FINAL REPORT

Australian edible oyster RD&E investment via Oysters Australia Strategic Plan 2014-19

Dr Len Stephens

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FRDC Project No 2014-405

Australian edible oyster RD&E investment via Oysters Australia Strategic Plan 2014-19
2014-405

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

EXECUTIVE SUMMARY

This report describes the outcomes from a four-year Industry Partnership Agreement (IPA) between Fisheries Research and Development Corporation (FRDC) and Oysters Australia (OA). The primary objective of the IPA was to coordinate oyster R&D funded through FRDC and other sources.

During the four years 33 oyster R&D projects to the value of $10.1 million were conducted. The IPA was involved in all but three of these projects.

The majority of projects supported by the IPA were consistent with the priorities in the Oysters Australia Strategic Plan 2014-2019. However, during the first year of the project an outbreak of the disease Pacific Oyster Mortality Syndrome (POMS) in Tasmania killed a large proportion of the oyster crop. Follow on effects due to lack of spat supply had an equally devastating impact on South Australia. Consequently, the mix of projects that were supported changed from industry growth and market development, to industry survival.

It was extremely fortunate that during the course of the IPA, the industry received $5million over three years through the Commonwealth Government CRC-P program. These funds were used to support major projects aimed at controlling POMS and other diseases. The Future Oysters CRC-P projects are included in this report, but a full report on outcomes from the CRC-P will be available in March 2020.

Twenty-two of the 33 projects are now complete, or almost complete. All of the projects have delivered significant benefits to the industry.

The industry is well on the way to recovering from POMS, in large measure due to the foresight exhibited by the industry leaders in establishing a levy system to maintain the industry owned Pacific oyster breeding program. This, plus many of the projects described herein, enabled POMS resistant oysters to be supplied to hatcheries within a year of the first POMS outbreak in Tasmania.

There was also significant progress in the Sydney Rock Oyster (SRO) breeding program, achieved by discarding the mass selection approach and moving to a single pair mating and family pedigree system. As a result, more families were produced, breeding started earlier each year, and resistance to QX disease improved. Unfortunately, the business model for the long term financial viability of the SRO breeding program operated by the Select Oyster Company (SOCo) and New South Wales Department of Primary Industries (NSW DPI) is still unresolved.

Planning is now underway for a new strategic plan that will guide oyster research in a new IPA to cover the period from 2020 – 2025.

ACKNOWLEDGEMENTS

This report is primarily about research that delivered benefits to oyster growers. This research is completely dependent on the scientists that conduct the research and the institutions that support them. To them the industry offers a sincere acknowledgement. Alongside the scientists there are often growers and hatcheries who give their time, knowledge and resources freely, for the benefit of the industry. They are also offered a debt of gratitude.

Many people contributed to the Future Oysters CRC-P, which was a significant component of this project. For their involvement in the planning, reporting, communication and management of the CRC-P, thanks are extended to Prof Graham Mair, Dr Steven Clarke, Matt Cunningham and Lewa Pertl.

Sue Grau and Wayne Hutchinson both served as Executive Officers of Oysters Australia at different times during this project. Their assistance is greatly appreciated.

The Directors of Oysters Australia are also gratefully acknowledged for the voluntary contribution of their time.

The FRDC is acknowledged for its long standing support for the oyster industry, with particular thanks to Patrick Hone, John Wilson and Wayne Hutchinson.

ABBREVIATIONS

a-EADRA	Aquatic Emergency Animal Disease Response Agreement
CRC-P	Cooperative Research Centre - Project
DIIS	Commonwealth Department of Industry, Innovation and Science
DPINT	Department of Primary Industries Northern Territory
FRDC	Fisheries R&D Corporation
IPA	Industry Partnership Agreement
NSW PDI	New South Wales Department of Primary Industries
OA	Oysters Australia Ltd
PIRSA	Department of Primary Industries and Regions, South Australia
POMS	Pacific Oyster Mortality Syndrome
SARDI	South Australian R&D Institute
SOCo	Select Oyster Company
SRO	Sydney Rock Oyster

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INTRODUCTION

The Australian Seafood Cooperative Research Centre (SCRC) supported national leadership and coordination of oyster R&D for nine years, finishing in June 2015. During the last year of the SCRC, Oysters Australia Ltd (OA) was established as an industry owned company with the primary purpose of continuing the national coordination of oyster R&D. This arrangement was consistent with FRDC's policy of encouraging self-determination by industries, by providing funds through Industry Partnership Agreements (IPA).

There were four major areas of activity required to achieve the desired level of coordination.

1. Manage project development across OA's member states. A co-ordinator and industry consultation budget was needed to facilitate this process.

2. Manage and co-ordinate access to most suitable funding sources for RD&E. This required efforts by members of OA to seek funds from sources in addition to FRDC.

3. Maintain cohesion and strategic direction of OA by adhering to the 2014 – 19 Strategic Plan and preparing to renew the plan during 2019.

4. Communication was needed to identity the most appropriate commercialisation path for R&D results, set strategy in consultation with growers, provide updates on investments as they are made and report on results to the growers.

The Oysters Australia IPA commenced on 21 August 2015. The 2014 -19 Strategic Plan set out four overarching objectives of:

- sustainable productivity improvement
- better oyster quality
- improved consumer demand
- Increased industry capacity

Nineteen strategies were planned to deliver these objectives, and a substantial number of projects were initiated to implement the strategies.

However, within a year of completion of the strategic plan, and six months after the commencement of the IPA, the industry suffered a major outbreak of the disease Pacific Oyster Mortality Syndrome (POMS) in Tasmania that had had drastic consequences for Pacific oyster growers in both Tasmania and South Australia. As a consequence, some elements of the strategic plan were put in abeyance.

OBJECTIVES

There were four objectives of the IPA:

1. Manage R&D project development between and within OA's member states
2. Manage and co-ordinate access to most suitable funding sources for projects.
3. Maintain cohesion and strategic direction of the Oysters Australia R&D group through a strategic plan.
4. Implement a multimedia communications package for growers and researchers and enable two-way communication through the investment process

The main outputs envisaged were as follows

1. Oysters Australia communication plan agreed following the recommendations from CRC project 2012/738
2. Oysters Australia members invest at or above 0.25% GVP
3. Oysters Australia partners in at least one cross sector or cross jurisdiction project within the FRDC
4. Oysters Australia strategic plan effectively implemented including finalised and complete research portfolio agreed with FRDC
5. Australian edible oyster strategic plan 2019 – 2024 drafted

The communication plan was expected to contain:

- continued use of annual state meetings with bolt on focused topics, e.g. benchmarking when needed
- continuation of virtual news (*enews*, blog site)
- continuation of updates as requested by OA member Executives (usually quarterly)
- video news, a short version of the full enews, called *Australia's Talking Oysters* based on a similar model from *Seafood Industry News* as was tested in CRC project 2009/747
- annual 'return on investment' one page report sent by mail via states.

METHODS

OA functions by leading and coordinating industry activities. It has no operational capacity to carry out tasks in its own right, being dependent on State members and R&D agencies for that purpose.

To fulfil its purpose, OA has a Board of Directors and an Executive Officer.

The Board comprises six directors who must be oyster growers from the foundation member organisations, and capacity for three independent directors.

The foundation member organisations are:

- Tasmanian Oyster Research Council Limited
- Tasmanian Shellfish Executive Council Inc.
- South Australia Oyster Growers Association Incorporated
- South Australia Oyster Research Council Pty Ltd
- The NSW Farmers' Association Oyster Committee
- The NSW Aquaculture Research Advisory Committee

The Board appoints the following office bearers from among their number: President, Vice President, Treasurer and Secretary.

It should be noted that there is no limit to the number of members and other State bodies can be encouraged to join. Also the Tasmanian Shellfish Executive Council Inc no longer and the Constitution will be changed to allow two directors to be appointed by the Tasmanian Oyster Research Council.

Executive Officers appointed by the Board were:

- Rachel King 2010 – 2016
- Wayne Hutchison, 2016 – 2018
- Sue Grau, 2018 – 2019
- Andy Myers, 2019 –

Lewa Pertl was contracted to establish a website (www.oystersaustralia.org) in 2018, primarily for communicating CRC-P outputs. She also assisted with other communication activities.

RESULTS

A summary of progress made toward each objective is given in Table 1.

Table 1. Progress against each Objective

Objective	Progress
1. Manage R&D project development between and within OA's member states	This was achieved to a degree, however there was a lot of project development activity outside the IPA.
2. Manage and co-ordinate access to most suitable funding sources for projects.	This was substantially achieved, particularly in relation to the Future Oysters CRC-P and emergency funding for projects concerned with control of POMS
3. Maintain cohesion and strategic direction of the Oysters Australia R&D group through a strategic plan.	The 2014-19 Strategic Plan provided the guidance and coordination necessary at the start of the IPA to initiate several important projects. After the outbreak of POMS in Tasmania (February 2016), the plan had less influence.
4. Implement a multimedia communications package for growers and researchers and enable two-way communication through the investment process	This only occurred in relation to the Future Oysters CRC-P, and was not to the scale originally envisioned.

A summary of the extent to which each desired outcome was achieved is given in Table 2.

Table 2. Progress against outcomes

Output	Progress
1. Oysters Australia communication plan agreed	A communications plan was not produced. However, the first milestone report for this project, submitted to FRDC in January 2016, detailed arrange of intended communication activities. The advent of POMS in Tasmania prevented implementation of any of them.
2. Oysters Australia members invest at or above 0.25% GVP	Voluntary industry contributions have been made to FRDC from each oyster growing jurisdiction
3. Oysters Australia partners in at least one cross sector or cross jurisdiction project within the FRDC	The Future Oysters CRC-P achieved numerous cross jurisdictional projects. Several small cross sector projects involving biosecurity were also delivered.
4. Oysters Australia strategic plan effectively implemented including finalised and complete research portfolio agreed with FRDC	Despite the Tasmanian POMS outbreak, a substantial number of research projects conducted over the period were in line with the strategic plan objectives.
5. Australian edible oyster strategic plan 2019 – 2024 drafted	Not achieved, but planned for March 2020.

While the outbreak of POMS in Tasmania caused disruption and devastation to many Pacific Oyster growers in that state and in South Australia, it should not be assumed that results were not achieved. In fact, it was quite the opposite. The industry and research agencies responded strongly to the hardship and delivered a series of activities that allowed the industry to recover from the outbreak faster than any other nation affected by POMS. These results are described below under the following headings:

- Research Projects
- Communication
- National Issues
- Governance

Research Projects

Project Funding

The projects described in this report were funded from a range of sources. These include:

a) Levies paid by growers to State Governments that are then paid to FRDC. Each year FRDC receives approximately $200,000 from this source, which FRDC matches dollar for dollar. OA is responsible for management of these funds, through the IPA.
b) Other FRDC funds, such as the Response Research Fund, the New and Emerging Aquaculture Opportunities Subprogram, the Aquatic Animal Health Sub Program, and levies from other sectors.
c) The CRC-P program conducted by the Australian Government Department of Industry, Innovation and Science.
d) Other grants from the Australian Government.
e) Grants from other agencies.

A detailed spreadsheet showing funding for all projects managed by OA and FRDC is provided in Appendix 1.

The income and expenditure from grower levies, (a) above, over the duration of this project is shown in Table 3.

Table 3. Financial summary of FRDC oyster levy funds.

Year	**2015-16**	**2016-17**	**2017-18**	**2018-19**	**Total**
Opening Balance	$519,600	$240,840	$135,218	$327,565	
Income	$445,405	$376,566	$571,922	$367,550	$1,761,443.00
Expenditure	$724,165	$482,188	$379,575	$250,741	$1,836,669.00
Balance	$240,840	$135,218	$327,565	$444,374	

When a new IPA has been finalised with FRDC the future income will follow these existing arrangements with increased funds available commensurate with growth of the Australian oyster industry GVP.

Pre-Existing Projects

When the IPA became operational, there were three projects that were already in place, funded through the IPA. These are shown in Table 4a. These three projects have been completed and the results distributed to industry via ASI or SafeFish.

Projects Established Through the IPA

In the first year of operation of the IPA, before the outbreak of POMS and during its initial months, eight projects were established with the use of IPA funds. These projects are shown in Table 4b. The SafeFish project and the project to establish sector-specific biosecurity plan templates were collaboratively funded.

With the exception of *SafeFish*, which is ongoing, most of these projects are complete, or nearly so. The status of the projects and communication of results are also shown in Table 4b.

Progress in the Sydney Rock Oyster (SRO) breeding program has been constrained in the past by the use of mass selection which has several disadvantages such as inability to control inbreeding and inability to select for multiple traits or predict genetic gains for each trait. However, during the life of the IPA important progress was achieved by discarding the mass selection approach and moving to a single pair mating and family pedigree system. Estimated breeding values (EBVs) have now been produced for QX disease resistance, growth, and condition in SRO. The commercial uptake of over 15,000,000 selected stock spat is a good indication of the performance of the new breeding program.

Unfortunately, the business model for the long term financial viability of the SRO breeding program and SOCo is still unresolved

Projects Established Outside the IPA

Nine projects of value to the oyster industry were initiated using funds, other than those controlled through the IPA. This projects and their status are shown in Table 4c. Six of these projects were directly related to the control of POMS and were funded from the South Australian government, Flinders Ports, the Commonwealth government and FRDC special initiatives. Of particular note were the projects that continued the research into breeding POMS resistant Pacific Oysters at ASI and SARDI.

CRC-P Projects

It was fortuitous that the Commonwealth Department of Industry, Innovation and Science (DIIS) opened a new round of CRC-P bids at exactly the time the oyster industry was finalising its strategic plan and was planning its research response to the threat of POMS. Oysters Australia facilitated the preparation of the application for the *Future Oysters CRC-P*. This was done by then OA Executive Officer Wayne Hutchinson and Professor Graham Mair (Flinders University) liaising with oyster researchers and industry to structure and assemble the CRC-P application.

The successful $5.0 million Future Oysters CRC-P assembled funds from industry (OA IPA $150K) combined with investment in R&D from CRC-P partners (total $1.85 million) and DIIS ($3.0 million).

The CRC-P had a national remit covering SA, NSW and Tasmania. The key outcomes sought from it centred around control of oyster diseases. For Pacific Oysters the focus was on POMS and South Australian Mortality Syndrome. For Sydney Rock Oysters the focus was on QX disease and winter mortality.

Three programs of research were implemented.

1. Better Oysters

This program aimed to accelerate breeding of disease resistant oysters by:

- Producing disease free spat from disease challenged broodstock.
- Developing reliable challenge tests to quantify resistance traits at different life stages
- Accelerating family production and rates of genetic gain by developing out of season spawning protocols and shortening generation times.
- Establishing a research project in South Australia for research into breeding POMS resistant oysters.
- Identifying genetic parameters and potential for selection for disease traits currently not selected

2. Healthy Oysters

This program aimed to define features of each disease that might assist in their control. This included:

- Defining the window of infection of POMS in Tasmania.
- Resolving unknown aspects for QX Disease, Winter Mortality and SAMS to inform breeding and improve survival
- Defining survival at different life stages for oysters exposed to aquatic diseases

- Pinpointing environmental drivers of disease outbreaks
- Investigating polymicrobial involvement in POMS
- Investigating nongenetic methods to supply POMS resilient spat
- Investigating mechanisms of POMS resistance and adaption
- Developing cost effective testing methods for expanded monitoring for spread of POMS.

3. *More Oysters*
   - This program aimed to facilitate commercial development of alternative oyster species to diversify production. It involved:
   - Assessing commercial potential of native oysters
   - Conducting R&D required to allow translocation of rock oysters from WA to SA

The terms of CRC-P Grants stipulate that the primary applicant must be an industry owned, for-profit company. The industry owned Pacific Oyster breeding company, Australian Seafood Industries (ASI) was able to fill this role and a management committee was established to overview the program.

The CRC-P was due to finish on 31 August 2019, but as frequently happens a number of projects are running over time. Dr Steven Clarke from SARDI has assumed the role of Executive officer for the CRC-P Management Committee and he is coordinating collation of all the final reports due form project investigators.

Table 5 contains a list if all the CRC-P projects, along with their status as advised by Dr Clarke.

A Final Report containing details of all the CRC-P projects will be available in mid-2020.

Project Summaries

A summary of each project listed above can be found in Appendix 2. The information provided is either the executive summary from the project Final Report, if available, or the project description in the case of unfinished projects. Summaries of CRC-P projects, where they are available, are provided in Appendix 3.

Table 4. Summary of Oyster Projects outside the CRC-P

Project Number	Project Name	R&D Provider	Total Budget ($)	Source of Funds	Status at Dec 2019
4a. Projects Inherited by the IPA in 2015-16					
2012-760	Genetic selection for resistance to Pacific oyster mortality syndrome	ASI	608,193	Seafood CRC	Complete. Results distributed through ASI
2013-234	Survey of Foodborne Viruses in Australian Oysters	SARDI	260,800	IPA	Complete. Results distributed through *SafeFish*
2015-212	*SafeFish* - research to support food safety, trade and market access	SARDI	75,291	Seafood CRC	Complete. Results distributed through *SafeFish*
2015-238	Rural R&D for Profit- Easy open oyster automation	Scott Automation & Robotics	$453,228	Dept of Agriculture Seafood CRC FRDC	Complete. Summary available from FRDC on request.

4b. Projects Established Through the IPA					
2018-004	*SafeFish* 2018- 2021	SARDI	60,000	IPA + various seafood sectors	Ongoing
2017-136	SOCo Financial Strategy Workshop 17 November 2017	SOCo	6,200	IPA	Complete. Report delivered to stakeholders.
2016-245	Development of sector-specific biosecurity plan templates and guidance documents for the abalone and oyster aquaculture industries	PIRSA	9,995	Dept of Agriculture (66.8%) IPA (16.6%) AAGA IPA (16.6%)	Complete
2015-230	Genetic services for the multi-trait, single pair mated Sydney Rock Oyster breeding program	SOCo	96,666	IPA	Complete. Report to made available on FRDC website
2015-037	The use of FRNA bacteriophages for rapid re-opening of growing areas after sewage spills	SARDI	270,273	IPA	Complete. Report to made available on FRDC website

2015-229	Workshop – identifying knowledge gaps for development of the native oyster aquaculture industry in South Australia	SARDI	19,074	IPA	Complete. Report delivered to stakeholders.
2014-405	Australian edible oyster RD&E investment via Oysters Australia strategic plan 2014-2019	Oysters Australia	238,997	IPA	This report.
2014-040	Pacific Oyster Mortality Syndrome (POMS) – closing knowledge gaps to continue farming *C. gigas* in Australia	University of Sydney	463,700	IPA	Complete. Report to be made available on FRDC website

4c. Projects Established Outside the IPA					
2019/039	South Australian Pacific Oyster selective breeding program: Building POMS resistance to reduce risk for the South Australian oyster industry	SARDI and ASI	630,743	FRDC,PIRSA, Flinders Ports, ASI	Ongoing
2018-165	Easy Open Oyster Machine Update	L Stephens	35,000	FRDC, commercialisation	Ongoing
2018-164	Commercial production trial with high POMS tolerant triploid Pacific Oysters in approved NSW estuaries.	ASI and Cameron of Tasmania	70,000	FRDC Response Research Fund	Ongoing
2018-118	Reinvigorating the Queensland Oyster Industry	Griffith University	40,000	FRDC Subprogram New and Emerging Aquaculture Opportunities	Ongoing
2018-102	Understanding Ostreid herpesvirus type 1 risk: alternative hosts and in situ hybridisation	Flinders University	62,500	FRDC Response Research Fund	Ongoing
2018-090	Improving early detection surveillance and emergency disease response to Pacific Oyster Mortality Syndrome (POMS) using a hydrodynamic model for dispersion of OsHV-1	PIRSA	70,168	FRDC Response Research Fund	Ongoing
2018-005	Where should I farm my oysters? Does natural Cadmium distribution restrict oyster farm site selection in the Northern Territory?	DPINT	123,272	FRDC Subprogram New and Emerging Aquaculture Opportunities, Collaboration Fund, Indigenous RG, NT RAC	Ongoing

2017-203	Risk from Diarrhetic Shellfish Toxins and Dinophysis to the Australian Shellfish Industry	University of Technology, Sydney	28,426	NSW RAC 20% SA RAC 10% TAS RAC 60% VIC RAC 5% WA RAC 5%	Ongoing
2015-001	Bonamiasis in farmed Native Oysters (Ostrea angasi)	Agriculture Victoria	395,832	Aquatic Animal Health Subprogram	Ongoing
2015-406	Oysters Australia IPA: development of a national Pacific Oyster Mortality Syndrome (POMS) response plan	Jan Davis	25,000	FRDC Response Research Fund	Complete
2015-232	ASI Pacific Oyster Mortality Syndrome (POMS) investigation into the 2016 disease outbreak in Tasmania - ASI emergency response	ASI	49,700	FRDC Response Research Fund	Complete
2015-239	Pacific Oyster Mortality Syndrome - resistant Oyster breeding for a sustainable Pacific Oyster Industry in Australia	ASI	984,455	FRDC and Emergency funds from C’wealth Gov’t	Ongoing
		TOTAL	$5,052,513		

Table 5. Summary of CRC-P Projects

Project Number	Project Name	R&D Provider	Total Budget ($)	Status at Dec 2019, as advised by Steven Clarke
MANAGEMENT & COMMUNICATIONS				
2016-800	Governance and management	OA and ASI	239,820	No specific FRDC report is required for this project. The relevant information will be included in the final report to DIIS
2017-233	Communication and adoption	OA and ASI	100,000	As above
R&D PROGRAM 1. BETTER OYSTERS				
2016-801	Enhancing Pacific Oyster breeding to optimise national benefits	ASI, CSIRO, SARDI, NSW DPI, Flinders Uni	1,972,777	Draft Final Report submitted
2016-802	Accelerated Sydney Rock Oyster breeding research	NSW DPI, CSIRO, SOCo, Macquarie Uni	507,650	Final Report submitted
2016-803	New technologies to improve Sydney Rock Oyster breeding and production	NSW DPI, Uni Newcastle, SOCo, Uni of Sunshine Coast	208,300	Draft Final Report submitted
R&D PROGRAM 2. HEALTHY OYSTERS				
2016-804	Advanced understanding of POMS to guide farm management decisions in Tasmania	UTAS	694,773	Final Report submitted
2016-805	Polymicrobial involvement in OsHV outbreaks (and other diseases	Uni of Technology Sydney, NSW DPI, Macquarie Uni, Uni of Newcastle, Uni Sunshine Coast	342,200	Final Report submitted
2016-806	Advanced aquatic disease surveillance for known and undefined oyster pathogens	SARDI, Flinders Uni, Uni of Adelaide, NSW DPI, DPIPWE	714,300	Draft Final Report submitted
R&D PROGRAM 3. MORE OYSTERS				
2016-807	Species diversification to provide alternatives for commercial production	SARDI, UTAS	243,426	Draft Final Report submitted
		TOTAL	5,023,246	

Communication

At the commencement of the IPA, a communication/extension plan was proposed with the following elements:

- Attendance at annual state oyster grower meetings, with bolt on focused topics, eg benchmarking when needed
- Virtual news bulletins (enews, blog site)
- Quarterly updates to OA member Executives
- Video news, a short version of the full *Seafood Industry News* used in the Seafood CRC.
- An annual, single-page report to growers on each project that detailed the return on investment expected.

This level of activity attempted to emulate the communications conducted during the Seafood CRC. However, OA did not have the human resources or the finances to conduct the activities. Consequently, the main method of communication involved the Executive Officer giving presentations to annual grower meetings. Fortunately, many of the individual projects conducted their own communications to reach end-users of their research. Examples include SOCo, *SafeFish* and ASI.

To address this situation towards the end of the CRC-P when project results were becoming available, OA contracted a communications specialist, Ms Lewa Pertl, through ASI. This enabled the following communication initiatives:

- An Oysters Australia website was established as the primary site for displaying CRC-P project results.
- A seminar was conducted in Sydney in April 2018 to provide an update on the progress of all CRC-P projects.
- A survey was conducted to obtain stakeholders' feedback on the CRC-P website and to refine the type of content stakeholders would like to see.
- Lewa Pertl updated the website on a monthly basis, with one project highlighted each month. Articles were Lewa to maintain a consistent tone, and the final versions were approved by the Project Investigators. CRC-P content included written, photographic and video content of each research project.
- To increase coverage these articles were also disseminated through additional sites, including:
    - the ASI mailing list,
    - Newsletters distributed by Oysters Tasmania, NSW Farmers, Ocean Watch and SAOGA.
    - An Oysters Australia Blog page and an "Australian Oysters" Facebook page.

Attention was also focussed on the CRC-P through the National Seafood Awards. The POMS resistance breeding program won the award for best R&D in Tasmania, then progressed to win the national R&D award.

A full report on CRC-P communication and extension activity will be available in the CRC-P Final Report.

National Issues

In the oyster industry it is the state industry bodies that conduct most of the liaison with government and media. This is logical because the Sate bodies have resources for the task and the issues are generally local, involving lease licences, food safety, training, etc.

Occasionally there are issues that involve all States and in those situations OA performs a coordination role. Three such issues occurred during the life of the IPA.

POMS Outbreak Emergency Support

The oyster industry was not well prepared for the incursion of highly infectious exotic disease. Facing an industry where many farms were losing 100% of their oysters over two to three days, the Commonwealth Government contacted OA with an offer of support. The President of OA, Bruce Zippel worked with FRDC to commission an investigation to identify the type of support that would be most useful to the industry. Ms Jan Davis, Agribusiness Tasmania, was engaged and subsequently produced her report, *A National Industry Response to Pacific Oyster Mortality Syndrome*. The principal recommendation was to support increased efforts to breed POMS resistant oysters. This work is conducted by ASI and is paid for through a levy on spat sales. With the outbreak of POMS, ASI's income from the levy would be reduced to the point that the breeding program could not be maintained.

In response, the government, through FRDC, provided $984,455 to sustain ASI's breeding program through to recovery of the industry. This was an industry saving move by OA and the government.

The Aquatic Animal Emergency Disease Response Agreement (a-EADRA)

Subsequent to the outbreak of White Spot Disease in farmed prawns in 2015, and POMS in oysters the following year, the Commonwealth Government initiated a project to put in place an agreement dealing with management of exotic diseases, similar to the agreements with other primary industries. These agreements set out how the response will be managed, how farms will be compensated and who pays.

Negotiations to establish the a-EADRA have been ongoing for the past two years and OA has represented the oyster industry at the meetings. Unfortunately, there seems little hope of a resolution in the near future.

The National Aquaculture Council (NAC)

The NAC represents all aquaculture industries on issues of national coverage and OA currently maintains membership. One of the major functions of NAC has been to liaise with APVMA to obtain minor use permits for the use of antibiotics and other medicines in aquaculture. A substantial amount of work has been done here. Epinephrine has been reapproved, Hydrogen Peroxide and Formalin permits have been extended and priority has been given to gaining approval for Oxytetracycline, Erythromycin and Praziquantel.

Governance

The governance structure of OA and its Constitution are suitable for an industry association and should work effectively. However, the governance of OA during the life of the IPA has been tested by several issues.

On the positive side, the advent of the CRC-P meant that the oyster R&D funds available in FRDC were fully allocated for the period of the IPA and a management committee was established in the CRC-P to oversee all the projects. Hence, there was little the OA Board needed to do with regard to R&D, which is its major reason for existence.

There were changes in senior personnel in all three Member State organisations and a change in OA Executive Officer midway through the IPA period. This undoubtedly contributed to reduced communication at an operational level. The consequences were a delay in the 2018 and 2019 AGMs, failure to prepare the new strategic plan, failure to renew the Executive Officer's contract and a delay in submitting this report.

New arrangements have now been put in place, including appointment of an independent chair. The appointments made are shown in Table 6.

Table 6. Oysters Australia Personnel, 2019-20

Position	**Person**
President (Independent Chair)	Dr Len Stephens
Vice President, Grower representative	Tony Troup (NSW)
Treasurer, Grower representative	Ian Duthie (Tas)
Grower representative	Caroline Henry (NSW)
Grower representative	Giles Fisher (Tas)
Grower representative	Gary Zippel (SA))
Grower representative	Judd Evans (SA)
Company Secretary	Graham Marshall, Risk Comply Pty Ltd
Executive Officer	Andy Myers (Ocean Watch Australia)

Alignment of activities conducted with the 2014-19 Oyster Strategic Plan

In January 2016 POMS was diagnosed in Tasmania and massive oyster mortalities occurred across the state. This had a substantial flow on to South Australia, where although POMS was not present, biosecurity measures meant that the supply of spat from Tasmania ceased. Under these circumstances it was not feasible to pursue the all strategies outlined in the Strategic Plan.

The industry received considerable support from government agencies to assist in controlling POMS. This included funding from the Commonwealth CRC-P program that enabled nine projects concerned with recovery from POMS to be established. These projects superseded some activities that were contemplated in the Strategic Plan.

The four overarching objectives of the plan were:

- sustainable productivity improvement
- better oyster quality
- improved consumer demand
- Increased industry capacity

The tables below align the activities conducted during the life of the IPA with each strategy, noting whether or not the Key Performance Indicator was achieved and the relevant projects.

Table 7. Projects addressing sustainable productivity improvement

Strategy	Action	KPI	Achieved?	Projects
Protect ability to farm (water qual, tenure security)	Enable grower access to technology that provides early warning of oyster stress & imminent mortality (linking environmental indicators and other relevant information	All oyster growing states have access to early warning device linking information by 2017	Partly	2016-804
Reduce costs of farming (measured through benchmarking, etc.)	Support involvement in periodical benchmarking program	Benchmarking program run once every 3 years i.e. in 2017 and workshop run on standout issues	No	
Facilitate greater production mechanisation & information technology including data collection, storage and management	Invest in technology that increases productivity through 'integrated farm management' ie allows combination of stock performance, mortality, stock movements, water quality, animal stress information in an easily accessible device	Open architecture technology developed and grower uptake facilitated by 2016	Yes	2016-803, 2016-804, Commercial App suppliers
Ensure industry sustainability	Identify and implement strategies to address climate change issues that may impact on oyster production e.g. through responding to real time and historical stock performance info	All oyster growing states have access to early warning device linking information by 2017	Partly	2016-804

Table 8. Projects addressing better oyster quality

Strategy	Action	KPI	Achieved?	Projects
Improve stock performance	Facilitate sustainable commercialisation of ASI and SOCo	ASI and SOCo are sustainable and have scoped or implemented a merge path by 2019	Yes	2017-136, 2015-239
	Invest in identified priority R&D needs in existing Pacific & SRO breeding programs	R&D investment in breeding programs is backed by grower evidence of demand	Yes	2016-801, 2016-802, 2012-760 2015-230
	Achieve high level resistance to POMS in Pacific oysters via breeding & husbandry techniques before 2018	Growers are purchasing POMS resistant stock (with other positive traits) ex hatchery by 2018	Yes	2019/039, 2016-801, 2016-802
Manage & protect against disease	Enable grower access to technology that provides early warning of oyster stress & imminent mortality (linking environmental indicators and other relevant information	All oyster growing states have access to early warning device by 2017	Partly	2016-804
	Invest in breeding and husbandry techniques required to manage emerging (unknown) diseases	R&D investment in breeding programs is backed by grower evidence of demand	No	
	Investigate ways in which mortalities can be efficiently recorded & interpreted	All oyster growing states have access to early warning device linking other information by 2017	Partly	2016-806
Manage & protect against environment related mortality	Enable grower access to technology that provides early warning of oyster stress & imminent mortality (linking environmental indicators and other relevant information	All oyster growing states have access to early warning device by 2017	Partly	2016-803, 2016-804, Commercial App suppliers
Maintain marketable trait focus alongside survival traits	Ensure marketable characteristics (condition, texture, colour, uniformity) are not lost when breeding for survival	R&D investment in breeding programs is backed by grower evidence of demand	Yes, non POMS traits held static	2016-801, 2016-802, 2012-760 2015-230
Support species diversification	Ensure native and exotic species diversification R and D strategies are supported	Uptake of native oyster *(O. angasi*)	Yes	2016-807, 2018-102 2015-001

Table 9. Improved consumer demand

Strategy	Action	KPI	Achieved?	Projects
Address consumer expectation through improving current product in market	Commercialise and broaden availability of generic oyster information at point of sale.	Oyster retail package taken up and commercialised in at least 10 businesses by 2016	No	
Partner with supply chain to improve product quality at point of sale	Identify strategies to maintain traceability & transfer of origin info of oysters along the supply chain.	At least one supply chain utilises chain traceability device/s by 2017	No	
	Identify and coinvest in new or adapted methods of reducing oyster processing and improving quality at point of sale – particularly facilitating the shift to the sale of a closed or part opened oyster	Alternative processing equipment is in commercial use by 2017	Partly	2015-238, 2018-165
Ensure harvested Australian oysters meet/exceed expected shellfish safety standards.	Coinvest in identified R&D needs required for ASQAP international equivalency	ASQAP is internationally equivalent each year	Partly	2018-004, 2015-212
Assist access to new markets (domestic and export)	Invest in consumer promotions and develop, make available and promote generic oyster material to supply chain partners & retailers.	Oyster retail package taken up and commercialised in at least 10 businesses by 2016	No	

Table 10. Increased industry capacity

Strategy	Action	KPI	Achieved?	Projects
Create and promote a national and coherent identity for the Australian oyster industry through effective process and communication.	Establish ongoing effective processes for growers to provide input into priorities and project areas.	OA holds annual face to face meetings. Information is sent to each state R&D meeting as requested.	Partly	2017-233 2016-800 2014-405
	Maintain a strong R&D group. Form an industry advocacy group if funds become available		Partly, for R&D group	2016-800
	Communicate R&D, marketing and advocacy matters using face to face via annual state conferences, a rotating 'Australian' oyster conference, quarterly enews and an annual summary.	Communication plan is executed. High	Partly, for R&D group	2017-233 2016-800 2014-405
Facilitate growers learning improved profitability techniques (including from other growers)	Encourage grower involvement, in training, bursaries and conferences. Communicate R&D, marketing and promotion and advocacy matters	Communication plan is executed.	No	
Provide a leadership culture across R&D, advocacy and market investment strategies	Ensure linkages are maintained with state organizations.	OA holds annual face to face meetings Information is sent to each state R&D meeting	Partly	2017-233 2016-800 2014-405
Develop effective, long term funding mechanisms for industry development activities	Build case & communicate with growers at each step, for a national levy comprising R&D, 'biosecurity' and marketing & promotion components.	Identify potential funding partners for key oyster industry issues	No	
	Ensure adequate resources are available for effective management and communication of existing and new R&D project activities.	Maximum leverage is achieved in all states, whether by alteration of state levy or introduction of national levy.	No	

CONCLUSIONS

There were four primary objectives of this project. Two objectives were comprehensively achieved, being the development of projects across states and managing access to fund sources additional to FRDC. The third objective, to implement a multimedia communication package for growers was partially achieved having commenced late in the project's life and only focussing on CRC-P outputs. The fourth objective, to prepare a strategic plan for 2019-24, was not achieved. However, plans are in place to prepare the plan in early 2020.

The extenuating circumstance, that prevented full achievement of all objectives, was the outbreak of POMS in Tasmania during the first year of the project. This devastating disease completely changed the priorities of the industry, from growth and market development, to survival. The industry was fortunate that Commonwealth and State governments provided a range of assistance measures to facilitate recovery from POMS.

Within that context, the IPA between OA and FRDC has been a successful method of coordinating R&D for the benefit of the whole oyster industry. Twenty-nine projects with a total value of more than $11.5 million have been implemented over the four-year agreement period. This includes $5million for the Future Oysters CRC-P, which is a significant achievement. All of these projects have delivered significant benefits directly to growers.

The industry's recovery from POMS is well advanced, in large measure due to the foresight exhibited by the industry leaders in establishing a levy system to maintain the ASI industry breeding program. This enabled POMS resistant oysters to be supplied to hatcheries within a year of the first POMS outbreak in Tasmania.

Over the next five years there will be opportunities to expand production, build markets, introduce new technology and enhance productivity. Continuation of the IPA will greatly assist these initiatives by coordinating R&D across states. With this in mind, the following changes and improvements are being considered.

i. Preparation of a new strategic plan.
ii. Engagement with emerging oyster industries in WA and NT, to expand opportunities and maintain OA's national remit.
iii. In depth consideration by OA shareholders of the breadth of activities to be undertaken. This applies particularly to OA involvement in NAC and ongoing *a*-EADRA negotiations. This should include identification of a source of funds for those activities that are continued.
iv. Maintaining contact with researchers conducting projects that are relevant to the oyster industry but do not come under the auspices of the IPA.
v. Implementation of a simple, realistic, affordable communications plan that allows effective communication with growers and researchers about OA activity.

APPENDICES

Appendix 1. Income and expenditure for all projects

Description	2015-16	2016-17	2017-18	2018-19	2019-20
Income					
TAS Contribution	52,500	52,500	52,500	52,500	50,000
SA Contribution	65,000	65,000	63,250	30,000	30,000
QLD Contribution					
NSW Contribution	81,119	85,460	101,838	116,683	126,106
Leveraged component of the $60,000 NSW Project contribution 2014-040	10,840				
FRDC management fee (8%)	- 33,513	- 32,474	- 34,814	- 31,869	- 37,760
FRDC Leverage	209,459	202,960	217,588	199,183	206,106
2018-004: Project Income				1,053	1,755
2015-212: Project Income		3,120	1,560		
2015-037: Project Income			170,000		
2014-040: Project Income	60,000				
Total	445,405	376,566	571,922	367,550	376,207

Expenditure					
2018-004:SafeFish 2018-2021				- 19,725	- 20,007
2017-136:SOCo Financial Strategy Workshop 17 November 2017			- 6,200		
2016-808:Future Oysters CRC-P: Income from ASI; FRDC OA PIRSA Contributions; and uncommitted extension funds management project		- 41,056	- 50,047	- 50,047	- 8,849
2016-807:Future oysters CRC-P: Species diversification to provide alternatives for commercial production			- 5,630	- 5,630	- 3,739
2016-245:Development of sector-specific biosecurity plan templates and guidance documents for the abalone and oyster aquaculture industries		- 833	- 8,329	- 832	
2015-706:Seafood CRC: overcoming technical constraints to Sydney Rock Oyster hatchery production	- 1,000	- 1,000			
2015-239:Oysters Australia IPA: Pacific Oyster Mortality Syndrome - resistant Oyster breeding for a sustainable Pacific Oyster Industry in Australia	0	0			

2015-232:Oysters Australia IPA: Australian Seafood Industries Pacific Oyster Mortality Syndrome (POMS) investigation into the 2016 disease outbreak in Tasmania - ASI emergency response	0	0			
2015-230:Oysters Australia IPA: genetic services for the multi-trait, single pair mated Sydney Rock Oyster breeding program	- 19,333	- 29,000	- 29,000	- 9,666	- 9,667
2015-229:Oysters Australia IPA -workshop – identifying knowledge gaps for development of the native oyster aquaculture industry in South Australia	- 18,074		- 1,000		
Description	2015-16	2016-17	2017-18	2018-19	2019-20
2015-212:SafeFish - research to support food safety, trade and market access	- 32,201	- 27,417	- 10,473	- 5,200	
2015-037:Oysters Australia IPA: the use of FRNA bacteriophages for rapid re-opening of growing areas after sewage spills	- 27,818	- 137,162	- 65,293	- 40,000	
2014-721:Seafood CRC: Australian Seafood Industries Quantitative Genetics Analysis and Training Services 2014-15 (2014/721 Communal)	- 22,281				
2014-405:Oysters Australia IPA: Australian edible oyster RD&E investment via Oysters Australia strategic plan 2014-2019	- 82,592	- 35,488	- 36,198	- 36,920	- 47,799
2014-040:Oysters Australia IPA: Pacific Oyster Mortality Syndrome (POMS) – closing knowledge gaps to continue farming C. gigas in Australia	- 121,333	- 157,852	- 99,075	- 42,720	- 42,720
2013-708:Seafood CRC: safe spat rearing experiment					
2013-234:Survey of Foodborne Viruses in Australian Oysters	- 22,380	- 22,380			
2013-054:Reducing the impact of paralytic shellfish toxins on Australian shellfish industries	- 37,912				
2012-760:Seafood CRC: genetic selection for resistance to Pacific oyster mortality syndrome	- 326,460	- 30,000	- 68,329	- 40,000	
2012-740:Seafood CRC: evaluating the impact of an improved retailing concept for oysters in fishmongers	- 12,782				
Total	- 724,165	- 482,188	- 379,575	- 250,741	- 132,782
Annual Balance	- 278,761	- 105,621	192,347	116,808	243,425
Cumulative Balance	240,840	135,218	327,565	444,374	687,799

Appendix 2. Project Summaries

PROJECTS SUBSTANTIALLY FUNDED BY OA IPA (2014-2019)

2018-004 *Safefish* 2018-2021

Alison Turnbull, SARDI

PROJECT OUTLINE
Maintaining and enhancing market access for Australian seafood is critical for future industry growth. SafeFish makes a significant contribution to this by carrying out three types of projects:

1. Food safety incident responses. The SafeFish partners come together during each incident to provide industry and government with immediate technical information required to respond to the incident. Subsequently, technical input is provided to update policies for prevention of similar incidents and respond to them should they recur. Appropriate technical responses reduce the impact of food safety incidents and ensure better outcomes for future management.

2. Technical input to inter-government consultations on food regulations and market access. It is essential for the Australian seafood industry to participate in consultations such as Codex to ensure that proposed new, or modified, regulations are pragmatic and cost-effective for the Australian seafood industry. It is far easier to influence standards under development than after they have been finalised. Similarly, it is essential for the seafood industry to stay in close contact with Food Safety Australia and New Zealand (FSANZ) when domestic food safety regulations are reviewed.

3. Proactive research, risk analyses and training. The safety of Australian seafood is not negotiable in domestic and international markets. Over recent years SafeFish has conducted many activities to assist the industry anticipate and minimize food safety risks. The objective of the activities has always been to identify and mitigate risks before they cause a problem, or to grow knowledge to enable us to improve our risk management in a cost effective manner.

Objectives

1. To deliver robust food safety research and advice to industry and regulators that underpins Australia's reputation as a producer of safe seafood.

2. To maintain and enhance the capabilities in Australia to provide that research and advice in a cost effective, efficient and timely manner.

2017-136 SOCo Financial Strategy Workshop, November 2017

SOCo

SUMMARY
The objectives of workshop were:

1) To leave the workshop with an approach, agreed by all, that sets a financially viable model for SOCo post 2019 and into the longer term. Possibly have a follow up workshop or meeting in one year’s time.

2) Have more than one roll out action plan in place for short and long term objectives to allow for flexibility / options if necessary. Action plan(s) must include industry consultation and fulfil the needs of SOCo and the industry.

The workshop participants recommended that an industry wide levy be applied to growers to fund the breeding program in the short term.

In doing so, workshop participants: 1. Affirmed the statement of support for this recommendation by the Chair of the Oyster Committee and workshop attendee Caroline Henry, and other participating committee members. 2. Recognized the commitment of the wider industry to the breeding program through the Oyster Industry Strategy. 3. Acknowledged that a levy to ensure the continuation of the breeding program must be supported by a raft of strategies to increase the hatchery production of selected lines.

As hatchery production increases, the breeding program and industry access to its commercial lines through SOCo operations will become commercially sustainable.

2015-037 Oysters Australia IPA: the use of FRNA bacteriophages for rapid re-opening of growing areas after sewage spills

Kate Hodgson, SARDI

SUMMARY
This project undertook an investigation of the use of FRNA bacteriophages (phages) as indicators of viral contamination in shellfish after adverse sewage events. The human enteric viruses Norovirus (NoV) and Hepatitis A virus (HAV) are the most commonly reported foodborne viral pathogens associated with shellfish. The viruses are bioaccumulated by shellfish when sewage enters water in the growing areas.

A background study was conducted over an 18 month period from July 2016 to December 2017. Five “at risk” growing areas were sampled on a monthly schedule. Three areas in NSW and two in Tasmania were selected on the basis of a history of previous sewage spills and closures. Five adverse sewage events that occurred in 2017 were also investigated, two in Tasmania and three in NSW. Samples were collected as soon as possible after the event ceased, then 7 and 21 days post the event. In addition to analysis for FRNA phages, these samples were also analysed for E. coli and NoV and HAV. A guidance document has been prepared for regulators and growers to assist in the application of FRNA phage levels as a management tool following adverse sewage incidents in bivalve shellfish growing waters. State based regulators and laboratories were invited to nominate appropriate staff to participate in training in the procedures for FRNA phage enumeration in bivalve shellfish.

Background FRNA phage levels have been established for the five ‘at-risk’ growing areas. A baseline of 60 pfu/100 g shellfish flesh is appropriate for all areas. Titres higher than 60 pfu/100 g shellfish flesh and very high spikes were noted in some samples collected in winter months from Brisbane Water NSW, Island Inlet and Pittwater Tas. The sources of these have not been elucidated but may be birds and/or domestic and agricultural run-off. A conservative approach would be to establish the 60 pfu/100 g shellfish flesh level year round in these three areas, however, the potential for maintaining a closure based on high FRNA phage titres in winter is recognised. Consequently, it may be worth collecting more data on the levels and sources of phage in these growing areas during winter in order to consider setting a higher baseline for during this season. The aim of the adverse

sewage event investigation was to confirm the validity of using FRNA phages as indicators of human enteric viruses in bivalve shellfish. A conservative indicator may or may not be present in the absence of the pathogens, however, it should always be detected if the pathogen is detected. FRNA phages were below the level of detection (30 pfu/100 g shellfish flesh) for 53 of the total 76 adverse event samples. FRNA phages were detected on 16 occasions in the absence of human enteric viruses. In one adverse event, a trace level of NoV was detected in one day 1 sample with a corresponding phage titre of 150 pfu/100 g. NoV was detected at very low levels in 6 samples where FRNA phages were below the level of detection, that is <30 pfu/100 g shellfish flesh. The results have not corroborated the presence of FRNA phages in all samples with detectable levels of NoV viral genomes. The molecular method for human enteric viruses, qRT-PCR, detects the viral genome which may be naked non-encapsulated or degraded viral RNA and viruses with damaged capsids that cannot initiate infection. There is no method available at this stage to differentiate between infective and non-infective viruses. FRNA phages are detected and enumerated by plaque assay resulting in an infective titre. PCR and the plaque assay are not directly comparable. No comment can be made regarding the infectivity of the NoV detected in those shellfish. Two growing areas were re-opened in under 21 days using the FRNA phage data. NoV was detected in day 1 samples from one growing area. No illnesses have been reported. The guidance document for regulators and industry on appropriate implementation of this method has been compiled. It outlines design of adverse event investigations including recommendations on the investigation design, appropriate

Laboratory training in the FRNA phage procedures was held on the 7th and 8th November 2017 at the SARDI FSI Laboratories in Adelaide with representatives from the Port Macquarie Hastings Environmental Laboratory, TasWater and SARDI in attendance. A detailed laboratory workshop manual was prepared including relevant appendices.

The application of FRNA phages as virus indicators has the potential to significantly reduce losses to the oyster industry due to sewage spills. The option to reopen growing areas in under 21 days, provided all parameters considered by the regulators are acceptable, should limit the financial impact of an adverse sewage event. For example, one three week closure in the Pittwater growing area was estimated to cost in the range of $250-$400k combined sales, depending on the season.

The industry has taken a conservative approach to shellfish production which has been responsible, in part, for the very low prevalence of human viruses in shellfish at production. FRNA phage data should complement this approach providing added confidence to industry and consumers of the safety of the product.

At the same time consideration must be given to the potential cost to industry if a growing area is reopened in under 21 days on the basis of FRNA phage results and then implicated in an outbreak of foodborne viral illnesses.

Expansion of background studies to other “at risk” oyster growing areas is recommended. Ideally a growing area will have determined the background phage level prior to applying FRNA phage testing after an adverse event. There will be a cost associated with the testing necessary to establish the background, however, a growing area could be disadvantaged if the background is higher than 60 pfu/100 g shellfish flesh and results after a spill could lead to an unnecessarily extended closure.

We also recommend further analysis of samples for FRNA phages, NoV and HAV after adverse sewage events to provide more information on the effectiveness of this technique. The number and types of events investigated was limited, therefore, more data relating to a variety of scenarios including large spills are required. In addition, epidemiological data must be included to verify, if possible, the safety of shellfish from growing areas where the reopening has been brought forward following an adverse event by the application of the ASQAAC guideline.

Investigation of the FRNA phage sources isolated from background and adverse event samples to confirm whether the origin of the phage isolates is human or animal is also recommended. Brisbane Water and Pittwater are recommended due to occasional elevated background phage levels. There are a number of published methods for source tracking and development of source tracking capability in an Australian laboratory would be valuable.

2015-212. *SafeFish*. Research to Support Food Safety, Trade and Market Access

Natalie Dowsett, SARDI

SUMMARY
During the three year project, SafeFish has built strong governance arrangements and has a clear model of operations that is detailed in the SafeFish Charter. SafeFish partners include representatives from DAWR, FRDC, FSANZ, SARDI, ASQAAC, STAG, SIA, Sydney Fish Market and an industry representative from the seafood processing company Simplot.

The partnership approach has been successful in leveraging the expertise and time provided by FSANZ, DAWR, FRDC, key industry members and researchers. It is an active, engaged group of representatives, investing time and resources in key issues that impact seafood safety and trade through a unified platform. This is a strong asset to the seafood industry going forward as a central point of contact for when issues arise, as well as a tool to assist in driving resolutions.

SafeFish monitored the activities of six Codex Committees during this project. As a result, over 300 documents were reviewed, resulting in actions on 40 items, including 17 submissions to support a response from Codex Australia. Topics included histamines, methyl-mercury, ciguatera, veterinary drugs, food additives, foodborne parasites, Aqui-S Isoeugenol (Korean SPS notification), and heavy metals (Hong Kong SPS notification). Technical representatives were funded to attend two Codex meetings to support Australian delegations. Input to Codex is essential to ensure the standards under development are not overly onerous and reflect the Australian situation. For example, SafeFish assisted in the changes to the histamine standard to provide simple risk commensurate standards with good practical advice on temperature control to achieve desired outcome, and changes to the methyl-mercury standard that will avoid rejection of significant volumes of high value Australian fish at export, but still support public health requirements.

SafeFish has produced technical reports on high priority issues identified by the SafeFish partnership through prioritisation exercises. These include reports on: validation of rapid test kits for use by bivalve shellfish sectors in detecting paralytic shellfish toxins; food safety risks associated with minimally processed, chilled and extended shelf-life seafood; the food regulatory systems covering bivalve shellfish in place in Australia (to assist with re-negotiating market access for bivalve shellfish to the United States); an application to allow Australian abalone containing sodium metabisulfite to be exported to China; a review of all available tools that can be used in determining the authenticity of Australian seafood products; and hazard identification sheets of current and emerging issues affecting seafood. This work has assisted the Australian seafood industry to meet their food safety obligations, provide novel risk-management options, assisted in maintaining or re-opening markets to Australian products, and provided technical support, training and capability to seafood businesses, the seafood industry, researchers and regulators.

Another important benefit from SafeFish has been the development of capability to address food safety and market access issues in Australia. SafeFish has invested in training regulators, researchers and industry personnel. We have provided opportunities for travel to technical conferences, organised expert working groups to address key issues and built laboratory expertise where required.

OA have extended commitment ($20,000 pa) to Safefish for a further 3 years through the project 2018-004: SafeFish 2018-2021

2015-229 Oysters Australia IPA -Identifying knowledge gaps for development of the native oyster aquaculture industry in South Australia

Xiaoxu Li, SARDI

SUMMARY
The 2015-229 “Oysters Australia IPA - workshop - identifying knowledge gaps for development of the native oyster aquaculture industry in South Australia” brought together oyster farmers, hatchery operators and scientists from across Australia to share their knowledge and experience with native oyster (*Ostrea angasi*) aquaculture and help to identify the key knowledge gaps in the production chain. Through presentations and group discussions, a number of research and development needs were identified. These were categorised into seven key areas: early life history/genetic improvement, farming, oyster health, post-harvest, marketing and branding, industry network and training and education. Across these categories, 19 key research and development needs were identified and prioritised via a post-workshop survey. The following four research and development needs were prioritised as being most important:

- Having a constant and reliable spat supply
- Development of a selective breeding program to improve Bonamia resistance, growth rate, meat/shell ratio, colour, lustre, etc.
- Establishment of good husbandry practices (e.g. handling, density, growing heights, sub-tidal vs. intertidal, seasonal effects, a system to suit *O. angasi* production)
- Increase the shelf life/improve packaging/develop processing methods.

Identifying these needs will help to target future research to meet industry priorities and establish/develop the South Australian/Australian native oyster industry.

2015-230 Genetic services for the multi-trait, single pair mated Sydney Rock Oyster breeding program

E Wilke, Select Oyster Company

The SRO breeding program historically used mass selection to achieve major improvements in fast growth and disease resistance. Mass selection has several disadvantages which include the inability to control inbreeding, select for multiple traits and predict genetic gains for each trait. Through refining breeding techniques, and quantitative genetics guidance, this program has transitioned to one that uses single-pair mated families for among-family selection where the parentage of individuals used as broodstock is recorded. This type of breeding program requires regular family breeding runs, broodstock holding facilities, field trials for performance evaluation, a data management system and quantitative genetics analyses for selection decisions, inbreeding management, and strategy formulation.

This project has seen the development of the first commercially accessible SRO family-based breeding program. The reasons for this project were to determine the technical feasibility of a SRO family breeding program for industry. It was done by developing SOCo Selective Breeding Database, which consolidated thirteen years of breeding program data. Historical data has guided and validated successive field data collection methods for future year classes, developed a robust breeding program methodology and, provided industry with stock containing the genetic gains defined by the SRO industry via commercial hatchery production. A technical committee consisting of representatives from SOCo, NSW DPI and CSIRO was created to ensure that targeted breeding objectives set by industry could be achieved using feasible and repeatable breeding operations.

The SRO family-based breeding program produced EBVs for QX disease resistance, growth, condition, width index and depth index for each family and currently includes 2014YC, 2015YC, 2016YC and 2017YC. Genetic parameters have been estimated for QX disease resistance, growth rates and condition. The breeding goals for QX resistance and total weight appear possible with two additional year classes, allowing commercial release of product that meet those criteria by 2021. The condition goal is more difficult, and it is expected to take 4 to 5 year classes to meet that goal given the request to prioritise QX resistance and growth. Progress to incorporate winter mortality disease resistance has been hindered due to the absence of winter mortality disease at field trial sites.

Through this project an annual SRO breeding strategy has been developed so that the next generation of EBVs are made available to commercial hatcheries, and therefore to industry, within a year from breeding from selected broodstock. The commercial uptake of over 15,000,000 selected stock spat is a good indication of the current performance of the SRO family breeding program.

This project has delivered the necessary components for industry to run the SRO breeding program, which is now commercial and readily accessible for industry. The data management system has been developed and industry, through the technical committee, have the capacity to manage the program. The method for performance evaluation of families has been determined and is being documented in a SRO Breeding Manual (part of the concurrent projects CRC-P Project 2016-802: Accelerated Sydney rock oyster breeding research and CRC-P Project 2016- 803: New technologies to improve Sydney rock oyster breeding). Outsourcing of specialised services is required for genetic advice and analyses as well as breeding. Future development is needed in securing ongoing quantitative genetics analyses, maintaining a data management system, and commercialisation of the breeding program.

2015-232 ASI Pacific Oyster Mortality Syndrome (POMS) investigation into the 2016 disease outbreak in Tasmania - ASI emergency response

M Cunningham, ASI Pty Ltd

SUMMARY
This report details the emergency response undertaken by Australian Seafood Industries in response to the POMS outbreak in Tasmania in January 2016. The project activities occurred from February to June 2016 in locations affected by POMS. The project had three main objectives. The first was to rescue the latest generation of ASI Pacific Oyster families located at Shellfish Culture’s Pipeclay

Lagoon land based facility. The second was to gather POMS mortality data from ASI family lines located in affected areas. The third was to be able to undertake activities which lead to a fast tracking of family line commercial multiplication to allow industry to have access to the best commercial families at the earliest possible time. To allow this survival data was collected, the results were analysed and compared to previously collected data in NSW and a broodstock inventory developed. This allowed ASI to swiftly provide the most resistant family lines to commercial hatchery producers to facilitate industry restocking. The outcome has been that growers will be restocking their farms with stock with useful levels of POMS resistance in the coming season. There is a clear requirement for ongoing work to both continue and accelerate the genetic gains in POMS resistance. Areas for further research and development are ensuring the gains made in POMS resistance are available nationally, developing the capability to breed from animals that have survived POMS and to develop better estimations of survival at different sizes and life stages.

2015-239 Pacific Oyster Mortality Syndrome - resistant Oyster breeding for a sustainable Pacific Oyster Industry in Australia

ASI Pty Ltd

PROJECT OUTLINE
This project was established with the help of the Commonwealth Department of Agriculture and FRDC to ensure the survival of the ASI breeding program following the outbreak of POMS in Tasmania.

The occurrence of POMS in Tasmania and the consequential quarantine and control procedures implemented between States to limit spread of the disease means that sale of normal oyster spat will be minimal for the foreseeable future. Ensuring the fast tracking of ASI's breeding program for improved genetic progress and commercial supply was assessed as the top priority for industry in the recently released report "A National industry response to Pacific Oyster Mortality Syndrome (POMS)" authored by Jan Davis for Oysters Australia. (FRDC project 201 5-406).

Objectives

1. To achieve genetic gains n� POMS resistance in the ASI population by 14% per year.
2. To commercialise the most resistant ASI families to improve commercial viability of Pacific Oyster growers in Australia. Broodstock with a predicted survival as 1 year old animals of 80% commercially available by the end of the project.
3. Support industry peak bodies in their consideration of mechanisms for emergency response arrangements.

2014-040 Oysters Australia IPA: Pacific Oyster Mortality Syndrome (POMS) – closing knowledge gaps to continue farming *C. gigas* in Australia

P Hick - University of Sydney

SUMMARY
Microvariant genotypes of Ostreid herpesvirus 1 (OsHV-1) have emerged since the first detection in France in 2008 to impact Pacific oyster farming in Europe, Australia and New Zealand. This virus is the cause of a high mortality disease that has reshaped farming of Pacific oysters (Crassostrea gigas). Several concurrent research methodologies have been employed to generate an understanding of

the epidemiology of OsHV-1 and the disease it causes, Pacific Oyster Mortality Syndrome (POMS). Long-term engagement with farms in affected waterways has enabled descriptive studies of disease outbreaks to generate hypotheses about the disease that have been tested with replicated field trials and a controlled laboratory infection model. Improved understanding of the epidemiology of POMS enables rational disease control strategies to be developed for use on farms.

This project was developed based on the findings of previous research and in consultation with industry. The unpredictable nature of POMS has hampered efforts to farm Pacific oysters in the presence of OsHV-1 and to plan for an industry with an unknown distribution of the virus. There was a requirement to better understand factors which influenced the occurrence and severity of disease to enable decision making at individual farms and at industry and policy level. The overall aim of better understanding the epidemiology of POMS was addressed through:

- Risk factors for occurrence of POMS were determined using a long-term intensive program of sentinel surveillance with deployment of spat and concurrent collection of environmental data.
- Risk factors in the setting of commercial farming were evaluated through detailed disease outbreak investigations of index cases.
- Descriptive studies of preliminary adaptive farming methods that incorporated window farming and stock management informed by monitoring of risk factors.
- Prediction of POMS risk in areas presently free of OsHV-1 was enabled by detailed data collection including high resolution water temperature monitoring at the location of oyster leases in all important growing areas.
- To better understand the host risk factors for mortality and determine if resilience of oysters to OsHV-1could be improved by
- Improving host oyster resilience to disease through manipulation of the age-size relationship and prior exposure to OsHV-1.

Characterisation of OsHV-1 isolates to determine if differences in virulence or transmissibility of the pathogen could contribute to variable disease outcomes

Across 5 summers of sentinel surveillance in the Georges and Hawkesbury Rivers, the earliest and latest date of disease occurrence was 28th October and 14th May. The onset date showed minimal variation across years. Mean daily water temperature in the oyster baskets rose above 20°C in mid-October and fell below 17°C after mid-May. These temperatures were taken to define the seasonal risk for POMS. It was noted that the surveillance sensitivity was not sufficient at the intra-estuary level to capture all OsHV-1 transmission events, despite the use of 15 sites. Disease investigations in commercial and research oysters detected additional incidence of POMS, consistent with the clustered nature of this disease. Mortality due to OsHV-1 in sentinel spat was diminished after 2013, although the transmission of the virus appeared to remain constant every year. Mortality due to diseases other than OsHV-1 observed in all years and was highest in the summer of 2015-16. Transmission of OsHV-1 occurred at all sites except Patonga Creek, indicating that the range of benthic communities, freshwater in-flow and oceanic influences were not important risk factors. However, disease did not occur at 1 of 2 sites at Kimmerikong which was partitioned by a tidal barrier. Taken together with the observation at Patonga Creek this suggested that local hydrodynamics are important in OsHV-1 transmission. The final season of the spat surveillance indicated more frequent incidence of POMS in spat that were unselected compared to a co-deployed POMS resistant line of spat, although the degree of mortality was similar when disease occurred in both batches.

Interstate water temperature monitoring predicted that the duration of POMS risk was longer than the Hawkesbury River in Northern NSW estuaries, and slightly shorter in Southern NSW estuaries that are not yet impacted by POMS. The window of infection in Tasmania is substantially shorter than NSW. This creates more profitable options when considering window farming and stock management calendars. In South Australia, the water temperature profile suggests a POMS risk period of similar duration to NSW. Challenge of spat with OsHV-1 at a sub-permissive water temperature and titration of the dose of virus was able to generate a high proportion of PCR positive survivors of disease. However, spat <6 months of age that survived pre-exposure did not have a survival advantage when rechallenged with OsHV-1. Preliminary experiments using spat >6 months of age and >5 cm shell length indicated that surviving an OsHV-1 challenge at 18°C conferred a specific reduction in the hazard of mortality when the oysters were subsequently challenged at 22°C compared to oysters pre-exposed with an OsHV-1 free tissue inoculum or no pre-challenge. Farmers are able to make stock management decisions based on the protective effect of increasing age. The hazard of death for oyster spat (8 months old) was 5.5 times that of adult oysters (17 months old) after adjusting for variation in exposure due to location in the field. However, accessing the substantial decline in susceptibility to POMS that is observed over 12 months of age requires an OsHV-1 free growing location for at least one summer season. In managing stock of any given age, the oysters which grow larger under standard growing conditions are more likely to survive POMS. The hazard of death for smaller spat and adult oysters was 1.9 times that of larger individuals from the same groups. However, no advantage was conferred by attempting to manipulate the growth of oysters to produce larger oysters at a given age. Laboratory trials using oysters prospectively differentiated for size indicated that growth restricted (smaller) spat were relatively protected (hazard ratio 0.6) compared to those grown to a larger size. Conversely, for adult oysters the hazard of death was higher (HR=2.3) for the growth restricted (smaller) oysters. Further investigation is required to understand how energetic reserves and physiological condition impact on POMS disease expression before attempting to manage disease by altering growth. Implications and Recommendations

Improved understanding of the potential for long range transmission of OsHV-1 indicate that disease management plans should consider the potential for the majority of growing areas in Australia to be impacted in the future. When OsHV-1 is present in a region it becomes endemic and causes seasonally recurrent disease. The attenuation in disease severity observed with surveillance using sentinel spat most likely reflects reduced stocking density in NSW estuaries.

Farmers need to develop stock management calendars and window farming that incorporates known risk factor information to minimise production losses caused by POMS. Considerations include the on-lease thermal profile, local hydrodynamics, the age-size profile of oysters and the exposure history of the stock to OsHV-1. To maximise production with advantages conferred by stock selectively bred for resilience to POMS requires management of disease at bay level. Coordinated stock management will be important in reducing the OsHV-1 infection pressure to maximise the advantage conferred by genetically resilient stock.

This research has highlighted key areas for further research activity that are likely to assist Pacific oyster farming:

There may be opportunities to increase the resilience of spat > 6 months of age through controlled pre-exposure to OsHV-1. Further research considering disease pathogenesis and immune response is necessary to underpin studies which might provide a practical disease management tool

- Epidemiologic approaches to understanding of the risk factors for diseases other than POMS that cause of mass mortality of Pacific oysters are required. Integrated approaches to disease management that consider methods of reducing the impact of all possible disease threats concurrently will be essential to assist farmers in the future.
- Surveillance for low virulence genotyopes of OsHV-1. Attenuated strains of the virus should be isolated and investigated to determine how infection with a low virulence OsHV-1 isolate might alter or prevent infection with more virulent genotypes.
- Further evaluation of the local hydrodynamic effects on transmission of OsHV-1 should be investigated in new environments where OsHV-1 becomes endemic. Consultation with farmers to develop and evaluate growing infrastructure that minimise the impacts of known risks for high mortality disease is warranted in conjunction with this objective.

2012-760. Genetic selection for resistance to Pacific Oyster Mortality Syndrome

P Kube, CSIRO

SUMMARY
This project has resulted in the commercial production of Pacific oysters that are resistant to Pacific oyster mortality syndrome (POMS). It has, therefore, provided the Australian Pacific oyster industry with a practical and immediate means to respond to the threat of this disease. The knowledge from this research has formed the basis for POMS resistance breeding and the seamless links between research and industry within this project have ensured that resistance breeding is now fully operational, it is the primary objective of the ASI selective breeding program, and disease resistant broodstock is available to hatcheries for commercial production. The genetic gains for POMS resistance already delivered to industry plus the surety of ongoing gains provide Pacific oyster growers in disease affected regions with a way forward and with confidence to continue in the face of the devastating consequences of this disease.

FRDC PROJECTS RELATED TO OYSTER AQUACULTURE NOT FUNDED THROUGH OA IPA

2019-039 South Australian Pacific Oyster selective breeding program. Building POMS resistance to reduce risk for the South Australian oyster industry

Xiaoxu Li, University of Adelaide

Funding source – FRDC Research response fund, Flinders Ports, PIRSA

PROJECT OUTLINE
Due to the recent detection of POMS in wild Pacific Oysters in the Port River, the SA industry urgently need POMS resistant oysters. Having POMS resistant oysters stocked onto farms prior to any potential outbreak will be critical for protecting the industry from significant losses and financial impacts.

To achieve a resistance level of over 90%, the SA Pacific Oyster selective breeding program will need to establish at least three more generations of families for genetic improvement after the completion of the Future Oysters CRC-P project in 2019.

Establishing the SA Pacific Oyster selective breeding program requires specific techniques and skills. SARDI is the only organisation in SA that has the purpose-built hatchery facility for this species and has produced target numbers of Pacific Oyster families over the last three seasons. SARDI also has a well-established team in oyster genetics and bivalve hatchery technologies.

To support the Stage 2 development of the SA selective breeding program, Flinders Ports, in partnership with the Fisheries Research and Development Corporation (FRDC), ASI, SAOGA and PIRSA-SARDI will jointly fund this project for the SA oyster industry to address POMS risks, and further mitigate the risk factors associated with the spread of POMS outside the Port River related to dredging activities in the Outer Harbour.

Objectives

1. Develop selective families with 90% POMS disease resistance for ≥ one year old Pacific Oysters

2. Support the SA industry by provision of high POMS resistant broodstock for commercial spat production

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2018-005 Where should I farm my oysters? Does natural Cadmium distribution restrict oyster farm site selection in the Northern Territory?

Matthew Osborne, DPIRNT

Funding source – FRDC Northern Territory Research Advisory Committee, FRDC Indigenous Fishing Subprogram, FRDC New and Emerging Aquaculture Opportunities Subprogram, FRDC Collaboration fund

PROJECT OUTLINE
RD&E that addresses critical hurdles to Aboriginal capacity and enterprise development (e.g. quality assurance strategies) have been identified as priority areas of the NT RAC and the Indigenous Reference Group (IRG). NT Fisheries has been conducting research to support Aboriginal aspirations to establish tropical oyster farms in the Northern Territory (NT). Heavy metals have been a longstanding concern as an impediment to the development of a tropical oyster industry. Cadmium

(Cd) bioaccumulates in the tissue of oysters, and unlike *E. coli* or toxic algae, has a long depuration period. As a result, Cd levels are a major determining factor on the saleability of farmed tropical oysters.

McConchie, D.M & Lawrance, L.M (1991) and FRDC Project 2012-223 identified high Cd concentrations, which varied considerably across locations and water depth, in blacklip oysters (Saccostrea echinata) at location in Shark Bay, WA and South Goulburn Island, NT respectively. Following these projects naturally occurring heavy metals have been a presumed barrier to the establishment of an oyster industry in the NT, due predominantly to the exceedance of Cd trigger levels in the Food Standards Australia and New Zealand (FSANZ). However, recent testing on market sized oysters farmed on long line trials at Pirlangimpi on Tiwi Islands have not shown high heavy metal concentrations and complied with the FSANZ. This suggests that Cd exceedance may not be an issue in all locations.

We propose a multi-location survey of blacklip oyster (Saccostrea echinata) heavy metal concentrations across the NT to identify the best locations for commercialisation of this emerging aquaculture species. With the aim of identifying locations, like Pirlangimpi, that could produce oysters that comply with the Food Standards Australia and New Zealand (FSANZ). The results are needed to inform the development of a NT tropical oyster industry and the establishment of a NT shellfish quality assurance program.

Objectives

1. Map the distribution and concentration of Cadmium in wild blacklip oysters across the Northern Territory.
2. Aboriginal communities better understand the role of shellfish quality assurance programs and the implications of Cadmium on oyster farming.
3. Risks associated with Cadmium are better understood and inform the development of a NT Shellfish Quality Assurance Program.
4. Knowledge is shared and retained through Aboriginal participation in the research project.

2018-090 Improving early detection surveillance and emergency disease response to Pacific Oyster Mortality Syndrome (POMS) using a hydrodynamic model for dispersion of OsHV-1

Shane Roberts, PIRSA

Funding source – FRDC Research response fund

PROJECT OUTLINE
Pacific Oyster Mortality Syndrome (POMS) is a disease caused by Ostreid Herpesvirus type 1 (OsHV-1) microvariant. On 28 February 2018 OsHV-1 was first detected in Port Adelaide River feral oyster populations. PIRSA and industry mounted an immediate emergency response aimed at containing the virus to the Port and preventing spread to the nearby oyster industry (>25km away). In the absence of accurate information, surveillance designs and emergency response plans (including translocation protocols) assume a disease spread distance of 5NM (<10km) to define epidemiological units for all water bodies. That uncertainty causes policy makers to take a conservative approach. Consequently, there is a need to improve the accuracy of predictive information used to manage such aquatic disease incursions.

A recent FRDC project (2006/005) demonstrated how various oceanographic data can be incorporated into a hydrodynamic model (e-SA marine system) to map past, present and future ocean conditions. This project will provide a case study for how such a model can predict pathogen spread to underpin improved surveillance designs, effective emergency disease response and appropriate biosecurity zoning for translocation protocols.

Objectives

1. To model viral particle dispersal at key locations around the State, including commercial oyster growing areas, known feral oyster populations and ports, and incorporating seasonal oceanographic parameters

2. Using hydrodynamic model outputs, identify epidemiological units to inform surveillance, disease management and emergency disease response activities

3. Demonstrate how hydrodynamic model outputs of predicted viral particle dispersal can be used to develop a risk-based surveillance design for the detection of OsHV-1.

2018-102 Understanding Ostreid herpesvirus type 1 risk: alternative hosts and in situ hybridisation

Peter Speck, Flinders University

Funding source – FRDC Research response fund

PROJECT OUTLINE
To understand the risk of OsHV-1 spreading to commercial Pacific oyster growing regions, vectors need to be understood. A major gap is to understand the importance of non-OsHV-1 hosts and their role as reservoirs and in transmission of the virus. This project will provide information to better understand this risk, and to inform the status of PIRSA's ban on take of shellfish from the Port River.

Objectives

1. Implement and validate OsHV-1 in situ hybridisation assay

2. Assess OsHV-1 infection in PCR positive non-*C. gigas* hosts using in situ hybridisation

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2018-118 Reinvigorating the Queensland Oyster Industry

Carmel McDougall, Griffith University Nathan Campus

Funding source - FRDC New and Emerging Aquaculture Opportunities Subprogram

PROJECT OUTLINE
This project is directly aligned with the FRDC's national research priority 'Developing new and emerging aquaculture growth opportunities'. There is currently considerable interest in the potential of tropical oyster aquaculture, and the blacklip oyster could represent a candidate species for the FRDC's target of advancing 'two or more emerging aquaculture species…'.

This project will provide the required baseline data of species distributions that would be required for licence/permit applications to be granted. It will also extend R&D into hatchery production technologies for the blacklip, working towards addressing the issue of poor larval settlement. The project also aligns with the Australian Government's Science and Research Priority to 'develop internationally competitive, sustainable, profitable, high intensity and high production capacity in new and existing food products'. Molluscan aquaculture has the lowest environmental cost of all animal production sectors (Hilborn et al, 2018, Front. Ecol. Environ. 16:329-335), and therefore represents the best option for the development of new, sustainable animal food products.

Objectives

1. Determine the distribution of Saccostrea species around the Queensland coast

2. Develop molecular tools to facilitate blacklip production

2018-164 Commercial production trial with high POMS tolerant triploid Pacific Oysters in approved NSW estuaries.

ASI Pty Ltd

Funding source – FRDC Research response fund

PROJECT OUTLINE

This project offers significant opportunity to accelerate the Australian Pacific Oyster industry to grow in production and value. The NSW Pacific Oyster producers, especially those in POMS affect areas require both POMS resistant oysters that have all the benefits demonstrated through the ASI breeding program, and due to local regulatory requirements, and ease of management - triploid Pacific Oysters. Triploid oysters have an additional set of chromosomes (Triploid 3n vs Diploid 2n), and this provides for increased growth and better condition for extended periods compared with diploids that lose condition through reproductive activities including spawning.

Triploid oysters are an important part of the broader Australian Industry, with producers incorporating them in production to ensure year round supply, especially in warmer climates such as NSW and SA where reproductive activity is enhanced. This project builds upon the proof of concept that ASI selectively breed lines have enhanced resilience to POMS, to deliver ASI breeding into a triploid product.

Objectives

1. Determine if POMS resistant triploid ASI oysters can improve the commercial viability of POMS affected NSW oyster farms, especially the Hawkesbury River.
2. Develop with ASI/CSIRO a recording and reporting format to assess the performance of triploid POMS resistant ASI Pacific Oyster spat cultured in the Hawkesbury River under commercial growing conditions.
3. Data collected from farms will determine performance and survival of predicted high POMS resistant triploid ASI Pacific Oysters cultured in POMS affected NSW oyster farms.
4. Develop protocols to test/sample for OsHV-u1, that are incorporated into regular assessment processes, to ensure that results can be reflected against a known challenge to POMS.

2018-165 Easy Open Oyster Machine Upgrade

Len Stephens

Funding source – FRDC National Priority 2 – Improving Productivity and Profitability of Fishing and Aquaculture

PROJECT OUTLINE
The existing prototype machine developed during the Rural R&D for Profit project needs to be ungraded to ensure it is reliable enough to be used to further test the market and attract investors. The issues to be resolved are: i. Unreliable start up and frequent stoppages. ii. The software does not have a user friendly interface, and frequent rebooting is required. v. The machine was designed to process large oysters (>65mm). With oysters in short supply it is necessary to modify the system to accept smaller oysters. vi. The robot gripping arm needs redesigning to accommodate oysters of variable shape. vii. Although the machine is operating at the speed specified at the beginning of the project, the production rate needs to be increased at least two or three fold to be profitable. viii. The manual loading and unloading of oysters requires two staff, which is unprofitable. The system needs to be reconfigured to facilitate manual handling and automatic loading and unloading must be incorporated in future machines.

This project will attempt to resolve the first four issues in the above list. Resolution of items vii and viii on the list will require significant redesign and construction of a new model of the machine. This project will facilitate the planning and early stages of the design, while the final design and costing work will be the responsibility of Scott Technology. This redesign process will also allow engineers at Scott Technology to adapt the design to accommodate production of multiple machines in future, which is an important step in reducing the capital cost of the machine.

Objectives

1. To upgrade the existing Easy Open Oyster machine to make it sufficiently reliable for commercialisation.
2. To prepare a plan for design and construction of an improved, Mark II Easy Open Oyster machine
3. To help establish Easy Open oysters in the domestic market and to assist Scott Technology to obtain orders for the Mark II machine

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2017-203 Risk from Diarrhetic Shellfish Toxins and Dinophysis to the Australian Shellfish Industry

Penelope A. Ajani, University of Technology Sydney

Funding source – FRDC Research Advisory Committees – SA, NSW, Vic, Tas.

PROJECT OUTLINE
DSTs are a significant, yet largely unquantified issue for Australian shellfish. A significant human poisoning event resulting in 56 hospitalisations from DST contamination of pipis (*Plebidonax deltoides*) in Ballina NSW in 1997. Since then, DSTs have been a major food safety challenge for the NSW pipi industry, with up to 40% of pipis in an end-product market survey between 2015 - 2017 (n=271) returning positive results for DTX, and two market place samples above the regulatory limit (NSW Food Authority 2018). DSTs have also been detected in shellfish from Tasmania with a review of data in 2015 (n=1710) finding that 0.4% of oysters (*Saccostrea glomerata*) and 0.6% of mussels (*Mytilus planulatus*) exceeded the regulatory limit (TSQAP). Since then the incidence of DSTs has increased in Tasmania, with DSTs responsible for a recall of mussels from Spring Bay Seafoods in 2016. Although low risk to date, positive DST detections occur in shellfish from South Australia (Madigan et al. 2006) and Western Australia.

In response to the significant shellfish contamination events with Paralytic Shellfish Toxins (PSTs) from 2012-17, which cost the Tasmanian economy ~$23 million, aquaculture industries are adopting efficient, fast and cost-effective management tools for PSTs and the phytoplankton producing them.

This response will mitigate the cost of harvest closures and lead to strong improvements in shellfish safety.

Objectives

1. Generate knowledge about commercial dst test kits and rapid molecular techniques (such as qPCR) for DST toxin and species detection
2. Identify DST profiles present in Australian shellfish and assess laboratory capabilities to detect these toxins
3. Compare the efficacy of commercially available toxin detecting kits using relevant sample matrices
4. Develop a quantitative PCR assay for dinophysis species detection for potential onsite farm
5. Provide cost versus benefit analysis of improved testing of DSTs in Tasmanian shellfish
6. Conduct a workshop to train interested shellfish industry members (Tas) in the use of rapid test methods for dinophysis detection and dst test kits in environmental samples

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2016-245 Development of sector-specific biosecurity plan templates and guidance documents for the abalone and oyster aquaculture industries.

Shane Roberts, PIRSA

Funding source – Then Department of Agriculture and Water Resources, Abalone Growers Association IPA, OA IPA ($9,995)

SUMMARY
This project developed industry endorsed biosecurity plans and guidance documents for the abalone farming industry and oyster hatcheries The project was led by PIRSA during late 2016 and 2017 in collaboration with co-investigators from other relevant state jurisdictions as well as industry peak bodies. At the request of industry, PIRSA facilitated the implementation of the draft biosecurity guidelines on abalone farms and oyster hatcheries, which provided good test cases. Upon Animal Health Committee (AHC) endorsement these documents will become nationally agreed guidelines and form not only an integral part of health accreditation and translocation protocols to assist in the safe translocation of oysters and abalone but also a fundamental means of protecting the sectors from disease risks.

This project was conducted in two stages for each industry sector (abalone and oysters). Stage one involved the delivery of an industry-government workshop for each sector where the proposed content for each biosecurity guideline was determined based on disease risks, disease risk pathways and risk management strategies appropriate and practical to the sector as identified by workshop participants. Stage two of the project involved a review of relevant literature, policy and biosecurity manuals of other sectors that was considered together with workshop outputs to draft guidance documents and templates. This stage also involved reviewing existing company plans and biosecurity practices used within the two sectors. Following completion of draft guidelines, all workshop participants were provided with another opportunity to actively collaborate on this project. Draft documents were provided for review prior to submission to ensure what had been produced was comprehensive, applicable on-farm and met the needs of the sector. Furthermore, PIRSA staff worked with individual farms to facilitate implementation of these guidelines. This involved reviewing farm biosecurity plans, site visits and auditing of individual farm biosecurity plans to determine appropriateness of the guidelines.

The biosecurity guidelines produced by this project provide industry with detailed guidance to develop new, or improve on existing, farm biosecurity plans and supporting documentation (e.g. Standard Operating Procedures). The guidelines include a 'farm biosecurity plan template', which was identified by industry as an important step to facilitate individual farms to implement biosecurity. Some individual farms volunteered to develop, or update, their biosecurity plan and have them audited by PIRSA to enable the testing and refinement of these guidelines. Farm biosecurity plans may be required as part of health accreditation programs, as a requirement of livestock translocation protocols or as an independent business decision to protect the farm, industry and community from disease incursions and disease spread. Depending on the enterprise's individual business needs, and cost benefit analysis, a farm may elect to adopt some or all of the best practice biosecurity recommendations outlined in the guidance documents. Following endorsement these documents will provide industry and relevant jurisdictions with a nationally agreed standard of farm biosecurity. In Australia, the current need for auditable farm biosecurity is a requirement in the AHAP for abalone livestock translocations and a requirement for oyster livestock translocation protocols (e.g. in Tasmania for movement of spat from hatcheries located within infected zones).

In order to gain the most benefit from these guidelines it is recommended that government and industry work together to implement best practice farm biosecurity. This requires an iterative process between a farm and government to develop, review, refine and adequately audit farm biosecurity. Similar farm biosecurity guidelines are now required for other sectors, particularly for sea-based farms which are heavily reliant on disease prevention measures to avoid impacts of disease. It is recommended that additional sector-specific guidelines be developed for the aquaculture industry.

2015-406 Oysters Australia IPA: development of a national Pacific Oyster Mortality Syndrome (POMS) response plan

Jan Davis

Funding source – FRDC Research response fund

There is unanimous agreement from stakeholders interviewed in researching this report that the only viable option to support recovery from the Tasmanian and NSW POMS events is the fastest possible development of a Pacific oyster resistant to POMS. This is also the only means of ensuring that the Pacific oyster industry has a long-term future in Australia as it is widely agreed that POMS will spread to South Australia at some point. The sustainable development of a POMS resistant oyster in Australia is the most important key to not only re-establishing currently affected oyster growing areas, but also to ensuring the continued growth of the Australian oyster industry.

2015-238 Rural R&D for Profit- Easy open oyster automation

Scott Automation and Robotics Pty Ltd

Funding source – FRDC National Priority 2 – Improving Productivity and Profitability of Fishing and Aquaculture

SUMMARY
This project attempted to overcome the shucking barrier by developing the idea of an *Easy Open* oyster suggested by Mr Robert Simmonds, owner of Oyster Bob Pty Ltd. This entailed making a slit in the edge of the oyster shell and resealing it with wax so that the oyster remained alive but could be easily opened later by placing a knife through the slit and cutting the muscle that holds together the two shells of the oyster. To enable production of sufficient volumes of *Easy Open* oysters the process had to be automated. It then had to be evaluated under commercial conditions.

This project used robotic technology plus vision and sensing systems based on three dimensional laser cameras to automate the *Easy-Open* process.

A prototype machine was designed and manufactured by Scott Automation and Robotics Pty Ltd and was evaluated for commercial suitability by Oyster Bob at a seafood processing factory in Adelaide.

Success criteria were established at the start of the project, as follows:

- At least 30 dozen oysters processed per hour, with minimal rejects.
- Processed oysters remain alive for at least eight days.
- Wax covering is neat and does not crack or break off during transport.
- Processed oysters can be easily opened by an unskilled person.
- Little or no shell dust found inside the oyster after cutting.
- Customer feedback is positive.
- Labels can be attached to the processed oysters.

All of these criteria were ultimately met. The process of cutting and waxing oysters is now protected by Australian Innovation Patent number 2018100256, owned by Fisheries Research and Development Corporation (FRDC).

An additional objective, of designing and manufacturing a disposable plastic opening tool, was not attempted and replaced with a more urgent need to develop a new wax delivery system. This was also achieved.

The machine and the finished products were shown to fifteen oyster wholesalers across Australia. All of these companies were impressed with the product and expressed interest in obtaining the product for their customers. Three of these wholesalers would consider co-investment in the production of additional machines, as soon as the machine is deemed to be sufficiently reliable.

Testing of vacuum packed *Easy Open* oysters held at 5℃, showed that shelf life could be extended for at least 17 days.

Thirty consumers were given the opportunity to open an *Easy Open* oyster, consume the contents and provide anonymous, written feedback on the product. Twenty-seven people described the opening process as "very easy" or "easy". When asked to indicate if they would buy *Easy Open* oysters in future, 27 people responded that they would be "very likely" or "likely" to do so.

While the project conclusively demonstrated the success of the *Easy Open* concept, the prototype machine has numerous inadequacies that must be overcome to achieve commercialisation. The following issues were identified for future research:

i. Unreliable start up and frequent stoppages.
ii. The software does not have a user friendly interface, and frequent rebooting is required.
iii. Although the machine is operating at the speed specified at the beginning of the project, the production rate needs to be increased at least two or three fold to be profitable.

iv. The manual loading and unloading of oysters requires two staff, which is unprofitable. The system needs to be reconfigured to facilitate manual handling and automatic loading and unloading must be incorporated in future machines.
v. The machine was designed to process large oysters (65mm). With oysters in short supply it is necessary to modify the system to accept smaller oysters.
vi. The robot gripping arm needs redesigning to accommodate oysters of variable shape.

A new project to resolve the above problems is planned by FRDC and Scott Automation.

Once the newly designed machine is available and commercially proven, it will deliver a revolutionary approach to oyster retailing based on the unique opening experience and the proven provenance of each labelled oyster. This will be the first time oyster provenance can be guaranteed by oyster growers. Ultimately, this invention should contribute to growth in the value and volume of oyster production in Australia. Unfortunately, this will not happen for at least three years due to the widespread outbreak of the disease Pacific Oyster Mortality Syndrome (POMS) which has decimated the supply of Pacific Oysters.

Of wider benefit to Australia will be the income and royalties from international machine sales.

2015-001 Aquatic Animal Health Subprogram: Bonamiasis in farmed Native Oysters *(Ostrea angasi*)

Tracey Bradley, Agriculture Victoria

Funding source – FRDC Aquatic Animal Health and Biosecurity Subprogram

PROJECT OUTLINE
Bonamia ostreae and *Bonamia exitiosa* are significant pathogens of oysters that cause high mortality rates and substantial economic losses to the oyster farming industry globally. As such, both pathogens are listed by the OIE (the World Organisation for Animal Health). In Australia, infection by a Bonamia sp. was responsible for the devastation of experimental aquaculture of the Native Oyster *Ostrea angasi* and adjacent wild beds in Victoria in the early 1990s. Indeed, surveys have found *Bonamia* sp. in Native Oysters in Tasmania, WA, and NSW and recent monitoring of apparently healthy stock on Victorian aquaculture sites has determined that prevalence of this Bonamia sp. is high and once again is causing clinical disease.

While the pathogen was identified as *Bonamia* sp. its relationship to the OIE-listed species, *B. ostreae* and *B. exitiosa*, is unclear. It is important to determine the identification of the Australian Bonamia to species level, to establish whether or not it is the presumed exotic species *B. ostreae, B. exitiosa*, or a different species endemic to Australia. Identification of the Australian species will clarify Australia's international obligations as a member country to the OIE, with respect to reporting and international trade. Moreover, the conditions that trigger clinical disease are unknown. Identification of the risk factors associated with the onset of disease in infected oysters is needed to implement control strategies to minimise the impact on production and industry value. This information is essential for the development of improved biosecurity and farming practices that mitigate against disease caused by Bonamia and provide industry and regulators with management and control strategies.

Objectives

1. Obtain nucleic acid sequence and compare with other, described Bonamia sp. and determine their taxonomic relationship and ensure that available diagnostic tools are suitable.
2. Improve understanding of Bonamiasis infestations in Native Oysters including the determination, under controlled conditions, of the stressors that induce clinical disease in sub - clinically infected oysters.
3. Develop a biosecurity plan and farm management practices to manage the risk of infestation and the mitigation of clinical infection with Bonamia sp.

Appendix 3. Future Oysters CRC-P Project Summaries

FRDC Project 2016/801 Enhancing Pacific Oyster Breeding to Optimise National Benefits.

Cunningham, M., et al. Australian Seafood Industries. (2020).

Executive Summary

This report details the research undertaken as part of the Fisheries Research and Development Corporation (FRDC) project **2016-801- Enhancing Pacific Oyster Breeding to Optimise National Benefits**. This was undertaken as part of the Future Oysters Cooperative Research Centre Project (CRC-P 2016-553805; Future Oysters - FO CRC-P), conducted as part of the Australian Government's Cooperative Research Centres Program. The project was led by the Australian Seafood Industries (ASI) with collaborating researchers from the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Institute of Marine and Antarctic Studies (IMAS)/University of Tasmania, South Australian Research & Development Institute (SARDI), Flinders University and New South Wales Department of Primary Industries (NSW DPI). Project activities occurred across the 3 major oyster producing states of Australia –New South Wales (NSW), South Australia (SA) and Tasmania (TAS). The research was conducted as a direct consequence of the 2016 TAS Pacific Oyster Mortality Syndrome (POMS) outbreak which decimated parts of this State's Pacific Oyster (*Crassostrea gigas*) industry and caused numerous flow on effects throughout the entire Australian industry. The project was aimed to allow continuation and improvement of the work that had been undertaken prior to the 2016 outbreak, which was not only a major disruptor to the industry but also the breeding program. New techniques needed to be established to allow continued breeding in TAS in the new POMS paradigm and operations were required to be established in SA due to the biosecurity restrictions brought about by the TAS outbreak. Aspects of the project also looked to increase the rate of genetic gains for POMS resistance by developing additional supporting technologies.

The project was conducted across multiple areas that reflected the objectives of the project. Researchers worked collaboratively to conduct research across breeding strategy development, capacity building in SA, genetic improvement, laboratory and field challenges, accelerated maturation and developing an identification tool.

The results have allowed the ASI selective breeding program to most importantly improve genetic resistance to POMS and allowed these results to be available to all Pacific Oyster growing regions. Specifically the results of this project have allowed:

- continued breeding in TAS by development of a biosecure breeding facility at the IMAS aquaculture facility. Family production has continued at the same level prior to POMS and enabled ASI to breed from Pacific Oysters which have been expose to the virus. The facility now has an approved biosecurity plan which has been externally audited and signed off by the Tasmanian Chief Veterinary Officer (CVO).
- production of 160 families in SA to enable POMS resistant broodstock to be deployed to the SA oyster industry. A project has been developed which allows further breeding in South Australia to deliver breeding outcomes for the medium term.
- improved rates of genetic improvement in the TAS population to fast track POMS resistance. The program has now developed and implemented spat POMS challenge trials that have increased gains.

- improvement in laboratory challenges which have increased correlations to field survival and a laboratory challenge at IMAS, which has been an important precursor to future work on genomics.
- accelerated maturation that has allowed increased usage of one year old animals in the ASI breeding program, which have been shown to offer increased rates of genetic gains in POMS resistance.
- development of an SNP identification tool which can differentiate between ASI and non ASI stock and different ASI families.

The results have had a massive impact on the Australian Pacific Oyster industry. In TAS there has been a significant recovery of the industry since the 2016 outbreak and this can be substantially attributed to the POMS resistant broodstock developed as part of this project. The recovery is almost complete and has resulted in the industry recovering to full stocking and employment levels within three years of the outbreak. This is internationally unprecedented with other international industries taking much longer to recover. The growers in TAS are returning to profitability and now have a very positive outlook for the future. In SA the production and commercialization of ASI family lines will see that industry partially insulated from the effects of POMS if/when it reaches the growing regions. Whilst POMS resistance is currently lower in farm stock in SA than TAS, the stocking of these oysters on farms can avoid the crippling losses experienced in TAS during the 2016 outbreak. The knowledge of this “insurance policy “ has allowed the industry in SA to invest in their businesses with greater confidence.

The other aspects of this project have allowed the breeding program to increase the rate of genetic gains and these have had direct impacts on Australian Pacific Oyster growers.

FRDC Project 2016/802 Accelerated Sydney Rock Oyster (SRO) Breeding Research

Dove, M., Kube, P., Lind, C., Cumbo, V., Raftos, D., O'Connor, W. New South Wales Department of Primary Industries (Fisheries). 2020. Port Stephens Fisheries Institute, Taylors Beach, NSW.

Executive Summary

This project focussed on increasing genetic resistance of Select Oyster Company (SOCo) breeding program Sydney rock oyster (*Saccostrea glomerata*, SRO) families to QX disease and winter mortality (WM) disease. NSW DPI has worked collaboratively with SOCo to develop a SRO family-based breeding program (BP) to replace the mass selection program used to develop fast growth and disease resistance since 1991. Family-based breeding has a number of distinct advantages over mass selection including; increased genetic gains, ability to select for disease resistance under biosecure conditions, improved selection methods for multiple traits, better estimates of genetic gains and trends as well as control over inbreeding. Annual family breeding runs commenced in 2014 to establish the SOCo breeding program. An FRDC project (2015-230) provided genetic expertise to establish and refine breeding methodology for a family-based breeding program.

The next step was greater understanding of the genetic parameters for QX and WM disease and how these related to other traits under selection, growth and meat condition. Genetic progress could be achieved by increasing the numbers of families available for selection, improved understanding of the genetic architecture of traits and reducing the length of breeding cycles for disease resistance. NSW DPI, SOCo, genetic specialists at CSIRO and oyster researchers at Macquarie University developed a multidisciplinary research program to deliver genetic progress for the SOCo breeding program.

The aims of this project were to:

1. double the number of families produced for the SOCo breeding program from 80 to 160;
2. halve the generation time for selection to QX and winter mortality resistance;
3. determine the heritability of the trait of winter mortality resistance in SROs; and
4. determine whether marker-assisted selection using reverse transcription can be incorporated into the SOCo breeding program.

Annual family production was approximately 40 when this project started and was increased to nearly 80 as a consequence of this project. Families in the 2014 and 2015 year classes continue to rank highly and are available for breeding runs taking the total number of families available to industry to more than 250.

Commercial hatchery production of SROs is more difficult compared to other species such as Pacific and eastern oysters. Further complexities are encountered when producing SRO families due to fertilisation deficiency in particular crosses, low rates of success when fertilisation occurs and poor levels of larval development in the period immediately after fertilisation. The increase in annual family production in this project was achieved through numerous stepwise improvements to protocols, facilities, husbandry and staff training. Whilst significant advances have been made, this area remains a high priority for further research. Improvements to guarantee better fertilisation success rates and larval yield in the early stages of a breeding run will further boost the number of SRO families possible in a single breeding run to a number well beyond 80. The ability to efficiently produce more families can provide increased genetic gains and program reliability in the future.

A one-year breeding cycle was successfully introduced for QX resistance, effectively doubling the rate of genetic progress for this trait. This required the use of quantitative genetics to understand the genetic architecture of traits, and knowledge of the reproductive and QX disease cycles to

determine a design that considered the logistics of all breeding program operations, including those for the other primary traits of growth and meat condition. This understanding allowed the production of SRO families to be advanced so that spat from SOCo families could be challenged to QX during the season following production allowing data to be collected and breeding decisions to be made within 12 months.

During this project, WM disease expression through field exposures was low and inconsistent across multiple year classes and sites. This reduced the level of discrimination between family survival. WM resistance in SROs has low to moderate heritability, and thus would potentially respond to genetic selection. However, the rate of gain is likely to be lower for this trait than for traits such as QX resistance and growth rate. No correlations were found between WM resistance and other primary traits under selection (QX resistance, meat condition and growth). The best estimates were obtained from the Quibray Bay site using survival data measured in December from 1 yr-old oysters. It is recommended that the SOCo breeding program continue WM field exposure trials of 1 yr-old oysters at Quibray to obtain further data if resources permit. A decision about including WM resistance as part of the SOCo breeding objective is required. This decision will need to be made in consultation with industry and with consideration of the impact of how this will influence gains in other traits. Whilst that decision has not been made, the knowledge generated from this project has enabled this process to be done.

This project developed a method to sample oyster tissue for genetic analysis that does not affect oyster reproduction or survival. Seven gene expression markers were identified that could be incorporated into the breeding program once further validation steps are completed. qPCR is a cost-effective method for screening large numbers of oysters and can provide results in sufficient time to make breeding decisions. Marker-assisted selection has the potential to increase genetic gains for QX resistance by enabling within family selection, and this project has identified candidate markers. Further development is required to determine if these genetic markers can identify susceptible individuals and to incorporate marker-assisted selection into the current logistics and schedule of the breeding program.

Major changes have been made to breeding logistics and are now used in the SOCo breeding program to increase genetic gains for QX disease resistance. The SOCo breeding program is operational using targeted multi-trait selection to increase the rate of genetic gain. Breeding goals have been set by industry based upon the need for SOCo to have a commercially viable product that provides clear benfits to oyster growers. The breeding goals are for SOCo stock to demonstrate 70% survival through a QX disease outbreak, 30% growth advantage compared to wild oysters, and no difference in condition compared to wild oysters. Estimates have been made on the timelines to achieve these goals, using data generated from this project and elsewhere, and these goals will be met in one to five years, depending on the trait in question. The commercial release of oysters with 70% QX disease resistance is expected in March 2020, 30% growth advantage over wild oysters is in March 2021 and oysters with no change in condition is in March 2024. These time frames are conservative estimates and can be reduced by using a more aggressive selection strategy if required.

This project changed the scale, logistics and schedule of the SOCo BP to reduce overall operating costs yet increase the genetic gains for QX disease resistance and now offers industry a viable risk mitigation strategy against disease impacts.

FRDC Project 2016-803 New Technologies to Improve Sydney Rock Oyster Breeding and Production.

Dove, M., Suwansa-ard, S., Elizur, A., Seeto, R., Clulow, J., Gibb, Z., Abramov, T., O'Connor, S., Kent, G., O'Connor, W. 2020. New South Wales Department of Primary Industries (Fisheries), Port Stephens Fisheries Institute, Taylors Beach, NSW.

Executive Summary

Hatchery production of Sydney Rock Oysters (SROs, *Saccostrea glomerata*) is a costly and high risk activity for the breeding program and industry exacerbated by factors such as: reliance on hatchery conditioning, low fertilisation success using strip-spawned gametes, extended larval rearing period compared to Pacific Oysters (*Crassostrea gigas*), and variable settlement rates. This project, one of a number that comprised the Future Oysters Coopoerative Research Centre project (Future Oysters CRC-P), was developed through discussions with the SRO industry hatchery sector and was designed to target specific hatchery production challenges. Four fundamental components were identified for research and development:

1. Production of tetraploid SROs for triploid hatchery production
2. Decreasing the time frame and increasing the reliability of hatchery conditioning
3. Producing a spawn inducing factor(s)/pheromone to trigger natural release of gametes
4. Physiological process that occurs following oocyte release to extend the duration of viability through the use of benchtop storage media

Each component listed above is designed to either decrease hatchery operation costs, increase production reliability or increase the market for hatchery produced seed. The highest priority for further development of the SRO Breeding Program (BP) is increasing the success rate of single pair mated crosses. Research for production of tetraploid SROs, producing a spawn inducing factor and investigating oocyte viability will produce valuable information that can be directly applied to increase the success rate of single pair mated crosses.

Tetraploid inductions were performed by Southern Cross Shellfish (SCS) and the NSW Department of Primary Industries (NSW DPI). Tetraploid inductions were not successful in producing a batch of tetraploid SRO that could be made available for commercial hatchery production of triploids using tetraploid male and triploid female crosses. Eleven attempts were made and the major challenges encountered was low egg numbers, asynchronous embryonic development in strip-spawned oocytes after fertilisation, poor development and poor larval survival. A very small number of spat were successfully settled from 2 trials, however, no tetraploids were found in these batches when oysters had reached a size where tissue could be taken to determine ploidy level.

Although the original milestones related to the tetraploid research were not achieved, there have been some significant outcomes from this Future Oysters CRC-P project with respect to production of triploid SROs and making these available to industry. Successful chemical triploid batches produced for the CRC-P tetraploid work have resulted in distribution of triploids from QX disease-resistant broodstock to industry. NSW DPI used this opportunity to commercially evaluate triploids and measured QX disease resistance and oyster growth performance. Although no QX disease occurred during field evaluations, triploid oysters had significantly faster growth rates compared to a group of selected 2017 year class (YC) families and non-selected oysters.

SROs require 10 weeks of hatchery conditioning to obtain suitable gametes for successful spawning. This requires significant hatchery resources in terms of algae, energy and labour over this period. Reducing the hatchery conditioning period and improving hatchery conditioning reliability with respect to producing ready-to-spawn broodstock reduces the financial impost for SRO hatcheries.

Results from three independent trials performed by the University of the Sunshine Coast (USC),

revealed that administering the individual forms of buccalin and APGWamide stimulated gonad conditioning in SRO. Comparing the stimulatory effect of two different forms of APGWamide, APGWa and RPGWa, USC found that the APGWa form was more potent than the RPGWa form. For buccalin, the buccalin-G form showed a better performance than the buccalin-A form in most of the reproductive activities assessed. The stimulatory effects of APGWa and buccalin-G on SRO conditioning appear to be comparable. Hence, either APGWa or buccalin-G can be used on SRO broodstock for both breeding runs and commercial spat production. With respect to peptide delivery, we found that using cocoa butter to allow a slow release of peptide was not appropriate as it caused high mortalities. Injection of peptides is therefore preferable and multiple injections are expected to help in maintaining the level of the peptides in the oyster's circulatory system in order to successfully control gonad conditioning. Yet, delivery of peptide by injection is relatively difficult and uncontrollable since different individual oysters could receive different amount of the neuropeptide per injection. To overcome this problem, delivery using other techniques such as, oral delivery by using peptide-encapsulated algae, should be considered and tested in the future.

Spawning inducing factor/pheromone was found to be present in SRO sperm by USC. SRO sperm was isolated and proteins semi-purified, giving two major extract groups - the intrinsic and extrinsic sperm membrane proteins. Further purification was performed using RP-HPLC, resulting in multiple fractions of sperm membrane proteins. Crude extracts and RP-HPLC fractions were tested in a spawning induction bioassay, in which fully mature oysters were treated with the crude extract or fraction, prior to observation of spawning activity over the period of 2 h. We found that proteins extracted from the extrinsic sperm membrane, but not the intrinsic sperm membrane, could successfully induce spawning in the SRO. Further purification of positive extrinsic membrane fraction S3 minute 41-45 led to sub-fractions that were also tested, resulting in two positive sub-fractions (at 6-10 min and 11-15 min). The MS analysis of each revealed 8 proteins, including: aminopeptidase N; calmodulin; 60 kDa SS-A/Ro ribonucleoprotein; protein bark beetle-like; helicase; failed axon connections homolog; nascent polypeptide-associated complex subunit alpha; and, a novel protein. We propose that these proteins may play a critical role in stimulating spawning of the SRO.

Another objective of this project related to a straightforward method for benchtop storage of SRO gametes. This work was done by The University of Newcastle (UoN) and required an understanding of the causes of oocyte degradation and to develop improved storage protocols for oocytes that extend the holding period in vitro after strip-spawning gametes. Specifically, the objective reported on here was to evaluate up to three methods for the improved benchtop storage of SRO gametes. This objective was achieved, but further work will continue to evaluate further approaches to gamete storage as part of a continuing PhD project. Typically, SRO oocytes show the best fertilisation rates if fertilised within 24 h of stripping; afterwards, the success decreases exponentially. Results in this experiment suggest that vitality can be improved if these characteristics are altered in the media, and when additives are included (such as antibiotics and polyvinylpyrrolidone (PVP)). This is a significant step in extending the life of a cell for breeding purposes, effectively extending the window in which quality testing and fertilisations can be conducted.

Research is ongoing for tetraploidy induction techniques (SCS), neuropeptide delivery to broodstock (USC), spawn inducing factors (USC) and oocyte storage for SROs (UoN). Further research is required to incorporate findings from this research into operations of the SRO BP. However, outcomes from this work are already providing benefits for the SRO BP, notably technical improvements to the fertilisation process. This has increased family production success from 27% to 45%. This outcome is relevant for the SRO BP and commercial hatcheries as it reduces the time it takes to create families and the numbers of valuable broodstock required for a breeding or commercial hatchery runs.

FRDC Project 2016/804 Advanced understanding of POMS to guide farm management decisions in Tasmania.

Crawford, C. and Ugalde, S. Institute for Marine and Antarctic Studies University of Tasmania. 2019. Hobart , Tasmania.

Executive Summary

The Tasmanian Pacific Oyster aquaculture industry was severely impacted by an outbreak of the disease Ostreid herpesvirus OsHV-1 µVar, known as Pacific Oyster Mortality Syndrome (POMS) in Australia, in January-February 2016. Massive oyster mortalities occurred on farms in four oyster growing areas in south-eastern Tasmania, and the two major hatcheries which supplied approximately 90% of oyster spat to South Australia (SA) and New South Wales (NSW) were also in the infected area. This had a significant immediate impact on the supply of oysters to the market place, as well as a longer-term effect on the supply of Pacific Oyster seed across Australia. The Tasmanian Institute for Marine and Antarctic Studies (IMAS) conducted research to advance the understanding of POMS disease and guide development of farm management systems that minimise the impact of POMS. Researchers at IMAS have worked closely with oyster farmers to be able to predict high risk periods and locations for POMS, to develop farming practices that reduce oyster mortalities from POMS disease and to document the effects of POMS on the Tasmanian oyster industry.

Background

POMS is a worldwide disease of Pacific Oysters that was first identified in Australia in the Georges River NSW in 2010, spread to the Hawksbury River in 2013, and then to four major oyster growing areas at Pitt Water, Pipe Clay Lagoon, Little Swanport and Blackman Bay in south-eastern Tasmania in January 2016, where 75-90% of oysters died on most farms. Various farm management techniques have been developed in other countries to minimise the impact of POMS, such as exposing large quantities of spat to the virus and ongrowing the survivors or determining the most cost-effective size and/or time of year to introduce spat to farm grow-out conditions. However, despite large research efforts overseas, there are still many unknowns about the OsHV-1 virus and POMS, including the reservoirs, carriers and hosts for this virus.

Aims

The objectives of our research have been to determine the high-risk periods for POMS infection and to develop a predictive framework so that the farmers can forecast danger periods for POMS. This includes developing a better understanding of where the virus exists in the environment and the factors that drive POMS disease outbreaks. We also aimed to work with the oyster industry to develop farm husbandry and handling protocols that maximise oyster production in POMS infected growing areas. Additionally, we surveyed the oyster farmers affected by POMS to get an overall view of the impact of POMS, especially socio-economic aspects.

Methodology

Our research was conducted on POMS infected Pacific Oyster farms in south-eastern Tasmania using commercially available oysters. Sentinel oysters were placed on farms approximately every fortnight to monitor survival rates during times when POMS outbreaks were likely to occur. Environmental data were collected using automatic, continuously monitoring data loggers recording temperature, salinity and other parameters every 10-30 minutes. Research trials investigating various farm management practices were developed in conjunction with oyster growers and were based around standard farming practices. They included replicate trials investigating the effects of handling, oyster density in culture containers, age and size of oysters and chilling on mortalities due to POMS. The role of feral oysters as a potential reservoir for the POMS virus was also examined. The surveys of the effects of POMS on oyster growers were confidential and involved voluntary structured face to

face interviews with oyster farmers individually. Human ethics approval was obtained from the University of Tasmania.

Key findings

Our research supports other studies that warm water temperature is a major driver of POMS outbreaks, with temperatures in south-eastern Tasmanian growing areas of 19 °C and above for around one week providing a high risk for a disease event to occur. The risk period for POMS disease outbreaks ranges from mid-November to late March. Other environmental factors likely to be important include water movements and density of infected oysters in a water body. Growing areas with extensive intertidal flats and poor water circulation, such as Pittwater, or with a high biomass of farmed and feral oysters in a relatively small area, such as Pipe Clay Lagoon, have shown to be more susceptible to POMS disease than the other farming areas. As feral oysters in Pipe Clay had a relatively high prevalence of OsHV-1, they may be contributing to the reservoir host of the virus.

Studies on farming practices conducted in close collaboration with oyster growers suggest that density of oysters in culture containers has limited effect on mortality rates, and that some handling is required during the POMS season to reduce biofouling and maintain stocking densities conducive to good growth and survival. Younger and smaller oysters are more susceptible to infection that larger and older juvenile and adult oysters. For oysters of the same age cohort, fast growers had higher mortalities than slow growers.

The surveys of oyster growers on the impacts of POMS on their farming operations has shown that mortalities from POMS have rapidly declined from an average of 67% of stock in 2016 to 9% in 2018/19. Changes to farming practices that have occurred during this time include a large increase in stock selectively bred for POMS disease resistance, reduced and more careful handling of oysters during the summer POMS season, selling a higher percentage of stock before the POMS high risk period, and purchasing spat when temperatures are declining.

Implications for relevant stakeholders

The impact of our research to develop a better understanding of the drivers of POMS disease and new farm management techniques to minimise POMS mortalities, along with major advancements in oyster selective breeding for POMS resistance, increased biosecurity measures and changes to farm management implemented by the oyster growers themselves, has led to a rapid turnaround in the Tasmanian oyster industry. It has changed from devastation and despair after the initial viral outbreak in 2016 to a positive outlook for the future in just over three years. Many farmers expect to be back to pre-POMS production levels by 2020 and have assessed their businesses as stronger, and more efficient, than before POMS.

Recommendations

Although major progress has been made with selective breeding for POMS resistance and changed farm practices to minimise POMS mortalities, it is still early days for this disease and consequently its management in Tasmania. The selective breeding program needs to continue to ensure greater reliability of disease resistance. Additionally, it is important that oyster farmers regularly observe and keep records of oyster health, mortalities and environmental conditions on their farms, especially during extreme heat events, in case disease outbreaks occur in the future. There are also still many unknowns about the OsHV-1 virus, which have important implications for management of POMS disease, and further research in recommended to better understand the reservoirs, carriers and hosts for this virus. Interactions with bacteria and the role of oyster health and family line genetics in the likelihood and severity of POMS disease events also require further study.

FRDC Project 2016-805 Polymicrobial involvement in OsHV outbreaks (and other diseases).

Seymour, J.R., Labbate, M., O'Connor, W., Jenkins, C., Dove, M., King, W., Siboni, N., Nguyen, V.K. 2019. University of Technology Sydney. Sydney, NSW.

Executive Summary

The principal goal of this research was to provide a detailed characterisation of the oyster microbiome and identify links between specific features of the microbiome and oyster disease and mortality events. The conceptual framework for this work is based upon: (i) increasing evidence, across a broad range of species, that the nature of a host organism's microbiome exerts a fundamental control on host physiology and health, and (ii) the critical paucity in knowledge on the factors contributing to oyster health and the triggers for oyster mortality events and disease outbreaks. The research reported here involved a collaboration between the University of Technology Sydney (UTS) and the NSW Department of Primary Industries (DPI), whereby the UTS members of the team provided expertise in molecular microbial ecology and the DPI team members provided expertise and support in oyster physiology and ecology and aquaculture. The research involved a large-scale screening of the microbiomes of both Pacific Oysters and Sydney Rock Oysters using high-throughput DNA sequencing technologies, providing a characterisation of the microbial communities associated with oysters. The outcomes of this analysis revealed that for both Pacific Oysters and Sydney Rock Oysters, the oyster microbiome is remarkably variable among different oyster families, and over space and time, indicating that both intrinsic physiological features of the oyster host and environmental factors play a role in governing the oyster microbiome. Notably, despite this heterogeneity, a small sub-set of the microbiome was shown to be conserved across oysters within a species, pointing to the existence of a core group of microbes with intrinsic links to oyster ecology and condition. Similarly, a small group of microbes, including members of the Vibrio genus, were consistently associated with diseased or susceptible oysters, indicating a potentially antagonistic role of these microbes. These observations support the hypothesis that the oyster microbiome plays a role in defining oyster health, but also reveal substantial complexities related to the marked heterogeneity of the oyster microbiome over space and time. Appropriately considering this microbiome heterogeneity, while also sharpening focus on the few core microbiome members identified in this research, will be important requisites for future efforts hoping to employ the oyster microbiome for diagnostic purposes.

Background

During the last two decades a number of disease outbreaks have led to mass oyster mortalities and the closure of several oyster-harvesting regions, resulting in multi-million dollar losses. These outbreaks mirror a global pattern of increased aquaculture disease, with disease emergence potentially linked to environmental degradation (pollution) and climate change related processes, such as rising seawater temperature. Within NSW estuaries, multiple microbiological agents have been implicated in oyster diseases, but a clear understanding of the ecological and environmental drivers of disease outbreaks has remained elusive. This means we cannot currently predict when outbreaks will occur, making it very difficult to manage infection events and develop strategies to mitigate future oyster disease events.

Across a wide-range of animal and plant systems, including several benthic marine organisms, there is growing evidence that the structure and function of a host organism's microbiome – the community of microorganisms living in prolonged association with the host macroorganism – plays a fundamental role in the physiology and health of the host and its susceptibility to disease. Shifts in a host organism's microbiome (dysbiosis) can either precede or follow measurable symptoms of syndromes and/or disease, with examples of both microbiome shifts causing disease or occurring in response to disease on-set.

There is a growing recognition for the potential importance of the microbiome in oyster health and physiology, with emerging evidence suggesting that the oyster microbiome might be directly related to oyster disease dynamics. However, the factors governing the structure of the oyster microbiome are very poorly resolved, with very little, to no, understanding of the inherent characteristics of a “healthy oyster microbiome” or the identity of core beneficial vs pathogenic microbes within the oyster microbiome. This lack of knowledge currently precludes the use of the oyster microbiome as a diagnostic marker for oyster health or disease status.

Aims/objectives

The three over-arching Objectives of this research were to:
1) Define microbial communities associated with oysters and identify potential microbial threats
2) Link changes in environmental conditions to shifts in the oyster microbiome
3) Better understand the association between the oyster microbiome and disease

These Objectives gave rise to the following more specific Aims, which evolved as the project progressed:

Aim 1 Characterise the composition of the Pacific Oyster microbiome across diverse oyster families, including those exhibiting different levels of susceptibility to OsHV-1 μvar disease

Aim 2 Define the composition of the Sydney Rock Oyster microbiome across diverse oyster families, including breeding lines generated for resistance to QX disease, and examine spatial and temporal heterogeneity in microbiome structure

Aim 3 Examine spatial heterogeneity in Pacific Oyster microbiome structure at the individual oyster level and across regional-scales

Aim 4 Define the Sydney Rock Oyster microbiome associated with QX disease events

Aim 5 Measure temporal patterns in the Pacific Oyster Microbiome during the Summer OsHV-1 Mortality period

Aim 6 Elucidate patterns in Vibrio community diversity and abundance within the microbiomes of oysters subject to disease and mortality events

Methodology

We focussed our research on two of the major commercial oyster species in Australia, the Pacific Oyster and Sydney Rock Oyster, with a focus on diseases affecting these species, namely OsHV-1 and QX disease respectively. Our approach involved a tiered characterisation of the oyster microbiome, which included:

(i) Characterising the “base-line” microbiome of Pacific Oysters and Sydney Rock Oysters
(ii) Examining variability in the oyster microbiome across diverse family/breeding lines, including families exhibiting differing levels of susceptibility to OsHV-1 and QX disease
(iii) Defining spatial and temporal variability in Pacific Oyster and Sydney Rock Oyster microbiomes across a continuum of scales, ranging from comparisons across different oyster tissues and between different estuaries.
(iv) Measuring patterns in Pacific Oyster and Sydney Rock Oyster microbiomes associated with disease outbreaks and mortality events

(v) Targeted screening of oysters for microbiome members putatively involved in oyster disease or mortality.

Throughout the course of this project we characterised the microbiomes associated with Pacific Oysters and SROs using 16S rRNA amplicon sequencing, which is currently the optimum approach for defining the diversity and composition of a microbiome. Briefly, this technique involves extraction of microbial DNA from oyster samples, amplification of the bacterial 16S rRNA gene and Illumina miSeq sequencing of the amplified DNA. This technique provides an inventory of the bacterial composition and diversity within a sample (a list of Operational Taxonomic Units; OTUs), allowing for inter-microbiome comparisons and the identification of specific discriminatory or indicator microorganisms. Using a suite of multidimensional statistical analyses we identified patterns in oyster microbiome structure across environments, over time and between different oyster breeding lines. This approach allowed us to both identify members of the "core oyster microbiome" and organisms most responsible for the discrimination of different oyster microbiomes.

Results

The key findings of this research included:

- The identification of a small sub-set of "core members" of the oyster microbiome, including members of the Spirochaetaceae family that were conserved over a continuum of spatial and temporal scales, which may be indicative of key oyster-associates that play a role in oyster physiology and health;

- Significant heterogeneity in both the Pacific Oyster and Sydney Rock Oyster microbiomes over space and time, indicating that local environmental factors govern the structure of the oyster microbiome;

- Variability in the oyster microbiome across different oyster family-lines, and between different oyster tissue types (e.g. gill, mantle adductor muscle etc) indicating that intrinsic genetic and physiological features of the oyster host also govern microbiome structure;

- Sub-sets of the oyster microbiome that were differentially prevalent in Pacific Oyster and Sydney Rock Oyster family-lines with differing levels of susceptibility to OsHV-1 and QX disease respectively, indicating that certain members of the oyster microbiome may either facilitate or protect the oyster from infection.

Implications and recommendations for relevant stakeholders

The outcomes of this research indicate the highly dynamic nature of the Pacific Oyster and Sydney Rock Oyster microbiomes and in some cases point to a potentially significant role of the oyster microbiome in governing oyster health and susceptibility to disease. This, on the one hand, suggests that the oyster microbiome may have substantial utility as a new diagnostic measure of oyster health, but on the other hand, the inherent heterogeneity of the oyster microbiome observed here means that it may be difficult to identify and subsequently use universal community signatures or indicator organisms across oyster microbiomes originating from different environments or genetically dissimilar oyster stocks. We therefore suggest that while the incorporation of characterisation of the oyster microbiome into assessments of oyster condition has substantial promise, care should be taken to ensure that data is collected and interpreted using a context-specific (e.g. environment, oyster genetic stock) approach.

FRDC Project 2016-806 Advanced aquatic disease surveillance for known and undefined oyster diseases.

Deveney, M.R., Wiltshire, KH (eds). 2020. South Australian Research and Development Institute. Adelaide, South Australia.

Executive Summary

Surveillance is a critical component of biosecurity and aquatic animal health activities. Surveillance supports understanding health status of populations of animals, provides evidence to support claims of freedom or understanding prevalence and increases the likelihood that a new or emergent disease can be controlled.

Mollusc diseases are less well understood than terrestrial and many finfish diseases. The recently emergent but well described Pacific Oyster Mortality Syndrome (POMS), caused by OsHV-1 microvariant, lacked information on several critical aspects of its diagnosis, including diagnostic sensitivity and specificity of commonly used tests. Critical improvements in time-to-diagnosis were also required to support business continuity when responding to mortalities in OsHV-1 free areas. Rapid diagnosis was also needed to support compartmentalisation, and in particular to provide real-time surveillance for hatcheries producing OsHV-1 free stock in disease-affected zones. Winter Mortality (WM) in Sydney Rock Oysters was described nearly 100 years ago but at the inception of this project had no case definition or aetiological agent identified, despite the importance and iconic status in Eastern Australia of the Sydney Rock Oyster. Similarly, mortalities of Pacific Oysters in South Australia (SA), termed SA Mortality Syndrome (SAMS) have been described since the 1980s but remained poorly understood.

This project sought to develop understanding and provide better information to support surveillance for oyster diseases. It included four main activities: improved understanding of tests for OsHV-1 and investigation of use of tests in a non-destructive manner; development of a low-cost, real-time test for OsHV-1; refinement of the case definition and investigation of the cause of SAMS; and development of a case definition and improved understanding of the cause of WM in Sydney Rock Oysters.

FRDC Project 2016/807 Species diversification to provide alternatives for commercial production

Li, X., Miller-Ezzy, P., Crawford, C. and Deveney, M. 2020. South Australian Research and Development Institute. (2020). Adelaide, South Australia.

Executive Summary

Pacific Oyster Mortality Syndrome (OsHV-1 microvariant; POMS) results in high and rapid mortality in Pacific Oysters (*Crassostrea gigas*) and has been responsible for significant economic loss to oyster industries in Australia and around the world. The diversification of commercial production into different oyster species (Native Oysters and Western Rock Oysters), not susceptible to POMS, has been proposed as a way to mitigate the risk of POMS in southern Australia. However, the Australian Native Oyster (*Ostrea angasi*) industry is still in its infancy, with knowledge gaps along the production chain. Additionally, Western Rock Oysters (*Saccostrea sp.*) have never been commercially produced in South Australia and translocation policies to move them around the state are non-existent. This project aimed to improve on-farm production of Native Oysters and develop safe translocation protocols for Western Rock Oysters in South Australia, in order to help Australian oyster growers diversify into these species.

On farm trials were run in South Australia and Tasmania to develop grow-out methods that maximise survival and growth of juvenile Native Oysters. The effect of farm location, site (high and low energy; intertidal and subtidal) and growing height on Native Oyster performance was evaluated. A cohabitation study of Western Rock Oysters with Pacific Oysters and Native Oysters was run to assess the risk of bringing Western Rock Oysters into existing South Australian oyster growing regions.

The results of the Native Oyster farm trials were different between South Australia and Tasmania, however, in both cases growing height had a significant effect on Native Oyster growth. In South Australia, subtidal treatments had the slowest growth, whereas in Tasmania, Native Oysters grown at the highest intertidal height had the least growth. With the exception of one South Australian treatment, Native Oyster survival was high (> 95%) across the on farm trials in both South Australia and Tasmania.

The high survival and growth rates (less but comparable to Pacific Oysters in South Australia) observed in the on farm Native Oyster trials indicate that diversification into this species could be a viable option to mitigate the risk of POMS. The findings from this project will help to advance the Native Oyster industry in Australia. Additionally, this project established a Native Oyster farmers' network for the sharing of knowledge and methodologies related to Native Oyster Aquaculture. Preliminary results from the on farm trials have been disseminated to this farmers' network through three industry workshops. Native Oyster on farm trials are continuing in Tasmania assessing the effects of stocking density and rotational movement between growing heights on Native Oyster growth and condition.