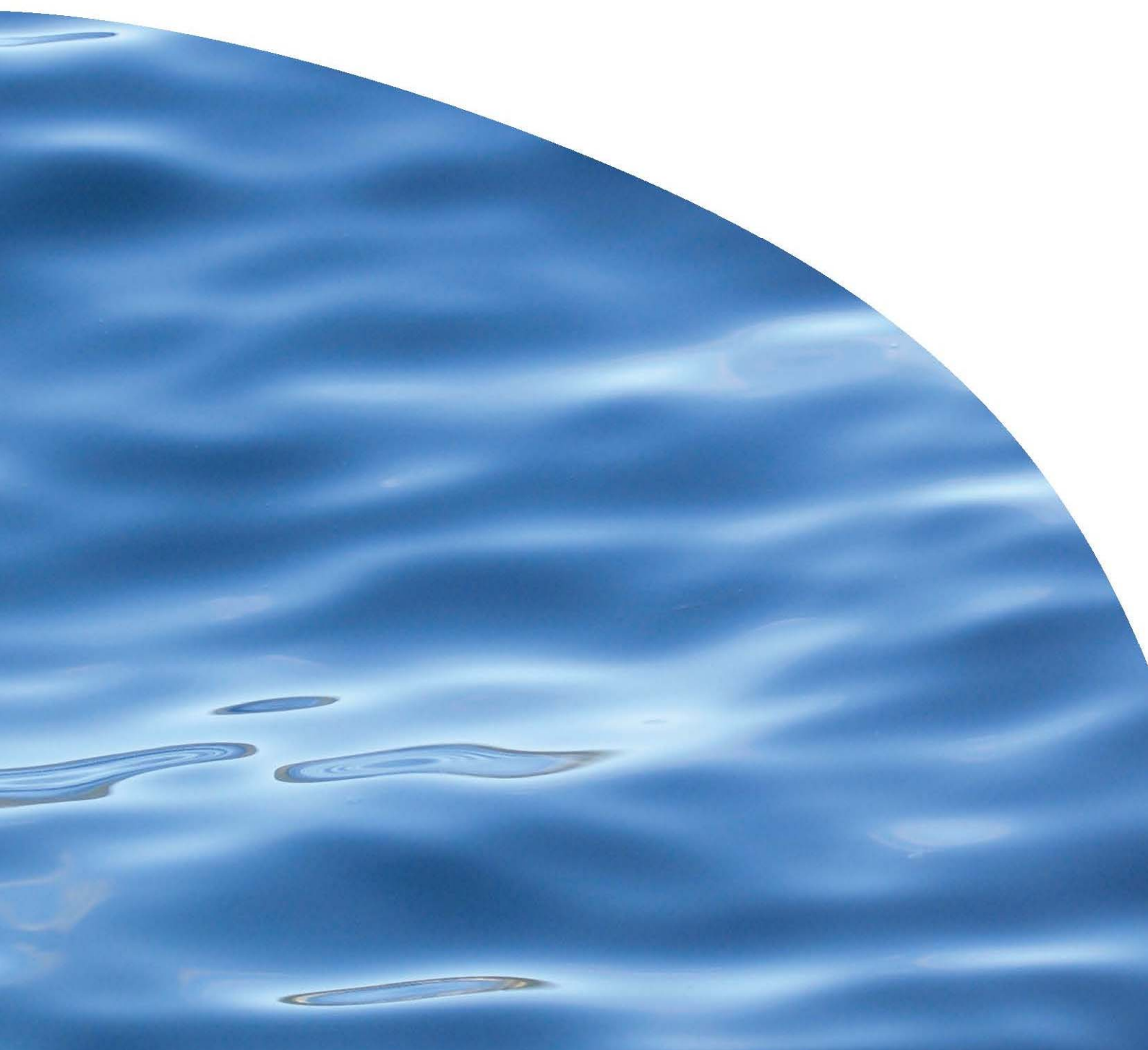


REPORT NO. 2567

**OSHV-1 MORTALITIES IN PACIFIC OYSTERS IN
AUSTRALIA AND NEW ZEALAND:
THE FARMER'S STORY**



OSHV-1 MORTALITIES IN PACIFIC OYSTERS IN AUSTRALIA AND NEW ZEALAND: THE FARMER'S STORY

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Shellfish Aquaculture Sector

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EXECUTIVE SUMMARY

Since 2010, disease outbreaks involving Ostreid herpesvirus type 1 microvariant (OsHV-1) have had dramatic impacts on Pacific oyster production and farmers' livelihoods across New Zealand and in New South Wales, Australia. These episodes of mass oyster mortality, known as Pacific Oyster Mortality Syndrome (POMS) in Australia, have highlighted the complexity of disease management in the marine environment. Oyster farmers' management decisions may have played a role in the extent of the OsHV-1 mortality outbreaks. But neither their perceptions of disease risk nor their management decisions have been documented within the context of biosecurity preparedness and operational risk.

We conducted structured, face-to-face interviews with oyster farmers in New South Wales Australia and New Zealand with the aim of capturing their views on disease risk and on strategies to prevent or manage OsHV-1 and other disease outbreaks on their farms. Participants were chosen to maximise diversity of views and practices in the Pacific oyster farming industry in both countries. The questionnaire was organised in five sections: (1) participant characteristics; (2) experience with OsHV-1 mortalities (POMS); (3) support during the disease crisis; (4) risk management strategies; and (5) risk and preparedness.

Twenty-two farmers (half from New Zealand and half from Australia) were interviewed about their experiences with POMS and other oyster diseases. Nearly all participants reported that the oyster mortalities had a devastating impact on their morale, particularly in New South Wales estuaries where growers tend to form a close community. During the disease crisis, governments in both countries remained a trusted source of advice, on a par with industry sources and other oyster farmers. For routine advice on animal health, participants preferred to consult the farming industry or the internet, though most respondents admitted that they were not likely to seek technical advice in the absence of disease on their farm. Overall the governments' responses to POMS left a mixed impression, with over 40% of participants having either no opinion or nothing positive to say about the experience. Movement controls were a positive point for 16% of farmers, but for 29% of them it was a negative factor, contributing to a slow and unstructured response.

Amongst the preventive strategies explored in the interview, adopting a collective risk management plan and varying the sources of spat (juvenile oyster) were seen as the two most effective approaches. On-farm biosecurity measures were ranked third in terms of perceived effectiveness but were the most likely to be applied of all proposed measures. The discrepancy between perceived effectiveness and inclination for uptake suggested limitations in the potential feasibility of some preventive strategies. In contrast, ranking of effectiveness and practicality of control strategies were more consistent. Stopping movements of stock and gear and zoning of farming areas by OsHV-1 status received the most support.

Following POMS, most affected farmers and more than half of unaffected farmers changed their approach to growing oysters, by modifying their husbandry techniques or adopting a different operational strategy. When asked about taking business risk in the near future, the group was clearly divided: 41% were not ready to take any risk whilst the rest of the

respondents were considering changes such as diversifying species, investing in hatchery spat and in new, more versatile infrastructure, or a mix of these initiatives. In terms of biosecurity readiness, the majority were confident that their business was as prepared as it could be to overcome disease challenges. Interestingly, even after the POMS event, only half of the respondents said they had a plan to cope with mass mortalities on their farm. But this aspect will need to be further explored as the concept of 'preparedness and planning' may not have been appropriately explained or understood by participants.

During the course of the project, the research team received funding from the New Zealand government to hold a two-day knowledge exchange between farmers, scientists and government to share views on oyster disease risk perceptions and management. Participants were farmers from New South Wales Australia and New Zealand, who had taken part in the survey. This meeting was an opportunity to present and confirm the study preliminary findings through consensual validation.

Based on the findings from the interviews, this research identifies potential strategic directions for an industry facing increasing environmental challenges in both countries. Disease prevention and control strategies should be included in business risk management plans for the shellfish farming industry. Farmers, scientists and governments will be more successful if they work in partnership to develop practical and effective measures to manage diseases as well as pests in the aquatic environment. Collaboration between all parties to optimise resources, expert skills and knowledge should be actively encouraged and enabled at all levels including industry, research and regulating bodies.

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1. INTRODUCTION

1.1. Basis for this study

Ostreid herpesviruses have long been known to occasionally cause mortality in larvae and juveniles of bivalve species, including the Pacific oyster *Crassostrea gigas* and the flat oyster *Ostrea edulis* (Hine 2002; Renault & Novoa 2004). But in 2008, a new variant (OsHV type 1 microvar) was described in association with mass mortalities of Pacific oyster spat in France, the United Kingdom, Ireland and Asia (Segarra *et al.* 2010; Peeler *et al.* 2012; Hwang *et al.* 2013). It was also detected in Pacific oysters in Spain and Italy but with no associated mortality (Dundon *et al.* 2011; Roque *et al.* 2012).

Mortality outbreaks involving the OsHV-1 microvar were first recorded in New Zealand and Australia during 2010 (Bingham *et al.* 2013; Jenkins *et al.* 2013). The disease has had dramatic impacts on Pacific oyster production and farmers' livelihoods in both countries. Mortality events have occurred every year since, generally from November to April-May but varying with location. In Australia, Pacific Oyster Mortality Syndrome (POMS), as it became known, was first detected in the Georges River in November 2010 (Jenkins *et al.* 2013) and months later was found in Sydney Harbour (Figure 1). About two years later, in January 2013, the disease spread to the Hawkesbury River (Paul-Pont *et al.* 2014) where it had a devastating impact on the local industry that was almost entirely relying upon Pacific oyster production (after Sydney rock oysters, *Saccostrea glomerata*, were wiped out by QX disease in 2005). In New Zealand, POMS first emerged in Northland, Kaipara Harbour and the Coromandel in autumn (March–April 2010). The same sites, as well as additional farming areas, were hit again in the following spring (November 2010).

Oyster farmers' decisions may have played a role in the extent of the POMS outbreaks. But neither their perceptions of disease risk nor their management choices have been documented from the perspective of biosecurity preparedness and operational risk. Epidemiologists from New Zealand (Cawthron Institute) and Australia (University of Sydney) saw this knowledge gap as an opportunity to collaborate under the Knowledge-Based Bio-Economy Forum (a cooperative initiative between the European Community, Australia, Canada and New Zealand, aiming to share knowledge and enhance collaboration and innovation in the bio-economy sectors).

A small-scale survey was conducted under the Cawthron Institute's Cultured Shellfish Programme ('Enabling, Growing, and Securing NZ's Shellfish Aquaculture Sector'). The aim of the joint study was to capture oyster farmers' views on disease risk and on strategies to prevent or manage disease outbreaks on their farms. OsHV-1-associated mortalities in Pacific oysters (POMS) were used as a common thread for questions and discussions.

1.2. Pacific oyster farming in Australia and New Zealand

1.2.1. Industry profiles

The oyster industry in Australia is located primarily in New South Wales, Tasmania and South Australia (oysters are also farmed in Queensland and Western Australia but to a much lesser extent). Farmers are referred to as *growers*. The Sydney rock oyster (*S. glomerata*) is the predominant species farmed in New South Wales, but Pacific oyster (*C. gigas*) farming has grown rapidly in the last decade and is now present in seven estuaries: Wallis Lakes, Port Stephens, Hawkesbury River, Georges River, Shoalhaven River and Clyde River and Wapengo Lake (Figure 1). All estuaries are currently growing triploid Pacific oysters. Pacific oysters are regulated under a Class 2 Noxious Species status, as their invasive behaviour could lead to the displacement of the native rock oyster. Triploid oysters cannot reproduce, so there is no risk of proliferation. Diploid Pacific oysters can only be farmed in the Port Stephens estuary, where the government has recognised their already high density (triploidy would not reverse the trend). Triploid Pacific spat currently originate from a large commercial hatchery in Tasmania (although there are plans for more hatcheries in New South Wales to produce triploid Pacific oysters in the future). Farming techniques are directly influenced by the nature of the spat used. In Australia, growers who rely on natural spat use wooden sticks or plastic slats to catch spat (and for on-growing) while plastic mesh baskets and cylinders with small mesh are used with hatchery spat.

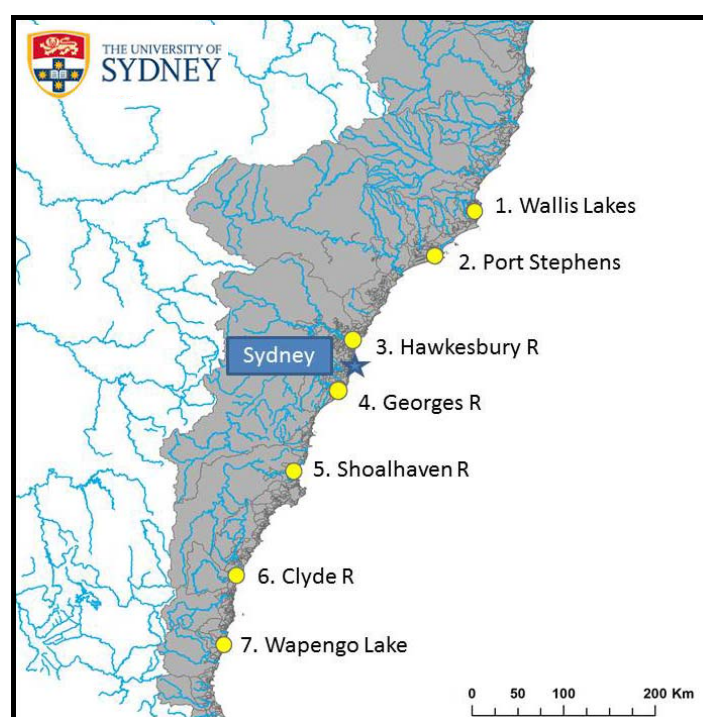


Figure 1. Current Pacific oyster farming areas in New South Wales Australia (Source: University of Sydney).

In New Zealand, farming of intertidal rock oysters (*S. glomerata*) was attempted during the 1960s in the North Island but was soon replaced by a flourishing Pacific oyster farming industry, after the species was accidentally introduced on a barge from overseas. Pacific oyster marine farms are concentrated in the upper North Island, with only a few farms at the top of the South Island (Figure 2). The vast majority of the spat used on Pacific oyster farms are natural, *i.e.* caught in the wild, for example in the Kaipara or Kawhia harbours. Hatchery (also called single-seed) spat is produced by a commercial hatchery located at the top of the South Island. Hatchery spat are not widely used across the industry yet but are generating more interest, especially in times of spat shortfall due to POMS or to unfavourable environmental conditions. Natural spat are collected on timber sticks that are transferred to growing farms and placed on intertidal racks. Hatchery spat are positioned on farms in baskets, mesh trays or bags in intertidal and sub-tidal systems. However other techniques are emerging with the increasing use of hatchery spat (for example the use of baskets attached to subtidal long-lines in more exposed areas).

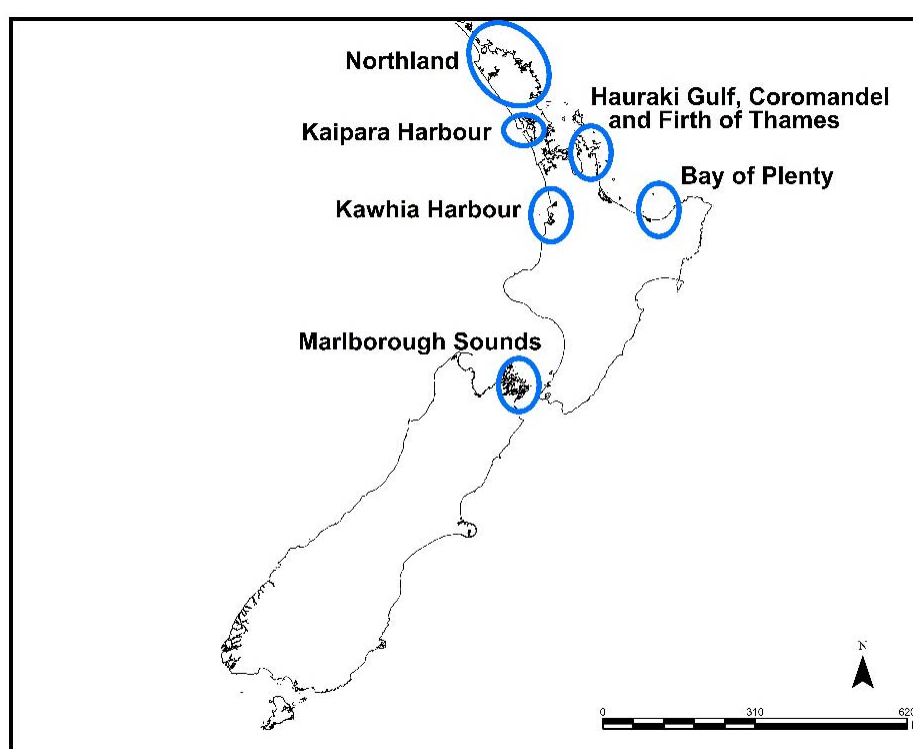


Figure 2. The main farming areas for Pacific oysters in New Zealand (Adapted from MPI 2013).

1.2.2. Disease challenges in farmed oysters

Bonamiosis

Bonamiosis is the generic term for disease caused by *Bonamia* species, a group of microcellular parasites that infect a wide range of oysters worldwide, with highly variable effects on the host. For example, *Bonamia ostreae* causes high mortalities in

the European flat oyster *O. edulis* (Culloty & Mulcahy 2007) but was not associated with any mortality in the New Zealand dredge oyster *Ostrea chilensis* when it was recently detected (Lane *et al.*, submitted). Likewise *Bonamia exitiosa* has been associated with significant losses in *O. chilensis* in Foveaux Strait, causing severe impacts on the dredge fisheries, but it is only detected with no or low mortality in the Sydney rock oyster *Saccostrea glomerata* and the Australian flat oyster *Ostrea angasi* in New South Wales (Carnegie *et al.* 2014). Other *Bonamia* species include *Bonamia* (formerly *Mikrocytos*) *roughleyi*, which may be linked to the disease known as winter mortality, a poorly studied disease affecting Sydney rock oysters in the cooler waters of New South Wales' southern estuaries. The disease may cause up to 80% mortality in oysters reaching marketable size (Nell 2007).

QX disease in Sydney rock oysters

QX disease is caused by a protozoan parasite *Marteilia sydneyi* reported for the first time in Sydney rock oysters from Queensland in the 1970s. Its distribution was further clarified in the 1990s. Its arrival has caused severe seasonal mortalities in New South Wales Sydney rock oysters and a selective breeding programme was set up to produce QX resistant oysters to optimise survival on farms (Dove *et al.* 2013). In the Hawkesbury and Georges Rivers the commercial production of rock oysters was so significantly affected that growers started farming Pacific oysters (see Figure 1), to rebuild or as a strategy to sustain their industry.

Measuring impact of disease

In general, the economic impacts from disease are poorly documented in shellfish aquaculture. A study by Girard and Perez Agundez (2014) provided a preliminary assessment of the economics of the oyster mortality crisis on the farming industry in France. The model followed by industry in the main producing region was analysed in the light of economic sustainability and industry structure. However the analysis was based on structural and financial data, not social data, and further socio-economic research is needed to help measure the impact of disease on farmers.

Prior to POMS, Pacific oyster aquaculture had never experienced significant mortalities caused by an infectious disease. When OsHV-1 mortalities first hit in 2010, the New Zealand industry reported dramatic production losses: between 90 and 100% of hatchery-produced spat died after being deployed on grow-out farms and up to 90% of natural spat was lost from culture sticks. According to growers interviewed for this study, those losses had a huge effect on harvest in the following year. As supply has fallen, the market value of Pacific oysters in New Zealand has kept rising since 2011 as it is demand-driven. Interestingly, this is not the case in Australia, perhaps because the Pacific oyster production has been maintained by growers in South Australia and Tasmania.

Social impacts have included rising unemployment in local communities that were strongly reliant on Pacific oyster farming and processing. For example, Sanford

Limited, a large New Zealand fishing company, had to close its oyster processing plant in the small town of Kaeo in Northland (population 500 in 2006), making 66 staff redundant after POMS decimated young oysters destined for future harvests¹.

The longer term impacts of OSHV-1 remain poorly understood. There is a lot of speculation about the fluctuations of wild spat availability in New Zealand (“spat falls”) and whether these are directly influenced by OSHV-1 microvar occurrence. Likewise the impact of the disease on wild stock (including natural resistance) has not been investigated yet in New Zealand (to the best of the authors’ knowledge).

1.3. Risk perceptions and biosecurity behaviour

1.3.1. Social epidemiology

Social epidemiology focuses on the effects of human intervention and of other social factors (e.g. education, cultural beliefs) on the occurrence of health and disease (Figure 3). This discipline is emerging as a powerful tool to improve risk management in primary production sectors. Behavioural studies have been conducted in the aftermath of disease outbreaks in farmed terrestrial animals and have effectively drawn attention to areas in need of improvement (e.g. Hernández-Jover *et al.* 2012a, 2012b, Schemann *et al.* 2012a, 2012b, Taylor *et al.* 2011). Whether commissioned by industry bodies or governments, surveys can help identify key behavioural drivers and barriers to effective risk management practices as well as help to identify groups who are more prone to misconceptions. Studying farmers’ perceived risks and attitudes towards biosecurity can be used to support industry’s risk awareness and enhance compliance with disease controls.

1.3.2. Social research in aquaculture

Research on risk perception and biosecurity behaviour is still scarce in the aquaculture sector but it could provide a valuable insight into farmers’ management and coping strategies (Bergfjord 2009; Ahsan & Roth 2010). Farmers can influence disease dynamics through their decisions and behaviours (Lupo *et al.* 2014). Their importance in the occurrence and spread of disease is beginning to be recognised; the social component of environmental risk factors nowadays tends to be added as a fourth element to the usual epidemiologic triangle and explored as a separate entity (Figure 3).

In New Zealand, the Ministry for Primary Industries (MPI) in partnership with the sector organisation Aquaculture NZ set up a three-stage project in 2014 to “strengthen on-farm biosecurity management” across the aquaculture industry. The first phase involved a survey of aquaculture biosecurity practices in the country, encompassing the main shellfish and finfish species in commercial farms and research organisations.

¹ Source: <http://www.stuff.co.nz/business/industries/6087592/Oyster-virus-costs-66-Northland-jobs>

The aim was to ‘understand the current farming practices, on-farm biosecurity management, and concerns and perceptions of the farmers themselves’ (Sim-Smith *et al.* 2014). (The MPI study was conducted independently from the present bilateral collaboration between the University of Sydney and the Cawthron Institute. Findings of relevance are discussed in Section 4 of this report.)

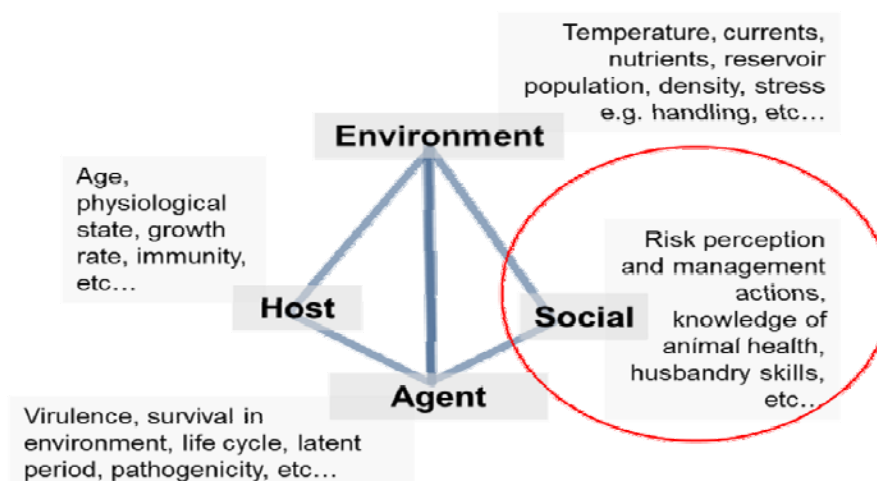


Figure 3. The four components of disease dynamics, showing social factors (circled) as a separate entity (Castinel *et al.* 2013).

1.4. Bilateral research: objectives and scope

The main objective of this bilateral research study was to better understand farmers' experience with disease outbreaks and their risk management decisions in relation to these events, in two countries with different farming systems but with a common biosecurity issue.

This was achieved by conducting face-to-face interviews to:

- record the impacts of the 'OsHV-1 crisis' as experienced by oyster farmers in New Zealand and Australia ('the farmers' story')
- collect farmers' perceptions on disease risk
- discuss prevention and control management strategies
- explore farmers' vision to sustain the Pacific oyster farming industry.

The expected benefits from this study included identifying both issues and needs to better support Pacific oyster farmers and their businesses during a biosecurity crisis. The study was used also to encourage discussions on oyster disease risk preparedness within industry. Lastly, this study sought to document social impacts from POMS in the oyster farming industry in New Zealand and Australia.

The present report is primarily intended for Pacific oyster farmers in Australia and New Zealand, but could also be valuable to the wider aquaculture industry and sector organisations, as well as government staff involved with management of disease risk, present and future, in the oyster farming environment.

2. DATA COLLECTION AND TRANSCRIPTION

2.1. Participant selection criteria and recruitment

Due to limited financial and human resources (the logistics involved with face-to-face interviews made data collecting an expensive process), the sample size had to be restricted to a maximum of 12 Pacific oyster farmers from each country.

A list of potential New Zealand participants was developed by Cawthron using existing contacts in the industry (e.g. the New Zealand Oyster Industry Association) and recommendations from those same contacts. A similar approach was taken by the University of Sydney for potential participants in New South Wales. Candidates were chosen to maximise the diversity of the sample, *i.e.* different business types and sizes, with varying experiences with the OsHV-1 mortalities. In Australia, POMS has been restricted to the central part of the coast of New South Wales and the target population was farmers in the POMS-affected and adjacent regions where information about POMS was most likely to have been readily available (*i.e.* farmers in the unaffected regions Tasmania and South Australia were excluded). In New Zealand POMS was widely distributed among farms on the North Island, so these farmers were the target population.

Each potential participant was sent an email, using a carefully-written script that outlined the research objectives and the interview process without pressuring anyone to participate. There was no financial incentive to take part in the survey.

Farmers who replied positively to this first email were recruited as study participants and were subsequently sent a survey pack containing:

- an introductory letter
- a participant information statement
- a consent form, which they were requested to complete and sign before the interview could take place.

All of the above documents had been pre-approved by the Human Research Ethics Committee of the University of Sydney (see paragraph 2.2.2 and Appendix 1).

2.2. Questionnaire

2.2.1. Design and piloting

We developed a questionnaire to investigate oyster farmers' perceptions of disease risk and on-farm management, using POMS as a thread for discussion. The questionnaire contained a total of 43 questions, of which 35 were closed, 1 was semi-open and 7 were open-ended. Questions were formulated in plain English to

facilitate engagement with respondents and maximise response accuracy. The survey was structured in 5 sections:

- Section 1 – Participant’s characteristics: to collect data on individuals that may be pertinent to interpret and compare the views provided in the subsequent sections
- Section 2 – Experience with OsHV-1: to stimulate the participants’ recollection of events and the impacts (direct or indirect) on their business during the disease outbreaks
- Section 3 – Support during crisis: to document the resources available to farmers and their interactions with the rest of industry and government during the initial response to POMS
- Section 4 – Risk management strategies: to explore the perceived effectiveness and likelihood of uptake of various preventive and control measures commonly used in animal biosecurity
- Section 5 – Risks & preparedness: moving forward: to explore the respondents’ approaches and open up dialogue on risk management.

The questionnaire was piloted during face-to-face interviews with two oyster farmers, one each in Australia and New Zealand, prior to engaging with the study participants. The survey pilot resulted in minor amendments to the questionnaire (*i.e.* to rewrite some questions to improve clarity) and helped the researchers prepare for the subsequent series of interviews. The estimated completion time for the survey was 45 minutes but given the number of open questions this time was increased to 1 hour. A copy of the questionnaire is available from the authors upon request.

2.2.2. Ethics approval and protocol

The methods for this study have been approved by the Human Research Ethics Committee of the University of Sydney (Project number: HREC 2014/396, approval date 26 June 2014—see Appendix 1). This procedure aimed to provide confidence to all survey participants that their information would remain strictly confidential, thus enabling more free and frank information sharing.

2.3. Interviews

2.3.1. Procedure

The Participant Information Statement provided options to respondents for where the interview would take place. Location was not restricted to the oyster farm. For example, New Zealand interviewers took advantage of an annual oyster conference to organise appointments with farmers attending the 2-day event. Other face-to-face interviews were set up with local farmers at Cawthron in Nelson. Only two participants

were interviewed on the phone due to their remote location or unavailability at the conference. In New South Wales, growers were visited directly on their farms and all interviews were conducted face to face.

2.3.2. Data recording & storage

We kept the interviewees' details anonymous, as per the consent form. Digital recordings or handwritten notes (or both) were used to capture the participants' answers, depending on their preference given in the consent form.

Digital recordings were stored as electronic files on a secure server. Similarly, interview notes and signed consent forms were scanned and electronic files stored securely. Hard copies were kept in a locked cabinet in a secure office. All paper records from the interviews will be destroyed after publication of the study but their scanned copies and all other related electronic files (including digital recordings) will be kept in a central location (University of Sydney) for a period of 7 years from their creation date, as per the Ethics Committee approval.

2.3.3. Data transcription and analysis

After all interviews were completed, the responses were compiled in an Excel file. Any personal information that could potentially identify the respondents (e.g. names, address of property, including the estuary in New South Wales) was omitted.

The values collected for closed questions were either continuous (e.g. farming area in hectares), dichotomous (yes, no) or multi-category (e.g. negligible, moderate and severe). For purposes of analysis, continuous data were converted to categorical data. Several categories were intuitively created for several variables, including farming area (0–30 ha, 30–100 ha and > 100 ha) and residency in the local community (< 10 years, 10–30 years and > 30 years).

Responses to semi-open and open-ended questions were transcribed and coded into categories that preserved the intent of the answers and grouped similar responses. Variables that required coding included: sources of information, sources of advice (during crisis and routine), positive and negative features of government response, type of farming changes, potential business risks, and actions for improving disease management. In order to minimise information loss through coding and amalgamation of responses, a number of anonymous quotes were selected to illustrate the participants' views in the Results section.

The outcome variables of interest comprised: impact on operations; impact on finance; impact on morale; impact on community; potential business risk taking; business preparedness; plan to manage mortality; research awareness and selective breeding awareness.

Due to the small sample size, only limited statistical analysis was performed. Frequencies were calculated for outcome variables in each section using the SAS statistical program 9.4 (© 2002-2003 SAS Institute Inc., Cary, NC, USA). Contingency tables for selected variables helped investigate any potential association between outcome variables and potential risk factors. Associations were considered significant for $P < 0.05$ (Fischer's Exact Test). Possibilities for further analysis with a larger dataset are discussed in Section 4.

2.3.4. Study strengths and limitations

This study was carefully designed to gather data from a broad range of farmers to maximise the diversity of opinions. Face-to-face interviews were preferred over a distance survey to encourage responses from open questions and to open up the dialogue on biosecurity. The diversity of participants and the depth of data (*i.e.* an accurate transcription of farmers' views) are the study's foremost strengths.

However, any such study presents a number of challenges and limitations at different stages of the project. They included:

- Study design and project management
 - limited resources (funding and staff) to undertake the study and manage at distance a trans-Tasman project
 - application of an emerging concept (social epidemiology)
- Recruitment of participants
 - non-inclusion of farmers who left the industry because of POMS
 - recruitment of sufficient numbers of oyster farmers (low numbers could affect the precision of the study estimates)
- Interpretation of data
 - Coding of open-ended questions and potential loss of information.

In addition, potential sources of bias were pre-empted before the study started. As in other surveys, this study is likely to have recall bias as farmers who experienced severe losses are more likely to remember the facts, compared to those who experienced mild to moderate losses or did not experience any outbreak. Selection bias was another potential concern as participants had been purposively selected to represent diverse profiles within industry, but this was taken into account in the interpretation of the survey answers.

3. RESULTS AND INTERPRETATION

3.1. Analysis by sections

3.1.1. Section 1: Survey demographic information

A total of 22 farmers were interviewed, with equal numbers of participants in the two countries. About 14% of the farmers were under 35 years of age and the same proportion were over 60 years old. The age distribution was similar between Australia and New Zealand (Figure 4).

Almost half of the group had lived in their local community for more than 30 years and this was even more pronounced in Australia. There were more New Zealand farmers in the middle category, having lived locally for 10 to 30 years.

About 60% of the study group had received some form of training related to shellfish farming. Training could mean a marine science degree, certificate and diploma in biological sciences or food safety, study units in aquaculture, certificate in oyster farming and in aquaculture and training workshops or conferences.

Just under half of the participants, mostly from New Zealand, had previously been employed in another primary sector (e.g. shrimp aquaculture, horticulture or sheep, beef or dairy farming). Only two out of the 11 Australian growers had some experience with a primary industry other than oyster farming.

All of the New Zealand farmers interviewed had been farming Pacific oysters for more than 5 years, while two Australian participants became involved in oyster farming more recently. Some growers in Australia had been farming Sydney rock oysters before the early 2000s, when they invested in a new species like the Pacific oyster or the flat oyster (*O. angasi*). It is therefore common to see mixed oyster farming businesses in New South Wales estuaries.

Participants were predominantly farming areas under 30 hectares (68.2%) and only 4 farmers were involved in operations larger than 100 hectares. Lastly, all the Australian participants owned their oyster farming business while one in four New Zealand farmers was a company employee (the remainder were business owners).

Perhaps the most notable difference between Australian and New Zealand participants was their previous experience with significant oyster mortalities linked to disease. This could potentially influence the farmers' responses. Most of the growers in New South Wales had already been affected by QX disease, which had effectively wiped out populations of Sydney rock oysters in the early 2000s. In contrast, on-farm mortality in New Zealand before POMS mostly involved mudworms and harmful algal blooms (HABs), but no infectious pathogen comparable to OsHV-1.

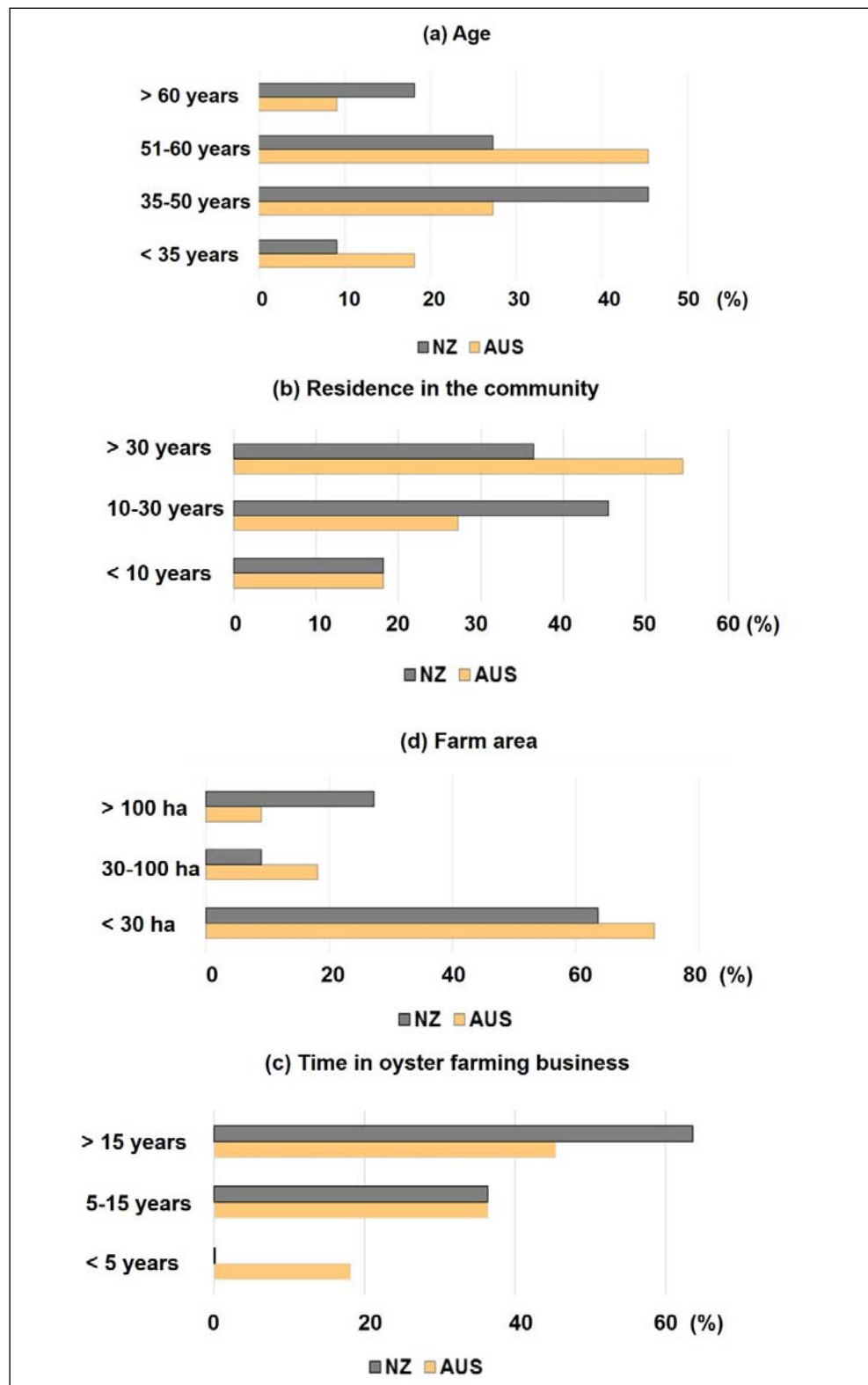


Figure 4. A selection of key characteristics of study participants (given in percentages for each sub-group): (a) age of participants, (b) years of residence in the local community, (c) time in the oyster farming business and (d) area currently farmed in hectares.

3.1.2. Section 2: Experience with OshV-1

The second section of the survey asked about impacts, direct or indirect, that POMS could have had on oyster farmers in relation to their farming operations, business and financial positions, and on their confidence in their businesses but also for the oyster industry and the community to which they belong. The tone of responses changed noticeably compared to Section 1. Some participants became more focused and others provided a passionate narrative.

Current disease status

The number of farmers currently affected by OshV-1 mortalities was quite different between Australia (New South Wales) and New Zealand. Out of the 22 farmers interviewed, 12 had experienced POMS on their farm (this was usually ongoing): eight were from New Zealand and four from Australia. There are currently only two estuaries affected by POMS in Australia— the Hawkesbury River and Georges River, both in New South Wales (see Figure 1). Because the sample aimed for representation of the entire industry within a coherent region, rather than only targeting those who had experienced POMS, this meant fewer participants in the Australian subgroup had experienced POMS compared to the New Zealand subgroup. Indeed, in New Zealand, the vast majority of the oyster farming industry has been affected by OshV-1 mortalities, except for the South Island and some rare sites on the West Coast of the North Island (e.g. Kawhia Harbour). The results from this survey therefore need to be interpreted within the context of each country's experience with POMS.

Three Australian participants had not been farming Pacific oysters when POMS first emerged in Australia; one grower joined the industry afterwards and the two others had been farming Sydney rock oysters only. All three were in non-affected estuaries. This suggests that POMS did not deter oyster farmers from growing Pacific oysters, perhaps because the potential for profit outweighed the risk of losing stock from disease.

Impact of POMS on farming business

Participants were asked to rank the impacts of the OshV-1 mortalities on their farm operations and on their financial situation for the first year of the disease. The ranking of POMS impacts on their operations was identical to the ranking of financial impacts; therefore the results for the two questions have been combined in a pie chart (Figure 5a). Operational and financial impacts were reported as severe by 82% of the participants affected by POMS. Impacts included staff redundancies, stock losses ranging between 20-90%, and the inability to restock farms with juvenile oysters (up to 100% mortality of juvenile oysters).

“I didn’t know if the business was going to carry on” (Australian grower)
“[This disease] has changed my whole perception of biosecurity risks – it used to be abstract, now it is very real” (New Zealand farmer)

Only about a fifth (18%) of respondents (all from New South Wales, mainly from the unaffected Clyde and Shoalhaven rivers) considered that POMS did not affect their business. Interestingly, amongst the unaffected farmers in New Zealand, one respondent reported a significant positive impact of POMS on their business, as they could supply wild-caught spat to affected farmers who urgently needed to restock their farms. In contrast, another unaffected farmer suffered indirectly as his natural spat could not be deployed onto his customers’ farms during the risk period in affected areas (farmers were reluctant to restock their farms with spat when there were ongoing mortalities on their farm, fearing that they would lose the juvenile oysters). In Australia, production in affected estuaries dropped dramatically (down to 0-5% of previous production levels, according to some participants). Farmers lost their income and had no cash flow to restock their farm or pay staff wages. Some farmers were fortunate enough to farm Sydney rock oysters using QX-resistant spat, which allowed them to maintain a minimum income. However those farmers recalled having trouble getting QX resistant stock at the time, citing poor planning of supply from industry.

Impact of POMS on farmers’ morale

The impact of oyster mortalities on farmers’ morale was highly variable (Figure 5b) and the presence of the disease on-farm did not significantly influence the responses (Fisher’s Exact Test, $P = 0.13$). The variability could be explained by differences in the participants’ own ways of coping with stress and adversity. Among farmers who considered the impact on their morale as negligible, some had been affected by OsHV-1 mortalities and others had not. Similarly, testimonies of farmers in unaffected areas revealed increased stress while waiting for the disease to strike, some saying that it was only “a matter of time”.

“The disease will come; it’s a matter of time” (Australian grower)
“Before POMS, there was no way of killing a Pacific oyster” “[POMS] has destroyed farmers. There is no future” (Australian growers)
“Biggest thing that ever hit the [Pacific oyster] industry” (New Zealand farmer)

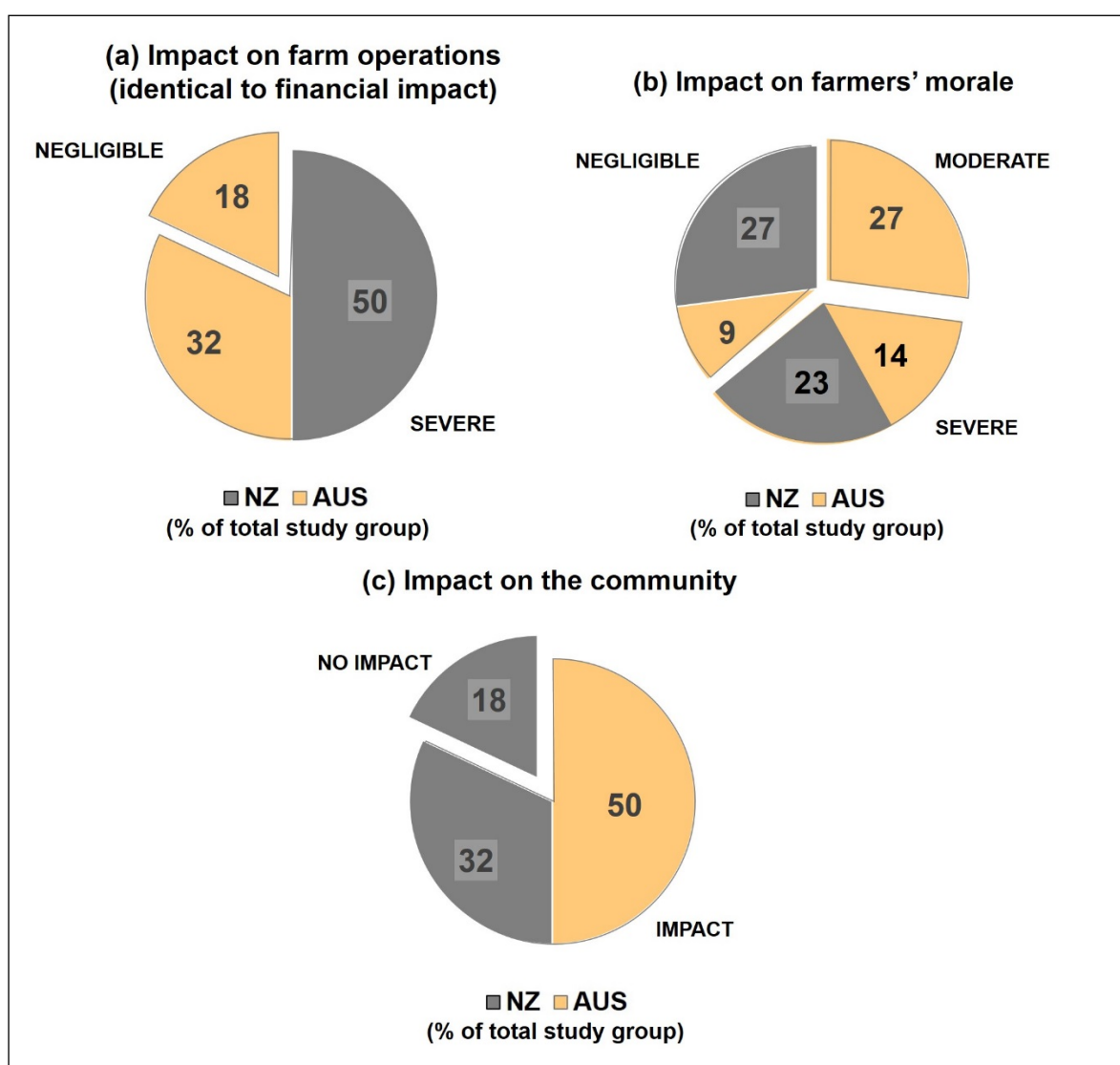


Figure 5. Ranking of impact of OshV-1 associated mortalities (POMS) on: (a) the farms' operations, (b) the farmers' morale, and (c) the community. Responses obtained for the financial impact were identical to the impact on operations (panel (a)).

Impact of POMS on the community

Most participants acknowledged that the community (farmers and local settlement) had been impacted (Figure 5c), often “hugely” or “dramatically”, with “devastating” and “catastrophic” effects on local employment and on farming businesses. Some growers in Australia had reportedly “walked away” in affected estuaries. Farmers were “destroyed” and their businesses “crushed” by POMS. As previously mentioned, some Australian growers had already been through severe financial struggles with QX mortalities in Sydney rock oysters. A second episode of disease outbreak likely increased the level of financial and personal stress considerably. This could explain why Australian participants unanimously ranked the impact on the community as severe, regardless of their POMS status (QX is found across more New South Wales estuaries than POMS).

A small group of New Zealand farmers did not believe that the disease and its consequences on industry had impacted the nearest community (perhaps due to the remote location of their farms).

“Some good people have lost everything” (Australian grower)

“The services that supported industry are no longer in business” (Australian grower)

“A lot of stress on everyone...some business relationships and marriages were broken” (New Zealand farmer)

“[Impact on community] comes down to what sort of person you are. Some walked away while others worked harder” (New Zealand farmer)

3.1.3. Section 3: Support during crisis

Section 3 of the survey examined the level and type of support that the oyster industry received during the POMS crisis, starting with the information that was available to them at the time. This was followed by questions on risk management advice, industry guidance and government response.

Information on OsHV-1 mortalities

Only four farmers out of the study group did not seek information on OsHV-1 in Pacific oysters when the mass mortalities first emerged in their country. Within this small group, two were unaffected by POMS (and only monitored impacts on industry at large), and two others were affected but did not actively search for information.

The sources of information that farmers remembered using are outlined in Figure 6.

They included, in order of importance:

- 1) other farmers and industry notifications
- 2) internet and overseas scientific reports (substantial research had already been undertaken in France on OsHV-1 microvar)
- 3) government officials
- 4) research institutions (domestic).

Australian growers were more inclined than their New Zealand counterparts to use a mix of sources to obtain the information they were after, with no clear preference between ‘Industry’, ‘Internet’ and ‘Government’. The vast majority of Australian participants (82%) were satisfied with the information they obtained but most New Zealand participants did not deem the level and type of information appropriate (82%). This could be supported by the fact that POMS first appeared in New Zealand where farmers may have had very little knowledge about the disease. At least Australian growers had a few months of prior information when POMS arrived in New South

Wales. By the time the disease emerged in the Hawkesbury River, growers had managed to develop biosecurity protocols and laboratory diagnostic methods were routinely used.

“No one knew what to do” (New Zealand farmer)

“There was a lot of speculation in terms of husbandry, etc [...] but mainly people’s opinion” “[We] needed more scientific input” (New Zealand farmer)

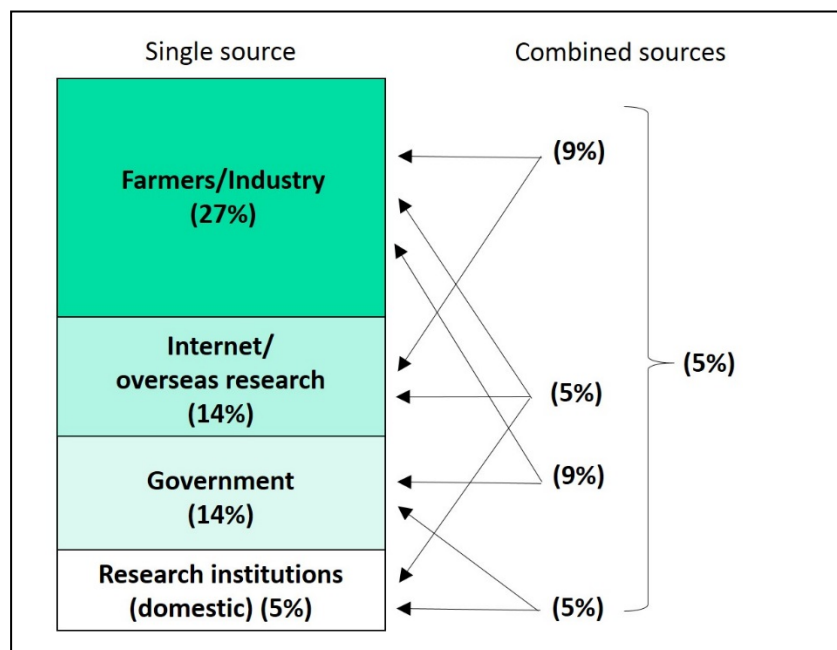


Figure 6. Sources of information consulted by Pacific oyster farmers when the first OsHV-1 associated mortalities emerged in their respective country. Frequency of answers by the study group ($n = 20$, two missing data) are expressed in percentages (%)—they do not add up to 100% as there were missing data.

Previous training and education (often linked with the age of the respondent) appeared to influence the answer to the question “*did you seek any information?*”. Those who had received tertiary education were more active in seeking technical information, while the others were reliant on other farmers or on industry bodies. No statistical test was undertaken to support this observation (due to the small sample size).

Critical and routine advice

Participants were asked who (an individual or an organisation) they would trust for advice during a disease outbreak. Most of them paused and hesitated before providing an answer. Responses ranged from “no one” to the sources of information presented in Figure 6.

Overall, government was named by more respondents (54%) as a trustworthy source of advice in a crisis, either alone (32%) or combined with other sources such as other farmers and industry bodies, as well as research organisations (22%) (Figure 7, top). Based on the answers obtained, the preference for government was especially prevalent among Australian participants, while the New Zealand respondents were more inclined to consult other farmers and industry bodies during a disease outbreak. In a biosecurity crisis, government would be expected to lead the operations and decision-making, so it seems reasonable to find that farmers expect the authorities to provide the best guidance possible to manage the crisis. Why New Zealand farmers seem to place more trust in other farmers and industry than in government is impossible to answer based on such a small sample, but may warrant further investigation.

Farmers were then asked who they would trust as a routine adviser for their day-to-day questions or issues with animal health (Figure 7, bottom). A large part of the study group did not know (22% overall) or would not trust anyone in particular (18%). In New Zealand, the main trustworthy source of routine advice was other farmers and their industry body rather than officials. The reason mentioned was the lack of or insufficient technical expertise in government. Australians reported various sources for routine advice, which probably reflected their personal relationships with fisheries officers or university researchers in their estuary (Figure 7, bottom).

In New Zealand, the only face-to-face contact that oyster farmers have with government officials is over food safety and testing for export certification. The role of MPI's Aquaculture Unit is also to provide advice to farmers on request, but there is no on-farm presence of animal health providers in the same way that veterinarians could be approached by dairy farmers. In Australia, though the local authorities (fisheries officers) patrol estuaries on a regular basis, they were not the growers' first choice for routine advice.

Industry guidance

Participants were asked if they had followed any industry guidance when POMS was declared in their country. About 68% of the respondents (both countries) did not follow any guidelines, mainly because they did not know of any existing standards. The others complied with the industry recommendation that was available to them, which was to avoid moving oyster stock to limit the extent of the outbreaks. In the absence of a uniform industry plan, a few farmers used common sense to manage the crisis and restricting stock movements was part of this. However, a number of New Zealand farmers admitted that most of the oyster industry was in "survival mode" and panicked, moving stock erratically to save what could be harvested.

“[It was] impossible to get people acting as a group – all acted as individuals doing what was best for their business”

“People were in survival mode”

“There was a restriction on stock movement but other farmers were moving stock so...I did too”

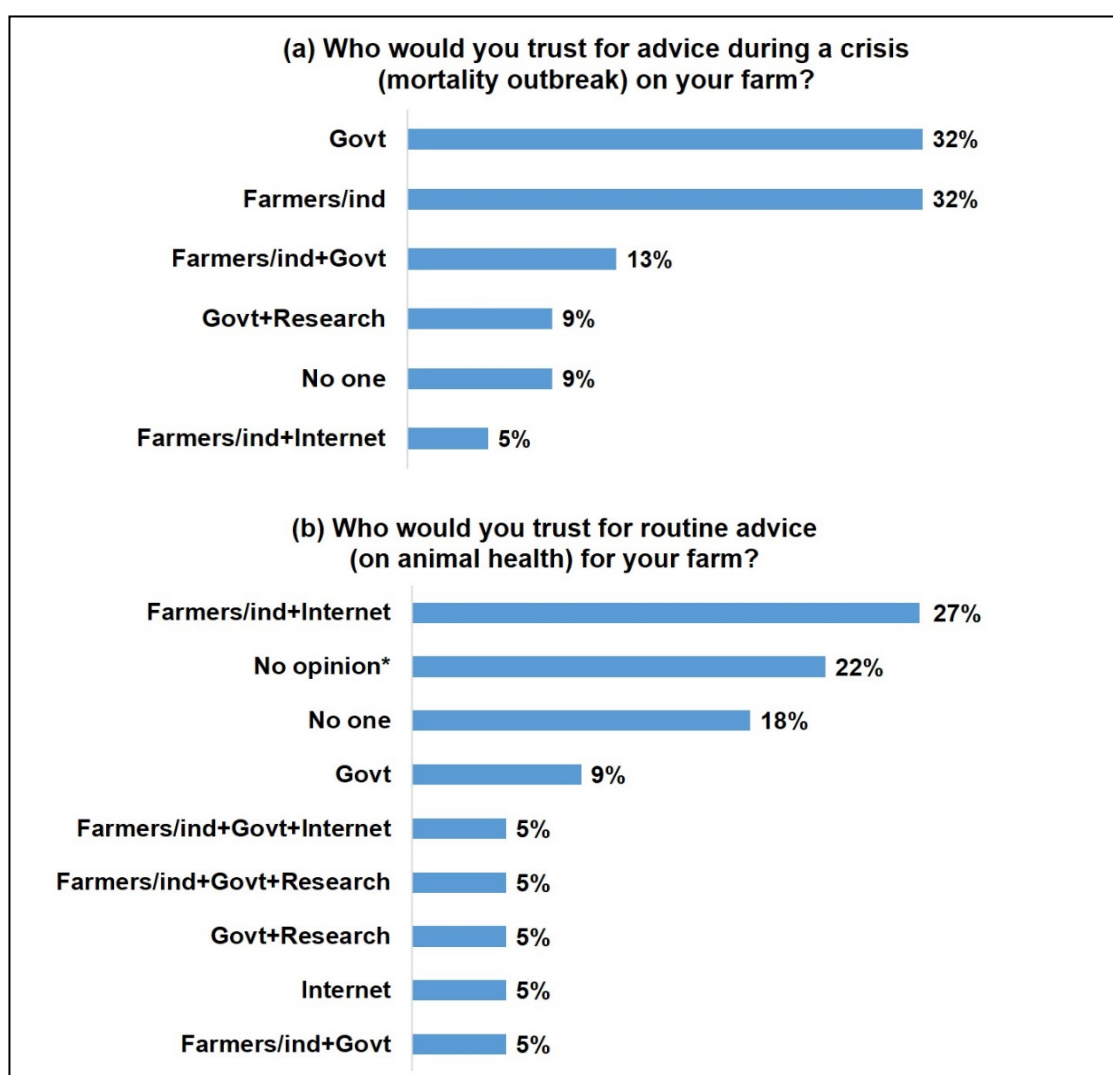


Figure 7. Trustworthy sources of advice for oyster farmers in the study group (countries combined): (a) during a biosecurity crisis; and (b) on a routine basis. * ‘No opinion’ refers to participants who did not know of anyone or preferred not answering the question. Govt: Government, Farmers/ind: other farmers and industry bodies, Research: research institution. Note that percentages do not add up to 100 for (b) as results were rounded up.

Government support

Firstly, participants were invited to talk about positive aspects of the government response to OsHV-1 mortalities. Almost half of the participants (42%) either had no opinion on the topic or had nothing positive to say about government (Figure 8a).

Another 42% found that movement controls and diagnostic testing were areas in which government had been effective. For instance, New Zealand farmers appreciated the promptness of getting samples tested across a wide range of farming sites and obtaining confirmation of diagnosis from an overseas reference laboratory, in order to find out how widely the problem had spread. Australian growers were the most supportive of movement controls to limit POMS spread, perhaps because they already had a positive experience with movement restrictions between estuaries to control QX disease. Another well-received initiative from government was the timely availability of funding, either towards research on OsHV-1 in Pacific oysters in New Zealand, or towards the clean-up by industry of abandoned sites in affected estuaries in New South Wales (though the latter scheme was during the QX aftermath, not POMS).

Participants were then asked to highlight the negative points about the government response (Figure 8b). Although five participants did not respond to this question, the most prominent answer mentioned the slow and/or unstructured government response. The overall impression was that governments did not respond quickly enough when the mortalities first hit. On most occasions in Australia, growers took the lead on actions to minimise disease risk for the rest of industry (e.g. in the Hawkesbury River). In New Zealand there was a feeling that the response largely consisted of delimiting the distribution of OsHV-1 *via* widespread testing of oyster production sites, but that there was no follow-up after this.

While some farmers saw funding as a positive point in the government response, others perceived it as a negative feature (18%), claiming a lack of overall financial support and involvement throughout the crisis. It was suggested by 18% of the group that inadequate measures were a downside of government response; e.g. ineffective or deficient management of stock movement, and absence of quarantine of affected zones or estuaries. Communication was an area where government did not perform well according to participants. Most said they were kept in the dark regarding the test results and what it meant in practice for their business. In New Zealand, those who were not affected by POMS (*i.e.* whose oyster stock tested negative for OsHV-1 in the absence of high mortalities) felt left out of government's communications with stakeholders.

The last question of this section asked if anything had changed with regards to government support since the first outbreaks. Most of the group (83%) did not think that anything was different. The remaining respondents highlighted improvements in preparedness (New Zealand) and funding of a breeding programme seeking disease resilience in Pacific oysters (Australia and New Zealand).

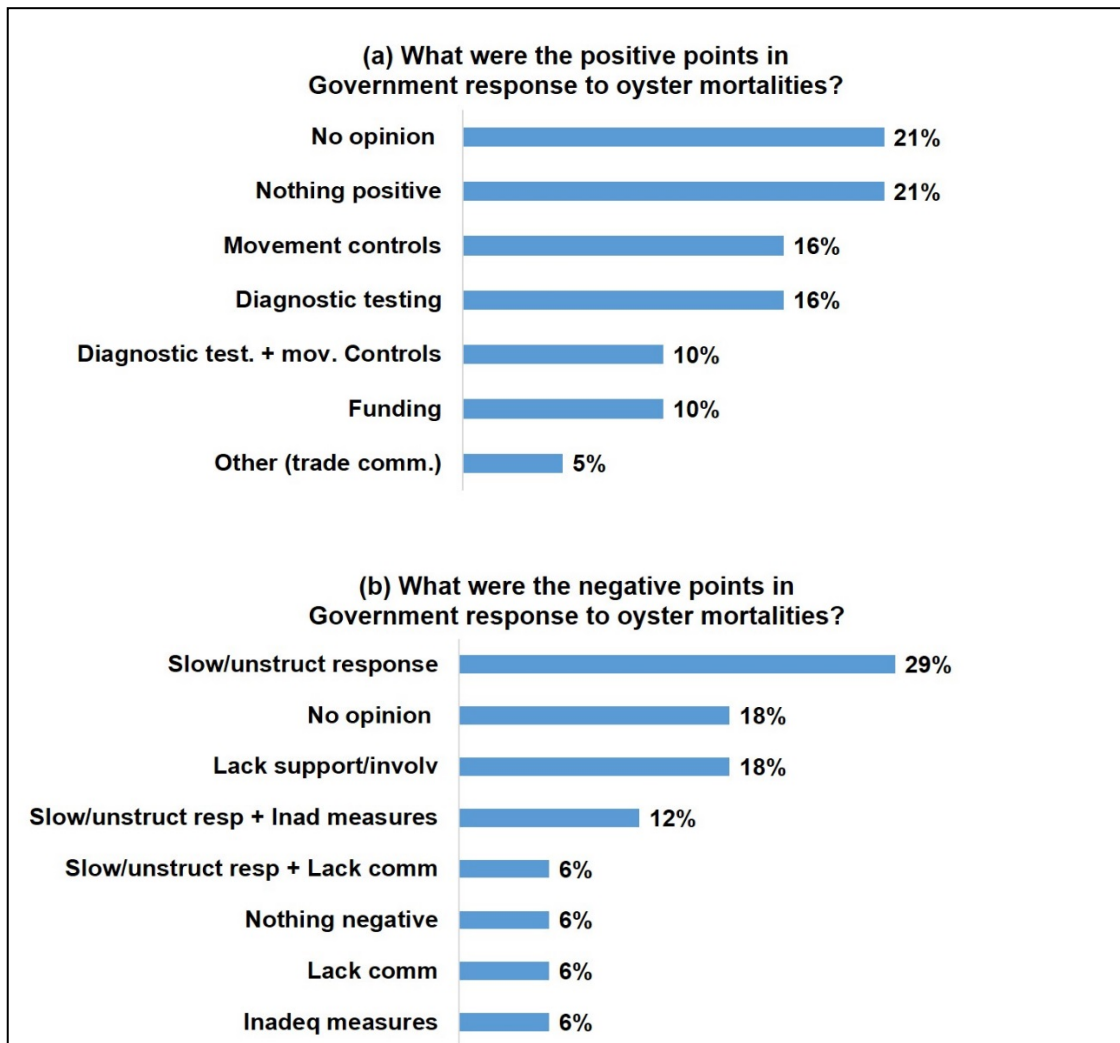


Figure 8. Positive (a) and negative (b) points about Government response to OsHV-1 associated mortalities according to the study group (countries combined). Slow/unstruct response: slow and/or unstructured response, Lack support/involv: lack of support or involvement, Inad measures: inadequate measures, Lack comm: lack of communication. Note that percentages do not add up to 100 as results were rounded up. n=19 for panel 'a' and n=17 for panel 'b'.

3.1.4. Section 4: Risk management strategies

The fourth section of the interview explored participants' views regarding a range of strategies (prevention and control) to manage animal disease risk. Prevention strategies consist of measures taken in anticipation of an issue (here the spread of OsHV-1 and associated mortality outbreaks), to reduce or eliminate the likelihood of it happening. In contrast, control strategies would be used when POMS is present in the farming area to contain mortalities and reduce potential spread of the disease to unaffected populations.

Prevention strategies

Respondents were asked to reflect on five preventive strategies and to indicate whether these measures could be effective to help prevent or minimise the impact of POMS on their farming business. Managing disease risk is quite different in an aquatic environment compared to a terrestrial environment. Although the strategies presented were successfully applied in other animal production systems (including finfish farms), they may not be effective against POMS. A number of strategies were listed by the authors, drawing from their experience in terrestrial animal health.

The prevention strategies were as follows:

- **Diversify the species farmed** to secure minimum production and income: in New South Wales some growers already farm Sydney rock oysters or flat oysters as well as Pacific oysters, and in New Zealand some Pacific oyster farms have consent to farm other shellfish species such as green-lipped mussels
- **Monitor the environment** for early detection of disease: this has proven very useful in terrestrial animal production systems (for example bird migration and avian flu outbreaks)
- **Adhere to a collective risk management plan** with neighbouring farmers: there are numerous examples of similar initiatives in primary industries (e.g. in New Zealand, kiwifruit growers and Psa bacterium; in Australia, ovine virulent foot rot)
- **Diversify the sources of spat supply**: this means having more than one site for spat supply, whether it is wild-caught or produced in hatchery (in case one source becomes unavailable due to disease)
- **Apply systematic on-farm biosecurity measures**: these could include cleaning and disinfection of gear, keeping records of seed and stock movements, separating age classes within farm layout or developing generic response plans for disease outbreaks.

For almost all of the strategies proposed, a small percentage of respondents remained uncertain about their effectiveness to control disease (between 4 and 9%, which corresponds to one or two participants each time). “Collective [risk management] plan”, “vary sources of spat” and “on-farm biosecurity” were largely supported by the participants: between 82% and 95% considered that these measures would be effective. Although environmental monitoring got positive responses from 59% of respondents, in further discussion soem of these respondents said they did not believe this knowledge would prevent mortalities from happening and they also stressed that they did not know what parameters to monitor.

Figure 9b presents the overall inclination of the study group to implement any of the preventive strategies discussed, leaving the cost of implementation aside. Some of the measures had already been adopted by the farmers. In several instances the potential uptake was much less than the perceived effectiveness. For example, 95% of the participants deemed that a collective response plan would be a good way to

minimise the impact of OsHV-1 mortalities (or other disease) on their farm, but only 67% were prepared to implement it. Similarly, varying the sources of spat supply (natural or hatchery spat) was considered an effective preventive measure by 91% of the participants but only 62% would look into this strategy for their own business. Environmental monitoring was the least likely option for uptake, with only 33% of farmers ready to consider monitoring the environment to manage disease risk.

The presence of POMS on-farm did not seem to influence the answers in this section ($P > 0.1$). One exception was a collective plan to manage disease outbreaks and mortalities; those without POMS did not consider this strategy as worthy as the affected farmers (Fisher's Exact Test, $P = 0.016$).

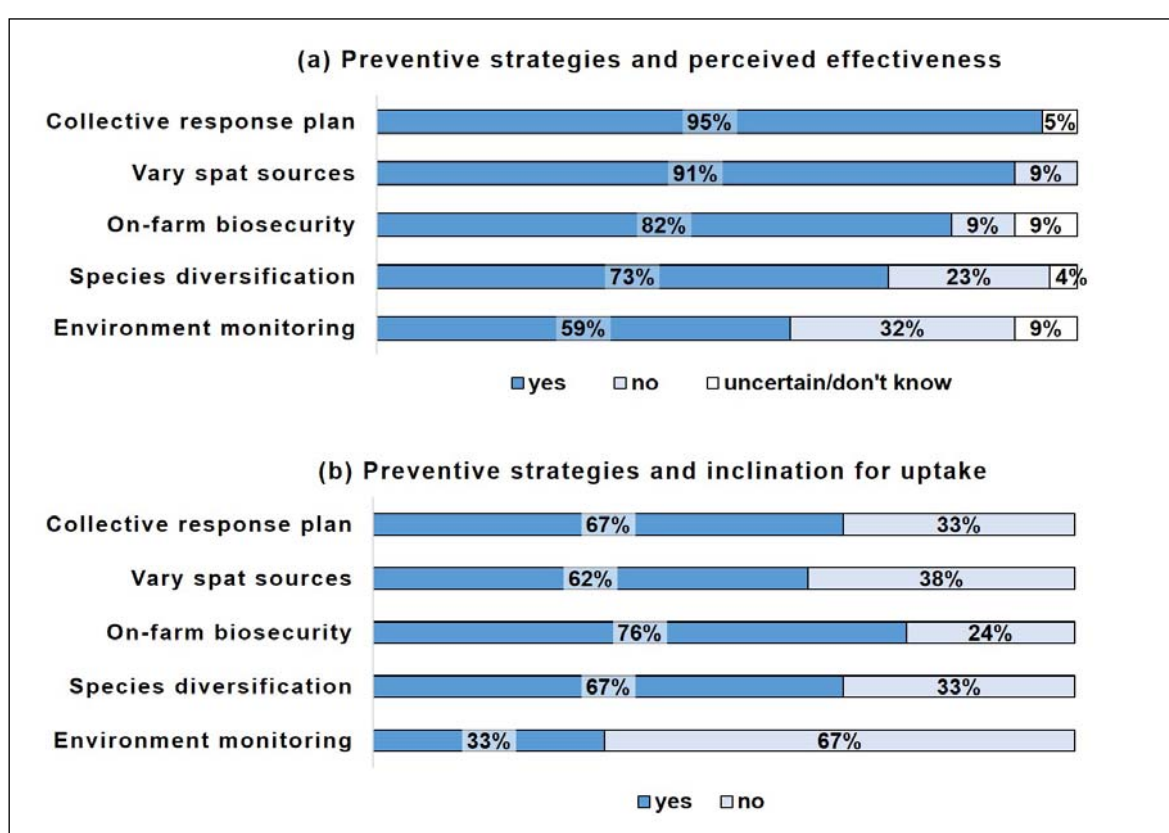


Figure 9. Preventive strategies for on-farm disease risk management: (a) perceived effectiveness (n=22) and (b) inclination for uptake (n=21). Information was not split by country.

Control strategies

Participants were asked to consider six control strategies and to indicate whether they were likely to adopt any of these measures with adequate guidance. The proposed strategies were:

- **Stop all movements** of oyster stock or farming gear
- **Clean and disinfect farming gear**: rather than simply holding gear on an infected (or presumed infected) farm, these could be cleaned and disinfected

- **Clean barges and vehicles** used for transporting oyster stock or any equipment from an infected farm
- **Test all shellfish stock** for OsHV-1 and only allow movements of stock with negative results (regardless of boundaries)
- **Put zones in place** and only allow movements of stock and gear within the same zone or from a non-affected to an affected zone (no testing required)
- **Engage with the local community** to prevent the introduction of POMS into a non-affected area through potential vectors (e.g. kayaks, fishing gear).

As with the preventive strategies, some respondents felt uncertain about the effectiveness of some control strategies and refrained from providing an answer (Figure 10a). ‘Stopping movements of oyster stock and farming gear’ received the most support as an effective strategy (82%), followed by ‘zoning farming areas’ (73%) and ‘cleaning and disinfection of gear’ (68%). Participants remain sceptical about the true efficacy of cleaning and disinfecting gear, especially when used with barges. Other factors were the impracticality of this task and the inability to control recreational vectors (yachts and powerboats), which would undermine this cleaning and disinfection strategy, as well as other strategies.

“Really hard to get everyone on-board as people are not willing to share information” (New Zealand farmer)

“Hard to trust growers to follow a plan” (Australian grower)

“The second source [of spat] is a bit of insurance for us” (Australian grower)

This discussion continued with the topic of engaging with the local community; 62% of respondents saw merit in adopting this strategy (Figure 10b). Most of the farmers expressed their concerns about ‘dealing with the community’, citing the unlikelihood of support and the impossibility of reaching out to recreational boat users from outside of the farming area in question.

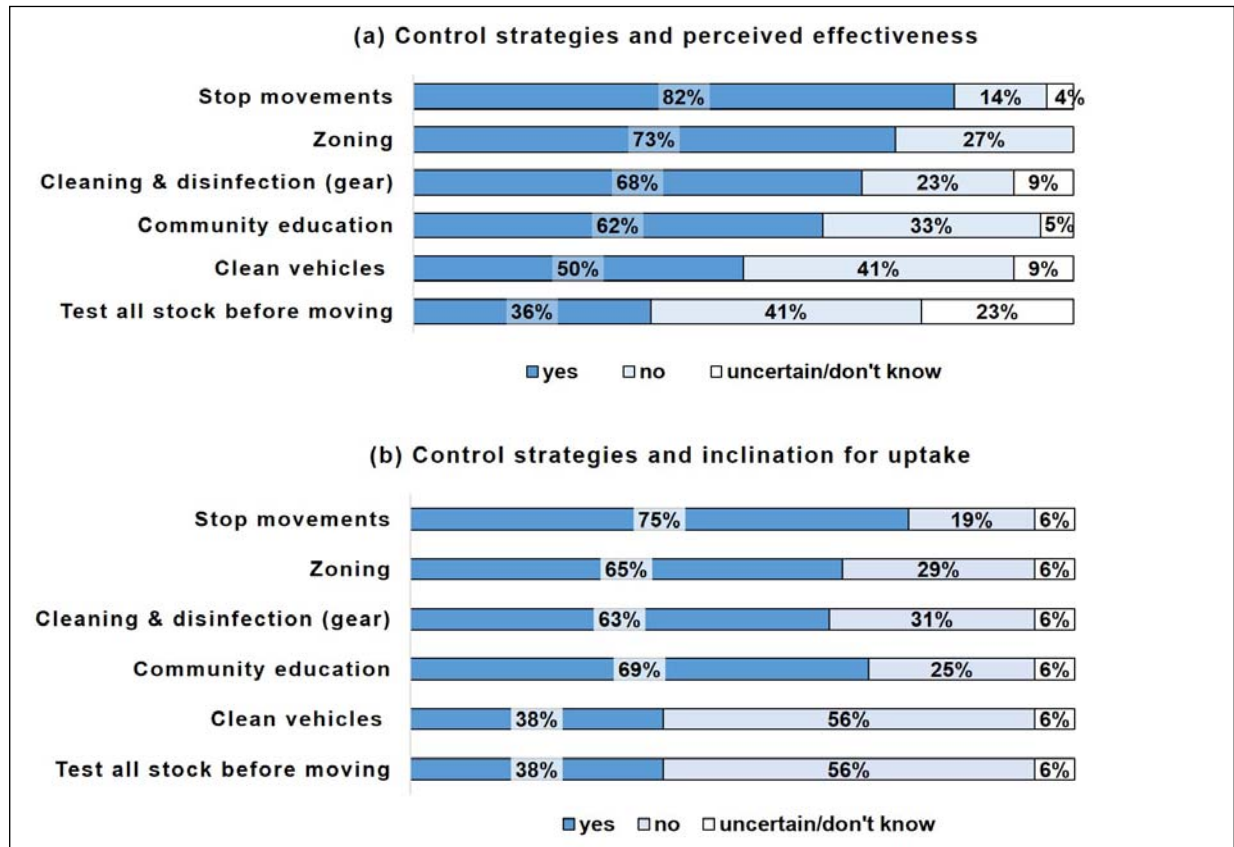


Figure 10. Control strategies for on-farm disease risk management: (a) perceived effectiveness and (b) inclination for uptake. Note that for (b) there were between 5 and 6 missing data for each question, which makes the interpretation difficult. Information was not split by country.

'Testing of all stock' as a condition of movement ranked the lowest, for both its perceived effectiveness and inclination for uptake. Some farmers voiced concern that a positive test was not necessarily associated with disease and on-farm mortalities but the vast majority invoked the prohibitive cost of this strategy and the likelihood that farmers would keep moving stock regardless of testing. Supporters for the OsHV-1 testing strategy were mainly from New South Wales, where testing is already required for hatchery spat to be introduced into any estuary. None of the views provided on control strategies were significantly influenced by the presence of POMS on the participants' farms ($P > 0.1$).

“People would move stock anyway” (New Zealand farmer)

“The lesser movements, the better” (New Zealand farmer)

“Yes for zoning across estuaries but not within estuaries” (Australian grower)

“[Engaging with the local community]: yes in theory but difficult to put in practice” (New Zealand farmer)

Changes to farming methods for Pacific oysters

Regardless of country and POMS status, 73% of participants reported changing their approach to farming oysters since the mortalities first occurred. The key motivation behind the changes was to minimise the loss of stock nearing market size, in order to make a profit.

In the New Zealand group, only one affected farmer had not changed their farming practice since dealing with POMS but none of the unaffected farmers had changed. The reasons given for not changing farming practices included the ongoing uncertainty about disease onset and the absence of mortalities on their farm. This was a clear difference with the Australian growers, the majority of whom had already modified their business strategy and husbandry practices in response to POMS, regardless of their status.

Key changes included (the origin of answers is specified after each change):

- **Switch to single-seed oyster farming** (*i.e.* using hatchery spat, which implies a number of financial and operational adjustments)—New Zealand
- **Diversify sources of natural spat** (by mixing hatchery/natural spat or by varying the sites for natural spat collection)—New Zealand
- **Diversity species farmed** (or increase the ratio of Sydney rock to Pacific oysters)—New South Wales Australia
- **Delay spat catching** (spat caught later in the season seemed to have a better survival rate according to some farmers)—New Zealand
- **Increase the amount of spat initially stocked on farm** (to ensure a viable number reaching market size)—New Zealand
- **Reduce stress on animals** (*e.g.* avoid handling stock where possible)—New Zealand
- **Use local natural spat** (*i.e.* no introduction of spat from another area or estuary)—New South Wales Australia.

The time spent in the oyster farming industry (years in business) had little influence on farmers' inclination to make changes on farms. The two farmers who had been growing oysters for less than 5 years either turned to species diversification or changed their business strategy. The majority of those who had been farming between 5 and 15 years and for over 15 years also modified their approach to farming (75% and 67%, respectively).

3.1.5. Section 5: Risks & preparedness

Section 5 of the survey gave the respondents the opportunity to voice their solutions to oyster disease. First an open question asked farmers about the risks they were willing to take. Then they were invited to comment on their own state of preparedness and how they felt others in industry and government were prepared. This was

followed by questions on their ability to invest in their business and on their current awareness of research on POMS. Lastly, participants had the opportunity to conclude the survey with one or more ideas that they believed would help the oyster farming industry overcome POMS, at all levels of management.

Business risks

Approximately 41% of farmers (equally distributed between the two countries) were not prepared to take any or further business risk but preferred maintaining their current position (Figure 11). Overall, farming more than one species was considered by 32% of the respondents as a risk they would be prepared to take, often in conjunction with investing in infrastructure to accommodate this strategic change. Husbandry changes made up 19% of the remaining answers (when combined with diversification of species).

The size of the business did not seem to influence the type of business risk prepared to be taken. Larger businesses were expected to have the necessary cash-flow to make on-farm investment. But in this small-scale survey, smaller businesses appeared similarly predisposed to invest in species diversification and to change their husbandry approach to sustain their farming activities on a long-term basis.

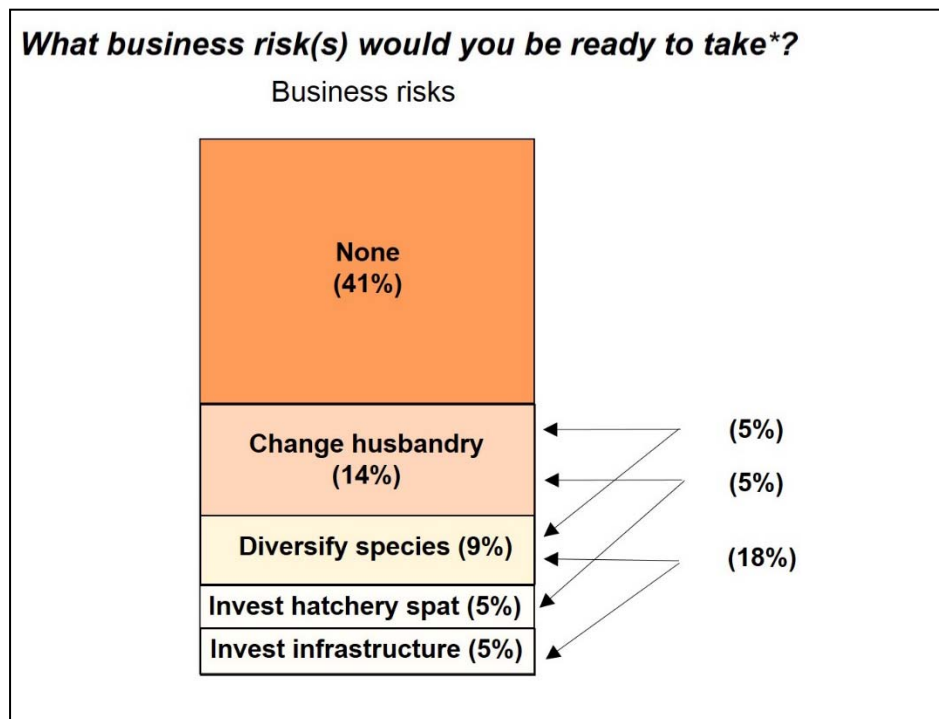


Figure 11. Types of business risks that survey participants would be ready to take to sustain farming activities. *Note that percentages do not add up to 100 as results were rounded up.

(In)ability to invest into business

The inclination to invest was tempered by the reality of the crisis within the industry. Two-thirds of the respondents (62%) agreed that POMS had reduced their ability to invest in their business, for example to replace or maintain their infrastructure. Rather than employing new labour, most farmers had to lay off their staff and increase their debt.

Some affected farmers recognised that they were fortunate to be part of a larger group or company that could support them during disease outbreaks and provide hatchery spat to maintain minimum production levels. For others, it had taken 3 years to recover financially from the first outbreaks and they remained very cautious about future investments. A few non-affected farmers had kept building their assets, either by buying more stock and expanding or by acquiring new infrastructure to farm more oysters or to diversify species.

State of preparedness for disease challenges

In terms of preparedness, the majority of the study group (71%) felt that their business was as ready as it could be to face disease challenges. Although statistical analysis did not show any association between business preparedness responses and experience with oyster farming (Fisher's exact test; $P = 1$), it is difficult to interpret this finding without further evidence. Farming several species was positively associated with business preparedness (Fisher's Exact Test, $P = 0.0456$). Three of the four larger businesses (> 100 ha) had a plan to cope with on-farm mortalities while most of the other businesses (medium and small) acknowledged that they did not have such plan (9 out of 16). The content or detail of these plans was not discussed. The concepts of *preparedness* (i.e. contingency planning for maintaining minimum income) and *having a plan* (to cope with mortality/disease) could have been understood differently by respondents; hence, these associations should be interpreted with caution.

We asked participants to comment on the level of preparedness of their government, including both local and central agencies. They expressed substantial concern regarding the lack of preparedness of government for a biosecurity crisis like POMS, in particular among local agencies. Around 73% of respondents did not believe that government was adequately prepared to manage oyster disease outbreaks and 88% of them would not rely on external aid in such a situation. Local government had been expected to be more available to farmers and provide more hands-on support than central government during a biosecurity incident, but this had not been the case according to the survey participants.

Research directions for ongoing management

Participants were asked about their general understanding of OsHV-1 mortalities and the associated research currently undertaken in their country and overseas (Figure 12).

Most New South Wales farmers said they were aware of the disease mechanisms and the research carried out in Australia, while only half of the New Zealand farmers knew about it (Figure 12a). It is possible that some respondents felt that they had to show some awareness through respect for the interviewers (who were either from the University of Sydney or from Cawthron). For some participants who said that they understand the current scientific advances, this was not supported by their comments. Therefore the results for this question are likely to contain bias.

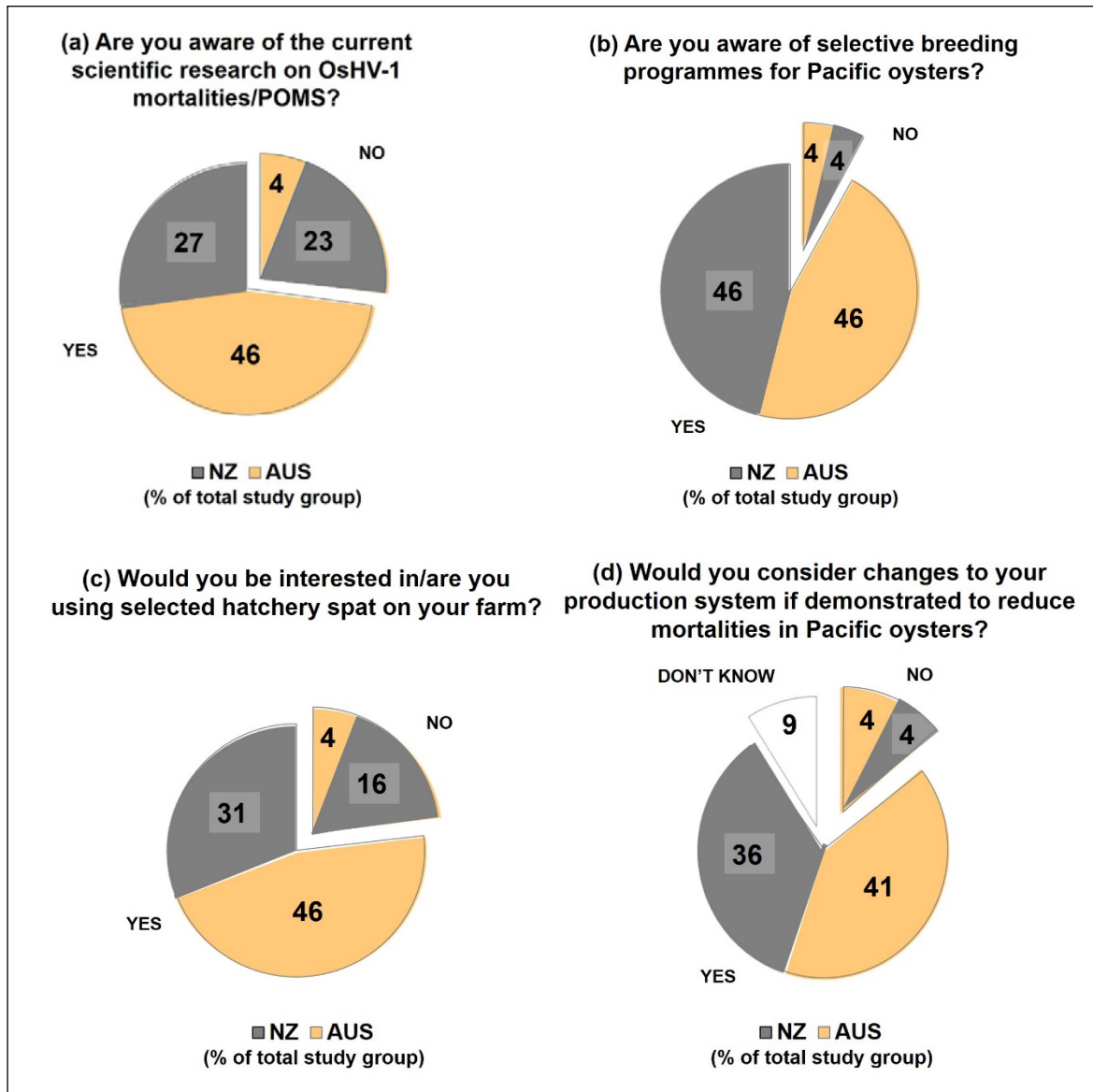


Figure 12. General awareness of survey participants for: (a) current scientific research, (b) selective breeding, (c) use of hatchery spat and (d) on-farm production practices to manage mortality outbreaks.

Selective breeding of Pacific oysters and production of hatchery spat that would be resilient to POMS were well-known subjects in both countries (Figure 12b). Up to 77% of the respondents would consider using selected spat on their farm if it was proven to

increase survival and sustain a higher production (Figure 12c). The other respondents were concerned that diploid-selected spat could modify the natural genetic pool for Pacific oysters or were not aware of the breeding programmes.

About 77% of participants would consider integrating new techniques in their approach to farming Pacific oysters (Figure 12d), if it was demonstrated scientifically that they effectively reduce mortality without lengthening the oyster production cycle. Overall the Australians showed more enthusiasm for change than the New Zealanders. The latter were at times sceptical about husbandry changes being the best strategy to reduce disease risk.

Farmers' priorities for action

A final open-ended question gave participants the opportunity to express their personal priorities for action to improve the way OsHV-1 mortalities are managed. A number of inspiring suggestions were put forward.

The answers were aggregated into 6 broad categories (Figure 13):

- biosecurity
- communications and training
- spat and selective breeding research
- environment
- husbandry
- other research (e.g. research farms, environmental studies).

'Biosecurity' and 'communications and training' got the most support among the group's suggestions. With reference to biosecurity, participants expressed the need for industry to develop generic response plans and quarantine protocols, as well as guidelines for managing stock movement. Throughout the survey, respondents highlighted the fact that voluntary restrictions on stock movements were unlikely to be complied with, and government should step in and make these measures compulsory to protect the oyster industry at large. In this final part of the survey, farmers voiced the need for biosecurity improvement at industry level and were also in favour of government intervention to enforce biosecurity measures (particularly on stock movement) during an outbreak.

Improving communications was a recurrent theme; it was a collective realisation that farmers were not sharing information amongst themselves and with government. Likewise, government and scientists needed to be proactive and improve their communication with farmers. Participants suggested the following actions:

- setting up a neutral body to coordinate communications
- enhance industry reporting (local disease notification and transparency for all farmers)

- upskill industry (on biosecurity, animal health and ecology)
- educate the community (on risk to industry)
- improve science reporting
- foster collaborations between industry and government.

‘Selective breeding research’, in particular producing a resilient Pacific oyster, remained a central expectation for most participants, especially those already using hatchery spat on their farm. There were some variations amongst selective breeding supporters: some were in favour of an industry-driven and owned programme, whereas others supported the idea of local breeding programmes (*i.e.* within an estuary) to preserve the existing strengths of the local oyster stock. Sourcing POMS-resistant oysters from overseas (*e.g.* from France) was advocated by one grower, who did not seem to be concerned with potential introduction of other oyster diseases *via* imported stock. Interestingly, one farmer suggested that “long-term, the oysters [would] get their own immunity”. Two farmers believed that no further action was needed, given what was already happening.

Several farmers called for government to enhance and financially support spat availability to the wider oyster industry, and in New South Wales, to review the Pacific oyster’s Noxious Species status and allow diploid oysters in all estuaries. There is currently only one commercial hatchery producing triploid Pacific oysters in Australia and it is located in Tasmania. Respondents said there should be another sustainable source of hatchery spat for industry to distribute the risk of production shortfall. However when the patent to produce triploid Pacific oyster spat (currently held by the hatchery in Tasmania) comes to an end, other commercial hatcheries, for example in Tasmania and in South Australia, should be able to increase the overall triploid spat supply for New South Wales growers. Similarly in New Zealand, there is currently one site producing hatchery spat. Industry demand may not warrant the expense of setting up and maintaining another commercial hatchery (notwithstanding selective breeding) but external investment could help mitigate the risk of single supply.

Australian participants felt very strongly about environmental monitoring, in particular the impacts of urban activities on water quality. New Zealand farmers also identified field monitoring as a knowledge gap but from a different perspective, with farmers interested in why mortalities had only occurred in some parts of New Zealand and not across the entire country (under the assumption that OsHV-1 microvar was widespread). Research farms, with students working alongside farmers, were also suggested as a potential good approach to improve on-farm disease risk management and training future generations of farmers in aquaculture biosecurity.

At farm level, priorities for action focused on promoting polyculture, adjusting farming systems to hatchery spat and diversifying business incomes. The first two points may

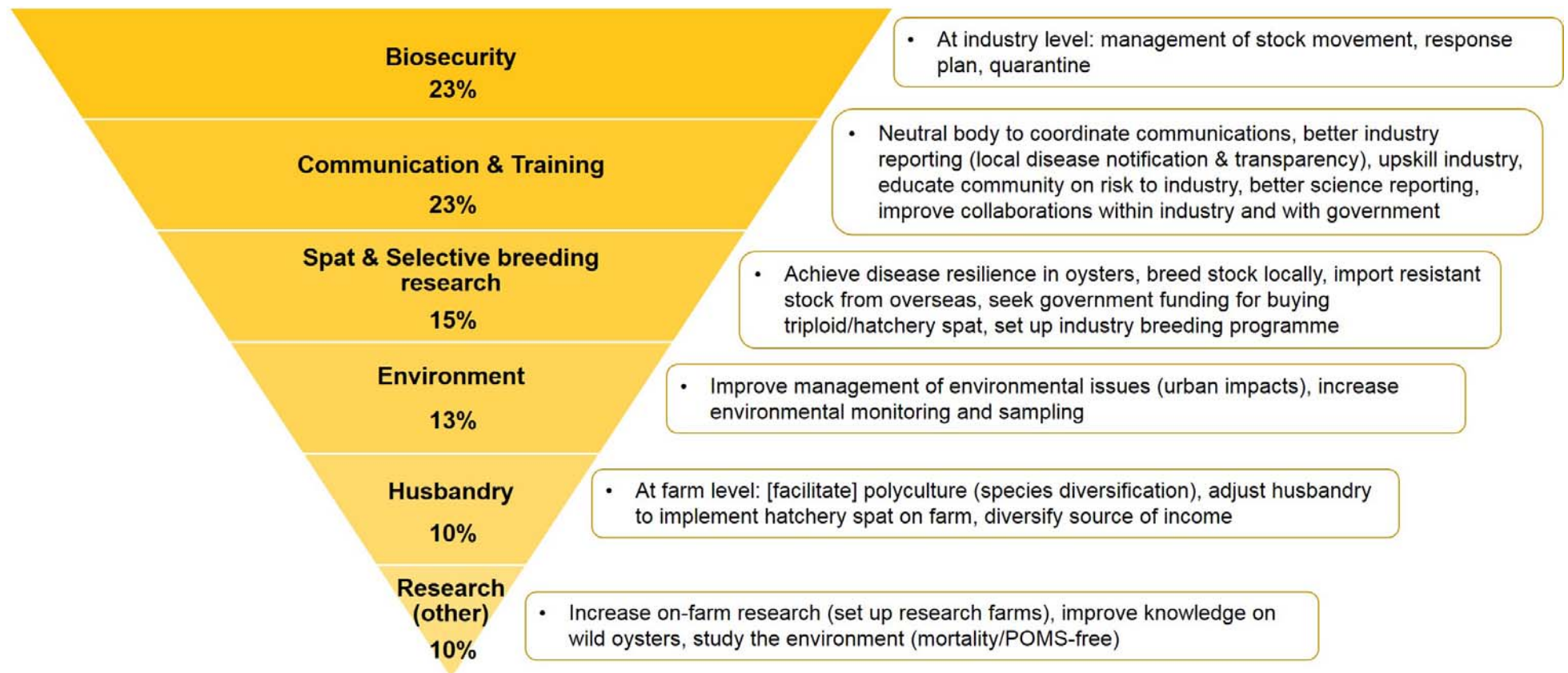
require considerable technical and financial support, either from government or from a coalition of industry partners, in order to minimise the R&D cost.

“Farmers need to get a better understanding of the big picture problem” (New Zealand farmer)

“Government should fund workshops to inform [growers] and help dealing with potential future outbreaks” (Australian grower)

“POMS will arrive; [we] need to avoid monoculture” (Australian grower)

“Need a response plan within industry to form some sort of strategy. [Disease] will happen again, it is a matter of when” (New Zealand farmer)



6% of participants indicated that no action was needed in their views (either because their business was profitable as such or because natural immunity to the virus will come eventually)

Figure 13. Areas of focus for better management of POMS, as identified by survey participants. The percentage for each area represents the frequency of answers by category

4. DISCUSSION

4.1. Roadblocks to biosecurity uptake

4.1.1. Biosecurity behaviour and risk perceptions

This trans-Tasman collaboration was a small-scale study on disease risk perceptions in the Pacific oyster industry. A larger sample of farmers would have made the analysis of risk factors and outcomes more robust. But by meeting face-to-face and interviewing a small number of farmers it was possible to explore their risk perceptions and operational knowledge in more depth and detail. The findings were validated during an oyster knowledge exchange held several months after the interviews. Furthermore, the information conveyed by this survey concurred with observations reported for New Zealand industry by Sim-Smith *et al.* (2014), using a much larger study population. To the best of the authors' knowledge, there was no comparable biosecurity survey available for the Australian aquaculture sector.

Perhaps the most remarkable finding in common with Sim-Smith *et al.*'s study was the contrast between industry's concern for prevention and control of pests and diseases and their belief that "nothing can be done". The same paradigm was reported by Carlier *et al.* (2013) who interviewed French oyster farmers in the wake of the OsHV-1 mortalities in 2011 about the perceived causes of mortality and on-farm management decisions. Results showed that the vast majority of farmers were concerned by the mortality outbreaks and admitted that inadequate husbandry could have contributed to weakening the oysters and thus enhanced the virus occurrence. However, only a third of the farmers changed their practices to limit disease spread and associated impacts on production, which showed a gap between collective intentions and individual actions at farm level. Another study on French oyster farmers' behaviour suggested that financial motives alone (*i.e.* compensation) became insufficient over time to motivate disease notification to government officials (Lupo *et al.* 2014). Most importantly, the lack of awareness of the benefits of early mortality reporting (*i.e.* for detecting exotic or emerging diseases or for surveillance purpose) was a strong roadblock to notification, and thus to biosecurity risk management at an industry level.

In the present study between Cawthron and the University of Sydney, farmers had mixed responses towards the actions of government and its ability to put effective measures in place during outbreaks. From experience with the New Zealand aquaculture industry, there has been a long-held apprehension that reporting disease or mortality may lead to overreaction from officials and a freeze on farming activities. The perceived negative aspects of reporting on-farm biosecurity issues and mortalities are a major roadblock to passive surveillance in the aquatic animal health sector in New Zealand. This perception may come from poor previous experiences or from the perceived lack of technical knowledge in government (expressed by participants in this survey), leading to a lack of trust from an industry perspective. In New South

Wales, growers are obligated to report unusual mortalities (*i.e.* > 5%) as part of their leasehold agreement. But based on this study, growers in general tend to only report mortalities when they are beyond 50%, saying that governments do not take them seriously for lesser issues (for which inadequate husbandry decisions, not disease, are usually incriminated).

As in New Zealand, when the New South Wales government investigates mortalities, tests are performed on oyster samples. But some growers argued that the investigation is limited to confirming or excluding known pathogens such as QX and winter mortality, and deplored the apparent lack of resources to undertake a systematic investigation into other potential causes of mortality. The implications of lack of trust for reporting biosecurity issues have been described by Palmer *et al.* (2009) in sheep and cattle farmers from Western Australia; poor communication and lack of transparency were amongst the deterrents for trusting government and its ability to help industry to manage risk from infectious diseases. However in the present study governments were not the only ones blamed for insufficient dialogue. Both countries showed deficiencies in communication within industry itself, for example when farmers omit to notify their neighbours of mortality on their farm and keep moving stock. This represents a major risk for spreading pests and diseases in the aquatic environment.

4.1.2. Stock movements: a call for regulation?

Participants clearly expressed their concerns about voluntary movement controls and the likely failure of industry to comply with this strategy. There were calls for government to impose movement restrictions through regulations (both New Zealand and New South Wales officials have the power to stop stock movements, under the Biosecurity Act 1993 and the Quarantine Act 1908² respectively). But even then, two conditions are essential: the need for compliance mechanisms and the timeliness of declaring movement restrictions, including appropriate communication with key stakeholders. Not achieving these conditions could compromise the value of movement restrictions.

Managing stock movements during an outbreak only reduces the risk of spreading the problem. Secondary pathways still exist such as recreational activities and potential associated vectors (*e.g.* yachts, kayaks). Other users of the marine or estuarine environment may trigger adverse events that will irremediably impact shellfish farmers (for example accidental pollution or disease outbreak). This suggests that measures to control other vectors may also be an essential component for industry movement controls to be effective. All in the study group agreed that it was important to engage and educate other waterway users about the risks they pose to oyster production during a disease outbreak and the positive role that they may play in looking for

² The Quarantine Act 1908 will be soon replaced by the new Biosecurity Act 2015, commencing on 16 June 2016.

environmental signs. But the group remained divided about how to initiate the dialogue and about their chances to influence people's behaviour.

4.1.3. Biosecurity leadership: government or farmers?

During the initial POMS biosecurity response in New Zealand, industry seemed disorganised and farmers in the study group believed that it should have been government's role to show leadership and provide clear directions for industry to follow. However, one New Zealand farmer recognised that the industry was slow and unstructured itself, and that government did its best given the circumstances. The role of local authorities (councils) during the biosecurity response should be clarified as most New Zealand farmers thought the local councils should at least help liaise with the community. In Australia, the New South Wales government responded promptly to the POMS outbreaks in the Georges River and in the Hawkesbury River, presumably because they knew of the New Zealand situation. However, without this prior knowledge, it is likely that the New South Wales response would have presented similar challenges to New Zealand (e.g. disease spread through numerous reactive stock movements). The New South Wales government (Department of Primary Industries, DPI) advised councils about restrictions on stock movements in relation to POMS, but made no recommendation to engage with the community to help contain the spread of the disease. Therefore the same communication issue was felt by industry in both New South Wales and New Zealand.

4.1.4. POMS: science, husbandry or patience?

The survey respondents appeared divided on actions to reduce future disease risk. While some farmers strongly believed that a POMS-resistant oyster would emerge from the current selective breeding programmes (in Australia and in New Zealand), others were in favour of a combination of selected hatchery spat and husbandry adaptations to manage POMS on-farm. A minority (New Zealand farmers) expressed confidence in natural selection mechanisms, either through attenuated virulence of OHsV-1 microvar over time, or with the Pacific oysters developing resistance. But this can only be envisaged with diploid oysters as triploids cannot reproduce. Notwithstanding expectations about research progress or development or natural resistance, biosecurity risk management at farm or industry levels remains important. POMS is one of a number of emerging biosecurity threats in the aquatic environment and shows the importance of managing business risk through adequate planning.

At the two-day forum held following the interviews, Pacific oyster farmers (most of whom had taken part in the survey), scientists and government experts shared their respective knowledge, observations and concerns and had their perceptions challenged with regards to managing diseases and mortality on their farm (details are in Appendix 2). The active participation of farmers led to some uplifting discussions showing the essential connection between industry, science and industry to best manage POMS.

4.2. Business risk management in shellfish aquaculture

4.2.1. *Prevention is better than cure*

The ability to prevent disease outbreaks in shellfish aquaculture is more limited than in other animal production systems, where a number of tools and strategies (e.g. separation of age classes and vaccination) have proven effectiveness and feasibility. But this should not be a barrier to business preparedness for oyster farmers. The difficulties of having to deal with no cash flow, increasing debt and shortage of spat supply outweigh the costs of emergency planning, for example, by identifying alternative ways of generating income as an interim solution.

There is no 'cure' to aquatic diseases in open systems. Eradication has been suggested as an option to manage POMS in Australia (Department of Agriculture 2015) but given the presence of the causal virus in wild oysters, this strategy seems unlikely to succeed. Instead, farmers should direct their efforts towards minimising the impacts of POMS on their business or preventing the occurrence of the disease if their site has not been affected yet. One farmer suggested that industry should no longer worry about POMS but about the next pathogen or pest that could cause mass mortalities. The way to go forward is generic preparedness.

Having a risk management plan does not guarantee immunity from aquatic pests or diseases. But being prepared can contribute to making faster decisions such as harvesting before onset of mortality or minimising stress during a risk period. All of these strategies and measures come from observations by farmers in the field, from their own experience.

POMS was the first long-term, nation-wide crisis for Pacific oyster farmers in New Zealand. In New South Wales, QX disease in rock oysters had already caused widespread mortalities. Were there any lessons learnt by Australian growers before POMS emerged, that made them better prepared? It is difficult to answer this question based on a small study sample, but the oyster industry in the Hawkesbury River had a biosecurity risk management plan for POMS before the disease arrived in their estuary. Did it make a difference for those growers to be prepared? Industry in that estuary praised the existence of pre-agreed protocols, which helped contain POMS to their estuary rather than spread it to other sites like the Shoalhaven River or the Clyde River. It also reduced the immediate impact, for example by slowing down the spread within the estuary. But most essentially it showed the possibility of having a cohesive industry and community working together in times of hardship. Having a plan of action in place also meant that a major communication network was effectively used by Hawkesbury River growers from the very first day of the outbreaks.

4.2.2. *Spat supply: balance between hatchery and natural spat*

Natural spat remains the main source of supply for Pacific oyster farmers in New Zealand; but would the current commercial hatchery (regardless of selective breeding) be willing or able to upscale its production to supply most of the industry? In contrast, for New South Wales growers, due to the legal status of Pacific oysters, hatchery production is the predominant source of spat. It is likely that the Pacific oyster farming industry will need both types of spat to sustain its future production for two major reasons: to maintain genetic diversity and to secure the volumes needed to restock farms. One current drawback for commercial hatchery production is the difficulty of forecasting the demand when both sources of spat are available to industry (a free source competes with a potentially costly one).

4.2.3. *Income diversification: towards polyculture?*

The Australian respondents strongly supported the strategy of growing more than one species, with the main reason being income protection. What would prevent New Zealand oyster farmers from adopting polyculture as a similar insurance policy? Firstly, the environmental conditions and farm infrastructure may not be adaptable to farming a different species, such as green-lipped mussels or flat oysters, and may or may not be allowed under the terms of a farm's legal consent. Transition to polyculture may have been easier for growers in New South Wales as they started farming Pacific oysters after farming rock oysters for decades, if not longer. The conditions and infrastructure for farming both species were available and favourable, which may have made the business decision somewhat more straightforward. In addition to Sydney rock and Pacific oysters, New South Wales growers could also consider growing flat oysters, for which the same infrastructure and lease areas (as for Pacific and Sydney rock oysters) could be used, with only minor husbandry adjustments to environmental fluctuations (e.g. rain events).

For farmers who want to consider polyculture as a sustainable business strategy, there are several points that should be addressed at the planning stage:

- Is the technical knowledge to farm the candidate species available? For example in New Zealand, it may be necessary to update the historical information on farming rock oysters (*S. glomerata*) or to work in partnership with scientists to develop effective and commercially-sound husbandry techniques for new species (e.g. geoduck).
- What is the risk from disease and is there a potential for transmission of pathogens between wild reservoirs and farmed animals and/or between all species present on farm?
- Is the farming infrastructure sufficiently flexible to vary the ratio of species (for example how easy is it to step up the production of rock oysters if the Pacific oysters are affected by disease)?

- Is the candidate species allowed under the farm's existing consent and, if not, what requirements must be met to include it?

4.2.4. *Management of community perceptions*

Risks arising from community perceptions and actions were a recurrent topic throughout the open discussions with participants. Social acceptability (formalised as a social license to operate) is an important part of aquaculture sustainability (Hishamunda *et al.* 2014), and requires farmers to be proactively involved with the community and other stakeholders. But relationships should not be built during “war time”. It is important to take the time to engage with key stakeholders, present what oyster farming activities consist of, and develop a durable network outside of any critical period such as disease outbreaks. For this it is essential that industry understands its own values to be able to communicate them clearly and convincingly to stakeholders with the view to achieve social license.

The potential impacts of farming activities on the community should also be considered. The oversight of some stakeholders in the assessment of effects of aquaculture was referred to as ‘policy-people gap’ by Krause *et al.* (2015), who highlighted the need to give equal consideration to ecological, social and economic issues in aquaculture management. In New Zealand, MPI commissioned a survey of the social effects of the aquaculture industry in the Southland region, where aquaculture activities have been operating for several decades (Baines & Quigley 2015). The report highlighted public involvement and commitment to aquaculture, but the survey was fundamentally about economics and culture, and did not integrate biological risk management and potential impacts of an environmental or biosecurity crisis on the community. In a similar approach, a project investigating the socio-economic value of New South Wales aquaculture including community perception is currently in progress, and should help understand and appraise the role of this primary industry in the region.

One way for shellfish aquaculture to uphold its public profile is through its connection with nature (known as *kaitiakitanga* in Māori), demonstrating the sustainability of its activities from environmental and social perspectives. In New South Wales, the Broken Bay Oyster Association (BBOA) was formed by oyster farmers from the Hawkesbury River in 2004 to promote an environmentally-sustainable oyster industry in their estuary through the implementation of an Environmental Management System (EMS). The means to achieve this goal include using eco-friendly methods for oyster farming and educating the community about their activities and roles in monitoring the estuary's health, such as extensive water quality testing for food safety. The group puts in common expertise, knowledge and experience, and has invested in common farming infrastructure (e.g. plastic trays and baskets) and capital equipment (e.g. forklifts, cranes). BBOA signed a Memorandum of Understanding with the local

council³ to formalise the association's public mandate in "generating employment, supporting local communities and improving the health of the Hawkesbury River". This recognises how instrumental the oyster farming industry is in safeguarding the environmental character of the River, for the wider benefit of the resident community.

4.3. Recommendations

A number of recommendations have emerged from this survey and a proposed approach is outlined for each focus in Table 1.

³ Memorandum of Understanding:
http://www.hornsby.nsw.gov.au/__data/assets/pdf_file/0013/42322/Memorandum-of-Understanding-Hornsby-Shire-Council-and-Broken-Bay-Oyster-Association.pdf accessed 28 August 2015

Table 1. Recommendations for improving business risk management in the Pacific oyster industry in relation to biosecurity threats.

Focus	Recommended actions	Suggested champions
Movement controls	<ul style="list-style-type: none"> • Develop a compliance framework in partnership with the oyster/shellfish industry to verify feasibility • Plan for staffing resources to communicate and enforce stock movement restrictions: more people on the ground, better trained, to explain the concept before a biosecurity crisis and facilitate implementation during a response • Assess feasibility of timely movement restrictions – ensure communication channels are effectively in place (test with desktop exercises) and that the information is well-understood by all concerned parties • Pre-agree on consequences for non-compliance with movement controls (in consultation with the wider shellfish industry) 	<ul style="list-style-type: none"> • Central government NZ (MPI⁴) • Local government NZ • New South Wales government (DPI⁵) • Industry representatives (can be farmers/growers representing their estuary/farming area)
Biosecurity planning at regional/national level	<ul style="list-style-type: none"> • Develop workable measures during biosecurity outbreaks (including movement controls, testing regime, etc), that are also compatible with the bigger picture (<i>i.e.</i> existing regulations and trade commitments) • Inform stakeholders of the country's obligations (trade, reporting, etc) 	<ul style="list-style-type: none"> • Central government NZ (MPI) • New South Wales government (DPI)
Communication	<ul style="list-style-type: none"> • Organise aquaculture industry forums at regional level (all species/sectors) and invite external stakeholders: find a common battle to initiate cooperations • Enhance relationships with communities: use Council's position for liaison, inform people about industry's role, activities and benefits for the environment (take advantage of public events or school education) 	<ul style="list-style-type: none"> • Oyster farmers/growers
Collaborative research	<ul style="list-style-type: none"> • Seek active input from industry into research activities • Improve reporting methods and address findings to the wider community • Disseminate research via printed newsletters or emails to a subscribing list 	<ul style="list-style-type: none"> • Research organisations

⁴ MPI: New Zealand Ministry for Primary Industries⁵ DPI: New South Wales Department of Primary Industries

5. CONCLUSION

This study provides an insight into how Pacific oyster farmers view the risk of disease in New Zealand and Australia. It also captures information on the disease events that often tend to be overlooked, such as socio-economic impacts on the farming community and how this may affect their risk management behaviour. The study managed to unlock farmers' practical knowledge and their understanding of disease prevention, control and dynamics. The outcomes of this research support a participative and inclusive approach in addressing disease risk, whereby oyster farmers and possibly the wider community would be involved in policy and decision-making. This concept, based on inclusive communication could form a basis for government, industry organisations and farmers themselves to improve biosecurity awareness and risk management.

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8. APPENDICES

Appendix 1. HREC approval dated 26 June 2014



Research Integrity
Human Research Ethics Committee

Friday, 27 June 2014

Dr Navneet Dhand
Vet Science Faculty; Faculty of Veterinary Science
Email: navneet.dhand@sydney.edu.au

Dear Navneet

I am pleased to inform you that the University of Sydney Human Research Ethics Committee (HREC) has approved your project entitled **"Oyster farmers and disease outbreaks in Australia and New Zealand: impacts, risk perceptions and management decisions"**.

Details of the approval are as follows:

Project No.: 2014/396
Approval Date: 26 June 2014
First Annual Report Due: 26 June 2015
Authorised Personnel: Dhand Navneet; Whittington Richard; Castinel, Aurélie; Taylor Melanie;

Documents Approved:

Date Uploaded	Type	Document Name
7/06/2014	Advertisements/Flyer	Participant Consent Form
7/06/2014	Advertisements/Flyer	Participant Information Statement
5/05/2014	Interview Questions	Questionnaire
20/06/2014	Recruitment Letter/Email	Introductory letter

HREC approval is valid for four (4) years from the approval date stated in this letter and is granted pending the following conditions being met:

Condition/s of Approval

- Continuing compliance with the National Statement on Ethical Conduct in Research Involving Humans.
- Provision of an annual report on this research to the Human Research Ethics Committee from the approval date and at the completion of the study. Failure to submit reports will result in withdrawal of ethics approval for the project.
- All serious and unexpected adverse events should be reported to the HREC within 72 hours.
- All unforeseen events that might affect continued ethical acceptability of the project should be reported to the HREC as soon as possible.
- Any changes to the project including changes to research personnel must be approved by the HREC before the research project can proceed.

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- Note that for student research projects, a copy of this letter must be included in the candidate's thesis.

Chief Investigator / Supervisor's responsibilities:

1. You must retain copies of all signed Consent Forms (if applicable) and provide these to the HREC on request.
2. It is your responsibility to provide a copy of this letter to any internal/external granting agencies if requested.

Please do not hesitate to contact Research Integrity (Human Ethics) should you require further information or clarification.

Yours sincerely

Professor Glen Davis
Chair
Human Research Ethics Committee

This HREC is constituted and operates in accordance with the National Health and Medical Research Council's (NHMRC) National Statement on Ethical Conduct in Human Research (2007), NHMRC and Universities Australia Australian Code for the Responsible Conduct of Research (2007) and the CPMP/ICH Note for Guidance on Good Clinical Practice.

Appendix 2 Oyster Knowledge Exchange (5-6 May 2015) – Workshop report

TRANS-TASMAN OYSTER KNOWLEDGE EXCHANGE – 5-6 MAY 2015:

ACTIVITY REPORT

Written by: Aurelie Castinel (Cawthron Institute)
Reviewed by: Lauren Fletcher (Cawthron Institute)
Report date: 19 May 2015

Background & rationale

In the wake of mortality outbreaks associated with an oyster herpesvirus (OsHV-1 microvar) and impacting the Pacific oyster farming sector worldwide, researchers from New Zealand (Cawthron Institute) and Australia (University of Sydney) initiated a collaboration to look at industry's disease risk perceptions, impacts and management from an operational perspective and at farm level.

Thanks to funding received from the New Zealand Government¹, the project team organised and facilitated a trans-Tasman knowledge exchange to further explore business strategies for managing diseases among oyster farmers from New South Wales (Australia) and New Zealand. Mortalities associated with OsHV-1 (otherwise called POMS² in Australia) were used as a thread to drive the technical sessions.

Objectives for the Oyster Knowledge Exchange

Workshop objectives

[As pre-agreed in the funding application]

- Share technical information in a format comprehensive for the audience, from oyster farmers' own experience with disease outbreaks to the latest research findings in Australia and New Zealand;
- Challenge farmers' views and perceptions with regards to disease prevention and on-farm management, using the ongoing oyster herpesvirus mortalities as a catalyst for discussions;
- Facilitate exchanges between farmers, government officials & scientists through open discussions.

Farmers' objectives

[Collected on Day 1 of the workshop]

- Network with other farmers and with scientists and government, and establish long-lasting relationships within the oyster farming sector
- Listen to, and talk about, what farmers are doing in each country to manage disease
- Test assumptions ("beliefs") on oyster diseases (mainly the oyster herpesvirus mortalities)
- Turn fear of oyster diseases into good business and risk management [decisions]
- Ensure science and research are relevant to industry

¹ Ministry for Primary Industries (MPI), Ministry of Foreign Affairs and Trade (MFAT) and Ministry of Business, Innovation and Employment (MBIE)

² Pacific Oyster Mortality Syndrome = New Zealand's mortalities associated with OsHV-1 microvar

Information sharing

The overarching theme of the workshop was *Pacific oyster disease risk and management*. In New Zealand, POMS has caused widespread mortalities of Pacific oysters in the North Island only and in Australia it has only been observed in two New South Wales (NSW) farming estuaries, namely the Georges River and the Hawkesbury River. Farmers from both affected and non-affected areas were present at the forum, which provided an interesting balance over the course of the two days.

The workshop programme (Appendix 1) was developed on the basis that farmers would own the meeting and that scientists would stimulate, facilitate and guide the discussions, in an effort to make the event a constructive experience for everyone.

The farmers' story

Two farmers from each country shared their own experience with POMS, telling about the significant impacts that the disease had (and still has) on their business and morale, on the local community and oyster farming industry in general.

New Zealand's perspective was convened from two different angles: a farmer relying on wild-caught (natural) spat and another using hatchery spat at the time of the first outbreaks. Though the response strategies varied between the two types of systems, it looked as if over the years the initial devastation had turned into optimism for the future in both situations. Inevitably there has been a need for adjusting to the reoccurrence of seasonal mortalities, which has stretched the production cycle by 4 to 6 months (from as short as 8 months before to as long as 14 months after). Another interesting observation was that hatchery spat that could "run through the virus and survive" on-farm could reliably grow into a market size product.

Australia's account of events somewhat differed from New Zealand's, as oyster growers in NSW had already been hit hard with QX disease in Sydney rock oysters, the only species originally farmed. Once rock oyster stocks were wiped out by the parasite in the early 2000s, and rivers cleaned up by the subsisting industry and government assistance, growers started farming triploid Pacific oysters. No one expected that disease could strike those same farms again, but POMS caused dramatic losses in the Georges River in 2010 and in the Hawkesbury River in 2013. One grower even made the analogy between QX and World War I, and POMS and WWII. The surviving farmers are now seeking any opportunity to stay in business on their river and they stressed how important it is to keep oyster farming alive in NSW estuaries for the future of the industry (the two Australian speakers had been farming oysters for over 5 generations).

After farmers told their story, an overview of the collaborative Cawthron-University of Sydney project on disease risk perceptions and impacts was provided and preliminary results were discussed.

Research updates

Scientists from Cawthron and the University of Sydney presented the latest advances in POMS research, alluding to environmental factors, virus management, husbandry techniques and selective breeding. The goal for those technical presentations was to improve farmers' understanding of the disease (POMS) epidemiology and of current applied research aiming at developing mitigation and management tools and strategies.

Generous time had been allocated for questions between the various presentations. All farmers actively took part in the discussions.

Forum discussions

One of the objectives for the workshop was to challenge participants' views and perceptions, in particular with regards to on-farm biosecurity. The exchanges were driven by farmers, while scientists only intervened to answer any technical question. A selection of key points addressed over the 2 days is presented below. Further details on the biosecurity and environment forum discussions are presented in Appendix 3 and Appendix 4, respectively.

Do you think that OsHV-1 microvar is widespread?

The New Zealand farmers present at the workshop seem to think that the virus is widespread around New Zealand, and if that had not been the case in 2010, subsequent movements of stock and gear have resulted in fast spread and establishment. It was also mentioned that the virus had been detected in oyster samples from the South Island during the initial response to POMS, but was not associated with any mortality outbreak. In Australia, more substantial testing and (passive) surveillance has taken place and the virus is currently only found in the two farming estuaries affected by POMS (Georges River and Hawkesbury River). Within those two sites, the University of Sydney has detected the virus in wild (healthy) Sydney rock and Pacific oysters. Research on wild oysters acting as a reservoir for OsHV-1 is under way and results will be available through the University of Sydney. The Australian farmers did not think that the virus was present on farms outside of the two affected estuaries but the general consensus was that it would only be a matter of time until POMS spreads more widely in NSW.

Do you think it is worthwhile having a biosecurity plan?

The responses were very different between the farmers who had been impacted by mortality outbreaks on their farm and those who had not been affected (whether it was POMS or QX disease in Australia). The former acknowledged that they would now make different business decisions and follow better biosecurity practices (so to minimise their losses). They also conceded that they would like to have a disease risk management strategy at industry level. The group of unaffected farmers did not see a full benefit in investing in biosecurity practices for their own business, mainly because other waterway users were careless about the risk of disease and pest spread in the estuary.

How would you compare hatchery spat (juvenile oysters) versus natural spat?

In New Zealand, sourcing natural spat is the predominant strategy for oyster farming, though hatchery spat is extensively used by the largest oyster producer. In Australia, because the Pacific oyster is legislated as a Noxious Species, the industry in NSW affected estuaries can only use triploid hatchery spat to supply their farms. Therefore the Australian participants brought considerable practical experience in the discussions on hatchery spat. The selective breeding component of single-seed farming was discussed in more detail. Some farmers expressed their concerns about potential physiological changes in spat selected for OsHV-1 resistance (e.g. could it be more vulnerable to other environmental stressors?) but there is no scientific evidence of this process occurring. In the end, it was unanimously acknowledged that the oyster farming industry, in Australia as in New Zealand, would need to rely on both hatchery and natural spat to sustain future challenges.

Conclusions

How the objectives were met

All of the objectives set before the workshop were met. **Networking** was effectively enabled through free and frank discussions, round-table fact-finding, frequent interludes and a cocktail function sponsored by New Zealand's Ministry for Primary Industries (MPI). Farmers were provided information on a variety of topics, largely introduced by technical presentations and subsequently discussed as a forum. This allowed **challenging their views and perceptions** of disease risks, biosecurity strategies and prospects for future management. Scientists present at the workshop were queried by the audience on the relevance of science for their

business, which represents the challenge to **connect science and research with industry needs**.

Next steps

- Keeping the network going. Various means for information sharing were suggested by the Australian participants, mainly existing websites such as *Oyster Health Sydney*, *DPI newsletter*, *NSW Food Authority* and *Ocean Watch*. The New Zealand Aquaculture Unit (MPI) volunteered to set up a bilateral newsletter for oyster farmers having attended this workshop, by collating and disseminating by email any information provided by farmers and scientists. It was agreed that this information could range from technical (e.g. research updates) to ad-hoc (e.g. links to websites of interest or to conferences), as long as it was brief and sent by a set deadline. Frequency of the newsletter was discussed and a quarterly to six-monthly frequency was agreed upon as a start.
- Exploring funding opportunities for a bilateral research collaboration on field epidemiology, between New Zealand and Australia. The widespread distribution of POMS in New Zealand represents a unique opportunity to monitor the disease under a wide range of environmental conditions, unlike in Australia where POMS is restricted to farms in two estuaries. It was agreed that a joint study between Australian (University of Sydney) and New Zealand scientists (e.g. Cawthron and/or NIWA or a New Zealand university) would be a great step forward to learn more about the epidemiology of the disease and the influence of environmental factors on its onset. As a result, three potential funds for collaboration were mentioned but further consultation with New Zealand oyster farmers will be needed to develop a research project concept and identify the most relevant funding opportunity.

MPI – The Sustainable Farming Fund (SFF) is dedicated to applied research and projects led by farmers, growers, or foresters. Applicants can apply for up to NZ\$200,000 a year for a maximum of 3 years. Projects require a non-government funding contribution of at least 20%. <https://www.mpi.govt.nz/funding-and-programmes/farming/sustainable-farming-fund/>

MBIE – Seafood Innovations Ltd (SIL) provides funding support for innovative research and development within the seafood industry, with the aim of adding value to the sector. All research projects must have one or more project sponsors who contribute a minimum of 50% of the total project budget and SIL will contribute up to 50% of the actual project budget. <http://www.seafoodinnovations.co.nz/>

OECD (Organisation for Economic Co-operation and Development) – Research Fellowships. Scientists working in fisheries are eligible for funding to conduct research projects abroad in another member country of the Co-operative Research Programme. The aim is to “strengthen international exchange of ideas and increase international mobility and co-operation among scientists”. Australia and New Zealand are both OECD member countries therefore an Australian student/scientist could apply to undertake the research in New Zealand. <http://www.oecd.org/tad/crp/researchfellowshipsandconferencesponsorship-co-operativeresearchprogramme.htm>

- Advocating for a second trans-Tasman oyster knowledge exchange in 2016. This two-day meeting has demonstrated the benefits of a bilateral workshop that focuses on operational issues and solutions. This joint project on disease risk perceptions and its spin-off knowledge exchange emphasised the need to connect people at farm level, so as to uphold practical observations and identify solutions. This was achieved by restricting the group to operational staff (farmers/growers) and keeping the numbers of participants low to encourage everyone’s input. There is no doubt that a follow-up workshop would be valuable to encourage innovation on the collaborative research front, to strengthen the relationships initiated during this 2015 workshop, and provide much-needed food for thought for industry, scientists and government. Cawthron and the University of Sydney will seek financial and logistic support to hold a second Oyster Knowledge Exchange in 2016.

Acknowledgements

Funding – This first Trans-Tasman Oyster Knowledge Exchange was funded by New Zealand's Ministry for Primary Industries (MPI), Ministry of Foreign Affairs and Trade (MFAT) and Ministry of Business, Innovation and Employment (MBIE).

Technical input – Presentations and technical discussions were delivered by Dr Brian Jones (MPI), Prof Richard Whittington (University of Sydney), Dr Paul Hick (University of Sydney), Miss Olivia Evans (University of Sydney), Dr Ana Rubio (University of Sydney/Hornsby Shire Council), Dr Mark Camara (Cawthron Institute) and Dr Aurelie Castinel (Cawthron Institute). Mrs Anna Crosbie (MPI) and Dr Lauren Fletcher (Cawthron Institute) provided some crucial facilitation and organisational skills during the two-day event.

Oyster farmers (NZ) & growers (Australia) – This workshop could not have been successful without the enthusiasm and interest from all oyster farmers and growers present at the event, in particular Mr Bob Drake (oyster grower, Australia), Mr Rob Moxham (oyster grower, Australia), Mr Jim Dollimore (Biomarine Ltd, NZ), Mr Nat Upchurch (Te Matuku Bay Oysters, NZ) and Mr Emmanuel Malpot (Aotearoa Fisheries Ltd, NZ) who shared their stories and experience with the rest of the group.

Staff at MPI's Auckland Biosecurity Centre (ABC) – for letting us use their facility and for assisting with transport from the ABC to the hotel.

Appendices

Appendix 1: Workshop programme

Appendix 2: List of participants to the 1st Trans-Tasman Oyster Knowledge Exchange

Appendix 3: Forum discussions on biosecurity - key points

Appendix 4: Forum discussions on environmental factors - key points

Appendix 1: Workshop programme



Ministry for Primary Industries
Manatū Ahu Matua



Trans-Tasman Oyster Knowledge Exchange - May 2015: Programme

Venue: Auckland Biosecurity Centre, Cnr Tom Pearce Drive & Jimmy Ward Cres, Auckland Airport

Day 1 – Tuesday 5th May 2015

Participants may arrive prior to workshop start for a cup of tea or coffee.

9.30 – 9.45 am: Introduction & house-keeping; objectives

9.45 – 11 am: Pacific Oysters & Disease - The Farmers' Story

9.45 – 10.15 am: Our Story – part I: New Zealand

10.15 – 10.45 am: Our Story – part II: Australia

10.45 – 11 am: Study findings: presentation

11 – 11.30 am: Morning tea

11.30 am – 12 pm: Study findings: discussion

12 – 1 pm: The Environment

12 – 12.30 pm: Presentations on key environmental factors investigated in France, NZ and Australia, in the wake of OsHV-1 microvar mortalities

12.30 – 1 pm: Questions & discussion

1 – 1.45 pm: Lunch (onsite)

2 – 3 pm: The Environment (cont.)

2 – 2.15 pm: Presentations on OsHV-1 transmission, including between wild and farmed Pacific oysters

2.15 – 3 pm: Discussion

3 – 3.30 pm: Afternoon tea

3.30 – 4.15 pm: Discussion in small groups

4.15 – 4.30 pm: Conclusions & thoughts from Day 1

Participants make their way to the Sudima Hotel for dinner.

Day 2 – Wednesday 6th May 2015

8 – 8.30 am: tea, coffee & muffins will be served at the venue

8.30 – 10 am: Case-Study: The Virus

8.30 – 8.45 am: Round-Table

8.45 – 9.15 am: Presentations on Ancient History, Survival and Cleaning & Disinfection

9.15 – 10 am: Discussion

10 – 10.30 am: Morning tea

10.30 – 12 pm: The Host (& The Farmer)

10.30 – 11 am: Presentations on research to date: from hatchery to farm (incl. selective breeding, husbandry)

11 – 11.15 am: Questions

11.15 – 12 pm: Discussion in small groups

12 – 12.45 pm: Lunch

1 – 2 pm: Forum: Business risks & management strategies

1 – 1.30 pm: Biosecurity measures - what worked, what did not

1.30 – 2 pm: Managing disease as a business risk: strategies

2 – 2.30 pm: Questions

2.30 – 3 pm: A network for Aus-NZ Oyster Farmers

3 – 3.30 pm: The End - Conclusions and Acknowledgements

Appendix 2: List of participants to the 1st Trans-Tasman Oyster Knowledge Exchange

<i>Participant name</i>	<i>Affiliation</i>
Margaret Hippolite	Okiwi Bay Aquaculture Ltd, NZ
Emmanuel Malpot	Aotearoa Fisheries Ltd, NZ
Andy Elliot	Kono Seafood, NZ
Aaron Pannell	Marlborough Oysters Ltd, NZ
Garth Richards	Pacific Marine Farms, NZ
Stu Te Tamaki	Clevedon Oysters, NZ
Barry & Carol Jessop	Parua Bay Oysters, NZ
Nat Upchurch	Te Matuku Bay Oysters, NZ
Jim Dollimore	Biomarine Ltd, NZ
Theresa & Robert Hill	Endeavour Oysters, AUS
Steve Jones	Oyster grower, AUS
Rob Moxham	Broken Bay Oysters, AUS
Len Drake	Oyster grower, AUS
Bob Drake	Oyster grower, AUS
Leon & Angela Riepsamen	Goodnight Oysters, AUS
Kevin McAsh	McAsh Oysters, AUS
Richard Whittington	University of Sydney
Ana Rubio	University of Sydney/Hornsby Shire Council
Paul Hick	University of Sydney
Olivia Evans	University of Sydney
Anna Crosbie	Ministry for Primary Industries
Brian Jones	Ministry for Primary Industries
Mark Camara	Cawthron Institute
Keith Michael	NIWA
Lauren Fletcher	Cawthron Institute
Aurelie Castinel	Cawthron Institute

Appendix 3: Forum discussions on biosecurity – list of key points from oyster farmers

CURRENT (MISCELLANEOUS) VIEWS

- “Do the best you can”
- Starting point should be farm biosecurity plans
- There are both within-industry [biosecurity] risks and outside-industry [biosecurity] risks
- Increase biosecurity [measures] for non-affected areas: risk prevention is essential (it is too late when disease is here)
- Do not mix different cohorts of animals on farm
- Species diversification:
 - Depends on business models
 - Why diversifying if the Pacific oyster sector is doing ok?
- New Zealand Government-Industry Agreement proposes cost-recovery system of biosecurity activities in primary sectors (preparedness and responses) – is it sustainable for the aquaculture industry (shellfish farming is impacted by other primary activities “upstream” yet it will have to pay for responses in the marine sector)?
- The Australian Oyster Strategy can be assimilated to legislation as it defines roles, responsibilities and states an environmental plan that protects the oyster industry (more details at: <http://www.oystersaustralia.org.au/sustainable-practices>)
- Industry should promote Pacific oysters as a premium product

PERCEIVED ROADBLOCKS

- Inability to influence others’ actions (e.g. fishermen). Australian participants referred to the “Fish Habitat Partnership”. Around a common statement, stakeholders with very opposed views have managed to collaborate to improve the fish habitat. More details at: <http://fishhabitat.org.au/>. Could this be an approach to managing risk at regional level?
- Collective [biosecurity risk management] plan
 - Problem: need people to agree
 - Voluntary does NOT work (need to be compulsory / legislated and enforced by government)
 - Different business models so such plan would need to be adaptable, dynamic (not too prescriptive)
- Government usually adopts a “zero risk” approach [within the context of closing down farms when an issue is reported] – reluctance to report biosecurity issues
- Need to “do the science” early so that industry can timely apply research findings on farm
- There are two approaches to the issue [disease outbreak]: 1) it is a “one-off” event; or 2) react fast and “own up” the problem
- Species diversification: need to adopt a collaborative approach within industry to learn about farming new species faster and more cost-effectively
- Water quality and environmental testing: currently the cost is borne by oyster farmers, even if the issues are not related to oyster farming. The cost should be put back onto the “cause” upstream. It is much needed to advocate and communicate this discrepancy to government/decision-makers

NEEDS FOR ACTION/FOLLOW-UP

- Increase on-farm monitoring [of environmental parameters]
- Reach out to other users and educate, especially the public: organise forum and lead discussions [between farmers, community, etc]
- Need to “invest” in the community and in the habitat (for example cleaning infrastructures, etc) to gain social license.
- Develop biosecurity plan at estuary/regional level

- Future-proof [industry] for the next disease
- Species diversification: high rock oyster spat abundance in NZ, in areas severely affected by POMS:
 - Need to save/recollect the “savoir-faire” for rock oyster farming in NZ (compile historical data and knowledge)
 - Need for a market for new species to ensure a return on investment (e.g. is there a domestic market in NZ for PO? For rock oysters?)

Appendix 4: Forum discussions on environmental factors – list of key points from oyster farmers

CURRENT (MISCELLANEOUS) VIEWS

- POMS should be viewed as an environmental problem, not just a disease
- Farm monitoring contributes to the risk assessment of what can go wrong [adverse biosecurity events] in the environment, e.g. pippis in Northland
- Oysters have a “canary in the mine” function – they help detect wider environmental issues. Need to work with other stakeholders in the coastal area to gain social license and promote the role of shellfish farming for the wider community. “Champions” should be identified to facilitate the communication and uptake process.
- It is essential to have the ability to monitor over multiple sites – New Zealand has an advantage over Australia as POMS is found in many different locations unlike in NSW
- It is important to make the difference between good ideas and opportunistic ideas when it comes to monitoring the shellfish environment [within the context of diseases/biosecurity issues]
- Developing relationships between industry, government and scientists; trans-Tasman and globally could help optimising specialised skills and knowledge to research the same issue
- Everyone needs to acknowledge the importance of applied science/research
- What is the level of expertise in NZ universities [i.e. shellfish farming] to help understand environmental factors? How can we better utilise them?

PERCEIVED ROADBLOCKS

- Which environmental parameters to use? What are the coastal drivers? Do tides have an influence on mortalities?
- How to fund [applied research] ideas?
- How to get New Zealand cultural understanding of shellfish aquaculture (and its importance for the environment) and get support for it?

NEEDS FOR ACTION/FOLLOW-UP

- Assess what is currently being done in terms of gaps & data sharing
- Start monitoring
- Find a common ground between the oyster farmers and coastal users, from which to build relationships and set common [environmental] goals