TRANSFORMING AUSTRALIAN SHELLFISH PRODUCTION

A Food Agility CRC project using real-time sensors and eDNA to improve production and harvest management

By Penelope Ajani, Mike Dove, Hazel Farrell, Wayne O'Connor, Matt Tesoriero, Arjun Verma, Anthony Zammit, Brian Hughes, Laura Parker, Shaye Carman and Shauna Murray

Australian Government

foodagility

UTS

NSW GOVERNMENT

[ISBN: 978-0-6486338-8-4]

Project Name: Transforming Australian Shellfish Production
Project No: FA 076

Citation: Ajani et al. 2024 Transforming Australian Shellfish Production Final Report, Food Agility CRC, Sydney.

Cover: Macleay River NSW, photo by Matt Tesoriero.

IMPORTANT INFORMATION

Author contact details
Name: Shauna Murray
Phone: +61 2 9514 1222
Email: Shauna.Murray@uts.edu.au

Food Agility CRC contact details
University of Technology Sydney, Broadway
Ultimo NSW 2007

+61 2 8001 6119
hello@foodagility.com
www.foodagility.com

Electronically published by Food Agility CRC at www.foodagility.com in August 2024

The Food Agility CRC is funded under the Australian Government Cooperative Research Centres Program.

ACKNOWLEDGEMENTS

This project has been funded under the Bushfire Local Economic Recovery Fund, co-funded by the Australian and NSW Governments in association with the Food Agility CRC and the NSW Farmer's Association. The Food Agility CRC Ltd is funded under the Commonwealth Government CRC Program. The CRC Program supports industry-led collaborations between industry, researchers and the community. The Department of Primary Industries and the University of Technology also provided project funding. The project team would like to acknowledge the invaluable assistance of oyster farmers in NSW, and Harvest Road Oceans in WA, for sample collection. We also wish to acknowledge the assistance of staff from The Yield Technology Solutions, ICT and In Situ Marine Optics, for facilitating access to the water salinity and temperature data used in the analyses. Routine phytoplankton monitoring sample data was funded by the NSW Food Authority in NSW and the shellfish industry. We thank Kyle Johnston and Brandt Archer (DPI) for oyster stock preparation and growth/survival data collection, and Dr Nahshon Siboni and Prof Justin Seymour (UTS) for source tracking assistance. Finally, we would like to thank Dr Torri Callan (UTS) for statistical analyses and Chris Komorek and Anika Berkman (Food Agility CRC) for report layout.

Table of Contents

PROJECT DESCRIPTION

The aim of this project was to use real time, high-resolution salinity, temperature and depth sensing, combined with novel molecular genetic methods (eDNA), to model oyster food safety, pathogenic bacteria, harmful algae, and oyster growth, with the aim of improving production and harvest management and to reduce harvest closure days for farmers.

As filter feeders, shellfish like oysters and mussels actively remove particles from surrounding waterways. Following high-risk events such as heavy rainfall or harmful algal blooms, regulators implement precautionary harvest area closures to manage potential food safety risks or implement shellfish movement restrictions to manage potential biosecurity risks. Shellfish farmers in Australia are not currently able to predict the likelihood of a harvest area closure due to these high-risk events. If farmers were aware of imminent closure, they could take meaningful action such as harvesting early, or moving stock to lower risk areas. The same environmental variables that influence food safety can also impact on oyster health and can increase the risk of certain diseases. Understanding these relationships and monitoring these variables could be used to reduce the risk and severity of disease outbreaks. This project delivered estuary-specific models relating to oyster growth, disease risk, harmful algal bloom risk, sources of contamination, and other supporting factors influencing industry productivity. Each of the model related biological data to high frequency water quality metrics as measured by real-time sensors deployed *in situ*.

2. End-User Problem(s)

The top 4 ranked problem priorities by growers in a recent industry survey were:

- Prediction of Harmful Algal Blooms (HABs)
- Longer harvest opening times
- Reduced stock mortalities/disease
- More information of stock growth/production

… each of which forms a critical component of this FA076 project.

Additionally, the threat of disease and productivity loss for the industry is particularly prevalent in 2021 given post-bushfire impacts and climate forecasts.

Today's alternative solutions

Today farmers must respond to instructions set by the NSW Food Authority, and otherwise just be as reactive as possible to disease/HAB risks

4. Our Solution

- Using the backlog of environmental, biological and oyster growth data from Phase 1, this project will deliver tailored models relating to oyster production on an estuary-by-estuary basis.
- Real-time data feeding into the models will be obtained from water quality sensors from ICT International
- Outputs of the modelling will be directed to growers via their existing farm management apps.

5. Key Results

1. # deployed models into farm management software
2. # use of supporting farm management software
3. # volume of time gained to manage for oyster risks ahead of outbreak
4. # of NSW estuaries approved for export clearance

3. Unique Value Proposition

- Fully automated harvest area management closure notifications, embedded in farm management apps
- Predictive information on the risks of disease and algal blooms in real-time, enabling growers to respond early to these risks by altering management practices (e.g. changing location of baskets in lease, flipping, pulling in, etc.)
- Insights into the optimal conditions and management methods for oyster growth – enabling greater yields from similar inputs.

12. Highest Risk Assumptions

The scalability of environment vs disease models to new estuaries – what is required to scale globally?

Cooperation between three technology providers.

That growers across each estuary have fair mechanisms to invest in tech post-project.

6. Partners + Team

UTS: Shauna Murray, Penny Ajani, PhD Scholar Hernan Henriquez

NSW Food Authority: Anthony Zammit, Hazel Farrell

NSW DPI: Wayne O'Connor, Mike Dove, Allen Benter

ICT International: Peter Cull

Smart Oysters: Ewan McCash

OysterCloud: Matt Toan

7. Pathways to Scale / Impact

Word of mouth promo via OceanWatch

National regulatory scalability via NSW DPI circle of influence (Anthony Zammit)

Global scalability via partnership between Smart Oysters and ICT International

- Global scalability by presenting results of project at international forums (ICMSS)

1. End-Users

Early-Adopters

- Active oyster & mussel growers in NSW and WA
- Regulators of the NSW Oyster industry (state and export)

Scale up users

- Shellfish producers from across Australia
- Global users of aquaculture farm management platforms (Smart Oysters) – already exist in US, Europe and Asia

Other value chain beneficiaries

- Consumers of safe, quality Australian seafood
- Exporters of Australian shellfish

8. Expected Contributions

- NSW Farmers (on behalf of the growers and industry): $514,400 cash
- Food Agility CRC: $245,016
- NSW DPI: $200,000
- UTS: $200,000 + data management system in kind
- ICT, OysterCloud + Smart Oysters: in-kind FTE
- WA DPIRD $250K

TOTAL: ~$1.4 million

10. Existing knowledge

- Existing knowledge has been generated directly from FA002 – it relates to the ability to model oyster disease risk against real-time water quality
- Additionally, it has been discovered that hand-held qPCR methods are a viable way for farmers to self-monitor eDNA in their leases – this is the focus of Food Agility HDR Hernan Henriquez

11. Research Questions

There are a number of critical research questions that were not answered in Phase 1, as the data analysis is ongoing:

- What are the key environmental and farm management determinants of oyster growth?
- How accurately can environmental metrics be used to predict onset of oyster disease or HABs?
- How far ahead of time can these predictions be made?
- How estuary-specific are disease and HAB models, and how quickly can they be rolled out in new estuaries?

9. Expected Project Costs

- UTS C3 team – expertise in oyster production and natural management of estuarine environment
- UTS Environmental Data Science – Stephen Woodcock
- NSW DPI - Shellfish research team & data management and sensor configuration
- ICT International – Sensor rollout and maintenance
- Oceanographic Field Services – JB sensor rollout and maintenance

TOTAL: ~$1.4 million

PROJECT PARTNERS

This project was a partnership between:

- Oyster farmers – NSW and WA
- University of Technology Sydney (UTS)
- NSW DPI (Department of Primary Industries, Biosecurity & Food Safety/NSW Food Authority and Fisheries)
- Western Australia Department of Primary Industries and Regional Development (WA DPIRD)
- NSW Farmer's Association
- Australian and NSW Governments
- ICT International
- The Yield
- Food Agility CRC Ltd

EXECUTIVE SUMMARY

Preserving food safety traditionally involves oyster harvest area closures after high rainfall. However, since rainfall does not always impact water quality, farmers are likely to suffer preventable financial losses. This project aimed to combine high resolution salinity and temperature data with state-of-the-art molecular tools to demonstrate that salinity was a better predictor of faecal contamination compared to rainfall (or river flow for WA) currently used in harvest management plans. This report focuses on data already analysed and summarised in each estuary-specific report[1-12].

To predict the impact of rainfall on potentially pathogenic bacteria, harmful algal blooms and oyster disease, we installed real-time, high temporal resolution sensors recording temperature, salinity and depth data in selected NSW estuaries and one location in Western Australia (Fig. 1). Estuary specific reports are now available for Manning River, Wagonga Inlet, Wallis Lake, Shoalhaven/Crookhaven Rivers, Pambula Lake, Georges River, Port Stephens, Wonboyn River, Wapengo Lake, Camden Haven, Hastings River and Hawkesbury River. Model data for three additional estuaries (Macleay River and Merimbula Lake in NSW, and Oyster Harbour WA) are currently being finalised.

Oyster farmers collected weekly environmental DNA samples and deployed/retrieved oysters for growth assessment at sensor sites, amounting to 11,803 DNA samples and 3,222 oyster growth assessments. We developed rapid molecular assays for *E. coli* and harmful algae *Alexandrium spp.*, *Pseudo-nitzschia spp.*, *Dinophysis spp. and Prorocentrum minimum*, as well as specific assays to identify the source of *E. coli* contamination (bird, cow or human). We developed predictive models of bacterial contamination in relation to environmental variables. Finally, we developed additional models linking oyster growth with such variables and assessed their predictive capability.

Data from real-time salinity sensors were generally better predictors of faecal contamination than rainfall (85% of all models). Mortality was rarely greater than the expected background mortality in oyster farm settings. Based on these results, we offered salinity-based management plans to 19 harvest areas across 13 NSW estuaries, and seven have been adopted so far.

Economic impacts assessments supported the benefits of the plan offered to farmers (see Impact section). Oyster farmers reported overwhelming satisfaction with project outcomes, citing improved relationships with regulators, heightened confidence to advocate for the protection of these environments, and increased collaboration within oyster farming communities. The benefits to society at large include greater continuity in oyster supply and increased confidence in the industry, possibly leading to further investments and growth.

Figure 1. High resolution sensor deployed in Macleay River (Photo credit: M. Tesoriero).

INDUSTRY IMPACT METRICS

Based on models run in 12 estuaries in NSW using high temporal resolution data, predictions of water quality are more accurate when based on salinity rather than rainfall. The adoption of real-time salinity-based management plans has increased harvest days (see metrics below)[1-12]. A 2023 Cost Benefit Analysis (CBA) showed that the net returns (profit after sensor and operational business costs) to oyster farmers from using real-time salinity sensors for harvest area management are positive in three case study harvest areas during both drought and above average rainfall conditions.

In addition, oyster farmers and regulators now have UTS-developed molecular assays identifying the source of pathogenic bacteria in estuaries (i.e., cattle, birds, human sewage), which can be used. These targeted data support shoreline remediation efforts to improve catchment water quality. We also developed rapid quantitative polymerase chain reaction (qPCR) assays for the quantification the harmful algae *Alexandrium* spp., *Pseudo-nitzschia* spp., *Dinophysis* spp. and *Prorocentrum minimum* for the early warning of harmful algal blooms.

To date, there has been 22 data requests from various universities, government departments, not-for-profit organisations and consultancies with widely differing applications. The project has supported four PhDs, two Honours and a Master student. The team has published 12 reports, as well as 8 related, peer-reviewed manuscripts; 12 articles published in news media, newsletters, or *The Conversation*; 27 presentations at conferences, including those at local/state meetings, national and international meetings; and finally, two additional large-scale research projects have stemmed from our work (UTS for $750k and Charles Sturt University for $300k).

Transition industry regulation to use real-time data		Deliver predictive models to farmers	
# harvest areas using salinity-based management plan 7 (19 offered)	# harvest days gained per year ~98	# environmental samples collected 11,803	# models delivered and integrated 46/48

Economic benefits to farmers

Annual net benefit (profit) in case study harvest areas (drought/above average rainfall)			Range of social and environmental benefits that can enhance oyster farming businesses.	Estimated potential benefit across NSW shellfish industry (farm gate value)
Pambula Lake *$116,679/$108,353*	**Cromartys Bay** *$15,923/$9,375*	**Wapengo Front Lake** *$37,774/$47,611*		$2.3-6.9M

Industry impact metrics

85

% of estuaries where salinity is a better predictor of water quality than rainfall

3-9

% increase in farm gate value estimated for the three case study areas assessed in 2023 cost benefit analysis (drought and above average rainfall conditions)

1

# of additional State (WA) requesting research on salinity-based water quality predictions

IMPACT STATEMENTS

INDUSTRY PARTNER

Dr Lisa Szabo, Director Food Safety & CEO NSW Food Authority
DPI Biosecurity & Food Safety/NSW Food Authority

The NSW Food Authority is the state regulator for food safety. Strong performance in compliance and regulation relies on science-based risk models, and stakeholder engagement across industry, consumers, research groups and government. In the context of this project, the NSW Food Authority classifies commercial shellfish harvest areas based on food safety risk and specifies environmental conditions suitable for commercial harvest.

The samples and data collected during this project presented a unique opportunity to modernise harvest area monitoring, and practically improved our work as regulators. The team developed a novel method to collect samples subsequently interrogated with molecular assays. The samples supported an evolution in surveillance tools to understand and manage food safety and biosecurity risks. Access to real-time data added transparency to decision-making and to changes in harvest area status, between farmers and regulators.

Sensor technology previously trialled on shellfish farms seemed to be either cost-prohibitive or unreliable. This project’s sensor data could be accessed online and in real-time, which was a fundamental improvement. Farmers have reported improved business efficiency based on access to data. Increased harvest opportunities were gained when sensor salinity data were used to manage harvest area closures instead of the traditional rainfall limits.

The project also contributed to scientific knowledge on water quality and estuarine environments, which regulators such as NSW Food Safety Authority will be able to use in the future. In addition, the high volume of data generated is invaluable to understand environmental conditions during severe events (e.g., bushfires, flooding), and during shellfish disease outbreaks or harmful algal blooms.

INNOVATION PARTNER

Professor David Lamb, Chief Scientist
Food Agility CRC

This project has been impactful from both a scientific and an industry point of view. The research delivered estuary-specific models relating to oyster growth, disease risk, harmful algal bloom risk, sources of contamination, and other factors influencing industry productivity. Each model relies on measurements from real-time sensors deployed across multiple commercial estuaries in both NSW and WA. The high-frequency data collection has allowed accurate modelling of harvest area conditions, informing farm management decisions for the local oyster industry.

Based on detailed economic assessments conducted by the team, and translation into our own (CRC) audited impact calculator, the project is set to yield substantial economic benefits across NSW and WA. For the Pambula Lake, the impact assessment estimated a Net Present Value of $15,039/ha across 20 years, and a Benefits Cost Ratio of 2.8.

Beyond the economic benefits, the impact of this project can be seen in the active engagement of producers, who have been a key component of the project, conducting water quality measurements, instrument deployment, proof-of-concept and pilot trials. The project fostered strong relationships between farmers, and between farmers and scientists. Together, the team generated the largest dataset of water quality and health measurements from oyster-producing estuaries in the world, as well as world-leading research at UTS. In addition, the fact that a project that originated in NSW, was adopted in WA, by request of the WA authorities, is a testament to its tangible impact.

END-USER PROFILE

Anna Simonds, Secretary of the Pambula River Shellfish Quality Assurance Program

Who are you and how did you become involved in this project?

I am a second-generation Pambula oyster farmer and the Secretary of the Pambula River Shellfish Quality Assurance Program (PRSQAP) – the group of Pambula River oyster farmers who carry out routine and event sampling as required by the NSW Shellfish Program. I became involved in May 2018 as part of the initial discussions on project design and scope. I worked on multiple aspects of the project: communication and coordination with local farmers, sampling, sensor monitoring, oyster data collection, reviewing of the final report, and discussions within the PRSQAP throughout the project.

What was your overall experience with this project?

Overall, I had a very positive experience, as did the broader Pambula Lake oyster farming community. We all felt well supported and a genuinely important part of the team. We were all provided with great technical training to ensure the reliability of sample collection, with additional support and mentoring always just a phone call away. The project validated much historic farmer hearsay. Many oyster farmers are scientists by training or through experience, as they see things every day and connect the dots themselves. However, this project scientifically validated these experiences. Over time, we have seen more and more farmers routinely using the salinity sensor data, to the point where this data now drives business decisions, as farmers can better estimate when the estuary will close and when to harvest. This itself highlights the huge impact of this work on the local oyster-growing community.

Can you identify long-term benefits of the project, for you or your industry?

Beyond day-to-day activities, and the local harvest management plans that we can now implement to benefit the industry, the data provide a scientific basis for our advocacy to protect and maintain our pristine oyster-growing estuaries. In addition, as a small business operating in a relatively small estuary, it's been great to feel part of a bigger community, where everyone works for the same purpose. The project really cemented my pride for the oyster industry, its collaborative and proactive nature. It highlighted how all the pieces of the puzzle can work together to achieve success – whether they be food safety regulators, marine scientists or farmers. We created communication lines and established networks that may not have happened otherwise.

OBJECTIVES

The objectives of this project were:

- To assess the potential for using salinity and temperature-based real-time data as indicators of water quality.
- To develop rapid molecular assays (qPCR) to model concentrations of *E. coli* as well as harmful algae *Pseudo-nitzschia spp.*, *Dinophysis spp.*, *Alexandrium spp.* and *Prorocentrum minimum* in relation to environmental variables.
- To further develop qPCR assays to identify the origin of *E.coli* (bird, cow or human).
- To assess the potential for using the high temporal-resolution dataset generated to predict water quality and apply this metrics to oyster food safety.
- To provide the oyster-growing industry of NSW (and beyond) and regulators with tools to improve oyster farm management practices and profitability.

METHODOLOGY

Weekly biological sampling and data collection were conducted by shellfish farmers across 12 NSW estuaries (Fig.2). Detailed methods can be found in the reports published for the estuaries[1-12].

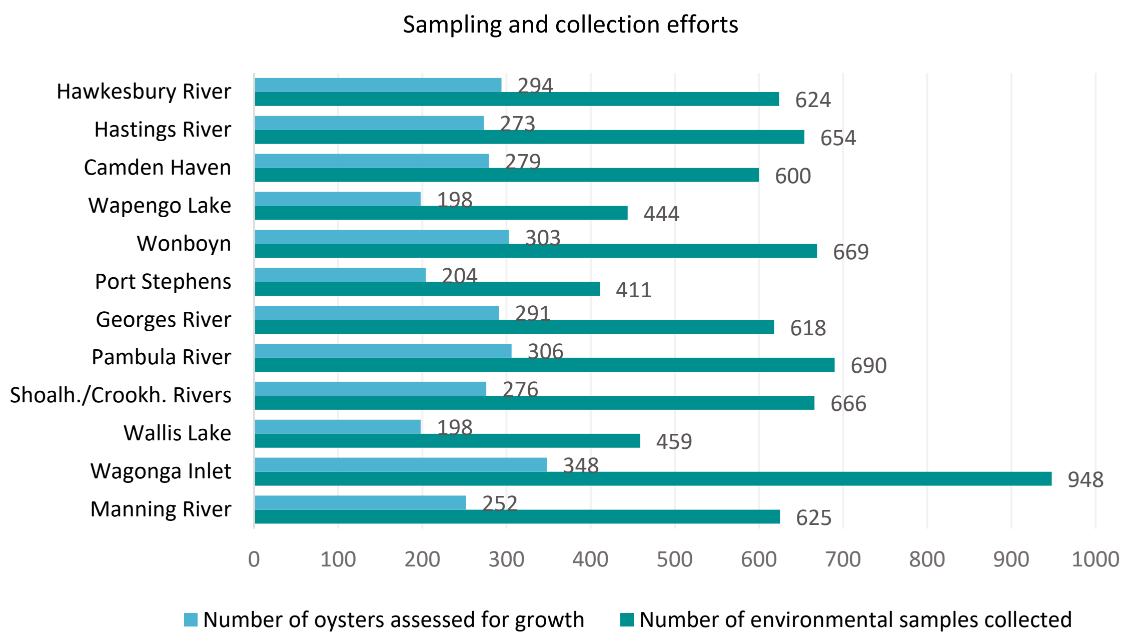

Figure 2. Sampling and data collection effort for each of the 12 NSW estuaries with data analysis completed. Data for another two NSW estuaries (Macleay and Merimbula) and one WA estuary are currently being finalised.

RESULTS

Key findings (Table 1) included:

- the number of days when harvest closures could have been avoided if food safety decisions had been based on real-time salinity;
- the predictive capacity of salinity sensors for *E. coli* contamination, compared to rainfall;
- oyster mortality observed throughout the project compared to background mortality.

Table 1. Sensor performance and mortality recorded for each NSW estuary.

Report # *	Estuary	# harvest closure days that could have been avoided	% of salinity sensors more reliable than rainfall §	Mortality levels compared to background farming ¥
1	Manning River	8	75	Not greater
2	Wagonga Inlet	4	75	Not greater
3	Wallis Lake	1	100	Not greater
4	Shoalhaven/Crookhaven Rivers	4	100	Not greater
5	Pambula River	9	75	Not greater
6	Georges River	10	25	Not greater
7	Port Stephens	8	100	Not greater
8	Wonboyn	6	100	Slightly above
9	Wapengo Lake	7	67	Slightly above
10	Camden Haven	8	100	2.5x greater than background farming mortality
11	Hastings River	2	100	2x greater than background farming mortality
12	Hawkesbury River	5	100	Not greater

* As seen on the webpage https://www.foodagility.com/research/transforming-australian-shellfish-production

§ Refer to Appendix Table 1 for additional data pertaining to the use of salinity-based sensors.

¥ Refer to original reports[1-12] for the time periods assessed.

These very positive results led to the proposal of salinity-based management plans, offered to 19 harvest areas, and seven were adopted at the time of writing (Table 2).

Table 2. Status of the 19 salinity-based management plans offered[1-12].

Sensor Estuary Order N-S	Harvest area	Status
Macleay River	New Entrance	new sensor 2021
Hastings River	Lower Limeburners Creek	offered
Camden Haven	Gogleys Lagoon	offered
Manning River	Pelican Point	adopted
Wallis Lake	Long Island (upstream)	offered
Port Stephens	Corrie Island	new sensor 2021
Port Stephens (DPI Fisheries Sensor)	Cromartys Bay	adopted
Hawkesbury River (HSC Sensor)	Coba Bay	adopted
Hawkesbury River (HSC Sensor)	Marramarra	adopted
Hawkesbury River (HSC Sensor)	Mullet Creek	adopted
Georges River	Quibray	offered
Shoalhaven/Crookhaven Rivers	Goodnight Island	offered
Clyde River (DPI Sensor)	Waterfall	offered
Clyde River (DPI Sensor)	Rocky Point	offered
Clyde River (DPI Sensor)	Moonlight	offered
Wagonga Inlet	Lower Honeymoon Bay	offered
Wapengo Lake	Front Lake	adopted
Merimbula Lake	Top Lake	new sensor 2021
Pambula Lake	Pambula Lake	adopted
Wonboyn Lake	Wonboyn Lake A	offered
Wonboyn Lake	Wonboyn Lake B	offered
Wonboyn Lake	Wonboyn Lake C	offered

HIGHER DEGREE BY RESEARCH STUDENTS

University of Technology Sydney

1. Dora Vig (PhD) 2022-present. Environmental water quality and other ecological factors impacting oyster aquaculture in South-Eastern Australia

2. Felipe Hernandez (PhD) 2020-present. Monitoring for food safety in the NSW oyster industry

3. Kate McLennan (Honours). Assessing the Use of Molecular Barcoding and qPCR for Investigating the ecology of *Prorocentrum minimum* (Dinophyceae), a harmful algal species. *Microorganisms* 2021, *9*(3), 510; https://doi.org/10.3390/microorganisms9030510

4. Matt Tesoreiro (Honours). *Abundance and distribution of pathogenic bacteria in NSW oyster producing estuaries*. Faculty of Science. 2020, University of Technology Sydney. p. 46.

Macquarie University

Alice Howie (MSc) using the high-resolution data

University of Newcastle

Finlay Johnson (PhD) using the high-resolution data

Southern Cross University

Meryl Larkin (PhD) using the high-resolution data

CONCLUSIONS AND RECOMMENDATIONS

Real-time salinity monitoring shows considerable promise and will increase profitability allowing for the growth of the industry

The project supported implementing a harvest area management plan based on salinity in most harvest areas. Available data indicated that the number of days when harvest area closures could have potentially been avoided amounted to 2-3 months in approximately 2-3 years (see previous reports[1-12] for details). As of August 2024, 19 salinity-only management plans had been offered, and seven adopted, in participating NSW estuaries.

Compared to background mortality levels in oyster farm settings, equivalent or slightly higher levels were recorded in 10 of the 12 estuaries monitored (83%). The pollution source tracking results were highly variable across the study period and estuaries, but real-time sensor data largely showed a higher predictive capability than rainfall for faecal indicator bacteria[1-12]. Elevated levels of *E. coli* were often variable, at times increasing with rainfall[1-12].

Considerable co-benefits

PCR-based assays demonstrate significant potential to supplement and/or replace classical environmental sample analytical methods. The benefits of PCR-based analysis include faster sample turnaround time and potentially the ability to analyse samples on-site, reducing sample transport and delays, ultimately reducing costs.

We have also produced an open access curated, large (temporal and spatial) scale estuary database (Ajani et al. 2024 accepted *Nature Scientific Data*) and have a large eDNA bank for further investigation. We have provided both high resolution estuary and eDNA to a range of other studies including those involving shark movements, fish communities, seagrass and oyster reef restoration, pathogenic bacteria, oyster disease and growth, and soft corals.

NEXT STEPS

This report summarises the results for the oyster harvest areas located in participating NSW estuaries. The next steps include finalising the reports for the two added estuaries in NSW (Macleay River and Merimbula Lake) and in WA (Oyster Harbour). We will continue to work with industry to adopt management plans based on real-time sensor salinity, where appropriate. This includes ongoing management and maintenance of sensors by industry beyond the life of the project. We will continue with our new project with the mussel industry to use real-time sensing for building resilience and expansion within this sector. We will continue ongoing research to extend the project findings and facilitate on farm testing using qPCR techniques. We will continue to publish and disseminate findings as the opportunity arises.

PUBLICATIONS LIST

Scientific Manuscripts directly or indirectly related to the project

1. Ajani et al. 2022. Mapping the development of *Dinophysis* spp. HABs using a novel molecular qPCR assay. *Harmful Algae* 16: 102253

2. Ajani et al. 2021. Using qPCR and high-resolution sensor data to model a multi-species *Pseudo-nitzschia* (Bacillariophyceae) bloom in southeastern Australia. *Harmful Algae* 108: 102095

3. Ajani et al. 2024. High-resolution temperature, salinity and depth data from southeastern Australian estuaries, 2018-2021. *Nature Scientific Data* (accepted Aug 2024)

4. Stelling-Wood et al. 2023. A deep dive into the ecology of Gamay (Botany Bay, Australia): current knowledge and future priorities for this highly modified coastal waterway. *Marine and Freshwater Research* 74 (12): 1003-1025. DOI: https://doi.org/10.1071/MF22268

5. Lenzen, M, et al. 2021. Impacts of harmful algal blooms on marine aquaculture in a low-carbon future. *Harmful Algae* 110: 102143.

6. McLennan et al. 2021. Assessing the use of molecular barcoding and qPCR for investigating the ecology of Prorocentrum minimum (Dinophyceae), a harmful algal species. Microorganisms. 9: 510 IF 4.1

7. Barua et al. 2020 First detection of paralytic shellfish toxins from *Alexandrium pacificum* above the regulatory limit in blue mussels (*Mytilus galloprovincialis*) in New South Wales, Australia. Microorganisms 8(6): 905.

8. Ruvindy R et a. 2024. An on-farm workflow for predictive management of Paralytic Shellfish Toxin-producing harmful algal blooms for the aquaculture industry. *Environmental Science and Technology Research* 58(16).

RESEARCH | PROJECTS

Transforming Australian Shellfish Production

Delivering real-time, estuary-specific predictive modelling for shellfish farmers to manage and reduce the cost of closures.

In Partnership With:

University of Technology Sydney

NSW Department of Primary Industries

WA Department of Primary Industries and Regional Development

NSW Farmers

Transforming Australian Shellfish Production

This project follows on from the success of the 'NSW Oysters Transformation' project, which proved that real-time temperature and salinity sensors used in regulatory harvest management can lead to cost efficiencies for oyster farmers.

The Challenge:

As filter feeders, shellfish like oysters and mussels accumulate particles from surrounding waterways. Following high-risk events such as heavy rainfall, harmful algal blooms, or shellfish disease outbreaks in the estuary, regulators like the NSW Food Authority implement precautionary harvest area closures to manage potential food safety risks.

Shellfish farmers in Australia are not currently able to predict the likelihood of a harvest area closure due to these high-risk events. If farmers were aware of an imminent closure, they could take meaningful action such as harvesting early, or moving stock to lower risk areas of their lease to reduce mortality risk.

The Solution:

This project will deliver estuary-specific models relating to shellfish growth, disease risk, harmful algal bloom risk, sources of contamination, and other factors influencing industry productivity. The project, led by researchers from The University of Technology Sydney and DPI Aquaculture Research, will continue working with NSW shellfish farmers from the **previous project**, and expand to include additional estuaries in NSW and WA.

Each of the models will rely on measurements from real-time sensors developed by ICT International (NSW) and In Situ Marine Optics (WA), which will be deployed across a number of commercial estuaries in both states. The high frequency data collection will allow more accurate modelling of harvest area conditions, which will inform farm management decisions for the shellfish industry in these areas.

These estuary-specific models will be used in two ways:

1. To inform revised regulatory procedures for the NSW and the WA regulators, which will use the models to determine in real-time whether shellfish are safe for harvest or not and communicate this with growers.

2. Integration into existing farm management software currently being used by producers which will send automated alerts to growers when real-time water quality data hits pre-determined thresholds. These alerts can be configured to fall ahead of any expected regulatory closures.

In addition to the project partners, this project is also proudly funded by the NSW Government through the Bushfire Industry Package Sector Development Grants initiative.

PROJECT REPORTS:

Stage One - December 2017 - March 2021

Pelican Point Harvest Area in the Manning River

Lower Honeymoon Bay Harvest Area in Wagonga Inlet

Long Island Harvest Area in Wallis Lake

Goodnight Island Harvest Area in Shoalhaven and Crookhaven Rivers

Pambula Lake Harvest Area - Pambula River

Quibray Bay Harvest Area - Georges River

Cromarty's Bay Harvest Area - Port Stephens

Wonboyn Lake A Harvest Area - Wonboyn River

Wapengo Front Lake Harvest Area - Wapengo Lake

Gogleys Lagoon Harvest Area - Camden Haven River

Lower Limeburners Creek Harvest Area - Hastings River

Coba Bay Harvest Area - Hawkesbury River


TRANSFORMING AUSTRALIAN SHELLFISH PRODUCTION
Pelican Point Harvest Area - Manning River
TRANSFORMING AUSTRALIAN SHELLFISH PRODUCTION
Lower Honeymoon Bay Harvest Area - Wagonga Inlet
TRANSFORMING AUSTRALIAN SHELLFISH PRODUCTION
Long Island Harvest Area - Wallis Lake
TRANSFORMING AUSTRALIAN SHELLFISH PRODUCTION
Goodnight Island Harvest Area - Shoalhaven and Crookhaven Rivers
TRANSFORMING AUSTRALIAN SHELLFISH PRODUCTION
Pambula Lake Harvest Area, Pambula River
TRANSFORMING AUSTRALIAN SHELLFISH PRODUCTION
Oatley Bay Harvest Area - Georges River
TRANSFORMING AUSTRALIAN SHELLFISH PRODUCTION
Cromartys Bay Harvest Area - Port Stephens
TRANSFORMING AUSTRALIAN SHELLFISH PRODUCTION
Wonboyn Lake A Harvest Area, Wonboyn River
TRANSFORMING AUSTRALIAN SHELLFISH PRODUCTION
Wapengo Front Lake Harvest Area, Wapengo Lake
TRANSFORMING AUSTRALIAN SHELLFISH PRODUCTION
Gogleys Lagoon Harvest Area, Camden Haven River
TRANSFORMING AUSTRALIAN SHELLFISH PRODUCTION
Lower Limeburners Creek Harvest Area, Hastings River
TRANSFORMING AUSTRALIAN SHELLFISH PRODUCTION
Coba Bay Harvest Area, Hawkesbury River

ACRONYMS & ABBREVIATIONS

AOAC	Association of Official Agricultural Chemists
CRC	Cooperative Research Centre
DPI	Department of Primary Industries
eDNA	Environmental DNA
GVP	Gross Value of Production
NSW	New South Wales
PCR	Polymerase Chain Reaction
qPCR	Quantitative Polymerase Chain Reaction
USyd	University of Sydney
UTS	University of Technology Sydney
WA	Western Australia
WADPIRD	Western Australia Department of Primary Industries and Regional Development

REFERENCES

1. Ajani, P. et al., (2023) Transforming Australian Shellfish Production: Coba Bay Harvest Area, Hawkesbury River Report on Stage 1, May 2018 - March 2021, Sydney, Australia.

2. Ajani, P. et al., (2023) Transforming Australian Shellfish Production: Lower Limeburners Creek Harvest Area, Hastings River Report on Stage 1, May 2018 - March 2021, Sydney, Australia.

3. Ajani, P. et al., (2023) Transforming Australian Shellfish Production: Gogleys Lagoon Harvest Area, Camden Haven River Report on Stage 1, March 2018 - March 2021, Sydney, Australia.

4. Ajani, P. et al., (2023) Transforming Australian Shellfish Production: Cromartys Bay Harvest Area, Port Stephens. Report on Stage 1, December 2017-March 2021, Sydney, Australia.

5. Ajani, P. et al., (2023) Transforming Australian Shellfish Production: Quibray Bay Harvest Area, Georges River. Report on Stage 1, October 2017-March 2021, Sydney, Australia.

6. Ajani, P. et al., (2022) Transforming Australian Shellfish Production: Wapengo Front Lake Harvest Area, Wapengo Lake. Report on Stage 1, December 2018-March 2021, Sydney, Australia.

7. Ajani, P. et al., (2022) Transforming Australian Shellfish Production: Wonboyn Lake A Harvest Area, Wonboyn River. Report on Stage 1, February 2018-February 2021, Sydney, Australia.

8. Ajani, P. et al., (2022) Transforming Australian Shellfish Production: Pambula Lake Harvest Area, Pambula River. Report on Stage 1, September 2016-March 2021, Sydney, Australia.

9. Ajani, P. et al., (2022) Transforming Australian Shellfish Production: Goodnight Island Harvest Area, Shoalhaven and Crookhaven Rivers. Report on Stage 1, December 2017-March 2021, Sydney, Australia.

10. Ajani, P. et al., (2022) Transforming Australian Shellfish Production: Long Island Harvest Area, Wallis Lake. Report on Stage 1, December 2017-March 2021, Sydney, Australia.

11. Ajani, P. et al, (2022) Transforming Australian Shellfish Production: Lower Honeymoon Bay Harvest Area, Wagonga Inlet. Report on Stage 1, December 2017-March 2021, Sydney, Australia.

12. Ajani, P. et al, (2022) Transforming Australian Shellfish Production: Pelican Point Harvest Area - Manning River. Report on Stage 1, December 2017-March 2021, Sydney, Australia.

APPENDICES

Appendix Table 1A. Data supporting the development of salinity-based management plans for oyster farming according to *E. coli* (max and max from birds).

Estuary (site)	Max *E. coli**	Trend	Best Model	% dev explained	Max Bird*	Trend	Best Model	% dev explained
Hastings River	39,159	R	S	28	8,180	S/A/SPR	S	33
Camden Haven	90,612	V	S	44	39,593	S	S	65
Manning River	141,841	R	R	62	32,632	S/A	S	19
Wallis Lake	4,508	R	S	15	11,543	A/W	S	36
Port Stephens	4,428	R	S	24	17,729	R&S/A/SPR	S	61
Hawkesbury River	34,456	V/R	S	36	12,324	S/A	S	58
Georges River	144,865	R	R	52	7,588	SPR	S	53
Shoalhaven/Crookhaven	11,281	R	S	24	2,010	S/A	S	46
Wagonga Inlet	31,390	V	S	13	4,780	S/A	S	33
Wapengo Lake	11,027	R	R	26	2,360	S/A	S	30
Pambula River	22,843	R	R	24	2,196	S/A	S	37
Wonboyn Lake	182,118	R	S	40	47,038	S/A	S	41

R: rainfall; S: salinity

Appendix Table 1B. Data supporting the development of salinity-based management plans for oyster farming according to *E. coli* (max from cow and humans).

Estuary (site)	Max Cow*	Trend	Best Model	% dev explained	Max Human*	Trend	Best Model	% dev explained
Hastings River	43,105	V/R	S	65	220	R	S	
Camden Haven	5,164	V/R	S	31	132	R	S	100@
Manning River	175,694	R	S	74	5,649	R	S	78
Wallis Lake	229	R	S	27	787	R	ND	ND
Port Stephens	28,302	R	S	66	474	V/R	S	66
Hawkesbury River	51,180	R	S	91	39,896	R	S	98
Georges River	529,176	R	R	94	452,515	R	R	92
Shoalhaven/Crookhaven	16,386	V/R	S	35	2,188	V/R	S	73
Wagonga Inlet	415	V	R	21	617	V	S	33
Wapengo Lake	15,765	R	S	40	65	R	ND	ND
Pambula River	36,780	R	S	40	990	R	S	39
Wonboyn Lake	19,469	V/R	S	30	411	R	S	61

R: rainfall; S: salinity

Transforming Australian Shellfish Production

Penelope Ajani, Mike Dove, Hazel Farrell, Wayne O'Connor, Matt Tesoriero, Arjun Verma, Anthony Zammit, Brian Hughes, Laura Parker, Shaye Carman and Shauna Murray
August, 2024

Project No.076

hello@foodagility.com
@FoodAgility
foodagility.com