster pots. This could pose a risk of AVG spread if it was present in the reef system or if divers did not practice recommended biosecurity measures between diving/fishing sites.

Stakeholders noted that SRL disperse from AVG outbreak reef systems when there has been a mass die off due to the high density of rotting abalone present. Stakeholders expressed concerns that SRL fishermen may set pots in an area that has had a recent, but undetected die off, and when they move and reset pots in a new area AVG will be introduced to new populations. SRL are held in wells in the boat and have water circulated through. Stakeholders noted this water is collected from close to the

surface. The risk this water would pose on the spread of AVG is dependent on where in the water column the virus is found.

No stakeholder mentioned finding abalone in or on lobster pots, but this does not mean that there is never any direct contact between abalone and fishing gear. Stakeholders noted during outbreak events the mucus plume that is present near the seabed is considerable and extremely viscous. Researchers commented that the action of pulling pots to the surface may not be enough to disrupt the matrix and remove it because it is so viscous. It is unknown whether detergents effective against HaHV-1 are sufficient to disrupt the mucus matrix and whether the mucus matrix plays any role in prolonging the period of infectivity and protection for HaHV-1.

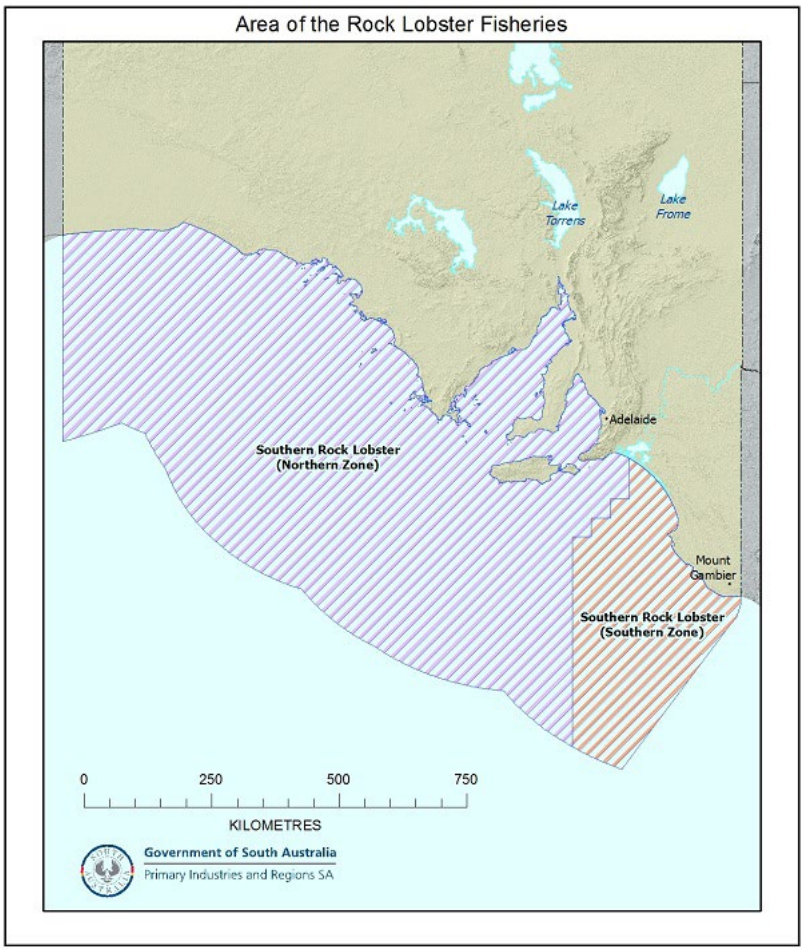

Figure 15 Southern Rock Lobster fishery zones of South Australia (PIRSA, 2024c)

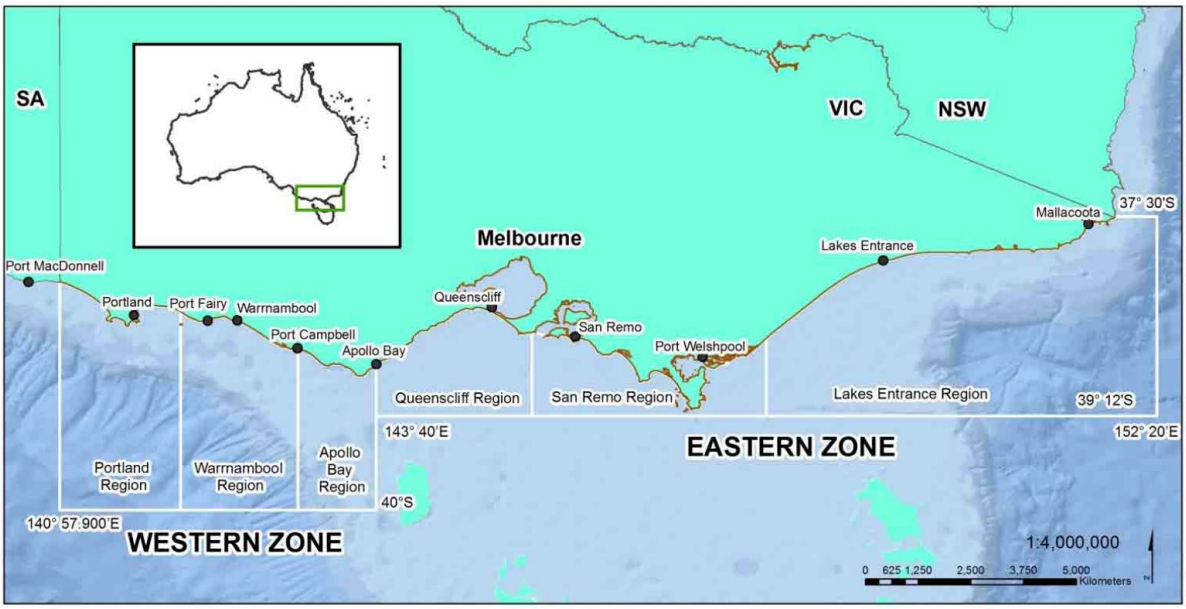

Figure 16 Southern Rock Lobster fishery zones of Victoria (Victorian Fisheries Authority, 2024)

Octopus fishery

Octopus (*Octopus spp*.) generally inhabit sea grass beds and rocky reef systems, similar to SRL and abalone. This fishery is another industry that utilises pots for capture. Baits are generally not required for octopus pots, therefore are more like to pose a lower risk of disease transmission. However, if baits are used, they may include molluscs, fish or crustaceans that are by-catch or caught purposely. The health and disease status of these bait products may be unknown and inadvertently lead to the spread or introduction of diseases such AVG into new areas. The Victorian octopus fishery is divided into a western, central and eastern zone, completely overlapping the abalone fishery (VFA, 2020a). In South Australia, the octopus fishery is incorporated into the marine scale fish industry and is also caught as a by-product in the SRL fishery with catch levels estimated to be about ~10t/annum (Martino et al., 2021).

Stakeholder consultations did not discuss whether they had noticed an absence of octopus in reef systems during outbreak events. However, the same issues may be present as with the SRL industry in that pots may be laid during an undetected mass die-off event and these pots may then become contaminated with HaHV-1 and inadvertently spread the virus to other areas.

Scallops and prawns

Scallops are typically caught in the Bass Strait central zone as well as Tasmanian and Victorian fisheries that lie within 20 nm from the respective coastlines (Australian Fisheries Management Authority, 2023). The natural habitat for commercial scallops (*Pectin fumatus*) is soft sediment ranging from mud to coarse sand at depths of 10-20 m, but can be found at depths of 120 m. The doughboy scallop (*Chlamys asperrimus*) is found in similar substrates, but may also attach themselves to solid objects. This species can be found at depths of 2-110 m (Australian Fisheries Management Authority, 2023). The species are harvested using a towed harvester that is used to dredge the sea floor. The harvester is a heavy steel frame, covered with a steel mesh, opened at the front which is dragged along the sea floor until it is full.

In Southern Australia, prawns are fished by trawling boats at night using the demersal otter trawl technique. This trawling technique involves the trawl net being towed along the sea bed (Australian

Council of Prawn Fisheries, 2024). In South Australia, the prawn fishery targets Western King Prawns (*Melicertus latisulcatus*) and includes the west coast, Spencer Gulf and Gulf St Vincent fisheries (Figure 17) and legal by-catch includes Southern calamari (*Sepioteuthis australis*), and Balmain bugs (*Ibacus* spp.) (PIRSA, 2020). Prawns are primarily caught by recreational anglers in Victorian waters.

While the location of the prawn and scallop fisheries have some overlap with the abalone fishery zones, the equipment used for harvesting is unlikely to come into direct contact with abalone habitats as the trawlers actively avoid reef areas and focus on sandy or muddy sea beds.

Net fishing

Net fishing encompasses a number of methods that use nets to fish for specific fish species. Trawls, such as those used for scallops and prawns are a form of net fishing as well as gillnets and entanglement nets, surrounding nets and Seine nets. The nets are either used on the seafloor or are suspended in the water column, depending on the net type and the target species. Due to the damage that reefs and rocky structures can cause to the nets, they are generally used in areas that are void of the marine structures. Gillnets may be an exception as they have been used to fish for reef species in Queensland.

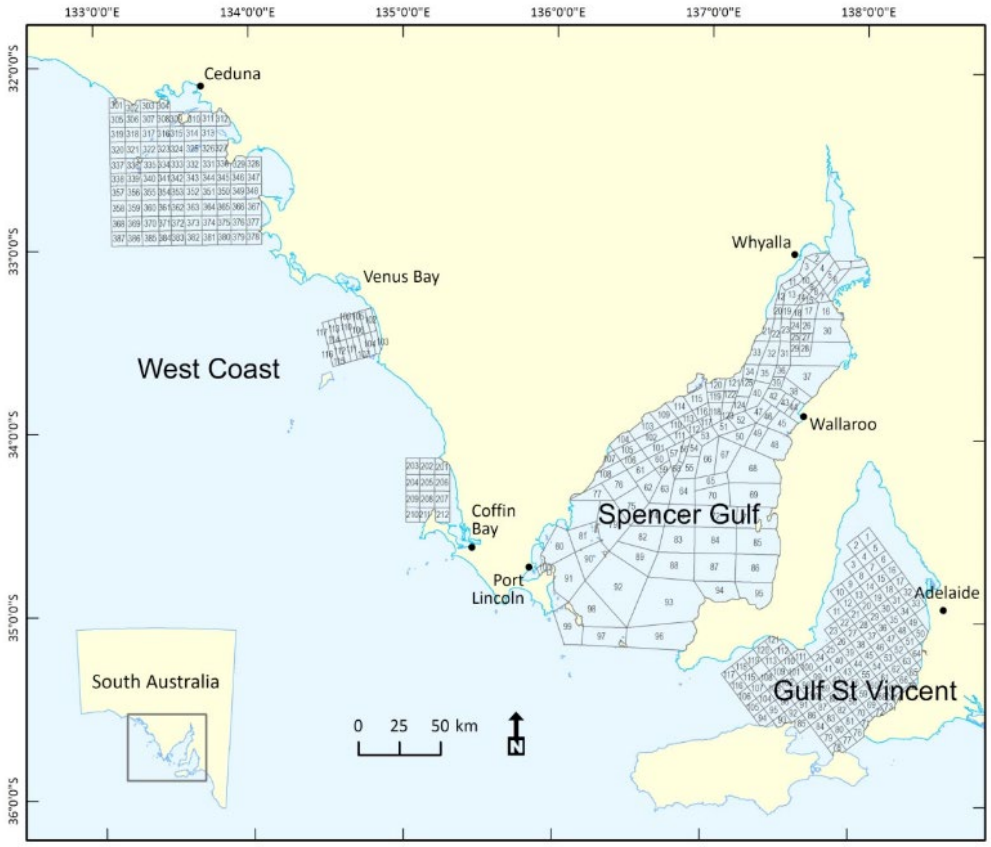

Figure 17 South Australian prawn fishery areas (PIRSA, 2020)

Recreational sector – diving and line fishing

Abalone may be harvested by recreational divers in South Australia and Victoria. There are shell size restrictions and bag limits that must be adhered too. In South Australia, collecting abalone from aquatic reserves and intertidal reefs are prohibited, but divers are allowed to remove the meat from the shell once they have moved beyond the high water mark (PIRSA, 2022b). Abalone fishing in Victoria involves similar restrictions regarding size and catch limits. However, it is slightly more controlled regarding abalone harvest areas. Marine parks and sanctuaries are excluded, along with waters less

than 2 m deep. In the central zone, harvesting is restricted to weekends during the 16 November – 30 April, inclusive and all Victorian public holidays during that period and then 25 December to the second Sunday of January (VFA, 2020b). *Stakeholder consultations have identified that "high grading", where recreational divers may visit other reef systems once they have reached their catch limit and swap small abalone for larger abalone may occur. They were unable to estimate the frequency of high grading. Other diving activities identified as possible risks were those diving for SRL, and divers that are not fishing but interacting with abalone habitats.*

Recreational fishing also includes line fishing from boats and land. Line fishing encompasses a diverse group of individuals, ranging from those who fish regularly (e.g. at least once a week) to those who may fish once a year. Due to the cultural, linguistic, educational and demographic diversity present these anglers may pose significant disease spread risk due to lack of awareness. Anglers that use live or dead bait may pose a risk in disease transmission, depending on where this bait is sourced. *Stakeholders queried whether live fish may become contaminated with HaHV-1 and whether these fish may play a role in spreading the disease if they are caught and then used as bait in a different reef system.*

Consultations also identified recreational divers not involved in fishing activities as a potential risk group. However, through the discussions it was acknowledged that a lot of these individuals are highly interested in marine biodiversity and conservation.

South Australia and Victoria both have active recreational fishing organisations that are well placed to disseminate information – RecFish SA and VRFish. However, compliance within this stakeholder group may be challenging. Fisheries officers are responsible for enforcing compliance, but are not able to continually monitor recreational divers. **Understandable, accessible information will be crucial in reducing the risk this stakeholder group may play in spreading AVG.**

Abalone Viral Ganglioneuritis

The disease and the causative agent

Abalone viral ganglioneuritis is the disease caused by the highly pathogenic abalone virus known as *Haliotid Herpesvirus-1* (HaHV-1). The virus is also referred to as *Abalone Herpesvirus* (AbHV). It was first detected in wild and farmed abalone populations in 2003 in Taiwan (Corbeil, 2020). The disease has only been detected in Taiwan and southern Australia. However, there have been reports of a similar disease complex affecting abalone in China since the late 1990s (Chang and Handlinger, 2022; Corbeil, 2020). Australia has at least four known variants: Vic1, Tas1, Tas2, Tas3 and Tas4 (Corbeil et al., 2016). **There are considerable knowledge gaps regarding the epidemiology of the disease and causative agent, and while industry and research groups have identified these, research has been slow to progress.**

Hypotheses discussed in stakeholder consultations that are biologically plausible will be used as 'expert opinion' to assess the risk of nodes for which data is absent or very limited. Uncertainty assessments will highlight nodes for which there is limited research or evidence informing the assessments and the impact of these on the risk value of the whole pathway will be tested through sensitivity analysis. If further data becomes available in the future, the risk assessment of individual nodes can be adjusted and the risk assessment repeated. In some cases, qualitative value of nodes may already have been adjusted as part of sensitivity analysis.

Epidemiology

Transmission

The mode of transmission of HaHV-1 is not well understood, despite several studies being conducted since its discovery. Being a herpesvirus, HaHV-1 is an enveloped virus, suggesting that it does not survive outside the host for long periods of time. Horizontal transmission is assumed to occur within the water column, and it has been **suggested that the point of entry is the gills, digestive tract and**

mucous membranes (Corbeil et al., 2012b; Department of Agriculture, 2014). It is suspected that offal and mucus from infected abalone may contribute to indirect transmission. **However, further research is required to confirm the point of entry or route of infection and the role of mucus in HaHV-1 viral infectivity and transmission**.

Further, research investigating vertical transmission is absent, which is potentially problematic for land-based farming using wild-caught broodstock. **There is also a lack of research examining the movement of HaHV-1 through the water column,** the distances it can move while infective, and the role of fomites. Other marine and aquatic herpesviruses are known to be transmitted indirectly, either via contaminated fomites or organic material (Curry et al., 2000; Purbayu et al., 2021). One theory suggested that HaHV-1 is moved via organic material or sediment, and filtration of sea water for land-based farms may be effective. **However, this is based on an *Ostreid Herpesvirus-1* hypothesis (Whittington et al., 2015), and further HaHV-1 research is required to support this theory.** *Stakeholder consultations provide anecdotal reports that populations located in protected bays had higher mortality rates than those populations located near headlands. It was theorised that those reef systems are protected by rougher seas and currents dispersing and diluting the HaHV-1 viral load during outbreaks.*

Disease dynamics

It appears that shelled life phases of abalone are susceptible to clinical AVG. There is no information available regarding larval susceptibility (Chang and Handlinger, 2022; Corbeil et al., 2012b; Hooper et al., 2012). *Stakeholder consultations did support the theory that the larval stage is not susceptible.* Seasonal trends have been suggested, with outbreaks being more common in cooler seasons and warmer water temperatures appearing to reduce virus infectivity (Chang and Handlinger, 2022; Corbeil et al., 2012b). **However, further research is required to confirm the seasonality of outbreaks in wild and farmed populations**. *Along with rapid changes in water temperatures stakeholders also suggested salinity changes may be sufficient to stress abalone. Sustained temperatures outside the normal range are also expected to create ongoing stress.*

For susceptible species, it is not believed that there is any innate or immune-developed resistance to disease (Crane et al., 2013). Research indicates that adaptive immunity cannot be developed in abalone, but molluscs are believed to have complex anti-viral responses (Agius et al., 2024, 2020). Abalone that survive an outbreak are suspected of being exposed to a non-pathogenic dose of the virus (Corbeil, 2020; Crane et al., 2013). **However, more studies with larger sample sizes are recommended to confirm this theory.** *Anecdotal reports suggest that exposing abalone to low levels of HaHV-1 can result in some degree of immunological priming and be protective. However, stakeholders also acknowledge that the data regarding infective dose is also lacking.*

There appears to be some susceptibility differences between abalone species, subspecies and geographic region. In China and Taiwan, *Haliotis diversicolour superexta* is the predominant abalone species impacted by AVG, while cohabiting *H. discus hannai* is typically infected without clinical disease (Bai et al., 2019; Chang and Handlinger, 2022; Corbeil, 2020; Gu et al., 2019). In Australia, HaHV-1 has been detected in farmed and wild populations in Victoria, South Australia and Tasmania. Species include greenlip abalone (*H. laevigata*), blacklip abalone (*H. rubra*) and their hybrids (Corbeil et al., 2012a). The disease was first detected in 2005-06 in Victoria (Corbeil, 2020). While infection has been detected in the Tasmanian wild population (Chang and Handlinger, 2022), clinical disease appears to only occur during periods of stress, such as in live holding tanks at processing facilities. Tasmanian cases were first seen in 2008-09 in processing facilities and then in a land-based farm in 2010-11 (Corbeil, 2020; Ellard, 2015). Clinical disease has been detected in Victoria's wild and farmed populations since 2025/6 and, more recently, in South Australia in 2024 (Corbeil, 2020; Hooper et al., 2007; PIRSA, 2024d). The current control zone in South Australia is shown in Figure 18. **It is not well understood why clinical disease was absent for approximately 10 years in Victoria, nor what has contributed to these new outbreaks occurring in wild populations in South Australia.**

Figure 18 Abalone viral ganglioneuritis control zone in the southern zone of the South Australian abalone fishery (Green et al., 2024)

At least one study has found that *H. rubra*, *H. laevigata* and *H. conicopora* (brownlip abalone) from southern Australia are susceptible to the five known variants of HaHV-1 (Table 13). However, there are differences in morbidity and mortality rates between these species (Corbeil et al., 2016). The New Zealand paua (*H. iris*) is resistant to infection and disease from HaHV-1 (Corbeil et al., 2017). **No confirmatory data exists to explain the lack of clinical disease in wild Tasmanian abalone stock. It has been theorised that environmental conditions, while not preventing infection, are more favourable to the disease remaining latent or subclinical** (Corbeil et al., 2016).

The question of latency was brought up in the stakeholder consultations. There are differing theories as to whether the infection is more widespread within the wild abalone populations. The currently available diagnostic tests are not sufficient to be able to detect latent virus; however, they are under development. There was one report that South Australian abalone divers have historically seen abalone die-offs. However, there is no way to corroborate this claim and if these die-off have occurred previously, they may have been caused by another disease or environmental event.

Herpesvirus disease dynamics

Herpesviruses can infect nearly all animals and humans. The viruses tend to be species specific, but some have the ability to infect non-host species. Infection with a herpesvirus of an immunocompetent host generally results in lifelong infection. The disease typically remains latent, however will intermittently recrudesce causing clinical disease and shedding (Wilkes and Kattoor, 2022). Stress events that cause immunological stress can lead to clinical disease.

The virus does not typically survive well outside the host and generally requires close contact for transmission to occur. However, in terrestrial animals, virus may become aerosolised and indirectly transmitted (Wilkes and Kattoor, 2022). Given low light and high levels of moisture can prolong infectivity of many herpesviruses, the marine environment may provide an environment that would increase the period of infectivity.

Oyster herpesvirus-1 is an example of another marine herpesvirus. It causes the disease known as Pacific oyster mortality syndrome (POMS). As with HaHV-1, the virus may be present, in the absence of disease. Clinically, the disease may present as rapid and high mortality events. Adults may gape, larvae may stop feeding and swimming and the digestive gland may be pale (DAWE, 2020). The disease has been present in NSW and Tasmanian populations. Horizontal transmission occurs, but it is unclear whether vertical transmission is a feature of the epidemiology. Higher mortalities occur during periods of higher water temperatures and overcrowding (DAWE, 2020).

Persistence of the agent

Research indicates that HaHV-1 remains stable when held in water at colder temperatures, but extended periods will reduce the virus infectivity (Corbeil et al., 2012b). In ideal conditions, a pristine seawater column with no known additional biological or physical factors at 15^0C can maintain HaHV-1 infectivity – it can cause disease in abalone one day after viral shedding, possibly up to three days (Corbeil et al., 2012b). This, along with the outbreaks occurring in winter months, supports the theory of disease seasonality.

Marine herpesviruses may remain infective on fomites out of the water for extended periods, such as on equipment or boat surfaces (Curry et al., 2000). Indirect transmission due to the presence of organic material in the water column is also thought to be an important factor in marine herpesvirus transmission (Curry et al., 2000; Purbayu et al., 2021). **As a result of this suspected prolonged infectivity, thorough decontamination of vessels and equipment will play an important role in reducing the risk of spreading AVG to new areas**.

The mucus produced by stressed abalone may play a role in transmission of HaHV-1. However, the stakeholder consultations highlighted that there were differing opinions regarding what activities are sufficient to disrupt this mucus matrix. ***Further research regarding the role mucus plays, and how it can be broken down is required. Current detergent recommendations, while they may be sufficient to inactivate the virus may possibly not be sufficient in disrupting and breaking down the mucus.***

Calcium hypochlorite, iodophors including *Buffodine* and a non-ionic surfactant *Impress* have been shown to be effective disinfectants in immersion and infection trials against different herpesviruses (Corbeil et al., 2012b).Virkon® Aquatic has been shown to be effective against *Salmoid Herpesvirus-3* in an aquaculture setting when used to disinfect contaminated nets (Purbayu et al., 2021). Disinfection is likely to contribute to a reduction in virus transmission when used with fomites and equipment involved in wild catch activities and with filtration and disinfection of water for aquaculture farms. However, **research into their real-world application, especially in the wild-catch industry, is lacking**. Further, many disinfectants can be corrosive to equipment and irritants for humans. These risks need to be clearly communicated to ensure safe usage.

UV light has been found to inactivate OsHV-1 (Hick et al., 2016; Schikorski et al., 2011). However, research confirming the effectiveness of UV light as a disinfectant for HaHV-1 is lacking (Baulch et al., 2013).

Clinical signs

The disease can present in an acute or chronic form. During acute disease, death can occur in the absence of clinical signs or within a couple of days of clinical sign onset. Chronic disease often results in death within 7-14 days following clinical sign onset (generally 60 hrs post exposure (Corbeil et al., 2012a)). While the basic clinical signs are relatively consistent in the different regions, some differences exist. In Australia, there is generally a high mortality rate (50-90% within 14 days) of abalone with the following clinical signs: necrotising ganglioneuritis characterised by swollen mouth parts with protrusion under the anterior foot, reduced pedal adhesion, absent righting reflex, and curling of the foot (irregular peripheral concave elevation of the lateral foot margins) (Corbeil, 2020; Hooper et al., 2007). In Taiwan, infected abalone lack the oral lesions seen in Australian abalone and

were found to have mantle recession and muscle atrophy. Mortality rates in Taiwanese farms have been up to 80% (Corbeil, 2020). Given to the acute nature of the disease and its detrimental impact on the ability of abalone to attach to substrates, it is not uncommon for the only evidence of mortality in wild populations to be empty shells (PIRSA, 2024e).

Diagnosis

Due to the potential clinical spectrum of HaHV-1 including infected, subclinical, acute or chronic disease, diagnostic tests are recommended to confirm AVG diagnosis. Histopathology is beneficial in determining the organs involved. Findings are expected to include increased cellularity and cell necrosis in the affected ganglia and associated nerves (Chang and Handlinger, 2022; Hooper et al., 2007). Lesions are generally confined to nervous tissue, including cerebral, pleuorpedal, buccal ganglia, cerebral commissure and associated peripheral nerves (Chang and Handlinger, 2022; Hooper et al., 2007). Abalone immune cells, referred to as haemocytes, are also impacted (Hooper et al., 2007). Lesions are often well demarcated, with muscular cells adjacent to affected large nerves showing fewer lesions. However, those sections with multiple affected smaller nerves may have more extensive cellulitis (Hooper et al., 2007).

Molecular diagnostics are currently limited to real-time polymerase chain reaction (PCR). No 'pond-side' diagnostic tests have been developed. The different circulating strains present some challenges. Therefore, histology is recommended for use in conjunction with any molecular testing (Caraguel et al., 2019). The World Organisation for Animal Health (WOAH, formerly OIE) Chapter for AVG provides further advice on acceptable diagnostic test methods (WOAH, 2021).

AVG impact on fishing industries

AVG is a devastating disease that negatively impacts abalone populations and industry sustainability. Due to the acute nature of the disease, lack of immune development and lack of vaccination options, it can be catastrophic to both farmed and wild caught abalone industries. Due to the risk human activities pose to spread of HaHV-1 to new areas, disease control measures also impact other fishing industries due to overlapping fishing areas. *The central and western fishing zones in South Australia host a more diverse range of fisheries than the southern zone, which is predominantly SRL and abalone. While there has been good cooperation between these two industries, if AVG were to spread to the other zones, it would be much more challenging to ensure other industries are as cooperative*.

Abalone do not migrate from their natal reef, so natural recruitment in reef systems is generally reliant on spawning events of mature abalone. However, this process can be delayed due to the slow maturation of the species and the isolated nature of each population. As discussed in the section *Abalone ecology*, some of the of the abalone populations in South Australia and Victoria are becoming depleted, which may severely affect their ability to effectively repopulate after an AVG event. Anecdotal reports from divers in Victoria have suggested that reef systems that suffer <75% mortality rates due to AVG are able to recover more quickly in comparison to those with mortality rates above 75% (Prince and Peeters, 2010). There are concerns that in heavily affected reef systems, the slow recruitment of abalone will allow an overgrowth of slow moving and sessile invertebrates, such as urchins and tube worms on suitable substrates, further reducing the ability of abalone to repopulate the reefs as free space is reduced (Miner et al., 2006; Prince and Peeters, 2010). *These concerns have been reflected in the stakeholder consultations, with divers reporting the significant biodiversity changes seen on the affected reefs. There were reports of reefs and surrounding areas being overgrown with marine vegetation that is not a suitable food source for many of the marine animals that are present. Affected reefs were described as akin to farm paddocks overrun by non-palatable weeds. This change in reef ecosystems could have lasting impacts on other marine species, such as SRL and reef fish.* Affected land-based farms generally practice complete depopulation and can recover if there is an adequate supply of replacement stock. However, even in farmed systems, abalone can take 3-4 years before reaching marketable size.

Australia plays a significant role in the global abalone market. In the 2004-05 season, the total wild catch in Victoria was 1,358 tonnes, which decreased to 781 tonnes by the 2010-11 season after the first round of AVG outbreaks (Conrad and Rondeau, 2014). However, by the 2012-13 season, the wild catch had rebounded to 1,196 tonnes (FRDC, 2024b). Tasmanian abalone alone accounts for 25% of the annual global yield, with 95% of the state's catch being exported. During the 2014-15 season, the industry was valued at approximately $212 million (DNRE Tasmania, 2023). In South Australia, the annual catch for 2021-22 was valued at $15.37 million, and the fishery sector generated 312 full time equivalent jobs, with the majority of those located in regional areas (PIRSA, 2023, 2021b). Overall, the Australian abalone industry is projected to be worth $152 million (2024-2025) (Tuynman et al., 2024). Consequently, the economic impact of a response to an AVG outbreak is expected to be in the tens of millions of dollars (Department of Agriculture, 2014). **Currently, there is no available economic impact study for affected industries. Further, there are many small communities tied to the various industries that may be impacted by AVG and its flow on effects. The social, cultural and mental health impacts to these communities must also be considered when assessing the impacts of this disease.**

Abalone Viral Ganglioneuritis Response Plans and biosecurity

Australian Aquatic Veterinary Emergency Plan

The Australian Aquatic Veterinary Emergency Plan (AQUAVETPLAN) is a suite of manuals developed to assist in the nation's preparedness and guide responses to emergency aquatic diseases. The manuals are managed by the federal Department of Agriculture, Fisheries and Forestry (DAFF) and authored by subject matter experts with the assistance of stakeholder consultations (DAFF, 2023). The Disease Strategy: Abalone viral ganglioneuritis has been developed to help authorities and industry prepare for, control and eradicate an AVG outbreak (Department of Agriculture, 2014).

Due to the complexities of disease control in aquatic settings, there are two main strategies outlined for AVG – eradication from managed facilities or containment, control and zoning in coastal regions. Eradication from farms follows basic disease control and biosecurity principles of rapid identification and depopulation, decontamination and disinfection with approved chemicals. Containment, control and zoning in coastal regions follows the basic principles applied to terrestrial animal diseases. Quarantine zones are established, including declared areas (infected and restricted zones), control areas and free areas. Movement controls are implemented, controlling the movement of abalone, vessels and fomites between areas and limiting certain activities (Department of Agriculture, 2014). While the basic principles of these measures are sound, **it is difficult to provide the scientific justification for potential movement controls due to the lack of research and understanding of the epidemiology of AVG, especially around natural spread.** Fomites, such as diving equipment, vessels and lobster pots, may play a role in the transmission and spread of the virus. **However, the research is lacking to elucidate to what extent and what decontamination measures may be effective. These restrictions may be further complicated by the lack of research confirming what causes infection to lead to clinical disease, especially in wild populations.**

Jurisdictional responses

In response to outbreaks occurring in Victoria and South Australia, the respective fishery regulators have developed codes of practice for industry members to reduce the risk of spreading AVG to new areas. The Codes outline basic standard operating procedures that focus on reducing the risk of spreading HaHV-1 through decontamination procedures (Bradley, 2023; PIRSA, 2024e). Review of the recommended procedures suggests they would be practical and easily implemented. However, while consultation with industry members occurred during the development of the recommendations, **it would be beneficial to repeat these consultations to determine whether the industries have adopted and implemented them.**

During the 2021 outbreak in Victoria, an emergency was initiated with two control areas implemented. Within the control zones the following activities were prohibited – fishing from shore or boat with a

sinker, use of commercial fishing or abalone equipment, using hoop net, bait trap, hauling net and abalone levers for recreational fishing and collecting any abalone, rock lobsters, sea urchins, or other aquatic invertebrates (dead or alive). Anchoring or using fishing equipment is not allowed in the control areas, but vessels can move through the area (Cooke 2021). *Stakeholders discussed how during the 2021 outbreak blanket movement restrictions were imposed in the Western zone VIC and were applied to abalone divers and SRL fishing boats until cases stopped occurring. Stakeholders felt that this action, which was not taken in the original outbreaks significantly contributed to the rapid control and minimal spread of the 2021 outbreak. No studies have been conducting to confirm a causal relationship.*

In response to the 2024 South Australia outbreak the Victorian government issued a fisheries notice (Abalone Disease Control No. 2) dictating measures with the objective of preventing active AVG being re-introduced to the state. Any fishing (commercial or recreational) equipment that had been used in the restricted zone of SA was not allowed in Victorian waters, unprocessed abalone was not allowed to enter Victoria. SRL vessel were required to remain in Victorian waters during fishing trips (Dowling 2024).

In South Australia an initial official control area was: Nene Valley to the SA/Victoria border and 5 nm out to sea. During the initial control phase there was a ban on fishing from shore or boats, anchoring for the purpose of fishing, using commercial fishing or abalone equipment, using hoop net, bait trap, hauling net and abalone levers for recreational fishing and collecting any abalone, rock lobsters, sea urchins, or other aquatic invertebrates (dead or alive) (PIRSA 2024b). Restrictions during the outbreak were in place regarding reef diving, use of catch, equipment cleaning and use of anchors (PIRSA 2024c). After the initial closure fishing and aquatic activities, including use of lobster pots was allowed to occur as long as equipment that has come into contact with the sea floor in the Southern zone is not moved to other waters (PIRSA 2024d). By 22nd March 2024, the official response was concluded, with the management phase continuing, and were focused on preventing the spread of AVG to other zones, but not to eradicate the disease from the wild population. The last detection of HaHV-1 was from an abalone collected on the 17th December 2024 and monitoring is ongoing (pers. comm. Stakeholder consultation).

Biosecurity measures for AVG

The key control measures outlined in the Codes include the rapid identification of diseased areas. This requires divers to contact local authorities as soon as they suspect unusual abalone deaths, and enact decontamination measures. The decontamination measures are focused on diving/ fishing equipment such as wet suits, air lines and bags, boats, trailers and any equipment used to move abalone on land. Instructions follow the basic principles of decontamination, including thorough cleaning of items, removing any visible organic material, ensuring wastewater cannot enter the marine environment and then the proper use of an effective disinfectant. Recommended disinfectants include Potassium monopersulphate (Virkon® Aquatic), hypochlorite solutions (e.g. EEZI pool, Barracude), iodophors (e.g. Agridyne), Didecyldimethylammonium chloride (Virukill), Sodium dodecylbenzene sulfonate (e.g. Truck wash), general detergent, laundry detergent and dishwasher powder and Impress. **While commercial operations are likely able to easily source some of these products, recreational divers may not, increasing the likelihood that they may not fully comply with recommendations. Further studies are also required to determine the survivability of HaHV-1 on fomites removed from the water.** This research would be beneficial for developing fit-for-purpose recommendations for the different fishery sectors.

In South Australia, AVG has only been detected in the southern zone. Vessels and divers in the western and central zones are still advised to practice basic decontamination measures, but there is less focus on the need to use effective disinfectants, and more focus on removing any organic material, using clean water and a safe detergent and allowing to air dry for 24 hours.

In Victoria and South Australia, abalone licences are restricted for the different fishery zones. Therefore, to fish in multiple zones, individuals or businesses must have multiple licences. Commercial divers must ensure they undertake the required biosecurity measures outlined in the relevant Codes when moving between the fishing zones. This includes decontaminating boats, hookah gear, cages, bags, abalone irons and personal dive equipment. The Codes outline recommendations for disposing of sea water from fishing vessels to minimise the risk of AVG being spread via bilge water accumulated during fishing and cleaning activities (Bradley, 2023; PIRSA, 2024e). Larger vessels that contain ballast water may pose a threat by inadvertently spreading HaHV-1 to new areas, if the water is not adequately disinfected before being released. **Further research is needed to determine at what depth in the water column HaHV-1 is found and the survivability of HaHV-1 in ballast water to determine the true risk of this being a fomite for the spread of AVG**.

Qualitative risk assessment

According to WOAH, risk is defined as the likelihood of the occurrence and the likely magnitude of the biological and economic consequence of an adverse event or effect on animal or human health. A risk assessment (RA) will evaluate the likelihood and the biological and economic consequences of entry, establishment and spread of a hazard (WOAH, 2018).

Risk assessments can be conducted for several reasons. These may include, at the policy level, assessing import risks associated with live animals or their commodities within clinical veterinary practice and during emergency events such as disease outbreaks to evaluate the risk certain activities may pose to the control efforts. They can be quantitative, utilising probability data associated with the proposed risks, or qualitative, which is more suitable when limited or poor-quality data is available (Horigan et al., 2023; MacDiarmid and Pharo, 2003; Makita, 2021; Stärk and Salman, 2001).

Regardless of the purpose of the RA, they should follow a framework that includes assessments for the risk of entry, exposure/release and consequences (Horigan et al., 2023; MacDiarmid and Pharo, 2003; Makita, 2021). Each assessment generally consists of the following activities: defining the risk or hazard, outlining the steps in the risk pathway, gathering data and information, identifying uncertainty and variability, logically combining the information and ensuring the risk assessment is fully referenced and transparent with reproducible methodology (Horigan et al., 2023). Furthermore, it is important to consider the level of uncertainty included in the assessment, as reducing the uncertainty can improve the risk assessment's confidence (Horigan et al., 2023). Qualitative risk assessments use descriptive risk and likelihood levels, with associated definitions, to communicate these.

The descriptors and definitions used in Australian Government biosecurity import risk assessments are shown in Table 15. The likelihoods of entry and exposure are generally combined in a matrix to provide an overall likelihood (Table 16). The combined likelihood of entry and exposure is combined with the consequence rating to provide the overall risk (Table 17).

Table 15 Descriptors and definitions used in Australian Government risk assessments (DAFF, 2022)

Likelihood	Description
High	The event would be very likely to occur
Moderate	The event is equally likely to occur or not occur
Low	The event would be unlikely to occur
Very low	The event would be very unlikely to occur
Extremely low	The event would be extremely unlikely to occur
Negligible	The event would certainly almost not occur

Table 16 Entry and exposure likelihood matrix (DAFF, 2022)

Likelihood of entry	Likelihood of exposure: *Negligible*	*Extremely low*	*Very low*	*Low*	*Moderate*	*High*
High	Negligible	Extremely low	Very low	Low	Moderate	High
Moderate	Negligible	Extremely low	Very low	Low	Low	Moderate
Low	Negligible	Extremely low	Very low	Very low	Low	Low
Very low	Negligible	Extremely low	Extremely low	Very low	Very low	Very low
Extremely low	Negligible	Negligible	Extremely low	Extremely low	Extremely low	Extremely low
Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible

Likelihood of exposure

Table 17 The risk estimation matrix (DAWR, 2016)

Likelihood of Entry/Exposure	Consequence of entry, establishment and spread: *Negligible*	*Very low*	*Low*	*Moderate*	*High*	*Extreme*
High	Negligible risk	Very low risk	Low risk	Moderate risk	High risk	Extreme risk
Moderate	Negligible risk	Very low risk	Low risk	Moderate risk	High risk	Extreme risk
Low	Negligible risk	Negligible risk	Very low risk	Low risk	Moderate risk	High risk
Very low	Negligible risk	Negligible risk	Negligible risk	Very low risk	Low risk	Moderate risk
Extremely low	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Very low risk	Low risk
Negligible	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Very low risk

Consequence of entry, establishment and spread

The Victorian and South Australian fishing industries have conducted a series of RAs regarding AVG. In 2006, the Victorian Fisheries Authority conducted a risk assessment workshop to identify and prioritise the risks associated with the transfer of AVG between the wild catch, land-based aquaculture and processing sites. The identified potential risk pathways are depicted in Figure 19 (Gavine et al., 2009). The identified risks and possible controls have been since incorporated into the Code of Practice. The control methods focus on thorough decontamination of fomites, including fishing vessels and diving gear, before moving to new areas.

The biologically plausible hypotheses identified through the consultations will be used to inform likelihoods at the nodes of the pathways when there is insufficient validated data. The uncertainty assessments will be used to highlight nodes where further research is required, and the sensitivity analysis will assess the uncertainty impact on the estimated risk value of the pathways. These results can then be used to identify research priorities, and as further data becomes available the likelihood and risk assessment of nodes and pathways can be adjusted and reassessed.

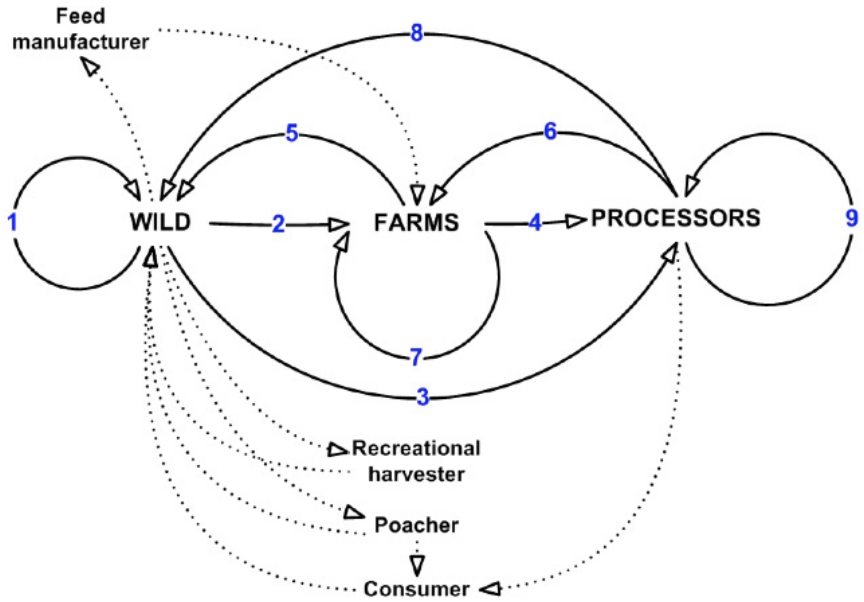

Figure 19 Risk pathways for the movement of abalone viral ganglioneuritis (Gavine et al., 2009)

Conclusion

The abalone fishing industry in Australia is facing challenges related to ecological sustainability and disease outbreaks, particularly due to AVG. While the industry is economically significant, the reliance on wild caught abalone makes it vulnerable to environmental changes and disease transmission. The complex life cycle of abalone, coupled with limited knowledge about AVG transmission and epidemiology, poses difficulties in implementing effective disease control measures. Although biosecurity protocols and fishing regulations are in place, their efficacy is uncertain due to limited research and potential non-compliance. The overlap between abalone fishing zones and other fishing industries further complicates the issue, increasing the likelihood of human-assisted disease spread either through the actual activities or increase in frequency of movements in potential risk areas. Addressing these challenges will require collaborative efforts from industry stakeholders, researchers, and government agencies to develop sustainable fishing practices, improve biosecurity measures, and expand research into AVG.

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Appendix 5

General biosecurity compliance, cleaning and disinfection responses:

- In the SA SZAF at-sea shucking has been prohibited for an extended period due to the risk of AVG in Victorian waters. Conversely, the WZAF and CZAF are permitted to shuck at sea, provided the activity occurs within the catch area. Specific areas within the Western Zone are subject to restrictions due to the presence of *Perkinsus* sp. There is ongoing discussion regarding the continuation of at-sea shucking in these zones. While these zones are currently considered 'free' of disease, shucking may continue. However, upon detection of a suspected case, at-sea shucking must cease until further notice.
- In SA waters recreational fishers cannot shuck at sea as they need the shell to comply with legal sizes.
- There is a Fisheries Notice in place that prevents the use of abalone as bait and burley. Authorities are unaware of breaches but would need to confirm with compliance officers. However, it is understood to not be a big issue.
- Industry wants a requirement for any diver who fish in SA and Vic to have two sets of gear and boats. Want the gear left in SA and not brought across the border.
- Sometimes feel like the biosecurity measures are too harsh, other times not harsh enough. Biosecurity measures are not enforceable - only voluntary so they cannot be enforced. SRL has not be proven to contribute to the spread of AVG but the abalone industry are scathing. There is concern that toward the end of the season the as the catch weight declines the pots may be moved further distances which could possibly lead to further spread of AVG.
- Vic fisheries haven't had a big poaching bust in a while - the industry members would crack down on it. WZAF very rough seas. Poachers usually on a snorkel or scuba. Central or eastern zones are more likely affected. In NSW poaching is a big issue and creeping across the border - suspected gang-based poaching using indigenous divers to avoid prosecution. There have been 300-400 shells every other day being detected from marine parks. Suspected they are being canned as tomatoes and exported.
- VFA officers will dive on the poachers in the Vic CZAF - there is no commercial industry in this zone and there is a very strict recreational fishing window. Officers patrol on jet skis.
- Currently, poaching is not believed to be an AVG risk but as summer progresses and people are illegally fishing across SA and Vic it may become an issue.
- Abalone fishermen must send their catch to official receivers. Many receivers hold live abalone; there is a need to monitor their processes to ensure subclinical aren't received. Cannery processors are not really a concern - just the ones that accept and hold live animals.
- Most poachers will be within 50m of shore so not big depths. Spread is limited as unlikely to move areas, unless being boat based (less common).
- Catch bins go to processing plants, and are thoroughly cleaned before being used again.
- When landing at port, abalone catch is unloaded straight into processor vehicle, on the rare occasion the catch may be taken home and then picked up from there.
- Abalone poaching less of a risk now.
- Some divers use a mild detergent such as a commercial wetsuit wash.
- Most will just hose dive gear with fresh water. Some will use a phosphate based mild wash. They generally won't detergent wash fins.
- Wild and commercial abalone catch has good compliance, VFA does do some compliance work but not as often as desired. In the WZAF most are aware but less so in CZAF and EZAF, recreational fisher compliance is near impossible to enforce.
- The code of practice is not enforceable. Comfortable with levels as it is an endemic disease now. Vic does not want transmission to flow east but there are no new measures to enforce.
- VFA is responsible for enforcing the COP. Processors are compliant. Wild catchers may not be 100%, but the VFA has a good relationship with WZAF stakeholders and expect compliance to be high.

- Did have a hose area at the main affected port. With a hose and disinfectant to clean gear before they leave. Unsure of whether it is still being done.
- During 2021 Virkon was placed in strategic positions/ports, but it is unclear whether still happening.
- Fishing across the zones is not common. If they do cross zones they stay out of the water for 2 weeks before fishing elsewhere as per Fisheries Notice - VFA Notice No 2.
- The abalone fishing community is small so the generally know what is going. The recreational fishers may be an issue.
- Fishing has only recently restarted out of Portland - fishers are meant to decontaminate after fishing.
- Decontamination is meant to include the use of Truckwash and soaking equipment.
- Boats are cleaned and general maintenance.
- Most abalone divers would dive 3 days in a row max - mostly 2 days in a row.
- Only one boat - but might have multiple wet suits. May wear then same gloves, same catch bags. If diving in SA, gear stays in SA.
- Tuna fishing occurs offshore, with charter boats and line fishing. Anchors may be an issue for disease spread - included in the Livestock Act, and the Code recommends to clean anchors.
- There is a feeling amongst some stakeholders that information and communications were lacking for some commercial and recreational sectors which can increase the risks.
- Recreational divers are seen as a risk. As well as anything (people or equipment) that interacts with the bottom will be a risk.
- Recreational fishers can't shuck until preparing for consumption. No issue with commercial - regularly inspected at sea, ramp and at processing. Some processors have cameras at drop off point. Can sea each bin, product in bins and weight on scales.
- Recreational sector - there has limited involvement and have struggled to implement proper controls. Can't control transit of vessels and wash down of gear whereas they can be enforced in commercial.
- Harder to target comms with recreational fishers due to the diversity.
- Recreational diver - mostly do shore diving. More likely to upsize crays rather than abalone.
- Gear will stay on boats for days or weeks depending on the markets.
- Recreational fishing is big in the SA northern zone so will potentially be a big risk if AVG spreads.
- Southern zone - inshore recreational fishing on reefs, beach fishing too - could possibly play a role in spread.
- Recreational fishers are generally knowledgeable, and keep gear clean. However, communications may be needed for further education on what needs attention and an explanation of why.
- There are different organisations that communicate with the different stakeholders.
- Land based recreational diving is generally confined to calm areas but might swap bays over headlands. SRL is generally the primary target so bays with specific habitat types are targeted.
- Recreational boats based between Barwon Heads and Torquay - would do significant distances e.g. 150km per outing.
- Making recreational fishers aware of the Code is the first issue. The COP could be simplified with the extension materials to target the different types of recreational fishers.
- Expert reference groups are used e.g. dive fisheries has a 10 member volunteer group - looks at issues in the dive fisheries. All the big groups are represented. Recommend how and who to talk to. What are the on the ground divers talking about, education and information gaps. What are the most appropriate comms channels.
- There seems to be a lot of compliance across the board but there are budget issues getting more compliance officers employed. For example, recruitment for compliance officers involved interviewing 150 candidates and then the process was stopped.
- Metro fisheries have coverage better.
- Recreational fishers may fish from one area and shuck at another area - even if that is not allowed.

- It would be recommended have recreational fishers involved in the discussion around AVG mitigation strategies.
- Restrictions need to be practical.
- In the SASZAF the SRL fishing boats don't anchor.
- On SRL fishing boats - deck, pot and rope cleaning would happen from time to time. However, the frequency is unknown but would be assumed to occur around 2-3 times a year. The areas the boats fish in can regularly experience inclement weather so recommended measures are not always practical.
- Some SRL fishing boats do cross between SA and Vic. The COP recommendation focus on the management of organic material on pots and ropes. In the initial stages of response there was a requirement to use disinfectant in the declared areas - return to port, use truck wash and dry for 72 hrs. That requirement still stands for moving zones in Victoria.
- SA SRL fishers were very involved in the development of the code. They worked closely with Biosecurity-SA and PIRSA. The COP is voluntary, but membership was strongly encouraged to comply. SRL was in constant contact with PIRSA and SASZAF to make sure they knew where new risk areas were. These risk areas were communicated with membership and advised to avoid to the best of their ability. The fishing boats have good tech so can avoid areas if they are provided with coordinates.
- SRL pots generally come up from significant depth, and are brought up with a motorised winch system and generally a lot of what is on the pot (i.e. organic material like seaweed) comes off the pots.
- Want to enforce SRL closures or prohibit SA SRL pots from being brought to Vic.
- SA SRL fishery has been involved and have been supportive in preventing the spread of virus but don't want to be unnecessarily impaired by mitigation strategies.
- In the SA NZSRLF - all the gear gets cleaned every season, cleaned with fresh water. Seasons are getting shorter - generally used only for 50-60 days a year.
- Pots in NZSRLF are more mobile, more movement. The eastern part of the NZSRLF has minimal fishing.
- Cleaning generally involves washing with fresh water and leaving to dry.

Appendix 6

Industry companion report

Project Overview

Abalone Viral Ganglioneuritis (AVG) is disease that devastates both aquaculture and wild fisheries abalone populations. AVG was first detected nearly 20 years ago in Victoria and has since spread to South Australia. It is sometimes detected in Tasmania caught abalone once they enter processing facilities.

FRDC recently commissioned some focused research to examine the risk of spreading AVG through certain fishing activities in Victoria and South Australia in order to recommend steps that can be taken to slow spread. The study looked at four fishing pathways that could spread AVG:

- Southern Rock Lobster fishing
- Recreational fishing and diving
- Commercial abalone fishing
- Commercial net fishing

The goal was to estimate the level of risk these pathways posed to the human-mediated spread of AVG to new areas where abalone are healthy and to make recommendations to manage these risks.

The research was a focused review, and did not include:

- New scientific research or experiments to allow better assessment of risks, though areas for future research were identified
- Assessing other ways AVG might spread, like through natural water movement

If natural spread is later found to be very important, this may downgrade the relative importance of these four fishing activities for spreading AVG and the risk mitigations identified for them, but it is too early to judge this. Further research on natural spread would be required to assess the relative importance of fishing activities verse natural spread. In the meantime a precautionary approach to fishing biosecurity is required.

Methods

The researchers used a few methods to assess the risk:

- A review of existing studies and information on AVG
- Discussions with experts from the fishing industry, government, and research
- A qualitative risk assessment to estimate the likelihood of AVG spreading through the four activities. This ranks risk of spread across pathways from negligible to high risks and allows risk mitigations for spread by pathways to be recommended.

Key Findings

The review and discussions with experts highlighted that there are still gaps regarding what we know about the spread of AVG. Therefore, the risk assessment was done using two different scenarios, based on two different possible situations.

- **Scenario A:** Assumes that the virus is easily removed from fishing gear and doesn't survive for long outside of abalone.
- **Scenario** B: Assumes the virus is harder to remove and can survive for longer, making it easier to spread.

The estimated risk of spreading AVG varied between the two scenarios (Table 18). Scenario B generally showed a higher risk for most activities.

Table 18 Estimated risks for assessed pathways

Pathway	Estimated Risks	
	Scenario A	Scenario B
SRL pathway 1 - Lobster pots are reset in the same location	Very low	High
SRL pathway 2 - Lobster pots a reset in a new reef system	Very low	High
Recreational – Diving	Very low	High
Recreational – Line	Very low	Low
Commercial abalone fishing	Low	High
Commercial abalone fishing with shucking	Low	High
Commercial net fishing	Very low	Low

Implications

Due to uncertainty regarding how AVG spreads (i.e. is Scenario A or B correct?), Scenario B should be assumed, and careful fishing access rules are required.

These careful fishing access rules are that during an outbreak in a wider fishing region, wherever there are abalone reefs that are currently experiencing active cases (dead and dying abalone), it is recommended that fishing activities that interact with these abalone habitats cease.

However, once the extent of an outbreak is discovered in a region, fishing can continue in that region, as long as active outbreak reefs are avoided, and the following steps are met:

- fishers should not move from an outbreak area to a free area without decontaminating their equipment before moving.
- to decontaminate equipment requires that all fishing equipment must be removed from the water, washed with detergent and allowed to dry in the sun for several days before moving to an area free of AVG. These steps are outlined in the Victorian and South Australian AVG Codes of Practice and the Victorian Southern Rock Lobster Code of Practice.
- if decontamination cannot occur then fishing equipment cannot be used between different reef systems

Reef systems in this context are defined by the abalone fishing regulatory bodies.

Further research should occur to allow future decisions about whether Scenario A or B is correct, If Scenario A is correct, less onerous conditions may be possible.

Research Needs

The report recommends more research in several areas to better understand and manage the risk of AVG. By answering these research questions, the uncertainty impacting the risk assessments should be reduced, improving confidence in risk estimates.:

- How mucus affects the spread of the virus – e.g. it is known that abalone mucus contaminated with virus is still infectious, but does that mucus protect virus on equipment out of the water and allow virus to persist.
- How to decontaminate equipment from AVG? At this stage it is assumed that detergent and physical action (e.g. scrubbing and hosing) to remove any biological material and drying are sufficient to decontaminate equipment. Research may demonstrate simpler methods such as hosing and drying are sufficient.
- How quickly and far the virus moves through water (natural spread)
- How much of the virus is needed to cause infection
- How the virus enters abalone
- Improving communication about biosecurity measures
- Analysing the costs and benefits of monitoring for the virus
- Bringing researchers together to plan future studies

Appendix 7

Pathway summaries

Wild Abalone diving

Abalone Viral Ganglioneuritis

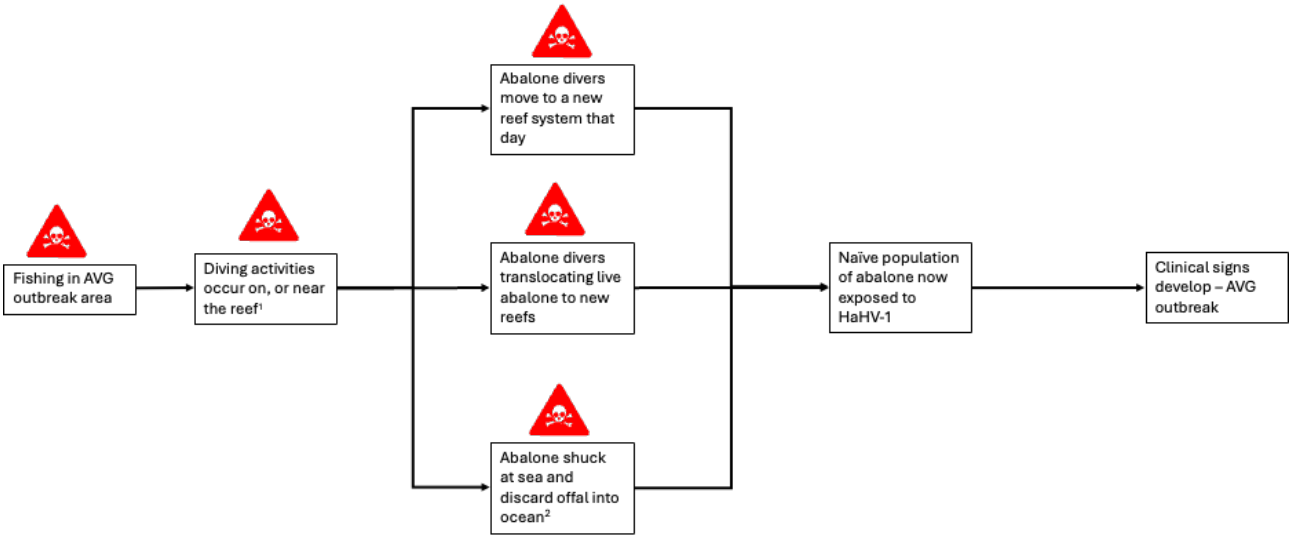
Abalone viral ganglioneuritis is a disease that can affect wild and farmed abalone. Abalone divers are likely to be the first people to spot the disease in wild abalone and play an important role in the surveillance, control and management of outbreaks.

Ways the virus can spread from abalone diving

Divers come into direct contact with abalone habitats and will likely become contaminated if diving in an outbreak area.

If divers then move to a new reef system without decontaminating their diving and fishing gear they will spread the disease.

If divers translocate abalone between reef systems, they could spread the disease.



[1]This includes diving and fishing gear and anchor, anchor ropes/chains
[2]This is only currently allowed in the SA CZAF and SA WZAF

Figure 20 The risk pathway for the spread of Abalone Viral Ganglioneuritis from the commercial wild abalone fishing. The red toxic triangles indicate the high-risk points along the pathway.

The virus is more likely to spread if there are lots of sick abalone in the area and if the fishing equipment gets contaminated. If you cannot disinfect equipment, you should AVOID fishing in areas of AVG outbreaks.

Current recommendations

We do not know how easy it is to remove the virus from equipment – using a detergent with degreasing properties and physical actions is recommended to break down and remove the mucus from equipment such as boats and dive gear. Detergents such as Truck Wash have been recommended.

We do not know how long the virus survives for out of the water – equipment should be cleaned – obvious organic material removed, washed with a detergent and then rinse with fresh water – and allowed to air dry in the sun for at least 24 hours before being used for diving in another reef system.

We do not know how much virus is needed to cause infection or how abalone become infected – to reduce the risk of transferring the virus to new areas avoid diving or fishing in areas that have an active outbreak.

Commercial net fishing

Abalone Viral Ganglioneuritis

Anyone coming into contact with abalone habitats can become contaminated with the virus (HaHV-1) that causes Abalone Viral Ganglioneuritis (AVG), and spread it to new areas if they do not decontaminate their equipment properly.

Ways the virus can spread from commercial net fishing

Commercial net fishing and abalone habitats do not usually overlap. However, sick with abalone might be found on the seafloor where they may have produced virus contaminated mucus. If nets become contaminated with this mucus they can spread the disease throughout the water column and to other reef systems as they are moved during fishing activities.

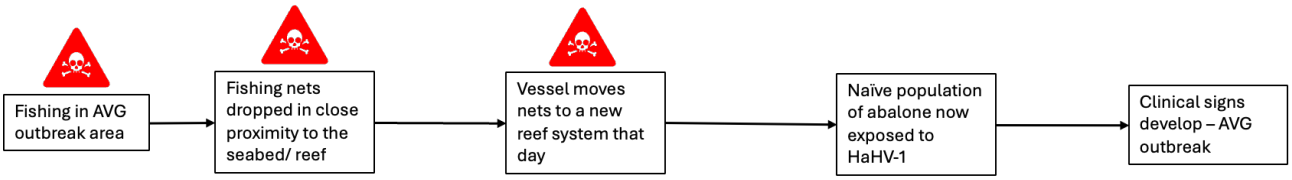


Figure 21 The risk pathway for the spread of Abalone Viral Ganglioneuritis from the net fishing sector. The red toxic triangles indicate the high-risk points along the pathway.

The virus is more likely to spread if there are lots of sick abalone in the area and if the fishing equipment gets contaminated. If you cannot disinfect equipment, you should AVOID fishing in areas of AVG outbreaks.

Current recommendations

Do not use nets in outbreak areas or make sure nets are lowered into the water away from reef structures.

We do not know how easy it is to remove the virus from equipment – using a detergent with degreasing properties and physical actions is recommended to break down and remove the mucus from equipment such as boats and dive gear. Detergents such as Truck Wash have been recommended.

We do not know how long the virus survives for out of the water – equipment should be cleaned – obvious organic material removed, washed with a detergent and then rinse with fresh water – and allowed to air dry in the sun for at least 24 hours before being used for diving in another reef system.

We do not know how much virus is needed to cause infection or how abalone become infected – to reduce the risk of transferring the virus to new areas avoid diving or fishing in areas that have an active outbreak.

Recreational Sector (in line fishing, scuba divers and people diving for catch)

Abalone Viral Ganglioneuritis

Anyone coming into contact with abalone habitats can become contaminated with the virus (HaHV-1) that causes Abalone Viral Ganglioneuritis (AVG), and spread it to new areas if they do not decontaminate their equipment properly.

Ways the virus can spread from recreational fishing and diving

Anchors dropped on reefs may become contaminated with the virus and may spread the virus to new areas if used again before being decontaminated.

Divers and their equipment may become contaminated with the virus if they are swimming over reefs and interacting structures and animals on the reefs. They can then spread the virus to other reefs if they visit them with the same dive gear in the same day.

The virus may be present on any live catch that divers have with them as they move around and between reefs. This can lead to the spread of the disease if taken to new reefs, especially if abalone are high-graded and swapped for larger abalone

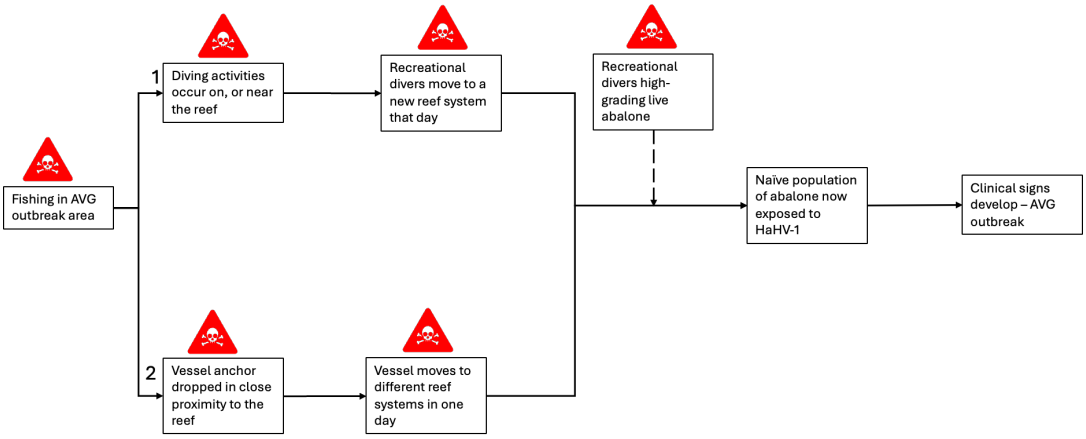


Figure 22 The risk pathway for the spread of abalone viral ganglioneuritis from the recreational sector. The red toxic triangles indicate the high-risk points along the pathway. Pathway 1 is representative of diving activities and pathway 2 is representative of line fishing.

The virus is more likely to spread if there are lots of sick abalone in the area and if the fishing equipment gets contaminated. If you cannot disinfect equipment, you should AVOID fishing in areas of AVG outbreaks.

Current recommendations

We do not know how easy it is to remove the virus from equipment – using a detergent with degreasing properties and physical actions is recommended to break down and remove the mucus from equipment such as boats and dive gear. Detergents such as Truck Wash have been recommended.

We do not know how long the virus survives for out of the water – equipment should be cleaned – obvious organic material removed, washed with a detergent and then rinse with fresh water – and allowed to air dry in the sun for at least 24 hours before being used for diving in another reef system.

We do not know how much virus is needed to cause infection or how abalone become infected – to reduce the risk of transferring the virus to new areas avoid diving or fishing in areas that have an active outbreak.

Southern Rock Lobster fishing

Abalone Viral Ganglioneuritis

Southern Rock Lobsters live in the same areas where wild abalone are found in South Australia and Victoria. Both species like to live in rocky reef systems. Abalone can get sick from a virus called HaHV-1 that causes a disease called Abalone Viral Ganglioneuritis (AVG). When fishermen catch lobsters in the same area where sick abalone live, their fishing equipment (including, but not limited to pots and ropes) might get the virus on them. We don't know how easy it is to remove the virus from equipment.

The virus can also get on the lobsters themselves, the water tanks on the boat, and even the boat itself. This could help spread the virus to new areas.

The ways the virus can spread from rock lobster fishing

1. Pots in the same location:

- The virus can spread if fishermen put their pots back in the same place where sick abalone live and then move their boats to a new location

2. Pots moved to new locations:

- The virus can also spread if fishermen move their pots to a new area, taking the virus with them.

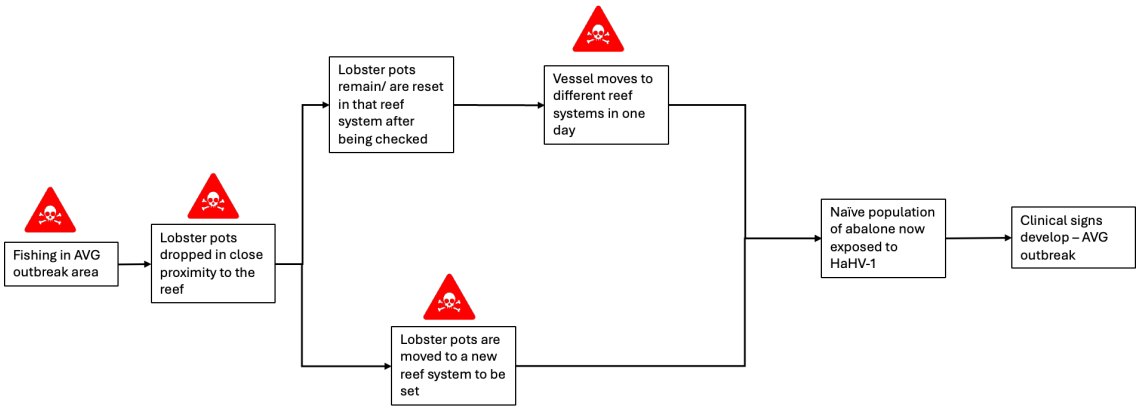


Figure 23 The risk pathway for the spread of Abalone Viral Ganglioneuritis from Southern Rock Lobster fishing. The red toxic triangles indicate the high-risk points along the pathway.

The virus is more likely to spread if there are lots of sick abalone in the area and if the fishing equipment gets contaminated. If you cannot disinfect equipment, you should AVOID fishing in areas of AVG outbreaks.

Current Recommendations

We do not know how easy it is to remove the virus from equipment – using a detergent with degreasing properties and physical actions is recommended to break down and remove the mucus from equipment such as boats and dive gear. Detergents such as Truck Wash have been recommended.

We do not know how long the virus survives for out of the water – equipment should be cleaned – obvious organic material removed, washed with a detergent and then rinse with fresh water – and allowed to air dry in the sun for at least 24 hours before being used for diving in another reef system.

We do not know how much virus is needed to cause infection or how abalone become infected – to reduce the risk of transferring the virus to new areas avoid diving or fishing in areas that have an active outbreak.