FINAL

An Impact Assessment of FRDC Investment in 2012-032: Pacific Oyster Mortality Syndrome (POMS) – Risk Mitigation, Epidemiology and OsHV-1 Biology

Agtrans Research

November 2017

FRDC Project No **2016-134**

An Impact Assessment of FRDC Investment in 2012-032: Pacific Oyster Mortality Syndrome (POMS) – Risk Mitigation, Epidemiology and OsHV-1 Biology
Project 2016-134

2017

The Fisheries Research and Development Corporation plans, invests in and manages fisheries research and development throughout Australia. It is a statutory authority within the portfolio of the federal Minister for Agriculture, Fisheries and Forestry, jointly funded by the Australian Government and the fishing industry.

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Acknowledgments

Agtrans Research and Consulting would like to thank Patrick Hone (Executive Director) and Nicole Stubing (Project Manager) of the Fisheries Research and Development Corporation for facilitating contact with relevant project personnel and for their guidance and feedback throughout the Impact Assessment process.

Jo-Anne Ruscoe, Project Manager, Fisheries Research and Development Corporation

Abbreviations

ABS	Australian Bureau of Statistics
ASI	Australian Seafood Industries Ltd
CRC-P	Cooperative Research Centre Project
CRRDC	Council of Rural Research and Development Corporations
DAWR	Department of Agriculture and Water Resources (Commonwealth)
DNA	Deoxyribonucleic Acid
FRDC	Fisheries Research and Development Corporation
NSW	New South Wales
OCS	Office of the Chief Scientist
OsHV-1 μVar	Ostreid Herpesvirus-1 Microvariant
PhD	Doctor of Philosophy
POMS	Pacific Oyster Mortality Syndrome
RD&E	Research, Development and Extension
Usyd	University of Sydney

Executive Summary

What the report is about

This report presents the results of an impact assessment of a Fisheries Research and Development Corporation (FRDC) investment in the *Aquatic Animal Health Subprogram: Pacific Oyster Mortality Syndrome (POMS) – risk mitigation, epidemiology and OsHV-1 biology*. The project was funded by FRDC and partners, including the University of Sydney (USyd) and the New South Wales (NSW) Department of Industries, over the period June 2012 to December 2015.

Methodology

The investment was analysed qualitatively within a logical framework that included activities and outputs, outcomes and impacts. Impacts were categorised into a triple bottom line framework. Principal impacts identified were then valued. Benefits were estimated for a range of time frames up to 30 years from the year of last investment. Past and future cash flows were expressed in 2016/17 dollar terms and were discounted to the year 2016/17 using a discount rate of 5% to estimate the investment criteria.

Results/key findings

The major impacts identified were of a financial nature and involving increased rate of recovery of Pacific Oyster production in the Hawkesbury River, improved efficiency of research, development and extension (RD&E) resource allocation, and a reduced risk of the POMS virus spreading to other NSW Pacific Oyster production regions. Environmental and social impacts were also identified but not valued. It is expected that NSW Pacific Oyster farmers and investors in the Future Oysters CRC-P (including the Commonwealth Government, State Government departments and private industry organisations) will be the primary beneficiaries of the investment.

Investment Criteria

Funding for project 2012-032 totalled $4.17 million (present value terms) and produced estimated total expected benefits of $6.30 million (present value terms). This gave a net present value of $2.13 million, and an estimated benefit-cost ratio of 1.5 to 1.

Conclusions

The investment in this project has likely resulted in improved outcomes for Pacific Oyster farmers throughout NSW and an increase in efficiency for RD&E expenditure under the Future Oysters CRC-P through improved resource allocation for POMS R&D.

The impacts valued were focused on the NSW Pacific Oyster industry. However, it is likely that the risk mitigation strategies identified also will improve outcomes for other POMS affected areas in Australia (e.g. Tasmania) and will support the future viability of Pacific Oyster farming in Australia given the presence of POMS.

Several environmental and social impacts were also identified but not valued as the linkages between the project and these impacts were uncertain and their contributions were considered minor compared with the impacts valued. Nevertheless, combined with conservative assumptions for the impacts valued, investment criteria as provided by the valued benefit are likely to be an underestimate of the investment performance.

Keywords

Impact assessment, Pacific Oyster, Pacific Oyster Mortality Syndrome, risk mitigation, epidemiology, biology, OsHV-1

Introduction

The Fisheries Research and Development Corporation (FRDC) required a series of impact assessments to be carried out annually on a number of investments in the FRDC research, development and extension (RD&E) portfolio. The assessments were required to meet the following FRDC evaluation reporting requirements:

- Reporting against the FRDC 2015-2020 RD&E Plan and the Evaluation Framework associated with FRDC's Statutory Funding Agreement with the Commonwealth Government.
- Annual Reporting to FRDC stakeholders.
- Reporting to the Council of Rural Research and Development Corporations (CRRDC).

The first series of impact assessments included 20 randomly selected FRDC investments worth a total of approximately $6.31 million (nominal FRDC investment). The investments were selected from an overall population of 136 FRDC investments worth an estimated $24.98 million (nominal FRDC investment) where a final deliverable had been submitted in the 2015/16 financial year.

The 20 investments were selected through a stratified, random sampling process such that investments chosen spanned all five FRDC Programs (Environment, Industry, Communities, People and Adoption), represented approximately 25% of the total FRDC RD&E investment in the overall population (in nominal terms) and included a selection of small, medium and large FRDC investments.

Project 2012-032: *Aquatic Animal Health Subprogram: Pacific Oyster Mortality Syndrome (POMS) – risk mitigation, epidemiology and OsHV-1 biology* was selected as one of the 20 investments and was analysed in this report.

General Method

The impact assessments followed general evaluation guidelines that are now well entrenched within the Australian primary industry research sector including Research and Development Corporations, Cooperative Research Centres, State Departments of Agriculture, and some Universities. The approach includes both qualitative and quantitative descriptions that are in accord with the impact assessment guidelines of the CRRDC (CRRDC, 2014).

The evaluation process involved identifying and briefly describing project objectives, activities and outputs, outcomes, and impacts. The principal economic, environmental and social impacts were then summarised in a triple bottom line framework.

Some, but not all, of the impacts identified were then valued in monetary terms. Where impact valuation was exercised, the impact assessment uses Cost-Benefit Analysis as its principal tool. The decision not to value certain impacts was due either to a shortage of necessary evidence/data, a high degree of uncertainty surrounding the potential impact, or the likely low relative significance of the impact compared to those that were valued. The impacts valued are therefore deemed to represent the principal benefits delivered by the project. However, as not all impacts were valued, the investment criteria reported for individual investments potentially represent an underestimate of the performance of that investment.

Background and Rationale

Background

Pacific Oyster Mortality Syndrome (POMS) is a devastating disease affecting Pacific Oysters. It is caused by the virus *ostreid herpesvirus-1 microvariant* (OsHV-1 μVar).

Oyster mortality resulting from the disease can be very high and occurs extremely rapidly (e.g. up to 100% mortality within days of initial detection). Studies in Europe found that POMS was detectable in oysters after mortalities ceased, which indicated that surviving oysters could act as carriers of the virus.

POMS was first detected in Australia in New South Wales (NSW) in 2010 when oyster farmers in the Georges River reported mortality of wild and farmed Pacific Oysters. It is not known how POMS arrived in NSW and little about the lifecycle of the virus was known.

Rationale

Already present in Australia, POMS has the potential to devastate the Australian Pacific Oyster industry, as it has done overseas.

There has been a pattern of emerging diseases in commercial molluscs around Australia. They have required a succession of government and industry responses with no clear solutions. Examples include QX disease in Sydney Rock Oysters in NSW and Queensland; oyster oedema disease in pearl oysters in Western Australia; and winter mortality in Sydney Rock Oysters in NSW.

In NSW, the impact of QX disease in the Georges and Hawkesbury Rivers led to the replacement of Sydney Rock Oysters by triploid Pacific Oysters to re-establish the industry in these estuaries, but the industry was then threatened by POMS. Apart from generic responses, in each case of a disease outbreak, it was not possible to devise a specific intervention strategy that would reduce disease spread or ensure the recovery of the industry given the presence of POMS.

In July of 2011, FRDC coordinated the first Australasian Scientific Conference on Aquatic Animal Health. Discussions at the conference lead to the identification of a number of priority areas for future POMS RD&E. As a result, an initial 'expression of interest' was sought for researchers to address nine specific POMS RD&E project objectives (Appendix 1).

FRDC responded by funding two separate projects. FRDC project 2011-053 (*Aquatic Animal Health Subprogram: Pacific oyster mortality syndrome (POMS) – understanding biotic and abiotic environmental and husbandry effects to reduce economic losses*, December 2011 to January 2013) was funded to address objective one independently.

Project 2012-032 was funded to address objectives two to nine and was as an attempt by researchers from the University of Sydney (USyd) to intervene in the face of an oyster disease outbreak and to discover ways to continue oyster farming long-term.

Project Details

Summary

Project Code: 2012-032 Title: *Aquatic Animal Health Subprogram: Pacific Oyster Mortality Syndrome (POMS) – risk mitigation, epidemiology and OsHV-1 biology* Research Organisation: University of Sydney Principal Investigator: Richard Whittington Period of Funding: June 2012 to December 2015.

Objectives

The project had eight key objectives. These were:

1. To determine/confirm the identity of the one or more variant(s) of *Ostreid herpesvirus* associated with the recent outbreaks of POMS
2. To determine the mechanism(s) of transmission of disease
3. To determine the major risk factors that contribute to precipitation of disease outbreaks thereby identifying potential risk-mitigation management practices
4. To identify the natural reservoir(s) for the virus
5. To determine the stability of the virus in the environment
6. To identify physical and chemical means for viral inactivation
7. To develop an infectivity model for POMS suitable for selection of resistant oysters and pathogenesis/environmental research
8. To address future shortages of technical expertise through the training and supervision of at least 1 PhD student

Logical Framework

Table 1 provides a brief description of the project in a logical framework.

Table 1: Logical Framework for Project 2012-032

Activities	**Sequencing of *Ostreid herpesvirus-1* associated with POMS outbreaks** • Representative tissue samples were obtained for DNA sequencing from oyster leases by researchers who worked closely with oyster farmers during the disease outbreaks. • USyd completed multilocus sequence typing of the OsHV-1 virus samples after an attempt at whole of genome sequencing was unsuccessful. **Mechanisms of transmission of disease and determination of major risk factors that contribute to precipitation of disease outbreaks** • Long-term field study sites were set up on oyster leases in both the Georges River and the Hawkesbury River at the start of the project. • Water quality probes were deployed in both rivers to monitor temperature, salinity, and chlorophyll-a. • Water level data was obtained for the period 2010 to 2014 at the mouth of the Hawkesbury River from the Manly Hydraulics Lab. • In addition to the field studies, retrospective analysis of environmental data was conducted in relation to OsHV-1 μVar disease occurrence. **Outbreak investigation, Hawkesbury River January-February 2013**

	• The project team conducted a real-time investigation of the first outbreak of POMS in the Hawkesbury River in 2013 at an oyster lease within the bay. • Existing stock levels were assessed and then physically surveyed for OsHV-1 infection at the end of January 2013. • The time of first infection with OsHV-1 for oysters in the Hawkesbury River was assessed by retrospective testing of archived 'sentinel' oysters and opportunistic samples that had been collected since September 2011. • Additionally, information was collected on the destination of movements of oysters and farming equipment over the previous year and farmer observations of mortality in oysters were recorded. • In February of 2013, the project team performed a physical audit of mortality in all actively farmed oyster leases in Mullet Creek, Porto Bay, Mooney Mooney Creek and Coba Bay. • The effects of age and size on mortality rate were evaluated using data pooled from a total of 21 leases. • From February to June 2013, approximately 1,500 certified disease-free spat every two weeks were placed at eight sites in the Hawkesbury and Georges Rivers. The spat were studied to determine and compare the window of infection for POMS between the two estuaries. A similar trial also was conducted in 2014. **Identification of natural reservoir(s) for the virus** • Wild oysters and other organisms (shellfish, crustaceans, algae) were sampled in Woolooware Bay before, during and after the POMS outbreak to check for the presence of OsHV-1 and identify a potential reservoir host. **Stability of the virus in the environment** • Triploid Pacific Oysters (disease-free) were grown in the Shoalhaven River and then transferred to a containment facility at the USyd where the specimens were then exposed to OsHV-1 in various forms. • The stability of the virus in naturally infected seawater was determined using bioassays at the Hawkesbury River estuary and experimental upwellers were set up to test whether the virus could be removed from seawater to protect hatcheries. • Several other water treatments for the virus also were tested. **Physical and chemical means for viral inactivation** • Various disinfection treatments were tested on OsHV-1 positive seawater and infected oyster tissue. Treatments included: heat, ultraviolet light, chlorine, virkon, iodine, alkaline detergent, sodium hydroxide, formalin, and an ammonium compound. **Development of an infectivity model for POMS suitable for selection of resistant oysters and pathogenesis/environmental research** • Four experiments were performed sequentially to test the infectivity of the Australian OsHV-1 μVar strain using infected material sampled from the Georges River during the summer of 2011/2012. • An infectivity model was developed, then adapted and applied for four specific purposes within the project: i) investigation of the role of feeding in OsHV-1 infection via co-habitation, ii) determining the effect of water temperature on the outcome of OsHV-1 infection in Pacific Oysters, iii) evaluating the stability of OsHV-1 in the environment, and iv) investigating the physical and chemical means for viral inactivation. **Addressing future shortages of technical expertise** • Ms Olivia Evans received a top-up scholarship and undertook her PhD candidature at USyd from 2012 to 2015. • Her project investigated aspects of OsHV-1 in seawater, particularly transmission factors. She was awarded her PhD in 2016.

	• Two honours students also were trained in techniques of field and laboratory science during the project. **Other** • An experiment was conducted to improve the external validity of a previous study carried out in FRDC project 2011-053 in Woolooware Bay. The experiment tested the effects of growth environment (plastic trays, plastic buckets, commercial hanging baskets and self-made pillow-shaped baskets) and different placement heights in the inter-tidal range on oyster mortality in the presence of POMS.
Outputs	• It was found that the virus that causes POMS in Australia is OsHV-1 µVar. It is similar to the virus that devastated Pacific Oyster aquaculture in France, other European countries and New Zealand. • Detailed investigation of the Hawkesbury River outbreak revealed that the virus was first detected months before the disease began, but it is likely that this was due to several separate infection events, the last one being massive and leading to widespread mortalities. • The study found that the source of virus was not the farming operation, and was most likely to have been from a distant environmental source. • Local spread of the disease from oyster to oyster and lease to lease was minor; large adult oysters were relatively resistant. Based on accumulating evidence, the major risk factors for POMS were identified as being pathogen, environment, and host related. • A consistent seasonal pattern of disease was observed in both rivers. POMS was present between October and May each year and was not present in the other, cooler months. • The Project found also that water temperatures in NSW when POMS occurred were about 4°C warmer than those observed in France when the disease occurs there. Mortality was minimal at temperatures less than 18°C in Australia. • Analysis of long term weather and environmental records revealed that the outbreaks in the Georges and Hawkesbury Rivers were not associated with anomalies in air or water temperature. • The major factors determining the extent of mortalities during an outbreak were found to be the age of oysters (spat are highly susceptible, adults relatively resistant); growing height/immersion time (raising growing height by 300 mm in the intertidal zone reduced mortalities of adults by 50%); and location (some sites within an infected river were not affected at all). The type of cultivation system and the presence of non-susceptible bivalve species on adjacent leases were not important factors. Host energy status (feeding) and cultivation density were not able to be investigated and could be important. • Wild oysters, both Pacific and Sydney Rock, tested positive for the virus, as did other molluscs and marine organisms. However, the levels of virus in their tissues were low, and their potential role in storing virus and amplifying and releasing it to infect farmed oysters is debatable. • The virus appears to remain stable in seawater for less than 48 hours. Water treatments based on ageing water for 48 hours and filtration to 5µm were successful and can be used to protect hatcheries. Several disinfectants were effective and will be useful for decontamination of equipment. These include heating to 50°C, exposure to a high dose of ultraviolet light, ammonium compound, virkon, sodium hydroxide, iodine and formalin. • Results of the growth environment experiment (replicated from project 2011-053) suggested that, for oysters in trays, spat had an increased hazard of death compared to adults and the magnitude of the hazard tended to be greater at high growing height. This was due to the protective effect of height acting more on adults. The study also found that mortality was similar for spat in either high trays or hanging baskets and averaged 71-73%. • The project identified seven potential risk mitigation practices. These were: 1. Hatchery production of larvae to spat using seawater that has been treated to remove the risk of mass mortality.

	2. Rearing of susceptible spat in seawater free of OsHV-1 (in a disease-free region or through water treatment). 3. Holding spat in safe regions, restricting their growth, and shipping them for growout when they are older and likely to be more resistant to OsHV-1 4. Using knowledge of the window of infection to place susceptible stock in known-infected estuaries when it is known to be safe to do so. 5. Using rapid growth strategies (including optimal management of stock placements according to feed availability and carrying capacity; trials of floating upweller systems) in infected estuaries during the safe period to enable spat to quickly reach a large size likely to be more resistant to OsHV-1. 6. Use of a high cultivation height (+300mm) for adult oysters during the summer risk period to reduce mortality to less than 50%. 7. Use of two stage growth strategies involving cooperation between growers in different estuaries. For example, commercial trials have commenced to import spat from Tasmania into estuaries in southern NSW where POMS does not occur, to grow them through one or two summers, then to move them for fattening to a POMS-affected estuary in the safe period. This takes advantage of opportunities and constraints that exist for growers in both locations.
Outcomes	• As of 2016, many farmers of Pacific Oysters have already adopted some of the risk mitigation practices identified by the Project. These practice changes include: o hatcheries treating incoming seawater, o farming oysters in affected estuaries except between late October and mid-May, o providing an elevated, intertidal growing height to reduce adult mortality, and o building partnerships between farmers in different regions to allow strategic movement of stock to take advantage of feed availability and avoid POMS danger periods in affected estuaries. • All of the risk mitigation strategies are compatible with the planned cultivation of genetically selected POMS-resistant oysters. However, these are unlikely to be commercially available before 2018. In the event that genetic resistance is partial rather than complete, the risk mitigation strategies will be of enduring importance. • Currently there is no strategy available to protect juvenile oysters from POMS in affected estuaries and further research was recommended to understand juveniles' extreme susceptibility to the disease. • Further research also was recommended to establish the role of wild molluscs in outbreaks in farmed oysters, identify the main environmental sources of OsHV-1, and determine the relationship of the disease with seasonal/climate factors. • It was suggested that policy makers should consider the findings related to disinfection guidelines for equipment in the formation of future biosecurity planning. • Ongoing surveillance has been put in place in regional oyster farming locations to act as an early warning system for future POMS outbreaks. • The infectivity model developed in this study informed development of a model for the genetic improvement program as part of project FRDC 2012-012. • Objective 7 (Development of an infectivity model for POMS suitable for selection of resistant oysters) was incorporated into a new FRDC project, 2012-052: Development of a laboratory model for infectious challenge of Pacific Oysters *(Crassostrea gigas*) with *ostreid herpesvirus* type-1.
Impacts	• Contribution to an increased rate of recovery of Pacific Oyster production in affected regions through the identification and subsequent adoption of POMS risk mitigation practices. • Contribution to a reduced risk of spread of the POMS virus through input to improved internal and external biosecurity measures. • Contribution to potentially reduced future production losses for Pacific Oysters farmed in POMS affected areas. • Possible negative environmental impacts from increased chemical use for decontamination of farming equipment. • Some contribution to improved resource allocation for future POMS related RD&E. • Increased knowledge and scientific capacity.

Project Investment

Nominal Investment

Table 2 shows the annual investment for the project funded by FRDC. There were no other contributors to the investment.

Table 2: Annual Investment in the Project 2012-032 (nominal $)

Year ended 30 June	FRDC ($)	OTHER ($)	TOTAL ($)
2012	156,609	0	156,609
2013[(a)]	95,016	923,012	1,018,028
2014	168,767	900,127	1,068,894
2015	152,141	812,704	964,845
2016	222,756	0	222,756
Totals	795,289	2,635,843	3,431,132

(a) FRDC funding in 2013 includes $12,243 in support costs for a workshop conducted as part of the project under project code 2012-032.20.

Program Management Costs

For the FRDC investment, the cost of managing the FRDC funding was added to the FRDC contribution for the project via a management cost multiplier (1.115). This multiplier was estimated based on the share of 'employee benefits' and 'supplier' expenses in total FRDC expenditure reported in the FRDC's Cash Flow Statement (FRDC, 2016). This multiplier then was applied to the nominal investment by FRDC shown in Table 2.

Real Investment and Extension Costs

For the purposes of the investment analysis, the investment costs of all parties were expressed in 2016/17 dollar terms using the Implicit Price Deflator for Gross Domestic Product (ABS, 2016). No additional costs of extension were included as the project included a high-level of Pacific Oyster farmer consultation and participation.

Impacts

Table 3 provides a summary of the principal types of impacts expanded from those listed in Table 1 and categorised into economic, environmental and social impacts.

Table 3: Triple Bottom Line Categories of Principal Impacts from POMS Risk Mitigation, Epidemiology and OsHV-1 Biology RD&E Investment

Economic	• Contribution to increased rate of recovery of Pacific Oyster production in the Hawkesbury river because of the identification and subsequent adoption of POMS risk mitigation practices. • Possibly, avoided production losses in areas not currently affected by POMS through a marginally reduced risk of the virus spreading because of the investment's contribution to improved internal (domestic) and external (international) POMS biosecurity measurers adopted by Pacific Oyster farmers and/or importers. • Contribution to reduced future production losses for Pacific Oysters farmed in areas currently affected by POMS, or in areas that may experience POMS outbreaks in the future, through the adoption of risk mitigation strategies that may reduce mortality rates during a POMS outbreak event. • Adoption of risk mitigation and other biosecurity measures has likely led to increased operating costs for Pacific Oyster farmers and/or importers (i.e. cost of compliance). Such costs are treated as additional costs along the pathway to impact for reduced and/or avoided production losses. • Some contribution to reduced costs for future POMS RD&E through improved efficiency of RD&E resource allocation for the Future Oysters Cooperative Research Centre Project (CRC-P) as a result of the project identifying information gaps and priority areas for future POMS research.
Environmental	• Increased chemical usage in the form of disinfectants used to decontaminate farming equipment potentially resulting in some negative environmental impacts.
Social	• Increased knowledge and scientific capacity related to the POMS virus and its arrival and spread in Australia. • Improved community well-being through the spill-over effects of the investment's contribution to the preservation of the Australian Pacific Oyster aquaculture industry.

Public versus Private Impacts

Major impacts identified in this analysis are both public and private. Industry related impacts include faster recovery of Pacific Oyster production for Hawkesbury River oyster growers and a reduced risk of the POMS virus spreading to other Pacific Oyster producing regions in NSW.

Private and public impacts will be realised through reduced RD&E costs for Government and private investment in future POMS RD&E (e.g. through the Future Oysters CRC-P). Public impacts may also include environmental impacts (from potentially increased chemical use).

Some social impacts were also identified including increased capacity and regional community spill-overs.

Distribution of Private Impacts

Beneficiaries of any private impacts will be captured by the individual Pacific Oyster farm businesses where practice changes have been made and subsequent sharing of such impacts along the supply chain.

Impacts on other Australian industries

There is no evidence of POMS affecting any other marine species (Davis, 2016). Therefore, it is assumed that project impacts will be confined to the Australian Pacific Oyster industry.

Impacts Overseas

No significant benefits to overseas parties are expected, with the possible exception where best practice biosecurity measures and/or POMS risk mitigation strategies may be shared with other countries (e.g. POMS affected Pacific Oyster industries such as in New Zealand).

Match with National Priorities

The Australian Government's Science and Research Priorities and Rural RD&E priorities are reproduced in Table 4. The project findings and related impacts will contribute primarily to Rural RD&E Priority 2 and to Science and Research Priority 1.

Table 4: Australian Government Research Priorities

Australian Government	
Rural RD&E Priorities (est. 2015)	**Science and Research Priorities (est. 2015)**
1. Advanced technology 2. Biosecurity 3. Soil, water and managing natural resources 4. Adoption of R&D	1. Food 2. Soil and Water 3. Transport 4. Cybersecurity 5. Energy and Resources 6. Manufacturing 7. Environmental Change 8. Health

Sources: (DAWR, 2015) and (OCS, 2015)

Valuation of Impacts

Impacts Valued

Analyses were undertaken for total benefits that included future expected benefits. A degree of conservatism was used when finalising assumptions, particularly when some uncertainty was involved. Sensitivity analyses were undertaken for those variables where there was greatest uncertainty or for those that were identified as key drivers of the investment criteria.

Three key impacts of the project were valued. These included:

(1) The investment's contribution to increased rate of recovery of Pacific Oyster production in the POMS affected Hawkesbury river.
(2) Improved efficiency of RD&E resource allocation for POMS related investments (non-breeding) under the Future Oysters CRC-P.
(3) Contribution to a reduced risk that the POMS virus would spread from the Hawkesbury to other NSW Pacific Oyster growing regions.

Impacts Not Valued

Not all impacts identified in Table 3 could be valued in the assessment. Environmental and social impacts were hard to value because of the difficulty in quantifying the causal relationships and pathways between the investment in POMS risk mitigation and the specific future impacts.

In particular, the economic impact from the investment's potential contribution to reduced future production losses for Pacific Oysters farmed in areas currently affected by POMS, or in areas that may experience POMS outbreaks in the future, through the adoption of risk mitigation strategies that may reduce mortality rates during a POMS outbreak event, was not valued.

This was because of a lack of available data on current and future adoption levels of the specific risk management strategies identified, the specific additional costs associated with each strategy, the likely effect of each strategy on potential production losses in various Pacific Oyster growing regions, and the probability of future POMS outbreaks. As a result, the impacts valued are likely to be an underestimate of the benefits of the investment in project 2012-032.

The economic impact identified but not valued included:

- Contribution to potentially reduced future production losses for Pacific Oysters farmed in POMS affected areas.

The environmental impact identified but not valued included:

- Increased chemical usage potentially resulting in some negative environmental impacts.

The social impact identified but not valued included:

- Increased knowledge and scientific capacity related to the POMS virus and its arrival and spread in Australia.
- Improved community well-being through the spill-over effects of maintained industry profitability given the presence of POMS in Australia.

Valuation of Impact 1: Increased rate of recovery of Pacific Oyster production for the Hawkesbury River oyster industry

The valuation of an increased rate of recovery for Pacific Oyster production in the Hawkesbury River focussed on the current and expected future production of Pacific Oysters in the region given the adoption of various risk mitigation strategies and the likely release of POMS resistant oyster varieties from the Australian Seafood Industries Ltd (ASI) breeding program.

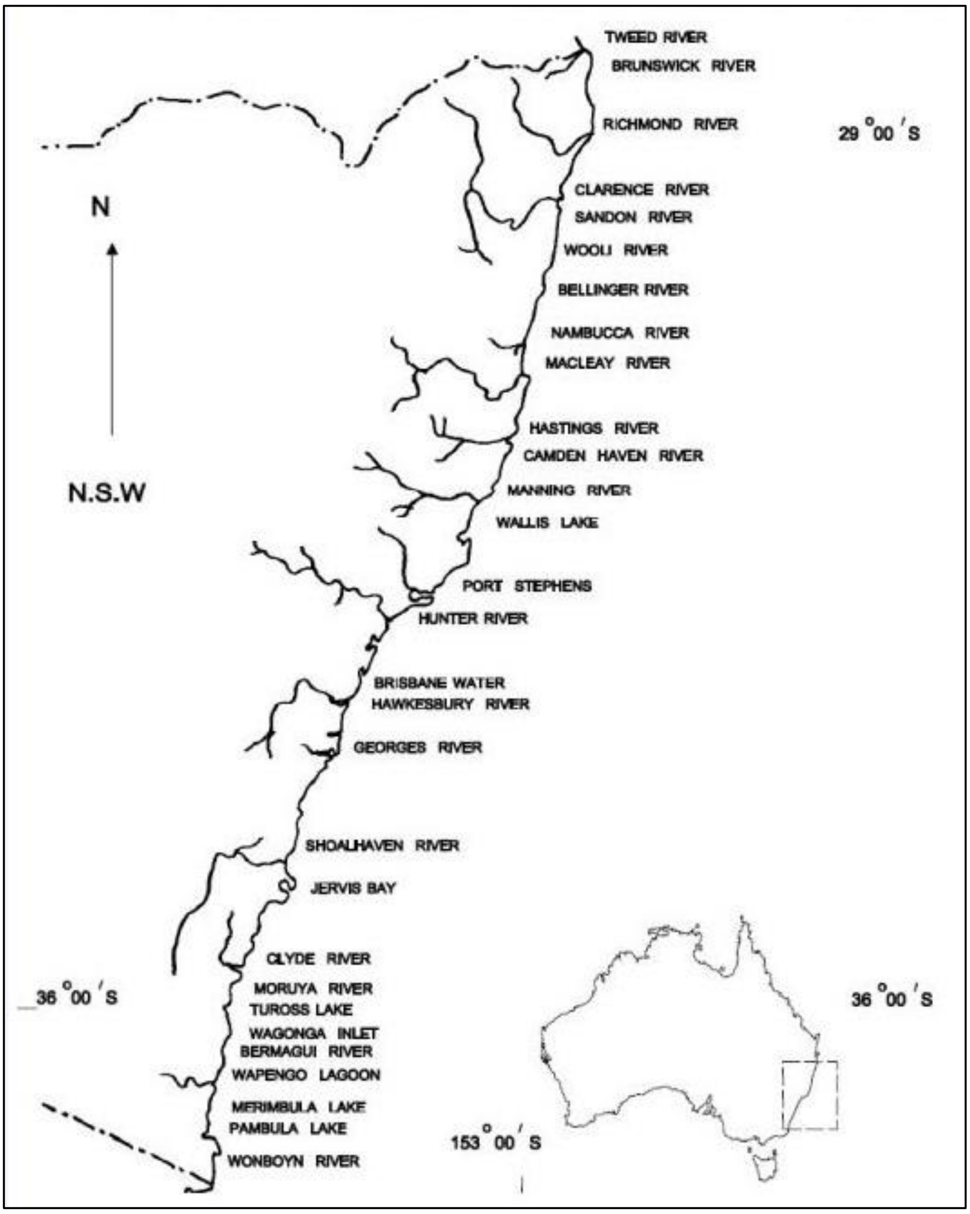
Investment in project 2012-032 is assumed to have increased the rate at which Pacific Oyster production in the Hawkesbury river is recovering from the 2013 POMS outbreak. The additional costs to Hawkesbury oyster farmers of adopting relevant risk mitigation strategies is then subtracted from the gross benefits.

Specific assumptions for valuing the impact are provided in Table 5.

Valuation of Impact 2: Reduced risk of POMS spreading to other NSW Pacific Oyster production regions

Oysters are farmed right along the NSW coastal region from the Tweed River in the north to the Wonboyn River in the south. Pacific Oyster production regions include Port Stephens, Hawkesbury River, Crookhaven River, Clyde River and other estuaries such as Shoalhaven River and Georges River.

Figure 1: Location of Major Oyster Producing Rivers/Estuaries in NSW



Source: NSW Deparment of Primary Industries, n.d.

It was assumed that the risk of the POMS virus spreading from already affected areas (e.g. the Hawkesbury and Georges Rivers) to other Pacific Oyster production regions in NSW would have been much greater if the investment in project 2012-032 had not occurred. The valuation of this impact takes into account that R&D to produce POMS resistant varieties was already underway.

Specific assumptions for valuing the impact are provided in Table 5.

Valuation of Impact 3: Increased efficiency of RD&E resource allocation

The valuation of increased efficiency of RD&E resource allocation centres on the investment in the Future Oysters CRC-P. Participants in the CRC-P include ASI, FRDC, Oysters Australia, CSIRO, several Universities and State Government departments and other private companies. The Commonwealth Government has invested $3 million over the three years while other participants have committed just over $8.3 million making the total investment in the Future Oysters CRC-P approximately $11.3 million over a period of three years (years ended 30 June 2017 to 2019).

The Future Oysters CRC-P defined three key program areas for RD&E investment:

i) Better Oysters – breeding
ii) Healthy Oysters – understanding aquatic diseases
iii) More Oysters – diversification

The Healthy Oysters program is largely focused on POMS RD&E. It was assumed that POMS related RD&E makes up approximately 25% of the investment by the Future Oysters CRC-P.

The findings of project 2012-032 are assumed to have improved the RD&E resource investment by identifying key knowledge gaps and priority areas for future POMS research. The investment in 2012-032, therefore, is assumed to have contributed to increased efficiency of the POMS related RD&E investment made through the Future Oysters CRC-P.

Specific assumptions for valuing the impact are provided in Table 5.

Counterfactual

It was assumed that, given the significance and severity of the POMS virus for the Australian Pacific Oyster industry, investment in POMS risk mitigation, epidemiology and OsHV-1 biology would have occurred anyway. However, the investment would have been funded in reaction to the considerable losses experienced from the 2013 POMS outbreak and therefore would have commenced later.

Specific assumptions for the counterfactual are provided in Table 5.

Attribution

Project 2011-053 as well as project 2012-032 contributed to the impacts valued. However, the activities of project 2011-053 targeted only one specific POMS risk mitigation strategy (growth environment) and the experiment was required to be replicated by project 2012-032 to confirm the validity of the findings.

Therefore, the contribution of project 2011-053 is recognised but no specific attribution of the benefits in the analysis was made.

Summary of Assumptions

A summary of key assumptions made for valuation of the impacts is shown in Table 5.

Table 5: Summary of Assumptions

Variable	Assumption	Source
Benefit 1: Increased rate of recovery of Pacific Oyster production in the Hawkesbury		
BASELINE DATA		
Historic Pacific Oyster production for the Hawkesbury River by year (dozens)		
2010	300,875	NSW DPI, Aquaculture Production Reports 2011 to 2017
2011	296,620	
2012	274,181	
2013	186,093	
2014	21,221	
2015	2,855	
2016	4,745	
Production recovery trend equation	y = 1890x + 965 where x = 1 for 2015	Based on trendline for 2015 and 2016 production
First year ASI to release POMS resistant varieties	Calendar 2018	Matt Cunningham, ASI Ltd, pers. comm., 2017
First year of impact for POMS resistant varieties	2019	Agtrans Research based on Hawkesbury River reaching maximum recovery by 2033 (see below), 15 years from first year of impact of the POMS resistant varieties
Increased rate of recovery due to release of POMS resistant varieties only	5.25x the base (2015-16) rate of recovery	
Maximum level of production recovery for Hawkesbury Pacific Oyster industry	70% of average, pre-POMS outbreak production	Agtrans Research based on a 70% resistance target for new varieties of Pacific Oysters through the ASI breeding program
Maximum recovery level in dozens	185,110 dozen	70% x 264,442 dozen (2010 to 2013 average NSW Pacific Oyster production)
Average farm-gate price of Hawkesbury Pacific Oysters	$10.50 per dozen	NSW DPI, Aquaculture Production Report 2017, average price of small and medium Pacific Oysters from Hawkesbury River (consituting approximatley 95% of sales)
WITH PROJECT 2012-032		
First year of impact	2017	Based on investment in projct 2012-032 ending in 2015/16
Increased rate of recovery with risk mitigation investment (prior to release of POMS resistant varieties)	1.75x base (2015-16) rate of recovery in 2017 (first year of project 2012-032 impact) then 3.5x rate of recovery in 2018	Agtrans Research based on Hawkesbury River Pacific Oyster production achieving maximum recovery by 2028 (70% of pre-POMS average production), 10 years from the first year of impact of the POMS resistant varieties
Increased rate of recovery with risk mitigation investment when POMS resistant varieties are available	7.0x rate of recovery from 2019	
WITHOUT PROJECT 2012-032		
Year of first investment in risk mitigation, epidemiology and OsHV-1 biology	2015	Agtrans Research based on the investment being funded in reaction to the severe January 2013 POMS outbreak

Period of investment	5 years	Based on same length of investment in project 2012-032
First year of impact of project findings	2020	Based on investment completion in 2019
Increased rate of recovery with risk mitigation investment, given release of POMS resistant varieties	7.0x recovery trend from 2020	Agtrans Research based on Hawkesbury River Pacific Oyster production achieving maximum recovery by 2028 (70% of pre-POMS average production)
ADDITIONAL COSTS		
Additional costs of adoption of risk mitigation strategies to Pacific Oyster farmers	20% of gross value of the increased production	Agtrans Research (applies to both the with and the without scenario)
RD&E investment in risk mitigation, epidemiology and OsHV-1 biology	$3.59 million over five years (2015-2019)	Agtrans Research (applies to the without scenario only); note: the same additional cost also applies to the without scenario for benefit 2
Benefit 2: Reduced risk of POMS spreading to other Pacific Oyster production regions in NSW		
BASELINE DATA		
Historic Pacific Oyster production for the NSW by year (dozens – excluding Hawkesbury River)		
2010	311,678	NSW DPI, Aquaculture Production Reports 2011 to 2017
2011	234,372	
2012	343,218	
2013	284,951	
2014	233,992	
2015	370,080	
2016	463,549	
Production trend equation	y = 22,064x + 232,005 where x = 1 for 2010	Based on trendline production from 2010 to 2016 (excluding Hawkesbury River production)
First year of release, and impact, of POMS resistant varieties	See Benefit 1 assumptions	
Maximum potential level of future production for NSW Pacific Oysters	600,000 dozen (excluding Hawkesbury River production)	Agtrans Research based on past maximum production levels of Pacific Oysters in NSW from 2010 to 2016
Average farm-gate price of NSW Pacific Oysters	$8.32 per dozen	NSW DPI, Aquaculture Production Report 2017, average price of small and medium Pacific Oysters from all regions (consituting approximatley 95% of sales)
WITH PROJECT 2012-032		
Proportion of NSW production (ex. Hawkesbury) susceptible to POMS prior to the release of resistant varieties in 2019	80%	Agtrans Research
Proportion of NSW production (ex. Hawkesbury) susceptible to POMS after release of resistant varieties	30% from 2019	Based on ASI target resistance level of 70%
Proportion of susceptible Pacific Oyster production lost in the case of further POMS outbreaks	90%	Based on reported mortality rates from POMS affected areas
Risk of POMS spreading to other NSW Pacific Oyster production	5% p.a.	Agtrans Research

regions given implementation of risk mitigation strategies across NSW Pacific Oyster production regions		
First year of impact	2017	
WITHOUT PROJECT 2012-032		
First year of investment in risk mitigation, epidemiology, and OsHV-1 biology RD&E	2015	Agtrans Research based on the investment being funded in reaction to the severe January 2013 POMS outbreak
Period of investment	5 years	Based on same length of investment in project 2012-032
First year of impact	2020	Based on investment completion in 2019
Risk of POMs spreading to other NSW Pacific Oyster production regions prior to 2020	80% p.a.	Agtrans Research
Risk of POMS spreading to other areas from 2020	5% p.a.	
ADDITIONAL COSTS(a)		
Additional costs of adoption of risk mitigation strategies to Pacific Oyster farmers	20% of gross value of the increased production from 2017	Agtrans Research (applies to both the with and without scenario)
Benefit 3: Increased efficiency of POMS RD&E resource allocation for the Future Oysters CRC-P		
Actual total Future Oyster CRC-P RD&E Investment	$11.3 million over 3 years	CRC Programme, 2016
Proportion of Future Oysters CRC-P invested in non-breeding, POMS RD&E	25% ($2.825m)	Agtrans Research based on the Future Oysters CRC-P RD&E program areas and projects (Hutchinson & Mair, 2016)
Efficiency dividend due to improved priority setting	19.5%	Agtrans Research (based on an overall efficiency dividend of 20% for POMS RD&E as a result of projects 2012-032 and 2015-406: National POMS Response Plan)
Additional RD&E expenditure required to achieve same outputs without dividend	$550,875 over the life of the Future Oysters CRC-P	$11.3m x 25% x (119.5/100) - $2.825m
Period efficiency dividend delivered (years ended June)	2017-2019	Based on the period of funding for the Future Oysters CRC-P, September 2016 to August 2019 assuming all final year expenditures are made prior to 30 June 2019
Counterfactual	Assumed that similar RD&E would not have been completed until 2019 and therefore would have had no impact on Future Oysters RD&E resource allocation	

(a) It was necessary to calculate the difference between in value of the real, discounted RD&E investment costs for the 'with' scenario and 'without' scenario (i.e. the real, discounted investment in project 2012-032 versus the real, discounted investment cost of similar RD&E commenced in 2015). The difference then was treated as an additional cost and subtracted from the aggregate, discounted net benefits.

Results

All benefits after 2016/17 were expressed in 2016/17 dollar terms. All costs and benefits were discounted to 2016/17 using a discount rate of 5%. A reinvestment rate of 5% was used for estimating the Modified Internal Rate of Return. The base analysis used the best available estimates for each variable, notwithstanding a level of uncertainty for many of the estimates. All analyses ran for the length of the project investment period plus 30 years from the last year of investment in Project 2012-032 (2015/16).

Investment Criteria

Tables 6 and 7 show the investment criteria estimated for different periods of benefits for the total investment and the FRDC investment. The present value of benefits (PVB) attributable to the FRDC investment only, shown in Table 7, has been estimated by multiplying the total PVB by the FRDC proportion of real investment before discounting (25.2%).

Table 6: Investment Criteria for Total Investment in Project 2015-406

Investment Criteria	**Years after Last Year of Investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present Value of Benefits ($m)	-2.86	6.30	6.30	6.30	6.30	6.30	6.30
Present Value of Costs ($m)	4.17	4.17	4.17	4.17	4.17	4.17	4.17
Net Present Value ($m)	-7.03	2.13	2.13	2.13	2.13	2.13	2.13
Benefit-Cost Ratio	-0.69	1.51	1.51	1.51	1.51	1.51	1.51
Internal Rate of Return (%)	negative	11.66	11.66	11.66	11.66	11.66	11.66
Modified Internal Rate of Return (%)	360.6	34.77	17.32	12.76	10.66	9.46	8.68

Table 7: Investment Criteria for FRDC Investment in Project 2015-406

Investment Criteria	**Years after Last Year of Investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present Value of Benefits ($m)	-0.72	1.59	1.59	1.59	1.59	1.59	1.59
Present Value of Costs ($m)	1.04	1.04	1.04	1.04	1.04	1.04	1.04
Net Present Value ($m)	-1.76	0.55	0.55	0.55	0.55	0.55	0.55
Benefit-Cost Ratio	-0.69	1.53	1.53	1.53	1.53	1.53	1.53
Internal Rate of Return (%)	negative	11.91	11.91	11.91	11.91	11.91	11.91
Modified Internal Rate of Return (%)	2033.49	36.49	17.98	13.17	10.96	9.69	8.87

Sensitivity Analyses

A sensitivity analysis was carried out on the discount rate. The analysis was performed for the total investment and with benefits taken over the life of the investment plus 30 years from the last year of investment. All other parameters were held at their base values. Table 8 presents the results. The results showed a low sensitivity to the discount rate. This is due to the benefits from the investment commencing early and only running for three years. Thus, the benefit cash flows were not subject to heavy discounting.

Table 8: Sensitivity to Discount Rate
(Total investment, 30 years)

Investment Criteria	**Discount rate**		
	0%	**5% (base)**	**10%**
Present value of benefits ($)	7.23	6.30	5.35
Present value of costs ($)	3.60	4.17	4.80
Net present value ($)	3.63	2.13	0.55
Benefit-cost ratio	2.01	1.51	1.11

A break-even analysis was undertaken assumption of the initial risk of POMS spreading to other Pacific Oyster production regions in NSW without the investment (benefit 2). This variable was a key driver of the results and was a variable with high uncertainty. The results reported in Table 9 show that, for the investment to break even, the original risk of spread had to be approximately 53.4%.

Table 9: Sensitivity to Discount Rate
(Total investment, 30 years)

Investment Criteria	**Assumed probability of POMS spreading to other Pacific Oyster production regions in NSW *without* the investment in project 2012-032**	
	Break-Even – 53.7%	**Base – 80.0%**
Present value of benefits ($)	4.17	6.30
Present value of costs ($)	4.17	4.17
Net present value ($)	0.00	2.13
Benefit-cost ratio	1.00	1.51

Confidence Ratings and other Findings

The results produced are highly dependent on the assumptions made, some of which are uncertain. There are two factors that warrant recognition. The first factor is the coverage of benefits. Where there are multiple types of benefits it is often not possible to quantify all the benefits that may be linked to the investment. The second factor involves uncertainty regarding the assumptions made, including the linkage between the research and the assumed outcomes.

A confidence rating based on these two factors has been given to the results of the investment analysis (Table 10). The rating categories used are High, Medium and Low, where:

High: denotes a good coverage of benefits or reasonable confidence in the assumptions made

Medium: denotes only a reasonable coverage of benefits or some uncertainties in assumptions made

Low: denotes a poor coverage of benefits or many uncertainties in assumptions made

Table 10: Confidence in Analysis of Project

Coverage of Benefits	Confidence in Assumptions
Medium-High	Low

The coverage of benefits was assessed as medium-high as the three impacts valued represented a large proportion of the most significant potential impacts of the investment. On the other hand, while the assumptions for impact valuations were partially supported by project reports and other source material, limited feedback was able to be obtained from project personnel directly. Therefore, the valuation assumptions for each benefit were somewhat speculative and therefore confidence was considered to be low.

Conclusions

The investment in this project has likely resulted in improved outcomes for Pacific Oyster farmers throughout NSW and an increase in efficiency for RD&E expenditure under the Future Oysters CRC-P through improved resource allocation for POMS R&D.

Funding for project 2012-032 totalled $4.17 million (present value terms) and produced estimated total expected benefits of $6.30 million (present value terms). This gave a net present value of $2.13 million, an estimated benefit-cost ratio of 1.5 to 1, an internal rate of return of 11.7% and a modified internal rate of return of 8.7%.

The impacts valued were focused on the NSW Pacific Oyster industry. However, it is likely that the risk mitigation strategies identified also will improve outcomes for other POMS affected areas in Australia (e.g. Tasmania) and will support the future viability of Pacific Oyster farming in Australia given the presence of POMS.

Several environmental and social impacts were also identified but not valued as the linkages between the project and these impacts were uncertain and their contributions were considered minor compared with the impacts valued. Nevertheless, combined with conservative assumptions for the impacts valued, investment criteria as provided by the valued benefit are likely to be an underestimate of the investment performance.

Glossary of Economic Terms

Cost-benefit analysis:	A conceptual framework for the economic evaluation of projects and programs in the public sector. It differs from a financial appraisal or evaluation in that it considers all gains (benefits) and losses (costs), regardless of to whom they accrue.
Benefit-cost ratio:	The ratio of the present value of investment benefits to the present value of investment costs.
Discounting:	The process of relating the costs and benefits of an investment to a base year using a stated discount rate.
Internal rate of return:	The discount rate at which an investment has a net present value of zero, i.e. where present value of benefits = present value of costs.
Investment criteria:	Measures of the economic worth of an investment such as Net Present Value, Benefit-Cost Ratio, and Internal Rate of Return.
Modified internal rate of return:	The internal rate of return of an investment that is modified so that the cash inflows from an investment are re-invested at the rate of the cost of capital (the re-investment rate).
Net present value:	The discounted value of the benefits of an investment less the discounted value of the costs, i.e. present value of benefits - present value of costs.
Present value of benefits:	The discounted value of benefits.
Present value of costs:	The discounted value of investment costs.

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Appendices

Appendix 1: Expression of Interest (RW044) objectives

1. To correlate biotic and abiotic environmental factors with QX, POMS and winter mortality occurrence in selected oyster populations;
2. To develop an experimental laboratory transmission model for POMS in Pacific oysters;
3. To confirm experimentally whether biotic and abiotic factors affect POMS transmission;
4. To determine whether there are measurable immune responses in POMS and other key diseases;
5. To determine whether Pacific oysters can be protected from POMS and other key diseases by manipulating environmental conditions;
6. To determine whether oysters can be protected from QX and POMS by prior artificial exposure to agent factors;
7. To determine whether natural selection is a key driver of population survival following QX, POMS and other disease outbreaks;
8. To promote oyster health through oyster information portals;
9. Provide training for three PhD students to serve future industry needs.