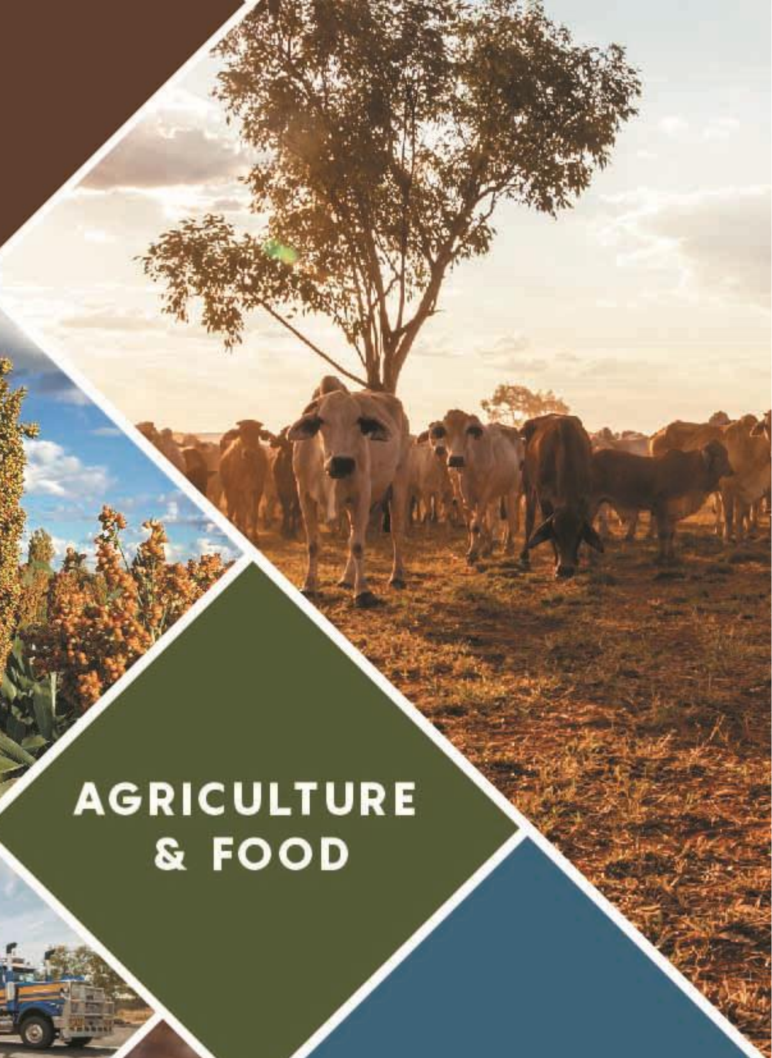
NORTHERN HEALTH
SERVICE DELIVERY



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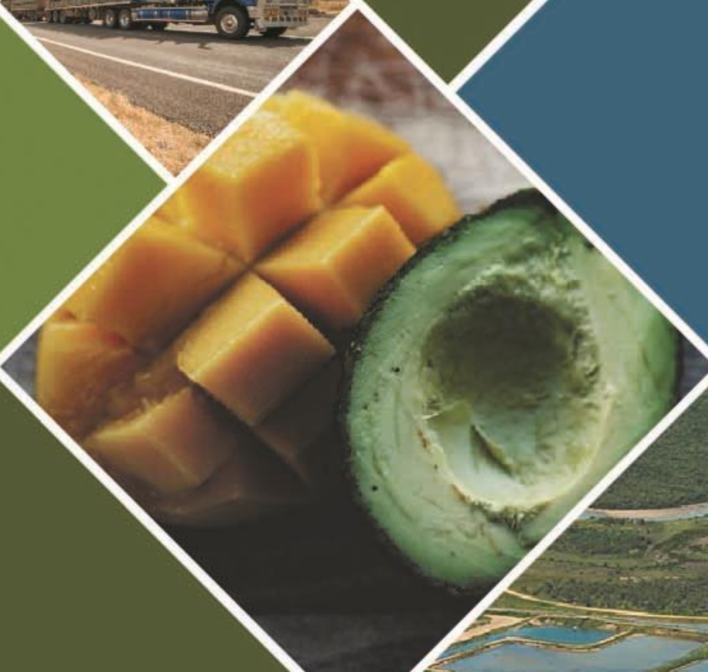

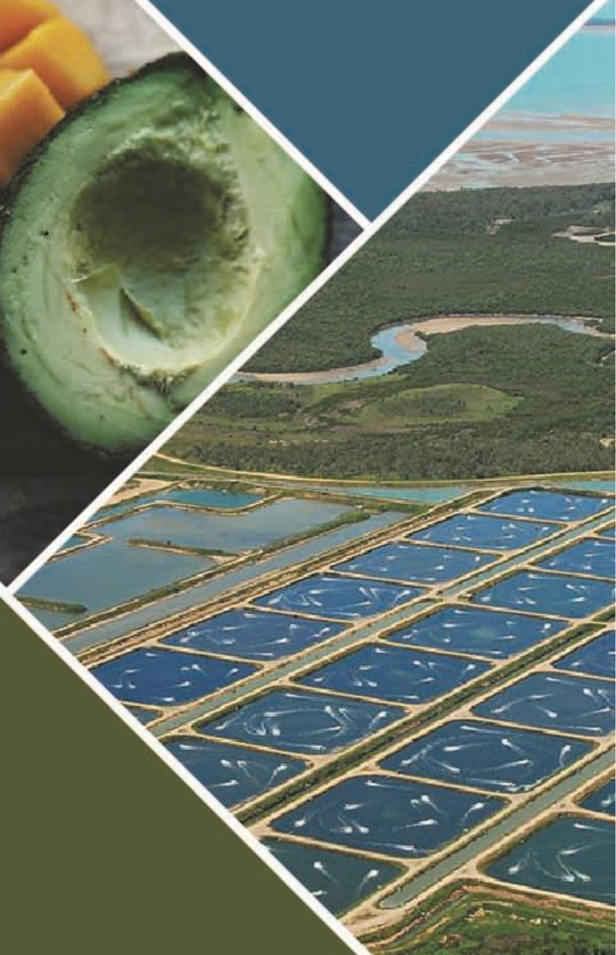

Pioneering Tropical Rock Lobster Raft Grow-out for Northern Australia

S. Infante Villamil and J. Blair

Ornatas Research & Development

CRCNA

DEVELOPING NORTHERN AUSTRALIA

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Australian Government
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AusIndustry
Cooperative Research Centres Program

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Acronyms

CRCNA	Cooperative Research Centre for Developing Northern Australia
DPIRD	Department of Primary Industries and Regional Development (Western Australian government)
FRDC	Fisheries Research and Development Corporation
HDPE	High Density Polyethylene
IMAS	Institute for Marine and Antarctic Studies (University of Tasmania)
JCU	James Cook University
NT	Northern Territory
ppt	Parts per thousand (commonly used for salinity)
PCR	Polymerase chain reaction
QLD	Queensland
qPCR	Quantitative polymerase chain reaction (where qPCR ct is the cycle threshold value; number of cycles at which the fluorescence signal of the amplified target reaches a detectable level above the background noise, which is a proxy of pathogen quantity in the tested sample)
RA	Risk assessment (refers to Pathogen Risk Assessment)
SCAAH	Sub-committee on Aquatic Animal Health (SCAAH) that provides scientific and technical advice to the Animal Health Committee (AHC). SCAAH comprises representation from the Australian, state and Northern Territory and New Zealand governments, the Commonwealth Scientific and Industrial Research Organisation - Australian Centre for Disease Preparedness (CSIRO ACDP), formerly known as the Australian Animal Health Laboratory, and Australian universities.
SIA	Seafood Industry Australia
TRL	Tropical Rock Lobster (*Panulirus ornatus*)
UTas	University of Tasmania
WA	Western Australia
WP	Work Package
WSSV	White spot syndrome virus

Project Participants

Project Lead Participant

The project received cash and in-kind contributions from – Ornatas

Project Participants

The project was made possible by in-kind contributions from – Maxima; Honey & Fox; JSJ Seafood; PFG Group; University of Tasmania - IMAS

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Peter Warner – PFG Group

Basseer Codabaccus and Greg Smith – University of Tasmania

Leo Nankervis, Nathan Hammel, Kelly Condon – James Cook University – complementary research outside this project

Executive Summary

The Tropical Rock Lobster, *Panulirus ornatus*, demonstrates promise as a valuable addition to the aquaculture sector in Northern Australia, offering both economic and environmental sustainability benefits. Advancements in hatchery and nursery technology have made it feasible to produce juvenile lobsters in land-based commercial scale systems. Hatchery-produced juveniles reduce reliance on wild-caught stocks and alleviate fishing pressure on natural populations. The ability of Ornatas to cultivate Tropical Rock Lobster (TRL) in controlled environments provides the opportunity to optimise growth conditions, leading to higher yields and optimal product quality. Additionally, the establishment of a Tropical Rock Lobster aquaculture industry has the potential to create employment opportunities and stimulate economic growth, particularly in regions where suitable farming conditions exist.

The overall outcomes of this project were to develop and evaluate onshore culture in raft systems and to establish production models for TRL aquaculture in Northern Australia. The research encompassed six work packages. The Farm site environment package investigated the impact of water quality on pilot Tropical Rock Lobster (TRL) production in ponds and pond productivity at the Toomulla site in Queensland. This assessment spanned a full production cycle, from stocking to achieving commercial size and taste testing. Variable environmental conditions were experienced, typical of North Queensland's tropical climate, characterised by seasonal fluctuations between summer and winter. Results indicate that effective water quality management protocols are deemed essential to ensure an optimal growth environment for land-based culture of TRL in North Queensland. The Production system package involved the evaluation and adaptation of an existing offshore Indonesian technology (Aquatech) for land-based TRL culture in Toomulla. Initial testing of an offshore raft system, primarily constructed of High Density Polyethylene (HDPE), was conducted to explore its suitability for potential future TRL grow-out operations in Cone Bay, Western Australia. The third work package focused on biosecurity, translocation, and health, with a primary objective of developing a pathogen risk assessment (RA) framework and protocol for the translocation of hatchery-produced TRL from Queensland to other jurisdictions in Northern Australia. Dr. Ben Diggles led the development of this RA, which serves as the scientific foundation for biosecurity planning, translocation policy, and operational protocols concerning juvenile lobster translocation. Protocols were established for Western Australia and the Northern Territory. The Feeding management package assessed feeding strategies for lobster in raft culture, utilising pelleted feeds formulated by the University of Tasmania (UTas) and hatchery-produced juveniles acclimated to this feed type. The lobster production performance package primarily aimed at developing business models for TRL grow-out operations, supporting opportunities for diversification among existing aquaculture producers, new entrants, and potential investors. Business models tailored for TRL of initial weights 3g and 50g indicated a difference of 3 months to reach commercial harvest size of 1.2kg (14 vs 11 months). Lastly, the market-ready lobster quality package conducted consumer demand research for premium Tropical Rock Lobster to inform ongoing market retention and expansion efforts, encompassing markets beyond China. Additionally, this work package explored technologies related to provenance and branding authenticity.

The project has delivered critical information about production systems, lobster performance, health risks, and demonstrated high quality lobster product from the first production cycle. Based on the results of this research, commercial development and research is continuing in Tropical Rock Lobster aquaculture in land-based raft systems in North Queensland. An industry value of $160 million p.a. and volume of 1,100 tonnes is projected by 2033, employing 120 people in feed manufacture, grow-out, downstream processing/distribution and marketing.

Introduction

The Australian Tropical Rock Lobster (TRL) (*Panulirus ornatus*) is a delicacy in high demand, prized for its excellent texture and flavour, often commanding a premium price (exceeding $80/kg in certain markets). However, the supply of market-size lobsters is currently restricted to wild-caught adults or lobsters grown in Southeast Asia from captured puerulus and juveniles. This places unsustainable pressure on wild TRL stocks, consequently limiting its availability in the medium to long term. The development of novel hatchery technology, regarded as a breakthrough in aquaculture and pioneered in Australia, now enables the production of TRL juveniles. This advancement supports the feasibility of commercialising hatchery-produced TRL and developing a new aquaculture industry.

Ornatas Pty Ltd (hereafter referred to as Ornatas) was founded in 2018 with the explicit goal of pioneering the world's first closed lifecycle Tropical Rock Lobster aquaculture industry for both Australian and international markets. Ornatas holds the Australian license to commercialise the hatchery technology, with the objective of establishing and supporting a grow-out industry in Northern Australia, thereby creating opportunities for diversification among current aquaculture producers. Over the period 2019 - 2029, Ornatas plans to invest more than $65 million in capital to develop this innovative aquaculture sector. Currently, Ornatas operates a commercial scale hatchery, nursery, and a pilot onshore grow-out facility located at Toomulla Beach north of Townsville, Queensland. This comprehensive facility was designed to replicate the oceanic environment necessary for the successful cultivation of spiny lobster larvae and juveniles.

This project, 'Pioneering Tropical Rock Lobster Raft Grow-out for Northern Australia', undertook the science required for the grow-out of hatchery-produced juvenile lobsters in raft systems that were trialled onshore at Toomulla. Multiple gaps in knowledge were investigated to support the development and evaluation of this production technology to meet market demands. The project partners brought expertise across the production-to-market pipeline and the research focus was on six areas: environment; raft design; translocation, lobster health and biosecurity; feeding strategies; lobster growth performance; and premium diverse market acceptability. Two business models for an onshore raft system were developed to inform quality investment in a brand-new grow-out aquaculture industry by current and new aquaculture businesses.

All aspects of the research included training of personnel and documentation of procedures that were made available by project participants to potential new lobster grow-out producers in Australia. The project team regularly communicated progress with stakeholders, including government (national, state and territory, local), jurisdiction agencies, community, aquaculture producers, training and research providers. A Field Day event was carried out to share the current status and production models for consideration by existing and potential new businesses. An industry value of $160 million p.a. is projected by 2033, with future potential of over $500 million p.a. that creates 1,000 direct jobs, 900 of those in Northern Australia, for people working in feed manufacture, grow-out, downstream processing/distribution and marketing.

Governance

Across the life of the project, seven steering committee meetings were conducted; two of which took place face to face, one in Broome, Western Australia and one in Townsville, Queensland. The remainder of the meetings were held via Zoom. The final meeting, carried out on May 6th 2024, provided a comprehensive overview of the project, including its accomplishments, encountered challenges, and discussions on future direction.

Steering Committee Members

- Scott Parkinson (Ornatas)
- Jennifer Blair (Ornatas)
- Sandra Infante Villamil (Ornatas)
- Steven Gill (Maxima)
- Jayne Gallagher (Honey & Fox)
- Nathan Maxwell (JSJ Seafood)
- Sarah Docherty (CRCNA)
- Wayne Hutchinson (FRDC)

Invited observers

- John Hutton (Maxima)
- Alison Hutton (Maxima)
- Martin Rees (Ornatas)
- Helen Johnston (Honey & Fox)

In addition to the Steering Committee, Ornatas and Maxima held fortnightly Zoom meetings to share updates and coordinate activities related to the Sea-Raft project. The lead Sea-Raft researchers had a final project update with the CRCNA and FRDC during the end-of-project Field Day, on 13 March 2024 (see Appendix G for a Field Day event Report and Appendix H for the Field Day presentations).

Work Package 1. Farm Site environment

Water Quality Final Research Report (Appendix A) includes a brief review of the environmental conditions in Cone Bay, located within Western Australia's Kimberley region, which was the original designated site for the project. This report also outlines the methodology and water quality findings from the control and grow-out systems at Toomulla throughout the project's duration. The environmental conditions closely reflected those typical of North Queensland's tropical climate, characterised by significant fluctuations between the summer and winter seasons. Summer months, characterised by heavy and frequent rainfall, resulted in decreased salinity levels and high water temperatures. Conversely, the dry winter period led to an increase in salinity levels and cooler temperatures (Table 1). These seasonal variations had a notable impact on overall water quality, often causing deviations from the optimal range for Tropical Rock Lobster (TRL) aquaculture.

Table 1. Total monthly rainfall as per records of the Rollingstone meteorological station (Bureau of Meteorology) and maximum and minimum levels of salinity and temperature from 16 Dec 2022 to 30 April 2024 in the Tropical Rock Lobster grow-out system at Toomulla Beach.

Year	Month	Total monthly rainfall (mm)	Max Salinity (ppt)	Min Salinity (ppt)	Max Temperature (°C)	Min Temperature (°C)
2022	Dec	210.0	34.4	32.4	33.9	28.0
2023	Jan	636.6	32.9	28.8	34.9	29.2
2023	Feb	372.4	28.5	25.9	34.2	28.5
2023	Mar	175.7	30.1	26.1	33.1	27.6
2023	Apr	101.5	33.6	29.7	31.9	25.9
2023	May	8.1	35.4	31.5	28.6	21.7
2023	Jun	2.2	36.0	35.4	26.0	21.7
2023	Jul	78.6	36.1	34.7	25.5	20.8
2023	Aug	3.2	36.1	34.9	25.4	21.9
2023	Sep	18.0	36.8	33.7	27.8	23.6
2023	Oct	15.8	36.6	34.8	28.8	24.1
2023	Nov	40.1	38.1	36.0	30.8	24.1
2023	Dec	112.0	37.2	34.5	31.8	25.6
2024	Jan	416.5	36.1	27.5	32.0	28.3
2024	Feb	547.8	29.6	25.6	31.1	26.4
2024	Mar	323.8	28.1	24.9	31.1	26.4
2024	Apr	45.8	29.9	25.7	29.8	24.4

To maintain suitable conditions for TRL growth, strict daily monitoring and adjustments to water quality were essential (detailed information in Appendix A). During the summer months, the implementation of a cooling tower was necessary to ensure that water temperatures remained below 32°C. Additionally, measures were taken to address the dilution effect caused by heavy rainfall. To counteract this effect, salt or hypersaline water, and sources of calcium and magnesium were introduced into the system. Furthermore, sodium bicarbonate was utilised to raise the pH levels and enhance the buffering capacity of the system. In contrast, during the winter season, the introduction of freshwater was essential to prevent salinity levels from exceeding the tolerance thresholds for TRL. While there was no period of ideal optimal water quality based on available research, throughout the life of this project it was shown that exposure to stressful conditions led to variable levels of TRL survival and growth (detailed in the production performance section; WP5). This study found that a broad range of seasonal temperature and salinity can support TRL survival and growth in North Queensland. Despite the presence of TRL in the system, the low stocking density resulted in minimal nutrient release by the lobsters and gradual decomposition of uneaten feed, indicating a negligible impact of lobster biomass on water quality within the system at the tested stocking densities.

Future developments

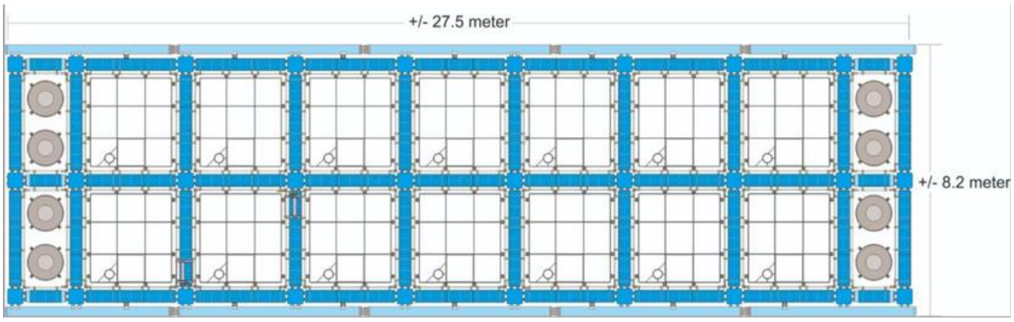
To reach commercial outcomes it is crucial to define levels of key water quality parameters for TRL grow-out to maintain an environment that promotes optimal growth, efficient feed conversion, high survival rates, and overall productivity. Additionally, defining appropriate and tolerance levels allows for the efficient use of resources and ensures the sustainability of operations in the long term.

Work Package 2. Production Systems

The system tested to culture hatchery-produced juvenile TRL in land-based systems at Toomulla Beach consisted of two Aquatec raft prototypes (Figures 1 and 2) with submerged enclosures for communal lobster grow-out. The original Aquatec system consisted of 14 large and 8 small mesh enclosures (Figure 2a). The upper, non-fixed side of each enclosure created an access point for the TRL in the water and this side was used to install the automatic feeder. In the second raft prototype tested the number of enclosures was increased to 16 large and 32 medium enclosures (Figure 2b). Two access points to observe and handle the TRL from the top of the large enclosures were incorporated in the second raft, to facilitate daily activities and feeding. Appendices B and C describe Ornatas' grow-out standard operations and specifications.

Figure 1. Lobster aquaculture raft prototype systems, supplied by Aquatec, Indonesia, for grow-out of juvenile Tropical Rock Lobster in fully submersible mesh enclosures.

a.



b.

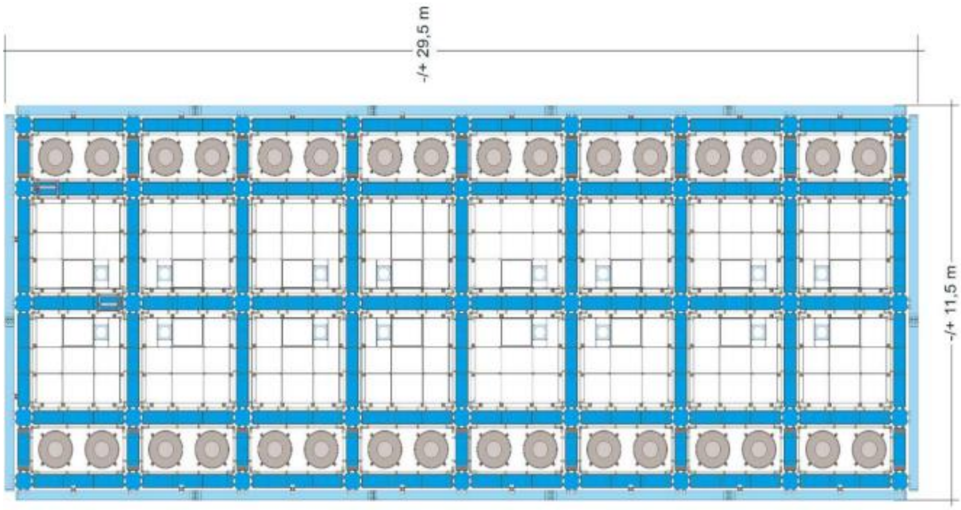


Figure 2. Lobster raft prototype frame system for nursery/grow-out of puerulus and juvenile TRL in submersible structures.

An investigation into the biofouling of equipment in the land-based raft system was conducted, with a particular focus on the mesh of the enclosures. After 22 weeks, heavy biofouling accumulated on the mesh without cleaning (Figure 3). When lobsters were inside the enclosures, internal biofouling was minimal due to the lobsters grazing on fouling organisms. The exterior of the enclosures was brushed clean once every 7 to 14 days to minimize external buildup.

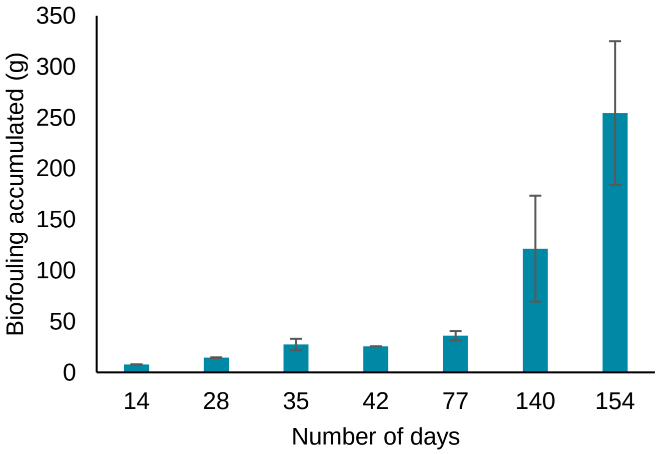


Figure 3. A biofouling trap located in one of the corners of the raft system (top left). A biofouling trap post-deployment showing heavy biofouling accumulated by day 154 (top right). Weight of biofouling accumulation in traps over time (lower graph) without cleaning, average represents average ± SD (n = 2) when available.

In Western Australia, a raft was designed, constructed, and deployed in Cone Bay (Figures 4a–d). However, this raft was not tested with lobster grow-out due to a shift in the project's focus towards research activities in North Queensland.

a. b. c. d.

Figure 4. First sea raft constructed and deployed at Cone Bay.

Future developments

There are several design criteria and operational requirements to consider for improvement of land-based raft operations for TRL production, including: the addition of an automated mechanical track to move around the pen lifting frame and winch; replacement of the small circular pens with rectangular pens for ease of access to lobsters; and, infrastructure to support cooling of pond water during summer (e.g. increased water depth, shading, different lining colour, earthen ponds). Further research is required to investigate scaling with land-based raft production systems, or an alternative technology. Modified systems will be required for nearshore or offshore TRL aquaculture in Northern Australia.

Work Package 3: Biosecurity, translocation and health

The comprehensive risk assessment *Pathogen Risk Analysis for Aquaculture Biosecurity and Translocation of Tropical Rock Lobsters (Panulirus ornatus) in Northern Australia* was developed by Dr Ben Diggles (Diggles, 2021; Appendix D). This risk assessment considered potential risks associated with known exotic and endemic spiny lobster pathogens, originating from the environment and animals housed in land-based systems. Additionally, it assessed the risks posed to existing aquaculture and non-aquaculture species in Northern Australia. The outcome of this risk assessment served as a scientific foundation for developing Ornatas' Biosecurity Management Plan. It also guided translocation policies and operational protocols related to the transportation of juvenile lobsters. The assessment requires regular updates based on scientific literature and experience gained on site and can be utilised for future assessments concerning translocation to Western Australia, the Northern Territory, and/or the Torres Strait, although such endeavours are beyond the current project's scope. A translocation protocol was established through the project for hatchery produced TRL to be sent to Cone Bay, WA, for research purposes (Appendix E). Likewise, a protocol was agreed for translocating juveniles to the Northern Territory into closed culture systems.

As part of this project, a *Health Surveillance and Management Plan* (Appendix F) was developed for Ornatas based on the pathogen risk assessment. This plan is essential to implement surveillance and monitoring initiatives aimed at promptly detecting and effectively responding to disease outbreaks, as well as providing early warnings regarding exotic incursions or emerging diseases.

In collaboration with AquaPath at James Cook University (JCU), and as a component of an Innovation Connections program, an eDNA pilot study was conducted. This pilot project aimed to monitor the bacterium *Aquimarina* sp. within the grow-out system and throughout the site at Toomulla. Figure 5 illustrates the results of bacterial monitoring using eDNA in the grow-out facility during April and May 2023. The findings suggest that *Aquimarina* is a component of the commensal community associated with TRL. While this bacterium has been linked to White Leg Syndrome, and its abundance may indicate bacterial dysbiosis in certain instances (as denoted by a lower qPCR ct value (red line) compared to the 16S value represented by a grey line), no disease was detected in the juvenile TRL held within the grow-out system.

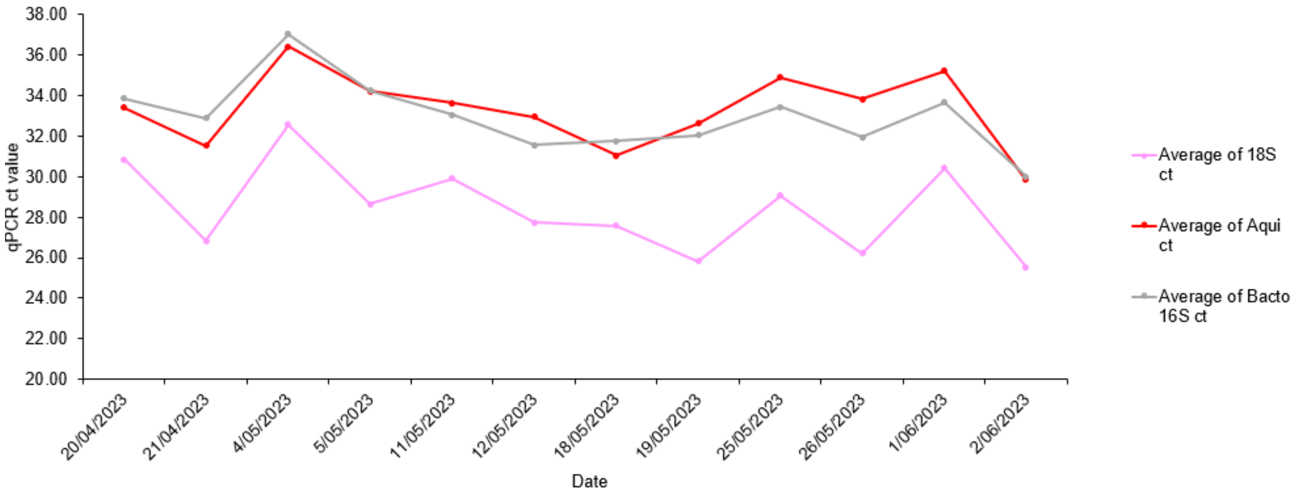


Figure 5. Variation in bacterial load (16S; grey line), *Aquimarina* load (red line) and *P. ornatus* load (pink line) based on qPCR results.

We acknowledge the contribution of Kelly Condon and Maria Andrade-Martinez towards this work package through eDNA research conducted. Suggested citation for this section:

Infante Villamil, S., Condon, K., Andrade-Martinez, M. and Blair, J. (2024). Work Package 3. Biosecurity, translocation and health. In Infante Villamil, S. and Blair, J. (2024). *Pioneering Tropical Rock Lobster Raft Grow-out for Northern Australia. Final Report CRCNA Project A.3.2021116*. Ornatas Research & Development. CRCNA, Townsville. 27 pages.

Future developments

Establishing a new tropical rock lobster aquaculture industry in Northern Australia requires continuous progress in the areas of biosecurity, translocation, and health management. Biosecurity protocols must undergo constant review and adaptation to address new and emerging disease threats and changes in farm conditions, including the scaling up of operations. Assessing the health of lobsters and evaluating methods to prevent and manage potential pathogens in TRL juveniles is paramount for ensuring the success and sustainability of the industry. This involves ongoing passive surveillance and prompt response to any moribund or unusual signs and symptoms observed among the juvenile lobsters, including changes in behaviour, lesions, or unusual morphology. Additionally, active surveillance and sample testing should be conducted for all incoming new broodstock, with a particular focus on PCR testing for white spot syndrome virus (WSSV). Conventional methods, such as routine health examinations and quarantine procedures, can be enhanced by innovative strategies like microbial monitoring and management, including the utilisation or development of probiotics. Probiotics have the potential to provide health benefits to the host, such as reducing the risk of opportunistic bacterial proliferation.

Work Package 4. Feeding management

Feeds developed by the University of Tasmania (UTas) through the ARC Research Hub for Sustainable Onshore Lobster Aquaculture underwent evaluation in the sea rafts. It is important to note that these feeds are protected under the intellectual property rights (IP) of both UTas and Ornatas, as part of their research collaboration background.

Feeding management is described in Appendix B (Best Practice grow-out operation). Briefly, automatic 12-h belt feeders (Figure 6) were used to dispense feed three times per day in the individual enclosures. The feed ration was calculated based on 2% of the initial lobster biomass per enclosure followed by adjustments based on observations of feed not consumed and weekly counts of lobsters in each enclosure. These observations in individual pens relied on optimal water quality to avoid undue stress to TRL and were dependent on water clarity to allow counting. Underwater video surveillance was carried out to observe feed attraction and consumption but was limited to periods of adequate visibility.

Figure 6. Belt feeders installed to medium size enclosures in the grow-out system.

As part of an Innovation Connections program with JCU, research in hydroacoustics was conducted to address visibility limitations and optimise feeding efficiency in the grow-out systems. This research is ongoing and can improve feeding by providing real-time monitoring and assessment of feeding behaviour. The main goal is to adjust feeding protocols to ensure the right amount of feed is delivered at the right time. This optimisation can lead to improved growth rates and minimise the risk of overfeeding, which can lead to water quality degradation. In the long term hydroacoustic monitoring can help identify abnormal feeding behaviour or changes in feeding patterns, which may indicate health issues or stress in TRL.

Hydroacoustic research started in Nov 2023 using an automated belt feeder, a hydrophone and an underwater video camera to precisely record and identify TRL feeding activity. Accuracy in feeding time was limited due to the design of the belt feeder. However, three different sounds produced by TRL were recognised: popping, rasping and slow rattle sounds. Throughout a 3-hour period around delivery of feed in a raft enclosure, the popping sound was the most common of the three sounds. This sound is generated through the motion of a lobster's appendages and the cavitation bubble mechanism during feeding. The "popping" sound can occur either as a solitary pulse (see Figure 7) or in clusters of up to three pulses (Figure 8).

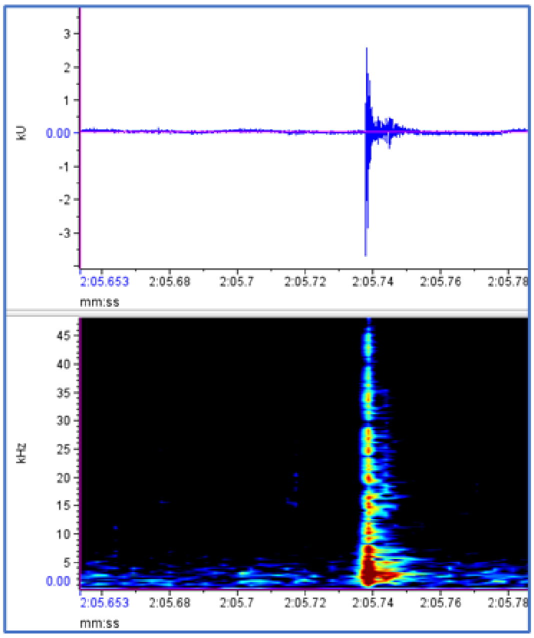


Figure 7. Popping sound of a tropical rock lobster as a singular pulse. The top quadrant shows the waveform view and the bottom quadrant shows the spectrogram view of the hydrophone recording.

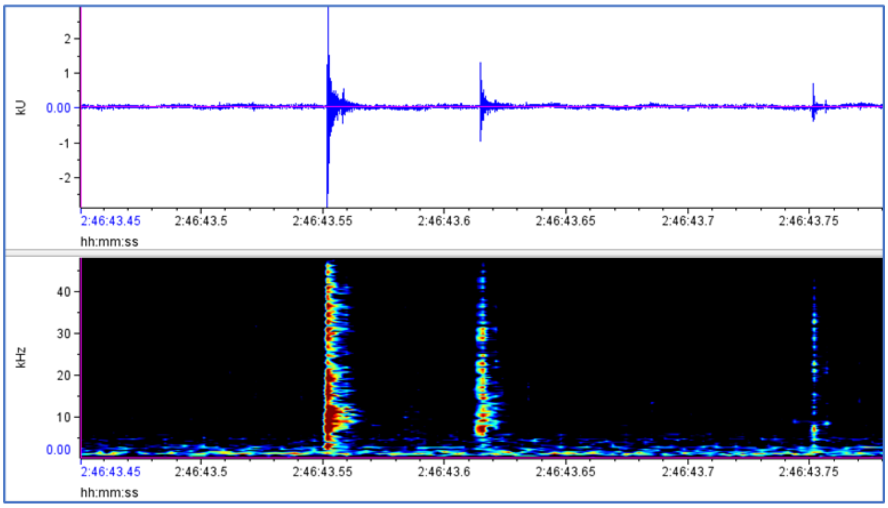


Figure 8. Popping sound of a tropical rock lobster as a group of pulses. The top quadrant shows the waveform view and the bottom quadrant shows the spectrogram view of the hydrophone recording.

During the 3-hour recording, 399 popping sounds of broad levels of amplitude and frequency were recorded. These broad levels could be associated with feeding background noise from TRL located in other enclosures within the raft system and TRL of different sizes. Figure 9 shows the number of popping sounds recorded by the hydrophone in 10-minute intervals. The highest number of “popping” sounds (n=40) was recorded during the 80 to 90 min interval after the first feeding. The second highest number (n=35) was recorded during the first 10 min after the first feed (Figure 9). If all the popping sounds recorded were from TRL in the same enclosure, results suggest that the animals fed at different times throughout the 3-hour tested (~15:00 – 18:00).

The rasping sound was less common than the popping sound and it had a longer duration and lower amplitude and frequency. This sound was detected 75 times in the 3-hour recorded. The highest number of rasping sounds was recorded in the 60 – 70 min interval after the first feed (Figure 10). It has been suggested that the emission of the rasping sound in lobsters occurs in response to perceived threats or disturbances in their environment. Hartoyo et al., (2022) proposed that this sound escalates in frequency during nighttime hours due to heightened sensitivity to environmental movement. Additionally, the rasping noise has been identified as a defensive mechanism against potential predators (Buscino et al. 2011). Furthermore, research conducted by Staaterman et al. (2010) indicates that simulation of contact with a predator can readily provoke this sound in lobsters.

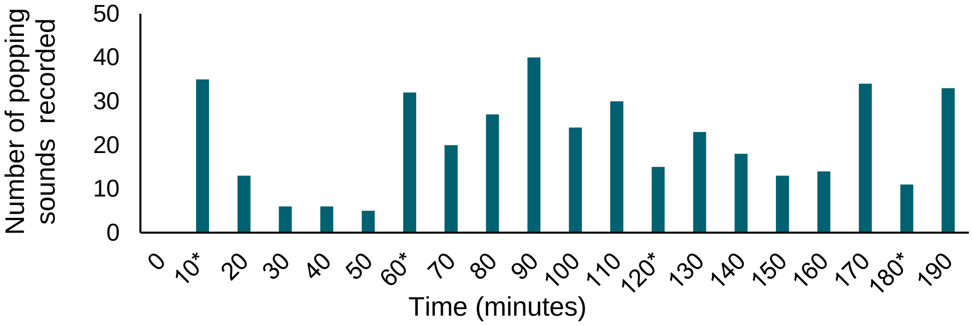


Figure 9. Number of popping sounds produced by tropical rock lobsters recorded by the hydrophone grouped by 10-minute intervals. "*" beside x-axis labels indicates feed input times.

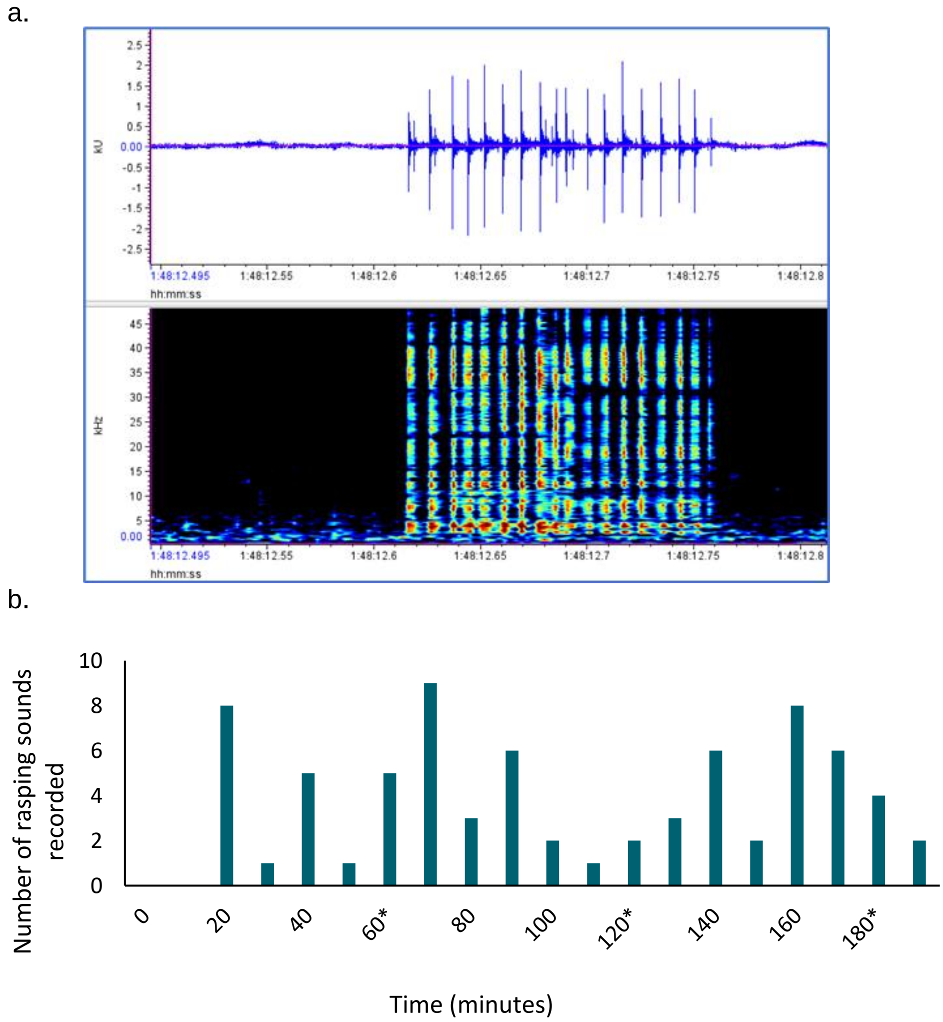
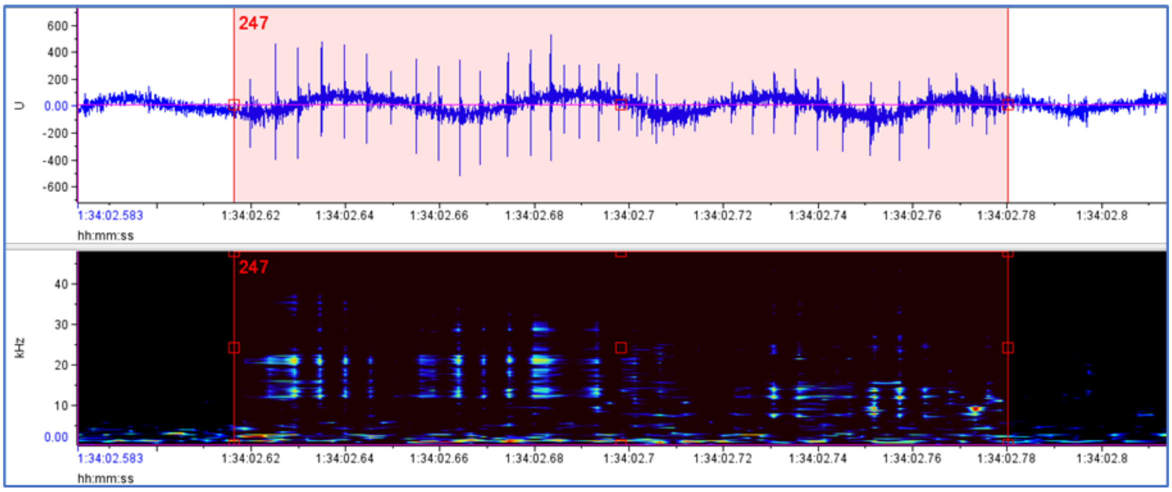


Figure 10. Waveform view (top quadrant a) and spectrogram view (bottom quadrant a) of the rasping sound produced by tropical rock lobsters. (b.) Number of rasping sounds recorded by the hydrophone grouped by 10-minute intervals after feeding. "*" beside x-axis labels (b) indicates feed input times.

The slow rattle sound is the least understood and it is believed to be produced in the same way as the rasping sound (Hartoyo et al., 2022). It was detected 25 times during the 3 hours of monitoring (Figure 11).

a.



b.

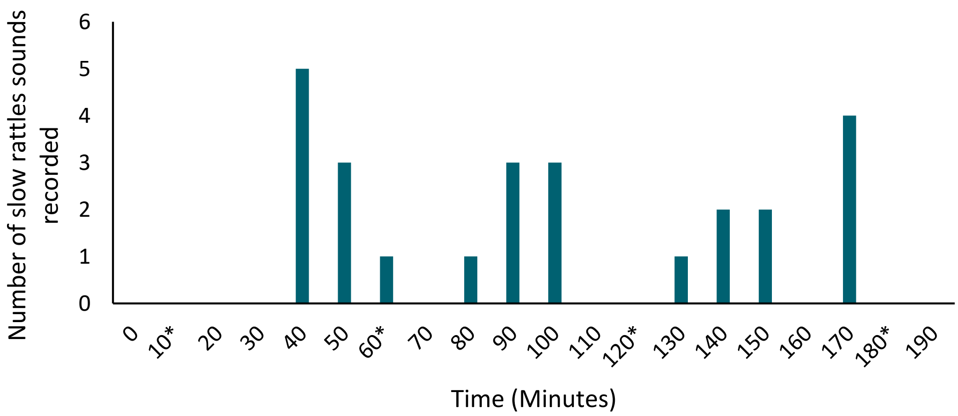


Figure 11. Waveform view (top quadrant a) and spectrogram view (bottom quadrant a) of the slow rattle sounds recorded that were produced by tropical rock lobsters. Number of slow rattle sounds recorded by the hydrophone grouped by 10-minute intervals after feeding. "*" beside x-axis labels (b) indicates feed input times.

A subsequent experiment was carried out to overcome the constraints observed in the previous trial. Firstly, an Arvo-Tec automatic feeder (Figure 12) was tested due to its capability to deliver precise feeding times and quantities. Secondly, the experiment was conducted in the second grow-out system, where lobsters were segregated within a single enclosure positioned at the far end of the system, away from the paddlewheel. The outcomes of this trial are pending analysis and will inform future research direction.

Figure 12. Arvo-tec feeding system installed to a large enclosure in the second grow-out system to increase accuracy in feeding time and volume.

We acknowledge the contribution of Nathan Hammel and Leo Nankervis towards this work package through hydroacoustic research conducted. Suggested citation for this section:

Infante Villamil, S., Hammel, N., Nankervis, L. and Blair, J. (2024). Work Package 4. Feeding Management In Infante Villamil, S. and Blair, J. (2024). *Pioneering Tropical Rock Lobster Raft Grow-out for Northern Australia. Final Report CRCNA Project A.3.2021116*. Ornatas Research & Development. CRCNA, Townsville. 27 pages.

Future developments

Feeding practices need to be continuously optimised to ensure efficient TRL growth and sustainability of production by avoiding feed waste. One key priority is the continued development and implementation of hydroacoustic technology along with automated feed delivery, to better align feeding regime with lobster feeding response and to minimise waste and potential water quality deterioration (potential environmental impact). Additionally, the development of a commercial feed through the exploration of alternative feed ingredients and formulations is ongoing, to improve feed efficiency and reduce production costs.

Work Package 5. Lobster production performance

The processes and parameters used to evaluate TRL performance in the grow-out system are described in Appendix B. Weight and survival based on weekly counts were the key parameters used to determine TRL performance by season and to develop the business model. A total of 886 hatchery-produced juvenile lobsters were stocked in the grow-out facilities between December 2022 (Group A only in Table 2) and February 2024, and reared until April 2024. Table 2 provides a summary of the fluctuations in weight and survival rates observed during the stocking events of hatchery-produced TRL across different groups throughout the duration of the project. The lowest survival rate (22.7%) was observed in Group A1, corresponding to the initial stocking event of the project. This poor survival rate is likely attributed to environmental parameters fluctuating beyond the tolerance level for Tropical Rock Lobsters (TRL). Specifically, high temperatures ranging from 33.1 to 34.9 °C, alkalinity below 2.5 Meq/L, pH levels below 8.1 with significant diurnal fluctuations due to low buffering capacity, magnesium levels below 1320 ppm and calcium levels below 380 ppm (refer to Table 1 and Appendix A). Survival rates equal to or higher than 40% were observed in the remaining groups (A2 – A8 and B1 – B2), with over 90% survival in the batches stocked in 2024.

Table 2. Summary of TRL performance in grow-out rafts at Toomulla Beach throughout the project.

Group	Date 1	Date 2	Initial wt (g)	SD	Final wt (g)	SD	Survival
A1	4/01/2023	27/03/2023	64.26	23.4	85.3	15.5	22.7
A1	30/11/2023	26/02/2024	530.7	74.0	663.5	177.5	**84.6**
A2	30/03/2023	12/05/2023	40.2	5.0	76.35	9.1	**61.3**
A2	12/05/2023	6/09/2023	76.35	9.1	228.0	47.9	**71.4**
A3	12/04/2023	15/06/2023	6.0	1.8	25.9	9.9	50.0
A3	12/04/2023	15/06/2023	7.2	1.4	23.7	10.8	46.7
A3	12/04/2023	15/06/2023	6.5	2.1	32.7	8.8	40.0
A3	15/06/2023	14/09/2023	27.1	14.2	99.0	50.0	**58.5**
A4	12/04/2023	15/06/2023	33.4	5.6	82.6	13.7	43.3
A4	12/04/2023	15/06/2023	32.3	3.4	77.6	16.8	50.0
A4	12/04/2023	15/06/2023	31.5	5.3	70.2	14.8	**60.0**
A4	15/06/2023	14/09/2023	76.1	15.7	178.3	42.1	**73.9**
A5	20/04/2023	16/05/2023	20.5	2.6	34.03	16.01	**76.8**
A5	16/05/2023	6/09/2023	34.03	16.01	125.8	41.6	**68.3**
A5	20/04/2023	16/05/2023	46.4	19.9	104.98	23.06	**92.0**
A5	16/05/2023	6/09/2023	104.98	23.06	265.6	75.8	**60.9**
A6	7/06/2023	22/08/2023	2.6	0.8			95.0
A6	7/06/2023	22/08/2023	2.6	0.8	23.1	9	47.4
A6	7/06/2023	22/08/2023	2.9	1.2			100.0
A6	7/06/2023	22/08/2023	2.9	1.2	19.7	9.0	45.0
A6	7/06/2023	22/08/2023	5.7	1.6			90.0
A6	7/06/2023	22/08/2023	5.7	1.6	32.3	12.6	**55.6**
A6	7/06/2023	22/08/2023	5.4	2.1			95.0
A6	7/06/2023	22/08/2023	5.4	2.1	32.3	18.7	47.4
A6	7/06/2023	22/08/2023	3.5	0.8			85.0
A6	7/06/2023	22/08/2023	3.5	0.8	23.4	5.5	**64.7**
A6	22/08/2023	30/11/2023	26.2	12.3	78.9	35.7	**89.6**
A6	30/11/2023	25/04/2024	78.9	35.7	317.4	94.2	**69.8**
A7	15/11/2023	24/4/2024	9.39	_	122.1	19.46	**86.0**
A7	15/11/2023	24/4/2025	6.83	_	104.68	22.11	**80.5**
A7	16/11/2023	24/04/2024	8.94	2.88	135.5	28.2	**96.0**
A7	16/11/2023	23/04/2024	8.07	2.23	121.06	21.46	**88.0**
A8	21/12/2023	25/04/2024	61.74	18.4	305.53	103.2	**78.8**
B1	8/02/2024	25/04/2024	45.15	14.42	105.6	24.11	**96.2**
B2	8/02/2024	25/04/2024	42.16	7.29	103.04	26.59	**96.3**
B2	8/02/2024	25/04/2024	38.08	10.05	97.33	17.64	**92.3**

A replicated size-at-stocking experiment involving TRL subjected to winter conditions (Groups A3 and A4), revealed that individuals of small (~6.6 g) and medium (~32.4 g) sizes stocked in medium enclosures (0.61 m²) demonstrated resilience and growth even at salinity levels exceeding 35 ppt (with a maximum of 36.0 ppt observed in June) and temperatures as low as 21.7 °C recorded in May and June (refer to Figure 13, Table 2, and Appendix A). By the conclusion of the 2-month experiment in mid-June 2023, survival rates for these groups approached 50%. Notably, following the consolidation of individuals from each size group from the medium enclosures into larger ones (6.75 m² each) in June, improved survival rates were observed in the larger size group (73.9%) compared to the smaller size group (58.5%) by mid-September. Throughout this period, the TRL experienced winter conditions, enduring temperatures as low as 20.8 °C in July and salinity levels as high as 36.8 ppt in September (see Table 2). It is plausible that smaller animals may exhibit increased cannibalistic behaviour or be less tolerant to such challenging environmental conditions, resulting in lower survival.

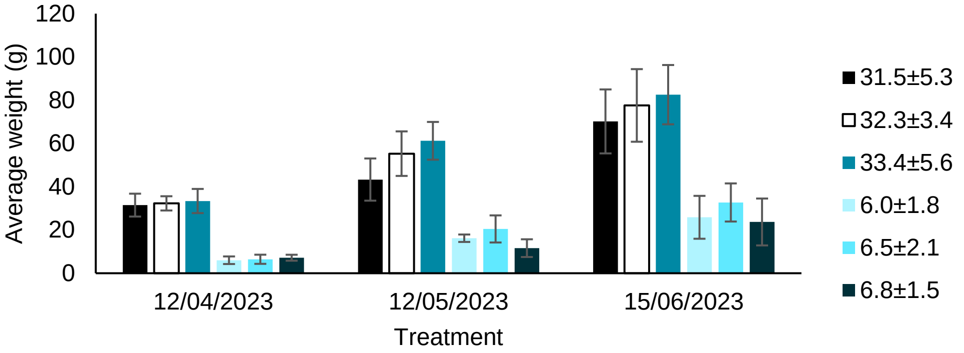


Figure 13. Variation in weight of TRL exposed to winter conditions in the grow-out system (size at stocking experiment; Groups A3 and A4). Legend indicates initial average size of lobsters in grams in each enclosure, small lobsters (6.0 to 6.8 g) and medium lobsters (31.5 to 33.4 g).

In a second replicated trial involving 100 animals, distributed across five medium enclosures (Group A6), approximately 50% survival was confirmed for small-sized animals during winter conditions (June 7th to August 22nd). The TRL weighed on average between 2.6 and 5.7 g, resulting in a survival rate of 52.0 ± 8.2%. Additionally, this trial revealed that 7% of mortality could be attributed to the stress associated with stocking, which involves the processes linked to the movement of animals from the nursery into the grow-out system. These two winter experiments highlight a limitation in stocking small-sized animals (approximately 32.0 g or smaller) during winter conditions in the tested land-based system, with only an estimated 50% survival rate among the stock. Upon transferring the surviving TRL into a large enclosure on August 22nd, with an average weight of 26.2 ± 12.3 grams, survival reached 89.6%, despite the group being exposed to the highest salinities of the year in November (reaching 38 ppt by the end of November). In addition, temperatures were warmer, ranging from 23.0°C in late August to 30.8°C in late November.

The highest survival rate achieved during the project (averaging 88%) occurred during the second summer season in 2024, as evidenced by a trial involving TRL smaller than 10 grams (Group A7; Table 2). Despite being exposed to high salinities in November (maximum 38.1 ppt), the addition of freshwater and the onset of rainfall events led to a decrease in salinity, with a maximum of 29.9 ppt recorded in April and a minimum of 24.9 ppt in March. Several factors may have contributed to this improvement, including a reduction in stocking density (55 or 75 TRL in large enclosures), warmer but not extreme temperatures ranging from 25.3°C in November to a maximum of 32.0°C in January (attributable to the effect of the cooling tower), and alkalinity and pH levels fluctuating within tolerance levels (refer to Appendix A). Conducting a summer stocking experiment with higher stocking density and using managed water quality conditions (implemented as standard procedure from March 2023) would serve to validate these promising results.

A business model based on the assumptions of no impact of the season on growth, and a worst-case scenario of 50% cannibalism from stocking, indicates that 14 months are required for TRL of initial weight 3 g to reach the commercial harvest weight of 1.2 kg. The model predicts 3 months less (11 months) for animals of initial weight 50 g to reach harvest size. Figure 14 indicates the change in biomass over time with these assumptions and starting from either 50 g or 3 g juvenile TRL. Research is ongoing to determine methods to mitigate cannibalism in grow-out.

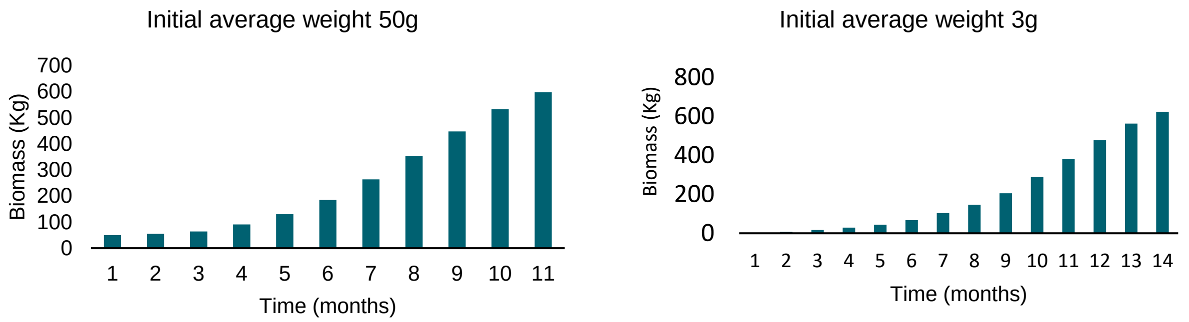


Figure 14. Business models developed for TRL of two initial sizes of juvenile Tropical Rock Lobsters based on growth and survival data gathered in the grow-out system.

Field Day

A Field Day was held on the 13th of March 2024. Participants from CRCNA including board members and Sarah Docherty (SC), FRDC, AusIndustry, JCU, IMAS, Office of Northern Australia, Steven Gill (SC Maxima), Ornatas SC (Jennifer Blair and Sandra Infante Villamil), Ornatas' General Manager and Nursery and Grow-out Manager. The main goal of the Field Day was to disseminate knowledge gained by Ornatas throughout the life of the Project on the development, current status and production models of the TRL aquaculture industry. The outcomes of the project were evaluated and the research needs and opportunities to develop the industry in Northern Australia were discussed. Refer to Appendix G for details of the Field Day and to Appendix H for the information shared with all participants.

Future developments

Continued monitoring of growth throughout a complete production cycle with adjusted water quality is required. Although the current water quality may not be optimal for Tropical Rock Lobster (TRL) growth, the collected data will demonstrate the effects of cost-effective adjustments and water quality (WQ) management on productivity.

Continued research and development efforts aimed at optimising stocking density and refining feeding strategies to enhance productivity are warranted.

There is the prospect of assessing the feasibility of TRL grow-out in nearshore ocean environments that provide different water quality conditions to the land-based site tested in this project. Opportunities in WA, where baseline water quality data is available, and the NT or Torres Straits could be explored to determine the suitability and potential for TRL aquaculture initiatives.

Work Package 6. Market-ready lobster quality

This work package comprised several approaches. It monitored the market and evaluated market demands by establishing a market monitoring system and conducting consumer demand research for premium Tropical Rock Lobster, which informs market retention and expansion efforts. Conducting demand research was crucial for informing the market acceptability of lobsters produced in sea rafts. This is particularly important as there was no prior information about the product appearance (e.g. potential for external biofouling), or flesh quality in hatchery-produced lobsters grown on a formulated feed.

Appendix I provides a summary of WP6 outcomes. Briefly, six markets were identified as suitable candidates for Ornatas to implement a diversified market development strategy, particularly as production scales up. These candidates are China, Hong Kong, the USA, Singapore, Taiwan and Korea. State-of-the-Market Reports are commercial in confidence. Market demand research included Chinese importers and Consumers. For Chinese importers, robustness (survival in tanks upon arrival) is the most important quality of live lobsters. Findings on modern Chinese consumers are detailed in Appendix J. This appendix includes people's perception of lobsters in general, a description of the most popular retailers, typical consumer profiles and purchase channels. Research conducted by Daxue, a specialist Asian market research agency, highlights the difference between Chinese, Korean and Singaporean lobster consumers (Appendix K).

Research on technologies related to provenance and branding authenticity is ongoing, beyond this project, and current options were captured on the *Provenance Technologies Report* (Appendix L).

This work package also evaluated onshore-grown lobster quality and market requirements by conducting an internal taste testing and a farm tour and taste testing with Australian chefs, wholesalers and retailers (Appendix M). Both experiences highlighted the high quality of the hatchery-produced product. Externally, there was no evidence of biofouling on the lobster carapace, which enhanced the appearance of the animals and the whole tasting experience. The experts characterised the hatchery-produced lobsters as robust, full of liveliness and with a clean taste. Different dishes were prepared with the no-waste goal; the tested product performed well in all circumstances.

Future developments

In relation to TRL quality and market demand, there are several areas for further research and development:

Emphasising the importance of animal survivability and robustness upon arrival to meet buyer expectations, it is important to develop harvesting, packing, and transportation capabilities for both live and dead products. Collaborating with businesses experienced in lobster export is key to leveraging their expertise and facilities.

Collaborate with chefs who participated in the taste testing to investigate various product formats and create a best practice guide to handling and cooking TRL using the 100% product utilisation approach. Carry out a second testing trial that includes the response of the chefs, the buyers and the consumers.

Maintain market monitoring and begin with market education to position the hatchery-produced TRL as a “world first”. An engaging product provenance story can be created emphasising sustainability, premium quality, Australian origin, and delicious taste. Market education efforts should be evaluated and provenance technologies such as QR codes and track and trace, should be tested.

Develop a market entry strategy in the local region while the volume of production increases and supply is continuous. Price premiums are likely to be achieved with small volumes of product if correct handling is coupled with premium branding and market positioning. A transition into a phased expansion can start with premium markets in Brisbane, Sydney, and Melbourne. This market strategy allows Ornatas to grow, establish processes, and train team members, supply chain and market partners. Once export to China is open for TRL, product testing in different Chinese markets can be explored.

Strategic recommendations

Key priority actions for sector development	Action owner and key partners	Pathways to implementation and timeline	Intended industry impacts
Additional research is required to support Tropical Rock Lobster grow-out aquaculture in Northern Australia. Priorities are: 1. establish an economical, commercially manufactured formulated feed, 2. investigate scaling land-based raft production systems, or alternative technology, 3. assess the health and management of potential pathogens of lobster juveniles, 4. define appropriate water quality for grow-out, and 5. test grow-out in nearshore ocean conditions.	**Ornatas**	Ornatas plans to continue to invest in collaborative research in TRL aquaculture, and has commenced discussions with potential funding agencies, industry stakeholders, and research providers.	Ornatas is scaling production with a goal of 1,100 tonnes p.a. of premium lobster product by 2033. This scale represents $160 million p.a. GDP, 120 jobs, and regional employment in Northern Australia, which includes opportunities for Indigenous-led businesses.
Streamlining translocation requirements for aquaculture species, including hatchery-produced and wild caught Tropical Rock Lobsters, within and between state jurisdictions - specifically harmonising cross-border biosecurity planning.	**Sub-committee on Aquatic Animal Health (SCAAH)** FRDC SIA	A workshop was hosted by SIA on 5 July 2023 with input from government and industry, including a presentation on TRL. A project identifying improvements to the translocation process for abalone, oysters and prawns is underway (supported by FRDC and SCAAH). Activities in other sectors to be progressed.	To manage the risks of pathogen spread and potential for disease outbreak and make the translocation process more efficient for industry and government agencies, with an agreed approach for each species/sector that is consistent across jurisdictions.

References

Buscino, G., Filiciotto, F., Gristina, M., Bellante, A., Buffa, G., Di Stefano, V., Maccarrone, V., Tranchida, G., Buscaino, C., and Mazzola, S. (2011). Acoustic behaviour of the European spiny lobster *Palinurus elephas*. *Marine Ecology Progress Series*, 441: 177-184.

Diggles, B.K. (2021). Pathogen risk analysis for aquaculture biosecurity and translocation of tropical rock lobsters (*Panulirus ornatus*) in Northern Australia. *DigsFish Services Report DF21-03b*, 29 November 2021, 120 pgs.

Hartoyo, H., Amron, A., Fitri, A.D.P., and Darmanto, Y.S. (2022). Sound productivity of spiny lobster *Panulirus homarus* (Linnaeus, 1758) due to crude oil contamination: the basic of bio-acoustic identification for water quality purposes. *Omni-Akuatika*, 18: 72-78.

Staaterman, E.R., Claverie, T., and Patek, S.N. (2010). Disentangling defense: The function of spiny lobster sounds. *Behaviour*, 147: 235-258.

Appendices

Note - Some appendices are confidental. For access to unrestricted appendices, please contact Ornatas - adminqld@ornatas.com.au

Appendix A	Water Quality Report 5 – Water quality variability Dec 2022 to April 2024 in TRL grow-out
Appendix B	Ornatas Best Practice grow-out operation
Appendix C	Ornatas Grow-out Standard Operating Procedure
Appendix D	Pathogen Risk Analysis for Aquaculture Biosecurity and Translocation of Tropical Rock Lobsters (*Panulirus ornatus*) in Northern Australia
Appendix E	Health Protocol for the Import of TRL Juveniles into WA (DPIRD)
Appendix F	Ornatas Health Surveillance & Management Plan
Appendix G	Field Day Event Report – 13 March 2024
Appendix H	Field Day Presentations
Appendix I	WP6 Market Ready Lobster Quality
Appendix J	Modern Chinese Consumer Research Report
Appendix K	Preference survey for lobster consumers in China, Singapore and Korea
Appendix L	Provenance Technologies Report
Appendix M	Farm Tour Taste testing