NORTHERN HEALTH SERVICE DELIVERY

TRADITIONAL OWNER-LED DEVELOPMENT

AGRICULTURE & FOOD

Investor guidelines: Rock oyster farming in Western Australia

A.2.1819053 WA

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Department of Primary Industries and Regional Development

CRCNA DEVELOPING NORTHERN AUSTRALIA

GOVERNMENT OF WESTERN AUSTRALIA

Department of Primary Industries and Regional Development

Acknowledgements

This research is funded by the CRC for Developing Northern Australia (CRCNA) is supported by the Cooperative Research Centres Program, an Australian Government initiative. The CRCNA also acknowledges the support of its investment partners: the Western Australian, Northern Territory and Queensland Governments.

The authors would like to acknowledge all Government of Western Australia Department of Primary Industries and Regional Development (DPIRD) employees that contributed to this report. The authors thank Aquaculture Management Officers Hayley Perhavec and Clara Alvarev Rodriguez for contributing to summarises of aquaculture management in Western Australia. Special thanks also to Amir Abadi Ghadim and Paul Mattingley of DPIRD's Industry Economic Analysis division for assisting to develop the Western Australian Tropical Rock Oyster bioeconomic model. The authors also acknowledge Steven Gill and Warren Ure of Maxima Rock Oyster Company Pty Ltd and thank them for their partnership throughout the project and significant contributions to the development of the bioeconomic model.

Disclaimer

ISBN 978-1-922437-55-6

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Acronyms and Abbreviations

AED	Aboriginal Economic Development
ASQAP	Australian Shellfish Quality Assurance Program
CAPEX	Capital expenditure
DoH	Department of Health
DoT	Department of Transport
doz	Dozen
DPIRD	Department of Primary Industries & Regional Development
EBIT	Earning before interest and taxes
EPA	Environmental Protection Authority
ha	Hectare
LCA	Levelized cost analysis
m	Metre
MEMP	Management and Environmental Monitoring Plan
mm	Millimetres
NPV	Net present value
NT	Northern Territory
OPEX	Operating expenses
PBC	Prescribed Bodies Corporate
TO	Traditional owners
WA	Western Australia
WASQAP	Western Australian Shellfish Quality Assurance Program

Glossary

Biofouling	The unwanted growth and accumulation of biological fouling organisms such as barnacles, oysters, soft corals, sponges, algae, and other small plants and animals on permanently and intermittently submerged oyster farming gear such as vessels, anchors, moorings, baskets, posts, etc.
Depuration	Oysters are placed into ‘clean’ water to allow them time to purge their biological contaminants and other impurities from their guts.
Intertidal	An intertidal farm sits within the high and low tidal mark for that area. Intertidal lines will be submerged and exposed with the incoming and outgoing tides exposing the farm to more extreme fluctuations in temperature, sun exposure, and salinity changes.
Farmgate	Describes the price the farmer fetches by selling directly from his farm to consumers and therefore does not include any markups by retailers or middlemen.
Growing area	Body or area of water that oysters are placed in to feed and grow up to market size. Oysters will not necessarily be harvested from these areas.
Harvest area	Body or area of water in which oysters will be harvested from for sale.
Lease	Authorisation for a person to occupy or use an area of land or waters for the purposes of aquaculture.
License	Authorisation for a person to engage in aquaculture activities within the leased area.
Overcatch	Overcatch in an oyster farming context refers to other juvenile bivalves and crustaceans that attach to and grow on cultivated/farmed oysters. In northern WA, it is often rock oysters of the same species, barnacles and mussels that recruit onto farm stock and become a problem.
Seed/Spat	Juvenile oysters. Also referred to as spat.
Subtidal	A subtidal farm is below the intertidal zone and always remains submerged.

Project Participants

Department of Primary Industries & Regional Development

Maxima Rock Oyster Company Pty Ltd

Athair Aquaculture Pty Ltd

Murujuga Aboriginal Corporation

Hexcyl Systems Pty Ltd

Zapco Aquaculture[1]

SEAPA

[1] Zapco Aquaculture have recently rebranded to 'Submurge'. They are referred to throughout this report as Zapco.

Executive Summary

Potential investors and farmers can use this document as a starting guide to undertake tropical rock oyster farming in Western Australia (WA). The intention of this document is to make investors aware of regulatory requirements for shellfish aquaculture in a WA context, whilst emphasising the variability in results and potential risks associated with oyster farming. The outcomes of an oyster farming operation will be unique to each proposed operation based on factors such as site and species selection, environmental and biological parameters, and business and management decisions.

A bioeconomic model incorporating growth and survival metrics from the WA tropical rock oyster project has also been used to compare several oyster farming scenarios. The model compares different scales of operation and key farming parameters such as mortality and growth rates to simulate the theoretical impacts of disease outbreaks or insufficient growth due to poor site selection. Readers should consider the information in this document general in nature (see Disclaimer) and are encouraged to seek advice about their unique farming proposition from subject matter experts in each of these areas (see Contacts).

Initial considerations for oyster farming in Western Australia

Department of Primary Industries & Regional Development (DPIRD) have a range of information about commencing aquaculture operations in WA waters and lands. This document brings together some of this information so prospective investors and farmers have an overview of the biological, environmental, economic, logistical, and regulatory considerations when planning an oyster farming operation in WA (Figure 1).

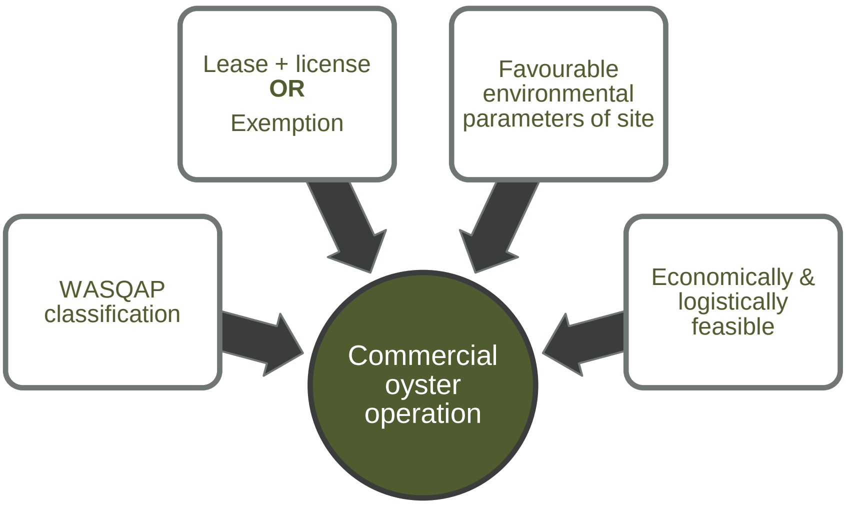

Figure 1. High-level summary of the major components when considering the feasibility of starting a commercial oyster operation in Western Australia.

Licensing and approvals

Aquaculture licence and lease

To undertake aquaculture operations in WA, you are required to hold an aquaculture licence and lease, or a research and development exemption[2].

An aquaculture **licence** authorises a person to engage in aquaculture activities within the leased area. An aquaculture **lease** authorises a person to occupy or use an area of land or waters for the purposes of aquaculture.

Applications for an aquaculture licence and lease can be made online.

[2] The research and development exemption are for trials only and not for commercial scale operation.

Aquaculture licence application requirements:

1. an aquaculture licence and lease application form;
2. a Management and Environmental Monitoring Plan (Guidance statement and template available);
3. a business plan;
4. Guidance Statement for Determining Categories of Marking and Lighting for Aquaculture and Pearling Leases/Licences (marking and lighting form); and
5. a translocation application form (if applicable).

Aquaculture lease application requirements:

Lease applications for sites within coastal waters and areas vested in the Minister for Fisheries are assessed by DPIRD and require additional information and an Aquaculture Development Plan.

Alternatively, if your area of interest is within port waters, you need to obtain tenure from the relevant Port Authority.

All applications for aquaculture licences and leases are assessed under principles set out in Administrative Guideline No. 1, Assessment of Applications for Authorisations for Aquaculture and Pearling in Coastal Waters of Western Australia.

Lease applications are further assessed against Administrative Guideline No. 2, Principles for Grant and Management of Aquaculture Leases in Coastal Waters of Western Australia. Please refer to Appendix 1 – Flow Chart of Assessment Process in Administrative Guideline No. 1 for a workflow with potential timeframes.

Applications may be referred to Department of Water and Environmental Regulation's Office of the Environmental Protection Authority (EPA) for assessment depending on the location and scale of proposed activities.

Research and development exemption

Where proponents are unsure of the feasibility of their proposed aquaculture venture, an application for a research and development exemption can be made in lieu of a licence and lease application. Exemptions are a short-term alternative, that allows investors to explore the farming potential of an area and operation by undertaking a research and development trial for up to three years.

Site sampling can be undertaken under a research and development exemption. However, permission to conduct the sampling activity may be required from relevant authorities (e.g., relevant Port authority for port waters, Department Biodiversity, Conservation and Attractions for marine parks etc.), subject to the location of the area of interest.

A list of fees associated with aquaculture lease, license, and exemption applications is available here. All fees are payable by the applicant.

Western Australian Shellfish Quality Assurance Program

As well as licencing, there are classification obligations to consider for all commercial harvesting of bivalve molluscan shellfish species. The Australian Shellfish Quality Assurance Program (ASQAP) is a national Government-Industry co-operative program designed to assure the food safety of bivalve shellfish such as edible oysters. The implementation of ASQAP standards is the responsibility of State Government agencies. In WA, the Department of Health (DoH) administers the WA Shellfish Quality Assurance Program (WASQAP).

Oysters filter feed on particulate matter from the surrounding marine environment, therefore, can bioaccumulate hazardous substances that are present within the water. As oyster are commonly consumed raw or lightly cooked, they are considered by health officials as a 'high-risk food' with the potential to cause foodborne illness in consumers. Shellfish harvest areas are therefore classified, in accordance with the requirements of WASQAP, through an environmental study, which includes comprehensive shoreline and sanitary surveys focusing on food safety.

Applications for WASQAP classifications are assessed by DoH who work with DPIRD and industry to deliver the program as outlined in the WA Shellfish Quality Assurance Program (WASQAP) Industry Manual/User Guide 2020. The respective roles and responsibilities of DoH, DPIRD and industry are outlined in Table 1 of the WASQAP Manual. There are seven classification criteria that may be assigned to a growing or harvest area of interest (Table 2 of WASQAP Industry Manual/User Guide 2020).

Industry and investors should firstly consult with DPIRD to consider if their proposed harvest and growing area(s) are suitable for oyster production. A comprehensive sanitary survey will then be undertaken to ascertain the appropriate classification standard for the proposed harvest and growing area(s). The sanitary survey consists of two parts: 1) a shoreline survey, and 2) a water sampling plan. The shoreline survey is undertaken to identify and record actual and potential pollution sources within the area. The shoreline survey is also used to inform the design of the sampling plan which is representative of all identified potential contaminants across a range of meteorological, hydrographical, and geographical conditions in the area. This sampling plan encompasses bacteriological and phytoplankton water sampling, and biotoxin, microbiological, and chemical contaminant flesh sampling. Upon completion, the data collected is evaluated and analysed to finalise the sanitary survey report. DPIRD will submit the sanitary survey report along with a recommended classification to the DoH for consideration.

It is important to note that WASQAP sampling plans take a minimum of 15 months, dependent on the identified pollution sources, and are conducted at the expense of the grower/investor. Sampling under the sanitary survey is usually more intensive than subsequent ongoing sampling that maintains classification, once determined. The logistics and freight associated with taking these samples can be high, especially in northern WA where labs aren't readily accessible. For example. bacteriological water samples need to arrive at the lab ≤24hours from collection. Therefore, farmers need to ensure that they meet any courier costs and deadlines at their end to ensure its timely arrival at the laboratory. DoH and DPIRD have developed the Western Australian Shellfish Quality Assurance Program (WASQAP) Sampler Manual 2021 as a guidance document with sampling collection, submission and interpretation information for prospective growers and investors.

The outcome of the classification process cannot be known prior to its completion and evaluation by DoH. There is no guarantee that a harvest or growing area will be classified favourably following sampling. DoH will review submitted sanitary survey reports and determine appropriate classification or request more information, which may include further sampling. Once classification has been achieved, it must be maintained as per a WASQAP Sampling Plan and annual audits.

This process is described in the Sanitary Survey Workflow (Figure 2). To assist and advise shellfish aquaculture licence holders in WA, DPIRD has appointed a WASQAP Officer, who is available to assist industry with; preparation of sanitary surveys, liaison with DoH and other consultants and stakeholders as needed, training and interpretation of content in sampling manual, to prepare funding applications for relevant research and development opportunities, and general navigation of the WASQAP classification process.

Traditional owner corporations

Traditional owner (TO) groups that are interested in tropical rock oyster aquaculture opportunities in WA are encouraged to contact DPIRD's Aboriginal Economic Development (AED) division. DPIRD are keen to engage and consult with salt water Prescribed Bodies Corporate (PBC's) through capacity building and strategic planning to empower them to develop and sustain lasting economic and social outcomes within their communities. The AED team are dedicated to building relationships with TO groups and working with them to facilitate and deliver a range of regional development and primary industry initiatives.

Site selection

Outside of management and classification requirements, it is also important to consider the environmental and biological factors that ultimately determine whether an area will support an oyster farming operation. As has been alluded to above, every site and operation is different. The only way to be sure that your proposed operation is feasible, is to run pilot scale trials with oysters to see if they grow. Some further site-specific considerations have been listed below.

Suitable water

Shellfish quality assurance

Are you going to be able to receive WASQAP classification to grow and harvest oysters in these waters (low cadmium and certification for harvest areas)? It's also important to consider how often your harvest area is likely to be closed and if this is economically sustainable for your operations. The first step should be to carry out the shoreline survey which forms part of the WASQAP sanitary survey. The shoreline survey will identify any obvious or potential source of contamination that may impact the harvest area. The site will not be suitable for shellfish harvest if direct pollution sources have been identified. These may include failing sewage treatment plants, effluent from industrial, processing and farming operations, etc.

The relay of stock is an operational option available to grow oysters in an area affected by some pollution. In this case stock is grown in a growing area before it is transferred to a harvest area where it will be finished for a period of time that is determined through growing area classification. As for harvest areas, growing areas require shellfish quality classification. However, classification of growing areas is less stringent than that of harvest areas, therefore providing opportunity to utilise water otherwise unsuitable for harvest. The nature of pollutants can make this type of operation complex to manage so proponents will need to work closely with DPIRD to develop this type of operational protocol.

Land-based depuration of oysters prior to market dispatch is another option for harvest from an area with unfavourable WASQAP classification. However, it is worth noting that there are currently no land-based depuration facilities in WA. Facilities such as this will require further investigation into additional sampling requirements, more extensive food management plans, increased auditing requirements etc. Again, proponents will need to work closely with DIPRD to develop this type of operational protocol and consider the additional costs and licensing requirements of a land-based operation.

WASQAP Workflow: Sanitary Survey

Figure 2. Western Australian Shellfish Quality Assurance Program (WASQAP) workflow to complete a site sanitary survey for shellfish growing and/or harvest area(s).

Farm type: Intertidal vs subtidal

Oysters are traditionally farmed in the intertidal zone, subtidal zone, or a mix of both. Both intertidal and subtidal farms have pros and cons which is why they are often used in combination. Subtidal will result is faster growth but shells will be thin which is not suitable for market (i.e., shorter shelf life and lower meat to shell ratio). Oysters grow slower in intertidal settings but tend to shape better and will have harder shells and better shelf life. While a mix of both intertidal and subtidal is often preferred, oyster farming can be carried out effectively solely in intertidal or subtidal settings. In northern WA, subtidal operations are likely to be challenged by abundant biofouling which will need to be managed. The intertidal vs subtidal decision will depend on the carrying capacity of the water, availability of water to farm, and technical, operational, and financial considerations regarding the appetite for investment to manage tropical environment constraints related to biofouling.

Carrying capacity

Carrying capacity refers to the growing/harvest area capacity to support the growth of oysters. The carrying capacity of shellfish waters relates to the volume of harvestable/marketable oysters produced. The higher the carrying capacity, the more oysters a body of water will produce. Carrying capacity is generally dictated by natural productivity and tidal exchange. Open water can be more productive than bodies of water with restricted flow such as harbours, estuaries, and bays. Some waters will only be suitable for on-growing (growing oysters to 30-50mm before they can be finished elsewhere), other more productive waters will be suitable for harvest. Accurate prediction of carrying capacity is difficult. Ways to estimate carrying capacity include extrapolation from existing farming areas and small-scale grow-out trials under an exemption granted by DPIRD. Other indicators prior to starting trials include the presence and abundance of large oysters on nearby rocks (Figure 3).

Figure 3. Areas that support large populations of wild rock oysters on available substrates can be an indication of productive waters.

Biofouling, pests, and diseases

Consider what kind of biofouling and predation is likely to occur in your area of interest. Are there known pests that will directly affect your oysters or prevent you from transferring stock elsewhere? Are there any known diseases in the area or nearby which may directly impact the survivorship of your stock and limit your ability to transfer stock elsewhere for biosecurity reasons. Will you be able to sustain a farming operation in these conditions?

Farming trials will inform proponents on issues relating to predation and biofouling and provide an opportunity to develop possible management options. DPIRD will be able to inform of known pests and diseases which may impact the operation.

Species suitability

Identifying the specie(s) you wish to farm is critical to the success of your operation. The WA State Government have facilitated aquaculture trials for several tropical rock oyster species and generally recommend *Saccostrea* A and *S. echinata* for aquaculture development in northern Australia as they have a known baseline disease and pathogen profile and encouraging growth results. However, if you are interested in other species, please refer to as a guide to rock oyster identification in WA and contact DPIRD to discuss your interest in other rock oyster species.

Some important considerations are whether you intend to use wild-collected or hatchery-reared spat. In each case, do you have a reliable source of wild rock oysters for either spat or broodstock collection and do you have the appropriate exemptions to collect these animals? DPIRD's aquaculture research team can help advise you on sourcing broodstock and/or wild-spat and the Aquaculture Management team will consider exemption requests for broodstock collection. If you intend to use hatchery-reared spat, you should first contact WA's commercial Albany Shellfish Hatchery who will advise if they can provide seed for your operation. DPIRD's Hillarys Research Hatchery may support requests for small-scale batches of rock oyster spat for field trials, however requests should go through the Albany Shellfish Hatchery in the first instance.

Farm installation

An oyster farm consists of on-water and land-based operations. On-water operations are farm equipment installed on the marine lease and depending on the technique (intertidal or subtidal) will include intertidal lines and/or rack, and/or subtidal long-lines. Each of these farming systems have different anchoring and mooring requirements which will generally require some trial and error depending on the substrata and hydrodynamics of your proposed site(s). Potential environmental ramifications of installing and operating different gear types should be included as part of the MEMP required to submit within a license and lease application.

There are many suppliers of oyster farming gear in Australia and overseas, each having developed their own basket and line systems to suit a range of farming environments. SEAPA, Hexcyl and Zapco offer a range of product and technical advice to select systems suitable for both intertidal and subtidal farming.

Farming Operations

Daily on-water operations involve the retrieval and deployment of stock, maintenance, and installation of equipment. Stock brought in on land is generally graded and re-housed in clean baskets. Mature stock ready for market and harvest is graded, cleaned, packed, and chilled as per prescribed food management protocols. A small operation (<50,000 doz per annum) may harvest once or twice a week. Beyond 150,000 doz per annum an operation will most days each week and larger volumes, therefore requiring at least two vessels and two crews to manage the workload of mature stock harvest and grading of smaller stock.

To determine the level of staffing and equipment gearing required to match a certain scale of operation it is best to research existing operations in places like South Australia, New South Wales, and Tasmania. DPIRD's bio-economic model may also make some useful assumptions to help guide investors.

Site marking

As outlined above (in Aquaculture licence and lease), DPIRD may consult with DoT for guidance around requirements for prospective farmers to install navigation buoys, lighting and other markers near their lease or exemption sites. Advice is dependent on the proposed activities and site. All licence and exemption applications over marine areas will need to be accompanied by a Marking and Lighting form.

Accessibility and serviceability

Investors should consider how their proposed farm site will be accessed and serviced. Many sites will only be accessible by boat so consideration should be given to the type of vessel required, where the boat will be housed, where it can be launched, and if a mooring is required. Further consideration should be given to how the site will be accessed and serviced around the extreme tidal ranges experienced in many parts of northern WA.

Land-based installations support the on-water operations with buildings that house staff amenities, vehicles and boats, oyster graders, oyster and equipment washers, processing and packing area, chillers, spare farming equipment (baskets, floats, lines, posts, anchors, etc.) and more. To effectively operate an oyster farming operation will require access to several ancillaries which may include boat ramps, docking for vessels with loading/unloading facilities, etc. Proximity to infrastructure and amenities can be advantageous for your operation, however strategies can be developed for the appropriate management of most farming operations.

Food Safety Management Plan

All oyster farms will require a Food Safety Plan that is established and submitted to DoH for approval when the business registers with DoH as a Food Business. Any areas of oyster handling and processing will be included within this Food Safety Plan. DPIRD and DoH are looking to develop Food Safety templates for WA, however they are not available at this time. The New South Wales Food Authority website has Food Safety Program templates which may be altered for use by WA farmers.

Other users

When applying for a lease and license or exemption, you should consider all stakeholders of your proposed area including traditional owners, recreational and commercial fishermen, and any other users of the waters and surrounding ecosystems that may impact your operation, or that your operation may impact.

Economics and Logistics

Oyster farming bioeconomic model

A tropical rock oyster aquaculture bioeconomic model was developed to evaluate the oyster farming activity in a northern WA context and highlight areas requiring additional information and research in the future. The economics of oyster production throughout the production cycle is modelled using product data (growth, survival, quality) as well as costs gathered for the different systems used at different stages of the cycle. The range of farming scenarios (large scale vs small scale) and supply chain models in WA provides an opportunity to develop and test the economics of different modes of production from egg to plate, to determine those with the greatest profitability for small- and large-scale investors in northern WA.

Model intention and availability

The current version of the tropical rock oyster bioeconomic model was developed by DPIRD’s Industry Economic Analysis division in consultation with the Marine Shellfish Aquaculture Research and Development team. Initial inputs were developed based on the experiences of commercial project partner Maxima Rock Oyster Company Pty Ltd. The model contains a range of inputs and assumptions that will vary greatly from one farming operation and business model to another. As has been highlighted above in this report, the success and feasibility of an oyster farming operation is dependent on a wide range of factors that cannot be known until research and trials are undertaken. For example, site and species suitability, ability to obtain WASQAP certification, obtaining lease and licensing approvals, and general farm management strategies. Whilst the model is not able to give an indication as to whether a farmer’s selection of the above categories will produce a successful and/or profitable operation, it can generate an indicative levelized cost of production with and/or without a margin based on your proposed operation and assumptions. The more site and operation specific data you have available to input into the model, the more accurate the model’s outputs are likely to be.

The intention of the model is to facilitate the exploration of theoretical oyster farming scenarios, allowing potential investors, and interested parties to compare the magnitude of impacts associated with different risks and inputs. As the model does not offer actual legal, business, scientific, agricultural or farm management advice to users it has not been made publicly available to minimise the likelihood that it could be used to mislead third-party investors or be used outside of its intended purpose. If you are interested in accessing the model, please contact DPIRD’s Industry Economic Analysis division who can work with you to run some scenarios and adapt the model as necessary.

Model disclaimer

Unless expressly stated otherwise, the information is not tailored to the circumstances of any person or entity, individual farm, or businesses, and does not constitute legal, business, scientific, agricultural or farm management advice. Before using the information, you should carefully evaluate its accuracy, currency, completeness, and relevance for your purposes, and obtain advice from appropriate professionals who have taken into account your individual circumstances and objectives.

DPIRD accepts no liability whatsoever, by reason of negligence or otherwise, arising from any use or release of the information or the model, or any error, inaccuracy, or omission therein.

This model is highly sensitive to numerous biological and financial factors; accordingly, we recommend that before making any significant decisions based on this information, you obtain advice from the appropriate professionals who have considered your individual circumstances, objectives and the relevant biological, financial and market factors.

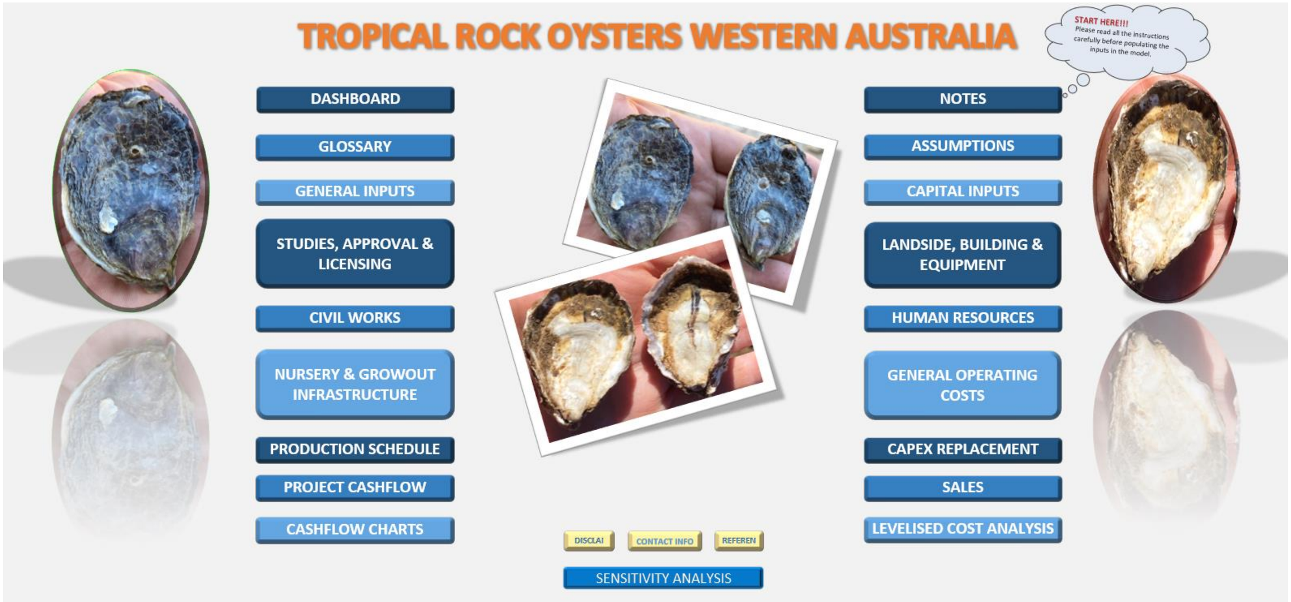

Figure 4. Screenshot of the tropical rock oyster bioeconomic model for Western Australia menu.

Sensitivity analysis

Scenario 1: Moderate farming operation with gradual scale-up

A theoretical ‘base’ scenario was created where several inputs were held constant whilst the following parameters were altered to determine the impact on profitability in the ninth year of operation:

- Mortality rates, and
- Initial size of operation (e.g., amount of spat purchased)

Scenario one depicts a relatively small-scale farming operation (by Australian standards) where 5.0mm spat are purchased from a hatchery at $0.05/spat. The farm is utilising intertidal lines only[3] with 17 x 150m lines installed on a 2.0ha lease. This size lease has the capacity to double the number of lines to 35 if (and when) required. Oysters grow at an average of 2.0mm per month and are harvested after 33 months at approximately 70mm shell height. As the operation is starting out small, the farmer has chosen to lease a building to operate out of and store equipment instead of investing additional capital upfront in building their own infrastructure[4]. A detailed (although not exhaustive) list of assumptions is available in Appendix A (Table App A.1).

In scenario one, plate size (70mm) oysters attract a farm gate price of $14.00/doz (or $1.17/oyster). The farmer starts by purchasing 500,000 spat per annum from a hatchery for the first three years of operations as the farmer will not be able to sell product until their third year of operation (as the first batch purchased grow to size). This would equate to a harvest of approximately 38,000 doz per annum when accounting for a 3% mortality in each stage of grow-out (~9% per batch). The farmer scales up their operation during years four to nine by doubling the seed they purchase to 1,000,000 spat per annum, leading to a harvest of approximately 70,000 doz per annum. This requires some additional capital inputs and farm expansion, which is achievable within the original lease size. Some of these additional capital inputs alleviate staff workload (e.g., automated oyster washing system, forklift, and refrigerated truck) and so no additional human resourcing is required at this scale.

The farmer breaks even in the seventh year of operation, and they decide to expand their farm to accommodate an annual purchase of 1,500,000 spat (harvest equivalent of ~110,000 doz per annum) from their ninth year. On top of

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[3] Most growth and biological data available from the Tropical Rock Oyster research and development project was obtained from intertidal sites. Subtidal lines can produce better growth rates than intertidal lines (as oysters are always immersed) and take up less space as baskets can be hung from a subtidal line in ladders to utilise the depth of the site. Subtidal lines in the Pilbara and Kimberley experienced a lot of fouling, however that is not to say they will not work in other locations with other management strategies in place.

[4] Although the model allows for these initial capital investments if infrastructure is required to be built.

additional farm lines and baskets, an oyster grader is purchased, and an additional farmhand is hired to help manage the increased workload.

To make a profit, farmers should charge a higher price at farmgate, minimise mortality (and therefore harvest a larger yield), and operate their farms on a larger scale as soon as practical within their initial investment capabilities and carrying capacity of the farms, thereby maximising economies of scale. Farmers cannot influence all market force factors which dictate a reasonable price per dozen at farmgate. Therefore, efforts are focussed on reducing costs and optimising revenue through sales to offer a buffer against factors that negatively impact the farmgate price. A sensitivity analysis was conducted for scenario one described above where the initial quantity of spat purchased (and reasonable associated farm capital, operating and human resourcing expenses) was increased from 500,000 to 1,500,000. The price charged at farmgate per dozen was also altered to show how market forces could impact the farms bottom line. All other model inputs were kept constant. The results of expected profit or loss for the farming operation during the ninth year of operation are shown in Table 1.

To test the theory and magnitude of economies at scale, we consider scenario one having started operations at three different scales: 500,000, 1,000,000 and 1,500,000 oysters/annum. With each of these operations there are greater initial capital costs to establish the farm and a third farmhand is included from day 0 for the largest scale (1,500,000 oysters/annum). Depending on market forces, farmers will be able to charge a different price for their oysters at the farmgate level. As farmers don't always have control over market forces that may impact this price, we used the model to compare the minimum price per dozen a farmer could charge in their ninth year of operation, to ensure a $50,000 profit margin for that year. If the farm started out purchasing 500,000 oysters per year (and slowly scaled up to 1,500,000 as described above), the farmer would need to be able to charge just over $19.50/dozen at farmgate in the ninth year to ensure a $50,000 profit. However, if the farmer had started out with 1,000,000 oysters per annum, they would only need to charge <$10.25/dozen to make a $50,000 profit. Finally, if the farmer had started out much larger at 1,500,000 oysters/year[5] they could still make $50,000 in the ninth year, even if they are only able to fetch $7.00/dozen at the farmgate. Working at economies of scale gives the operation a better buffer against market forces that impact the farmgate price.

Higher mortality rates reduce the farmers capacity to sell product by reducing their harvestable yield. A 20% mortality rate equates to losing a fifth of stock inputs by the time a batch is being harvested years later and therefore a higher mortality rate will reduce the farmers buffer capacity against market forces that impact farmgate price. In scenario one, the impact of mortality is somewhat buffered by the size of the farm. To break even (no profit, but no loss) in year nine, an operation purchasing 500,000 spat per annum would need to charge at least $20.75/dozen at a 20% mortality rate, compared to $15.25/dozen at a lower mortality rate of 3% per batch. Comparatively, an operation purchasing 1,500,000 spat per annum would need to charge only $7.25/dozen with 20% mortality or $6.00/dozen at a 3% mortality to make a $50,000 profit. Within this model, a 17% increase in annual mortality constitutes an increase in farmgate price of $5.50/dozen in a small operation compared to $1.25/dozen at a larger scale to break even. This is a big difference in the flexibility afforded to the farmer depending on what price they are able to ask given market forces at the time. Having to charge a higher price to break even may exclude farmers from certain markets once supply chain and other on-costs are considered e.g., selling to restaurants.

A combination of different mortality rates for the three scaled farms described above are represented in Table 1 for six different farmgate prices. The smallest farming operation has the least flexibility in its farmgate price and mortality if they hope to make a profit for that year. Whereas the larger farming operation has more flexibility across its pricing and mortality rates, only making a loss if mortality is more than 15% and only $7.00/dozen or less is fetched at farmgate.

Scenario 2: Comparison of two farm sites with different characteristics

In the second scenario we have drawn on experience gained whilst operating two intertidal farm sites in the Pilbara during the tropical rock oyster research and development project. This farming scenario is the same as the scenario one described above, except for a few key characteristics that differ between these sites (Table 2). The key differences are based on reduced oyster growth rates that were observed at one site and the differences in how sites may be managed due to factor such as location and accessibility. A 20-year operation was simulated with the bioeconomic model to compare the profitability of growing tropical rock oysters at each site. Table 2 shows a summary of the main differences that impact initial and ongoing capital investments and operating costs at these sites. More detailed model inputs are available in Appendix A (Table App A.2).

Site two has several operational advantages compared to site one. The annual cost of fuel associated with site one is nearly double that of site two because the site is 21km further by boat and it requires a more powerful and larger boat to get out to the site. This also results in a greater initial capital cost to purchase an appropriate vessel to service site one. Whilst site two requires a greater distance to be covered by road, the fuel efficiency of the car compared to the boat keeps the fuel cost low for site two.

---

[5] Including additional staff member and capital investments from the beginning.

Table 1. Sensitivity analysis for the scenario one showing the profit or loss to the business in the ninth year of operation. Mortality rate of rock oysters and the price fetched at the farm gate ($/dozen) are varied to show the differences in the farms profit for three different scale operations (500,000 spat to 1,500,000 oysters/annum).

Scenario One Sensitivity Analysis: Mortality and scale of operation

Initial spat:	500,000
Mortality:	9%
Farmgate price:	$14.00/dozen
Year 9 loss:	-$166,164*

	Mortality (total per batch)			
Farmgate price	**3%**	**9%**	**15%**	**20%**
Initial spat purchased: 500,000				
$7.00	-$414,081	-$431,581	-$449,081	-$463,664
$10.00	-$292,831	-$317,831	-$342,831	-$363,664
$13.00	-$171,581	-$204,081	-$236,581	-$263,664
$16.00	$50,331	-$90,331	-$130,331	-$163,664
$19.00	$70,919	$23,419	-$24,081	-$63,664
$22.00	$192,169	$137,169	$82,169	$36,336
Initial spat purchased: 1,000,000				
$7.00	-$156,164	-$191,164	-$226,164	-$255,331
$10.00	$86,336	$36,336	-$13,664	-$55,331
$13.00	$328,836	$263,836	$198,836	$144,669
$16.00	$571,336	$491,336	$411,336	$344,669
$19.00	$813,836	$718,836	$623,836	$544,669
$22.00	$1,056,336	$946,336	$836,336	$744,669
Initial spat purchased: 1,500,000				
$7.00	$101,753	$49,253	-$3,247	-$46,997
$10.00	$465,503	$390,503	$315,503	$253,003
$13.00	$829,253	$713,753	$634,253	$553,003
$16.00	$1,193,003	$1,073,003	$953,003	$853,003
$19.00	$1,556,753	$1,414,253	$1,271,753	$1,153,003
$22.00	$1,920,503	$1,755,503	$1,590,503	$1,453,003

*Additional capital investments and staff hiring occur in the ninth year to expand the operation. The associated increase in revenue for this expansion will take three more years.

The other big difference is that the oysters do not grow as fast at site one as they do at site two. An average shell growth of 1.5mm per month is achieved at site one, whilst site two achieves 2.0mm per month over their grow-out. This allows 70mm oysters to be harvested from site two within 32 months, whilst the oysters at site one require another 11-12 months before they can be harvested and sold. This also allows the operation at site two to begin to scale up its operations much sooner than site one with the farmer increasing his spat inputs to 1,000,000 oysters during his third year of operation. The farmer of site one, does not do this until his fifth year. These effects compound over the first few years and farm two breaks even and begins to make a profit in their fifth year of operation (Figure 5). Following a similar but slower scaling up pattern to farm site two, farm one does not break even and recoup their outgoing until their tenth year of operation.

Table 2. Summary of differing characteristics of two theoretical oyster growing sites used in Scenario two.

Site 1	Site 2
Long boat rides - nearest mooring and/or boat ramp 22km from the site.	Short boat rides - site is only 800m from nearest boat ramp.
Larger boat required to service this site as multiple trips to and from the site transporting stock and equipment is not usually practical around tides and weather.	Smaller boat can be used but it must be towed out to site.
Boat ramp/mooring is 30km from operational base and 2-3km of the road is unsealed. 4WD required.	Boat ramp is 52km from operational base. All roads are sealed.
Remote site.	Site near a popular tourist centre.
Poor growth rates.	Favourable growth rates.

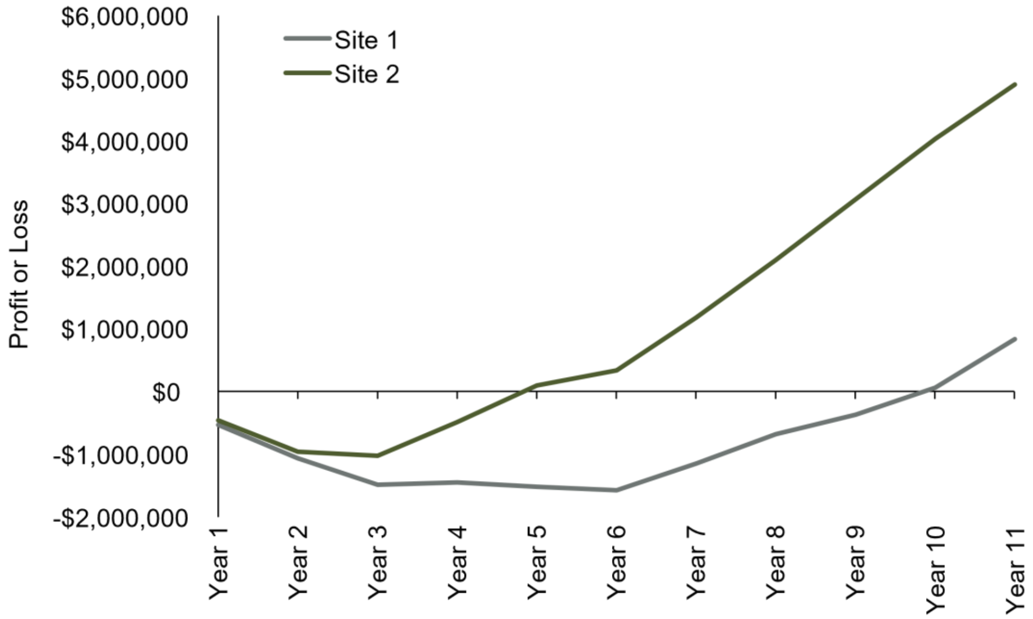

Figure 5. Annualised profit and loss for two theoretical oyster farm sites in northern Western Australia. Farm site 2 becomes profitable late in its fourth year of operation due to more favourable site conditions that include higher growth rates, lower fuel requirements (more favourable location and site accessibility), lower initial capital input requirements and ability to scale up the operation sooner.

Whilst these two theoretical sites are geographically close to each other, the realised differences in site productivity and management strategies to service each site offer two very different financial outcomes for farmers and investors. This scenario emphasises the importance of trialling sites to understand the capital and operating input requirements, but also the carrying capacity and productivity of the site before investing too heavily.

Scenario 3: Lifestyle/boutique farmer

The third scenario depicts a much smaller operation that could be described as a 'lifestyle' or 'boutique' farm. The farm operates under similar conditions to scenario one, however after a year of seeking approvals and doing some feasibility and water quality studies, the farmer purchases just 200,000 spat from a hatchery. The farmer experiences similar growth rates as seen in scenario one (2mm/month), however they only sell their oysters locally as a boutique tourist product. Their sales are made up of 20% bistro (60mm oysters) and 80% plate (70mm) oysters that they charge $14.00 and $16.00/dozen for at farmgate.

This intertidal farm is accessible by car so the farmer purchases a small second-hand boat on a trailer to be able to access the site if it is underwater, but they can generally do their grading, harvesting and farm management during low tides and therefore do not have the high operating costs associated with a boat. The farmer does not wish to have a large operation and won't expand their lease beyond 1ha. They scale up to 300,000 oysters in the second year and 400,000 in the third, but this is the maximum numbers of oysters they bring onto the farm in any given year. At this scale they manage the farm themselves with one part-time farmhand. They also reduce other ongoing costs such as insurance, accounting fees etc. The overall capital required for this operation is much lower than scenarios one and two as the farmer doesn't make purchases such as a forklift, refrigerated truck, or automated oyster washer. This also allows for a smaller building lease to be taken on. More detailed model inputs are available in Appendix A (Table App A.3).

Figure 6 shows the modelled cashflow over first ten years of the farming operation. The farm runs at a loss due to initial setup costs including capital and cost associated with lease, licensing and WASQAP approvals. Whilst peak debt is a limiting factor for this farmer, the most debt they take on is ~$650,000 (in years two and three), which slowly reduces until year seven when the business begins to make a profit. The levelized cost that the farmer must charge over the 20-year lifetime of their operation to make a 10% profit margin is $14.04/dozen, which is in-line with a reasonable asking price and therefore an overall profitable and sustainable operation.

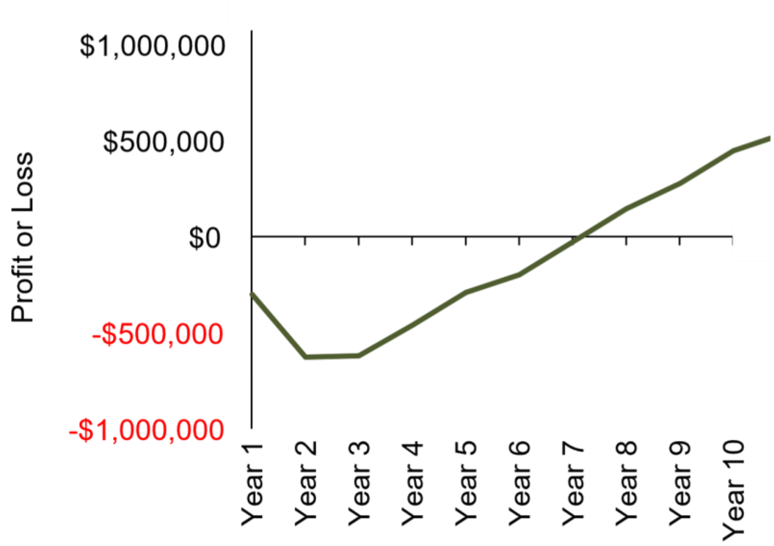

Figure 6. The profit or loss is modelled for the 'boutique' oyster farming operation described in scenario three. The farmer breaks even and begins to turn a profit during the seventh year of operation and is never more than $630,000 in debt.

Scenario 4: Fuel price increases

It was theorised that oyster farming operations in northern Australia would be particularly sensitive to fluctuations in fuel prices. The Pilbara and Kimberley regions of WA have many remote areas that may be considered for oyster farming operations. Therefore, the need to travel great distances by boat and car may be an important factor in determining the financial viability of a farming operation.

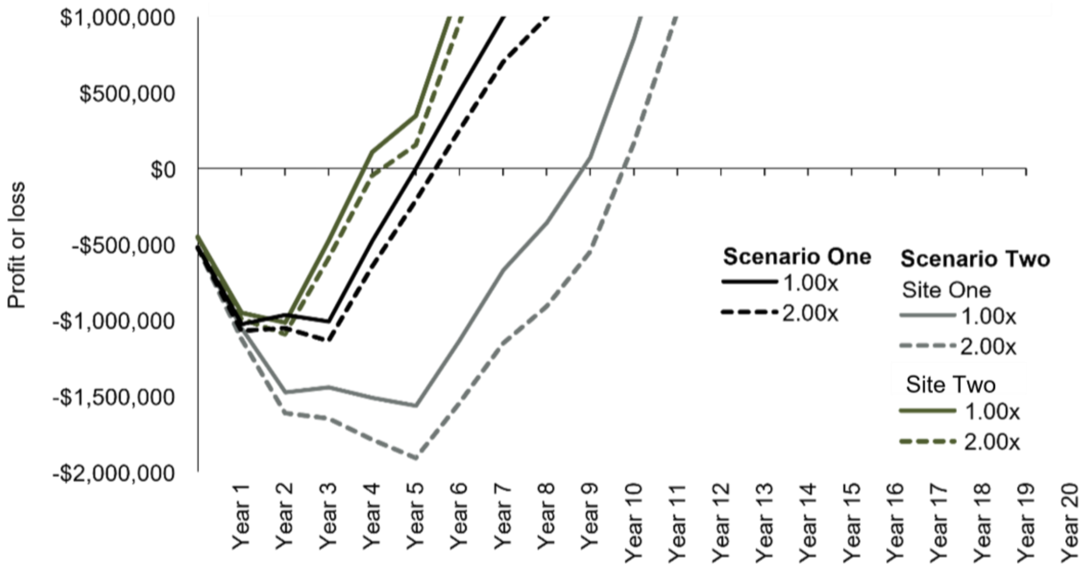

Figure 7. The profit or loss is modelled for scenarios one and two where the price of fuel is doubled (dashed lines) from today's prices (solid lines). The impact is greater for where farm management requires more travel by both boat and car (site two).

This scenario has modelled the impact of various changing fuel prices on the farming operations described in scenarios one and two. A doubling of fuel prices did not have such a significant impact on the farmers bottom line when operating at these scales. It may delay the profitability of a farm such as site two by a year but is not a significant factor for the farm.

This model has not taken into consideration the likely impact on the remainder of the supply and logistics chain which could also be significant given the isolation of northern WA and may exclude farmers being viable in export and domestic markets.

Risk-adjusted levelized cost analysis

A levelized cost analysis (LCA) was incorporated into the bioeconomic model. The LCA estimates the minimum price per dozen oysters that must be charged for the farm to make a 10% profit margin (before interest and tax) over its 20-year operation, taking all account of costs incurred throughout the lifetime of the project.

A randomly assigned risk probability was applied to the estimated annual yield to account for unknown risks the operation may encounter. The maximum possible risk was 50% which represents the probability that in any given year, the farm could lose up to 50% of its saleable product due to factors such as a cyclone, disease, predators etc. The risk factor is applied on top of the estimated mortality rate of 9% per annum that may naturally be expected. Figure 8 models the difference between the maximum annual yield expected in scenario one and the actual yield once the randomly generated risk factor is applied.

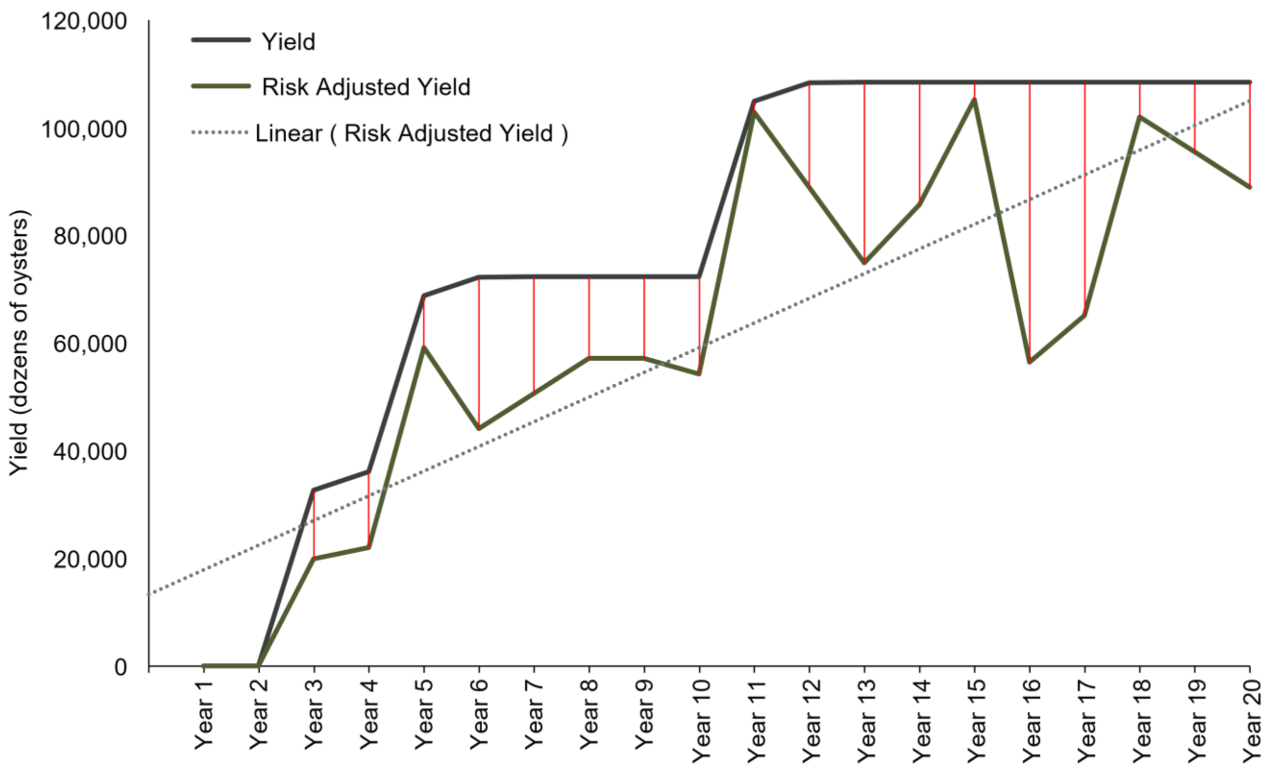

Figure 8. The potential annual yield for the Western Australian tropical rock oyster bioeconomic scenario one is adjusted with a randomly assigned risk factor each year. The maximum risk factor in any given year is 50%.

The calculations for Figure 8 are shown in Table 3. The LCA for scenario one estimates the minimum farmgate price to be charged to make a 10% profit margin over 20-years is $8.90/dozen. However, when accounting for random risks throughout the project's lifetime, the (risk-adjusted) levelized cost increases to $11.74/dozen.

Estimating a levelized cost for the product is a useful way for investors to incorporate the impact of risks. It can be challenging to decide on an acceptable risk probability for farming operations in emerging industries as there are still a lot of unknown factors around the causes and magnitude of mortality events.

Table 3. The levelized cost ($/dozen) of a theoretical oyster farming operation in northern Australia was calculated from the scenario one model described in this report. A risk factor is applied to the maximum annual yield to give a risk-adjusted levelized cost. The maximum risk probability was 50%.

Year	CAPEX	OPEX	EBIT + Profit Margin	Total expenses	Yield (dozens)	Risk factor	Risk adjusted yield (dozens)
1	$513,620	$7,500	-	$521,120	-	-	-
2	$118,533	$387,259	-	$505,792	-	-	-
3	$8,226	$387,259	$39,549	$435,034	32,604	0.12	28,692
4	$135,412	$412,259	$54,767	$602,438	36,036	0.17	29,910
5	$16,479	$412,259	$42,874	$471,612	68,731	0.15	58,421
6	$120,179	$412,259	$53,244	$585,682	72,163	0.43	41,133
7	$93,879	$412,259	$50,614	$556,752	72,253	0.31	49,855
8	$107,479	$412,259	$51,974	$571,712	72,253	0.22	56,358
9	$143,238	$528,759	$67,200	$739,197	72,253	0.47	38,294
10	$26,465	$528,759	$55,522	$610,746	72,253	0.36	46,242
11	$128,405	$528,759	$65,716	$722,880	104,858	0.26	77,595
12	$24,705	$528,759	$55,346	$608,810	108,209	0.35	70,388
13	$102,105	$528,759	$63,086	$693,950	108,380	0.01	107,296
14	$24,705	$528,759	$55,346	$608,810	108,380	0.47	57,441
15	$115,705	$528,759	$64,446	$708,910	108,380	0.03	105,126
16	$128,405	$528,759	$65,716	$722,880	108,380	0.14	93,207
17	$24,705	$528,759	$55,346	$608,810	108,380	0.11	96,458
18	$24,705	$528,759	$55,346	$608,810	108,380	0.29	76,950
19	$103,865	$528,759	$63,262	$695,886	108,380	0.20	86,704
20	$24,705	$528,759	$55,346	$608,810	108,380	0.12	95,374
NPV	**$1,345,390**	**$4,799,486**	**$515,105**	**$6,659,982**	**748,491**		**567,104**
				Levelized cost ($/dozen):	**$8.90**		**$11.74**

Contacts

DPIRD has dedicated personnel to assist with any enquiries and provide up-to-date information on aquaculture operations in WA.

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Appendix A Model Assumptions

Table App A.1. Constant model inputs and assumptions for scenario one.

<table>
<tr><th colspan="6">Farming & harvest inputs</th></tr>
<tr><td>Spat size at purchase</td><td colspan="5">5mm</td></tr>
<tr><td>Cost per spat</td><td colspan="5">$0.05/spat</td></tr>
<tr><td>Size at sale</td><td colspan="5">70mm (100% plate sales)</td></tr>
<tr><th colspan="6">Growth & survival</th></tr>
<tr><td>Oyster growth rate</td><td colspan="5">2mm/month</td></tr>
<tr><td>Mortality rate</td><td colspan="5">9% per batch</td></tr>
<tr><td rowspan="3">Production time in each stage</td><td rowspan="2">Nursery (5 - 12mm)</td><td rowspan="2">Stage 1 grow-out (12 - 24mm)</td><td colspan="3">Stage 2 grow-out (>24mm)</td></tr>
<tr><td>Cocktail (50mm)</td><td>Bistro (60mm)</td><td>Plate (70mm)</td></tr>
<tr><td>4 months</td><td>6 months</td><td>13 months</td><td>18 months</td><td>23 months</td></tr>
<tr><td>Total production time</td><td colspan="5">33 months</td></tr>
<tr><th colspan="6">Other model inputs</th></tr>
<tr><td>Project life</td><td colspan="5">20 years</td></tr>
<tr><td>Discount rate</td><td colspan="5">7%</td></tr>
<tr><td>Profit margin</td><td colspan="5">10%</td></tr>
<tr><th colspan="6">Scale-up</th></tr>
<tr><td>Year of operation</td><td colspan="5">New spat purchased per annum</td></tr>
<tr><td>1-3</td><td colspan="5">500,000</td></tr>
<tr><td>4-8</td><td colspan="5">1,000,000</td></tr>
<tr><td>9-20</td><td colspan="5">1,500,000</td></tr>
<tr><th colspan="6">Initial capital for farm installation</th></tr>
<tr><td>Number of lines</td><td colspan="5">17-64</td></tr>
<tr><td>Length of lines</td><td colspan="5">150m</td></tr>
<tr><td>Anchors</td><td colspan="5">2 anchors per 4 lines</td></tr>
<tr><td>Posts per line</td><td colspan="5">39</td></tr>
<tr><td>Baskets</td><td colspan="5">4 between each post or 152 per line</td></tr>
<tr><td rowspan="2">Maximum stocking densities per basket size</td><td>3mm</td><td>5mm</td><td>8mm</td><td>10mm</td><td>15mm</td></tr>
<tr><td>10,000</td><td>5,000</td><td>2,500</td><td>1,200</td><td>200</td></tr>
<tr><th colspan="6">Other capital (equipment) inputs</th></tr>
<tr><td>Work boat</td><td colspan="5">$120,000</td></tr>
<tr><td>Utility vehicle</td><td colspan="5">$70,000</td></tr>
<tr><td>Forklift*</td><td colspan="5">$30,000</td></tr>
<tr><td>Tractor</td><td colspan="5">$30,000</td></tr>
<tr><td>Refrigerated truck*</td><td colspan="5">$80,000</td></tr>
<tr><td>Oyster washing machine*</td><td colspan="5">$20,000</td></tr>
<tr><td>Oyster grader*</td><td colspan="5">$20,000</td></tr>
<tr><td>Other</td><td colspan="5">$6,000</td></tr>
</table>

**These items are purchased as the farm grows over time.*
Ongoing replacement costs have been estimated and included in the model over the 20-year lifespan.

Initial studies, approvals and licensing*	
Studies^	$35,000
Project approvals	$10,000
License and lease applications	$3,000
Initial WASQAP classification	$75,000

**These numbers are estimates only and should not be considered guides. Requirements will vary greatly depending on the operation and sites proposed.*

^Includes estimates for pre-feasibility studies and environmental surveys/studies to inform MEMP.

Operating costs		
	ULP - $2.20/L	**Diesel - $2.29/L**
Fuel	$24,090 / year	$18,549 / year
Building lease	$50,000/year	
Lease fee	$1,000/year	
Licensing fees	$455/year	
WASQAP sampling*	$25,000/year	
Repairs & maintenance	$5,000/year	

**This figure is based on an estimate for the ongoing expenses associated with maintaining WASQAP classification for a site with a systematic random sampling strategy with two sampling points.*
Costs of reopening a site in the event of a closure not included.

Human resources				
	Base salary	**FTE**	**Superannuation (12%)**	**On-costs (10%)**
Farm supervisor	$96,000	1.0	$11,520	$9,600
Farmhand	$75,000	1.0	$9,000	$7,500
Farmhand*	$75,000	1.0	$9,000	$7,500

**A third employee could be justified as the farm grows after ~5-7 years*

Table App A.2. Model inputs and assumptions for a comparison between two farm sites with different characteristics.

	Farm Site 1					Farm Site 2				
Growth & survival										
Oyster growth rate	1.5mm/month					2.0mm/month				
	Nursery **(5 - 12mm)**	**Stage 1 growout (12 - 24mm)**	**Stage 2 growout (>24mm)**			**Nursery** **(5 - 12mm)**	**Stage 1 growout (12 - 24mm)**	**Stage 2 growout (>24mm)**		
			Cocktail (50mm)	**Bistro (60mm)**	**Plate (70mm)**			**Cocktail (50mm)**	**Bistro (60mm)**	**Plate (70mm)**
Production time	5 months	8 months	17 months	24 months	31 months	4 months	6 months	13 months	18 months	23 months
Total production time	43 months					32 months				

Scale-up	Farm Site 1	Farm Site 2
New spat purchased	**Year of operation**	**Year of operation**
500,000	1-4	1-2
1,000,000	5-8	3-5
1,500,000	9-20	6-20

Other capital (equipment) inputs	Farm Site 1	Farm Site 2
Work boat	$150,000 (150hp)	$50,000 (60hp)

Operating costs	Farm Site 1		Farm Site 2	
Distance to site (or boat ramp)	**By car**	**By boat**	**By car**	**By boat**
	30km	22km	52km	0.8km
Km/year	10,000	N/A	23,000	N/A
Annual boat hours	N/A	730hrs	N/A	100hrs
	Diesel - $2.29/L	**ULP - $2.20/L**	**Diesel - $2.29/L**	**ULP - $2.20/L**
Fuel	$ 14,656 / year	$54,443 / year	$33,709 / year	$4,722 / year

Human resources	Farm Site 1	Farm Site 2
	Required to hire	**Required to hire**
Additional farmhand	Ninth year of operation	Sixth year of operation

Same inputs for both sites					
Farming & harvest inputs					
Spat size at purchase	5mm				
Cost per spat	$0.05/spat^				
Size at sale	70mm (100% plate sales)				
Farm gate price	$14.00/doz				
Growth & survival					
Mortality rate	3%/stage or 9%/batch				
Other model inputs					
Project life	20 years				
Discount rate	7%				
Profit margin	10%				
Initial capital for farm installation					
Number of lines	21-64				
Length of lines	150m				
Anchors	2 anchors per 4 lines				
Posts per line	39				
Baskets	4 between each post or 152 per line				
Maximum stocking densities per basket size	**3mm**	**5mm**	**8mm**	**10mm**	**15mm**
	10,000	5,000	2,500	1,200	200
Other capital (equipment) inputs					
Utility vehicle	$70,000				
Forklift*	$30,000				
Tractor	$30,000				
Refrigerated truck*	$80,000				
Oyster washing machine*	$20,000				
Oyster grader*	$20,000				
Other	$6,000				

**These items are purchased as the farm grows over time. Ongoing replacement costs have been estimated and included in the model over the 20-year lifespan.*

Initial studies, approvals, and licensing*	
Studies^	$35,000
Project approvals	$10,000
License and lease applications	$3,000
Initial WASQAP classification	$75,000

**These numbers are estimates only and should not be considered guides. Requirements will vary greatly depending on the operation and sites proposed.*

^Includes estimates for pre-feasibility studies and environmental surveys/studies to inform MEMP.

Operating costs	
Building lease	$ 50,000/year
Lease fee	$1,000/year
Licensing fees	$455/year
WASQAP sampling*	$25,000/year
Repairs & maintenance	$5,000/year

**This figure is based on an estimate for the ongoing expenses associated with maintaining WASQAP classification for a site with a systematic random sampling strategy with two sampling points.*
Costs of reopening a site in the event of a closure not included.

Human resources				
	Base salary	**FTE**	**Superannuation (12%)**	**On-costs (10%)**
Farm supervisor	$96,000	1.0	$11,520	$9,600
Farmhand	$75,000	1.0	$9,000	$7,500

Table App A.3. Model inputs and assumptions for scenario three.

Farming & harvest inputs	
Spat size at purchase	5mm
Cost per spat	$0.05/spat
Size at sale	70mm (80% plate sales) ($16.00/dozen)
	60mm (20% bistro sales) ($14.00/dozen)
Growth & survival	
Oyster growth rate	2mm/month
Mortality rate	3% per stage

	Nursery (5 - 12mm)	**Stage 1 grow-out (12 - 24mm)**	**Stage 2 grow-out (>24mm)**		
			Cocktail (50mm)	**Bistro (60mm)**	**Plate (70mm)**
Production time in each stage	4 months	6 months	13 months	18 months	23 months

Total production time	28 months for bistro oysters
	33 months for plate oysters
Other model inputs	
Project life	20 years
Discount rate	7%
Profit margin	10%
Scale-up	
Year of operation	**New spat purchased per annum**
1	200,000
2	300,000
3-20	400,000
Initial capital for farm installation	
Number of lines	13-17
Length of lines	150m
Anchors	2 anchors per 4 lines
Posts per line	39
Baskets	4 between each post or 152 per line

	3mm	**5mm**	**8mm**	**10mm**	**15mm**
Maximum stocking densities per basket size	10,000	5,000	2,500	1,200	200

Other capital (equipment) inputs	
Work boat	$40,000
Utility vehicle	$70,000
Tractor	$30,000
Oyster grader*	$20,000
Other	$6,000

**These items are purchased as the farm grows over time.*
Ongoing replacement costs have been estimated and included in the model over the 20-year lifespan.

Initial studies, approvals and licensing*	
Studies^	$25,000
Project approvals	$10,000
License and lease applications	$3,000
Initial WASQAP classification	$75,000

**These numbers are estimates only and should not be considered guides. Requirements will vary greatly depending on the operation and sites proposed.*

^Includes estimates for pre-feasibility studies and environmental surveys/studies to inform MEMP.

Operating costs		
	ULP - $2.20/L	**Diesel - $2.29/L**
Fuel	$1,445 / year	$13,577 / year
Building lease	$25,000/year	
Lease fee	$1,000/year	
Licensing fees	$455/year	
WASQAP sampling*	$25,000/year	
Repairs & maintenance	$5,000/year	

**This figure is based on an estimate for the ongoing expenses associated with maintaining WASQAP classification for a site with a systematic random sampling strategy with two sampling points.*
Costs of reopening a site in the event of a closure not included.

Human resources				
	Base salary	**FTE**	**Superannuation (12%)**	**On-costs (10%)**
Farm supervisor	$96,000	1.0	$11,520	$9,600
Farmhand	$37,500	0.5	$4,500	$3,750