

FRDC Submission to the Inquiry into the Australian Aquaculture Sector

Submission Contact Details

Fisheries Research and Development Corporation (FRDC)

Locked Bag 222

Deakin West ACT 2600

frdc@frdc.com.au



Australian Government

**Fisheries Research and
Development Corporation**

Contents

Summary	3
Background	5
Research, Development and Extension	5
The nature and current status of Australia's aquaculture sector	6
Global context	6
Australian aquaculture	7
Opportunities and barriers to the expansion of the aquaculture sector: including ability to access capital and investment.	11
OPPORTUNITIES	11
Northern Australia	11
Access to sites for sustainable industry growth	12
Off-shore Aquaculture	13
Changing consumer expectations.....	13
Domestic market.....	14
Export markets.....	14
Indigenous participation in aquaculture.....	15
BARRIERS.....	15
Access to capital.....	15
Achieving scale of production.....	16
Infrastructure	17
Country of Origin Labelling	17
Demonstrating sustainability	18
Aquatic biosecurity	18
Aquatic Animal Health and welfare	19
Access to veterinary medicines.....	19
Social license	20
Need for Industry cohesion.....	20
Climate change.....	21
The ability for businesses to access and commercialise new innovations to expand aquaculture..	21
REFERENCES.....	25
Appendix 1. FRDC research project reports for Australian aquaculture sectors.....	27
Appendix 2. FRDC submissions related to the Australian aquaculture industry.	28

Summary

The Fisheries Research and Development Corporation (FRDC) has a long history supporting the development of the Australian aquaculture industry. In response to this inquiry the FRDC has identified the following observations and recommendations.

Observations

1. FRDC's value proposition is closely tied to its role as a provider and communicator of robust and independent science-based information. Communicating that independence is a key dimension of the FRDC's brand, and is a key consideration for how the organisation communicates science.
2. The Australian government assist transformation of Australia's agrifood production system through recognising the potential that support for the Australian aquaculture industry can achieve towards meeting the target of growing Australian agriculture to \$100 billion by 2030.
3. The Australian government and industry stakeholders note the recommendations presented by the Joint Select Committee on Northern Australia report: Scaling Up – Inquiry into Opportunities for Expanding Aquaculture in Northern Australia (Anon. 2017b).
4. FRDC has previously provided a submission to the Independent review of the agvet chemicals regulatory system. 2021 (<https://haveyoursay.awe.gov.au/agvet-chemicals-regulatory-reform/widgets/330976/documents>).

Recommendations

1. The Australian government and industry stakeholders implement the recommendations on development of aquaculture across Northern Australia, in particular, the recommendations of the Northern Australia Aquaculture Situational Analysis (Cobcroft et al., 2020).
2. The Australian government and industry stakeholders recognise that scientific evidence is needed to set realistic harmonised regulatory requirements, and improve the approval pathway for aquaculture development taking into account land and aquatic multiple-use planning.
3. The Australian government develop a clear planning and regulatory framework for undertaking aquaculture in Commonwealth waters.
4. The Australian government and industry stakeholders support innovations that increase traceability along the supply chain to confirm quality, safety and sustainability credentials of aquaculture products, and provide the capacity for investigation and enforcement of seafood fraud.
5. In supporting growth of aquaculture in Australia, it is recommended that this be pursued in a manner that delivers significant economic and social benefits to Indigenous Australians.
6. Co-ordinated access to and incentivisation of capital across all levels of government to improve supply chain infrastructure for fisheries and aquaculture (e.g. cold chain infrastructure) and to support the adoption of new technology. This will enable the sector to be more efficient across the entire supply chain and reduce costs. Inquiry into growing Australian agriculture to \$100 billion by 2030. Submission 11 - FRDC. 2019 (https://www.apf.gov.au/Parliamentary_Business/Committees/House/Standing_Committee_on_Agriculture_and_Water_Resources/Agriculturegrowth/Submissions)
7. The FSANZ Food Standards Code 2.2.3 should mandate the use of the Australian Fish Names Standard to support expanded country of origin labelling (<https://fish.gov.au/-/media/fish-frdc/corporate-documents/submissions/cool-submission-from-frdc-april-2014.ashx>).

8. The Australian government support the aquaculture industry to achieve greater sustainability through moving towards a future regenerative or “circular economy” that utilises all wastes produced within aquaculture systems and creates benefits beyond profit.
9. The Australian government and industry stakeholders work to implement the areas of need identified in AQUAPLAN 2021-26 (<https://www.agriculture.gov.au/animal/aquatic/aquaplan>)
10. The Australian Government continue to co-invest through the Council of Rural Research and Development Corporation’s Climate Initiative to enable aquaculture as part of a broader agrisystem to continue to thrive irrespective of a changing climate.
11. The Australian government apply a system level approach in the development and application of policy and investment settings to encourage aquaculture growth while also integrating needs of other users of the aquatic landscape.
12. Recognising the significant impact of the FRDC’s historical investment to enable aquaculture development, and ongoing need for coordination of RD&E to enable continued sustainable growth, it is recommended that the FRDC be afforded increased authority to drive strategic planning, coordination, and investment in RD&E.
13. The Australian government and industry stakeholders continue implementation of the remainder of the National Aquaculture Strategy 2017 by establishing and resourcing a body tasked to drive this strategy to achieve national aquaculture industry development goals. Ideally this body should combine a balance of expertise and knowledge and operate as a meaningful collaboration to actively progress the National Aquaculture Strategy through to 2027 together with addressing key recommendations from this inquiry.

Background

The FRDC is a co-funded partnership between its two stakeholders, the Commonwealth Government and the fishing and aquaculture sectors. The FRDC is a Statutory Authority, fully owned by the Commonwealth Government, and accountable to the Minister for Agriculture. FRDC's role is to plan, fund and manage fisheries and aquaculture research, development and extension (RD&E) activities in Australia. The FRDC achieves this through facilitating consultation across its stakeholders to establish RD&E priorities and coordinating government and industry investments (Appendix 1) to address them. The FRDC is an important part of the Australian Government's role to help aquaculture grow to its potential through planning, managing and coordinating RD&E. Insights collected through consultation with industry, regulators and the RD&E community are used by the FRDC to inform submissions to the Australian federal and state governments on issues related to the Australian aquaculture industry (Appendix 2).

Aquaculture offers significant potential to increase sustainable production of Australian seafood. To achieve this potential, the Australian aquaculture sector needs to: address sustainability along its value chain; improve its productivity and economic performance through a market and consumer oriented approach; and adopt methods to achieve higher social acceptability and better governance.

The Australian government (including the FRDC) has a leading role to ensure these needs are addressed, and to also assist industry to navigate and benefit from the changing set of social and technological shifts that are reshaping the economy, jobs and quality of life (Anon., 2017a).

Research, Development and Extension

As outlined in the National Aquaculture Strategy:

“Individual operators continue to be innovative on-farm. Publicly funded RD&E is needed to ensure the growth and efficiency of Australia's aquaculture industry, especially in areas such as emerging aquaculture species, animal health, biosecurity and sustainable industry development. The existing matching of industry contributions through the Fisheries Research and Development Corporation (FRDC) is efficient and timely and is strongly supported by industry. FRDC has an Indigenous Reference Group that helps ensure that fishing and aquaculture RD&E delivers improved economic, environmental and social benefits to Aboriginal and Torres Strait Islander peoples.

Research on aquaculture by industry and research organisations has increased. Operators in sectors such as Atlantic Salmon, Southern Bluefin tuna, prawns, oysters and Barramundi are taking greater stewardship in prioritising, planning and managing RD&E for their sectors.”

The FRDC R&D Plan 2020-25 (<http://rdplan.frdc.com.au/>) has identified the requirement to support RD&E required for production growth as well as adapt to a dynamic and at times uncertain and unpredictable future. As the Australian aquaculture industry has grown the FRDC has provided increased funding to address research and development priorities (Figure 1) through engagement with the jurisdictions as well as specific industry sectors via the Industry Partnership Agreements (See appendix 1). These investments are executed with a suite of public and private providers including CSIRO, AIMS, Universities such as the University of Tasmania, state based research agencies such as SARDI and independent consultants. The total value (i.e., FRDC funds, cash and in-kind contributions) of aquaculture related research and development projects managed by FRDC over the past five years is \$108.7 million (Table 1). This investment is primarily to address “industry”

production issues (i.e., aquatic diseases, improved culture methods, genetics, nutrition), and increasingly over recent years, environmental research. Recently investment is growing to address people development and assess the contribution of aquaculture to regional communities.

Table 1. Total 5 year cumulative value of research and development projects managed by FRDC over the five years until 2020/21.

Item	Value (\$)
FRDC Project expenditure (includes industry co-contribution and Federal government matching contribution)	35,929,148
Cash (income) contributions from project stakeholders	9,828,424
In-kind contributions from project applicants	37,732,013
In-kind contributions from other project stakeholders	25,215,072
TOTAL	108,704,657

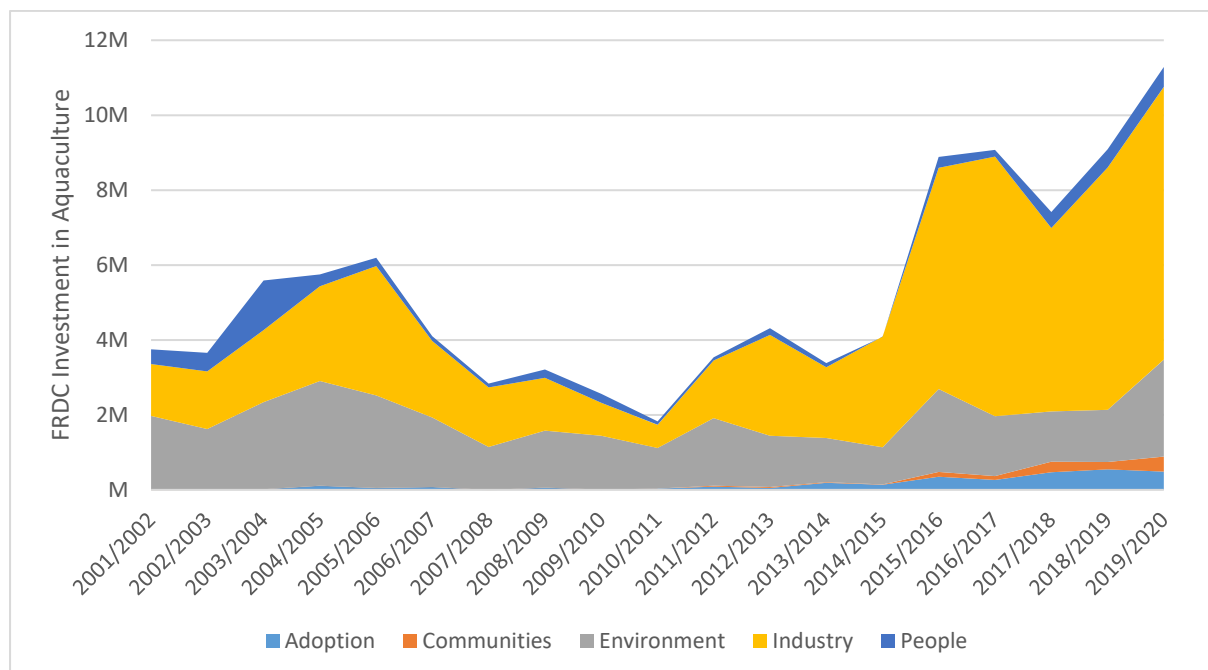


Figure 1. FRDC investment in aquaculture projects by Program (These programs are based on the “Objects” of the PIRD Act 1989).

Observation 1

FRDC’s value proposition is closely tied to its role as a provider and communicator of robust and independent science-based information. Communicating that independence is a key dimension of the FRDC’s brand, and is a key consideration for how the organisation communicates science.

The nature and current status of Australia's aquaculture sector

Global context

Aquaculture forms a critical element of the future of global seafood supply and is the fastest-growing food industry in the world, already a \$243.5 billion industry (O’Shae *et al.*, 2019) and in 2018 provided 52% of seafood for human consumption (FAO, 2020). From an estimated global population of 7.7 billion people in 2019, the global population could grow to 10.9 billion in 2100

(United Nations, 2019). To feed these people food production must double in the face of limited resources and a changing climate. Seafood based food strategies have the potential to substantially contribute to global food and nutrition security (Hicks *et al.*, 2019). While the global protein consumption market could increase by up to A\$111 billion between 2018 and 2025, the market value of aquaculture is expected to grow at an annual rate of 12%, leading to a substantial rise of its share of the total protein market from 12% in 2018 to 21% in 2025 (FIAL, 2019). Global seafood production is currently about 170 million metric tons, and by 2030 an additional 44 million metric tons will be needed to meet the demand for seafood (World Bank, 2013) of which a projected 109 million tonnes of fish, providing 60% of the world's fish consumption, will come from aquaculture (FAO, 2018). Collectively these statistics present a significant challenge for the agriculture and food sector and need to be met to avoid potential conflicts around food security.

Aquaculture includes production from both fed (i.e., species that require feed inputs such as finfish and prawns) and unfed (i.e., species that obtain feed from the environment such as shellfish and seaweeds) systems. Aquatic animals that are fed in aquaculture systems typically have favourable, or low, food conversion ratios (FCR) in comparison with terrestrial farmed animals because they are ectotherms and are buoyant in water instead of standing against gravity. FCR for fish and shrimp are similar to chicken, typically half that of pigs and less than a quarter for cattle. In addition, the high fecundity (reproductive potential) of most cultured aquatic species results in a high broodstock to market fish ratio with little additional feed and other resource inputs (i.e., land, water, energy) needed when compared to the considerable broodstock inputs for low fecund terrestrial animals (Tlusty *et al.*, 2018). Consequently, aquaculture has advantages over terrestrial animal proteins that allow it to have lower feed conversion and energy demands, positioning the industry to be regarded as the most resource efficient and sustainable supplier of animal protein as measured by nutrient, water and land use, carbon production, and ecological interaction.

Australian aquaculture

When the National Aquaculture Strategy 2017 was released the Australian aquaculture industry was valued at \$1.347 billion (Steven *et al.*, 2020), and when the most recent production figures available from some jurisdictions are included, the industry is currently valued at \$1.57 billion (2020-21, Figure 2). The proportion of the value of Australian seafood production attributed to aquaculture has grown from 29% (2000/01) to 51% (2019/20) and is responsible for most of the growth in value of the Australian seafood industry (Figure 3). Atlantic Salmon farming in Tasmania has dominated Australian aquaculture production since 2005-06, and has been responsible for most of the growth in Australian aquaculture since then. Consequently, Tasmania has the largest aquaculture production followed by South Australia and Queensland (Figure 4). Other significant established aquaculture sectors are prawn farming, oyster farming, Barramundi farming, pearl farming, abalone farming and Southern Bluefin Tuna ranching (Figure 5). There are also several growing aquaculture industries with a limited number of companies that cannot be reported separately (due to commercial confidentiality). These include Yellowtail Kingfish farming, Murray Cod and other native fish, mussel farming, aquarium species, brine shrimp, algae farming and regenerative aquaculture (eg Blue Carbon). There are currently over 90 species being farmed in Australia.

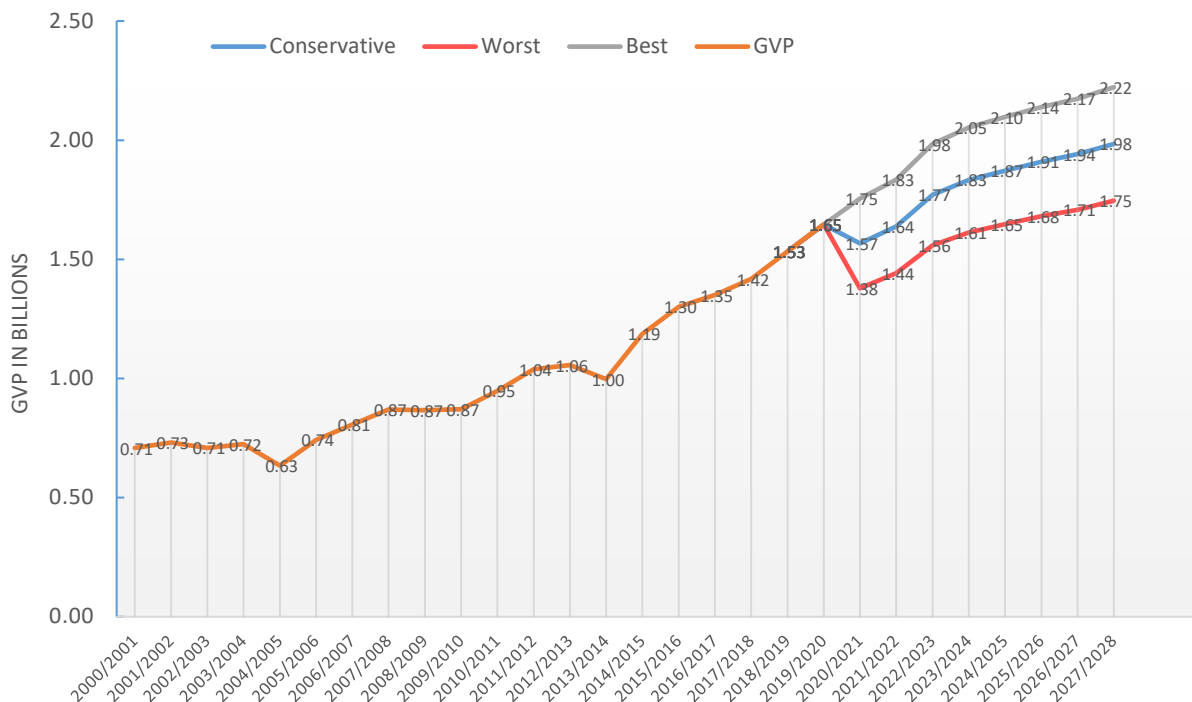


Figure 2. Value of Australian aquaculture production. Values to 2019-20 from FRDC including most recent production reports. Projections based upon ABARES industry growth estimates (Mobsby et al., 2021) with best case + 12% and worst case – 12% variation.

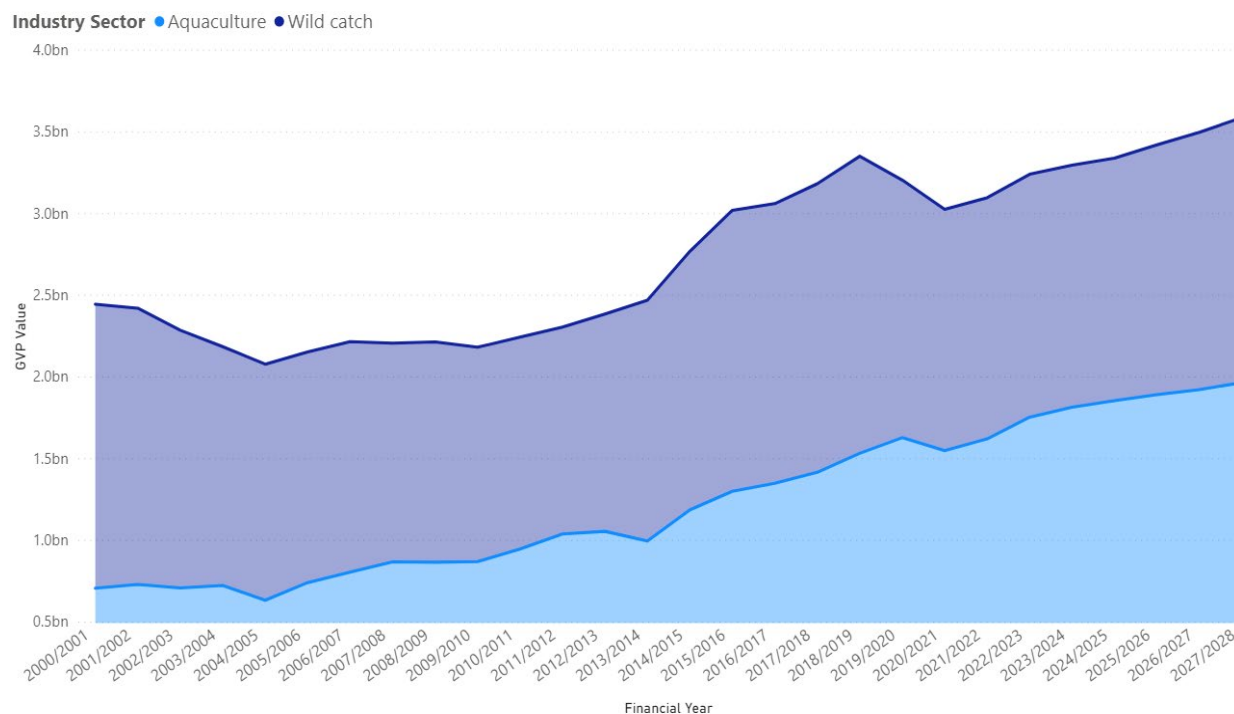


Figure 3. Value of Australian seafood production from the fishing and aquaculture sectors. Values to 2019-20 from FRDC including most recent production reports. Projections based upon ABARES industry growth estimates (Mobsby et al., 2021).

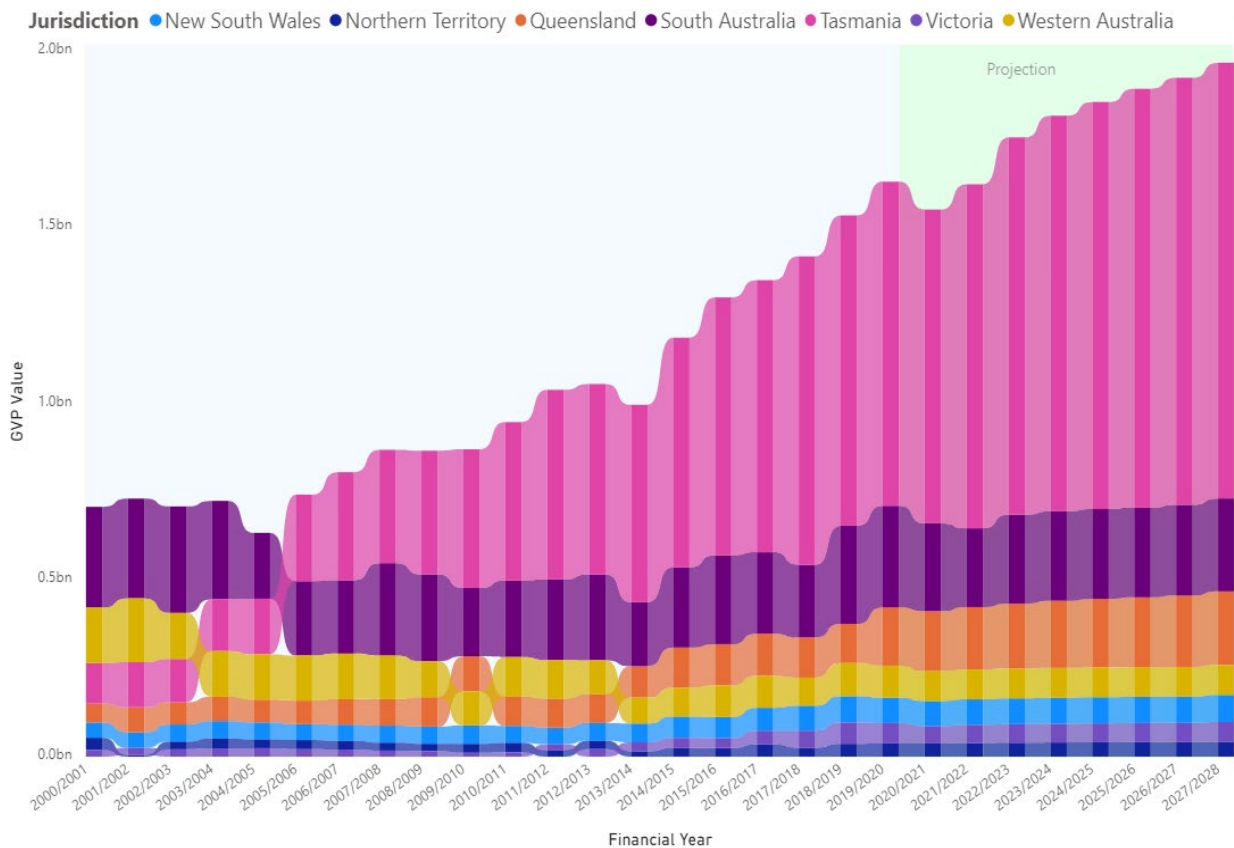


Figure 4. Value (GVP) of the Australian aquaculture industry for each jurisdiction. Values to 2019-20 from FRDC including most recent production reports. Projections based upon ABARES industry growth estimates (Mobsby et al., 2021).

Over time the value of some industry sectors has increased while others have declined (Figure 5). Prior to the 2000’s pearl farming was Australia’s highest value aquaculture industry but has since declined due to factors largely beyond control of the industry. These factors include widespread pearl oyster mortality, with a poorly defined cause, and the impact of the global financial crisis on luxury products and now COVID-19. FRDC and industry are funding research to improve pearl oyster health while industry addresses market challenges for the world’s best quality pearls. Over the same period Southern Bluefin Tuna ranching has declined in value primarily due to exposure to a dominant Japanese market and the growth of tuna farming in other countries that have access to more preferred tuna species. However, both sectors expect to have improved outlooks in coming years.

In addition to the growth of Atlantic Salmon farming, these declines have been balanced by the rise in production and value from prawn and Barramundi farming that are mostly located in Northern Australia. Both sectors have ambitious growth plans and farm species that have production and market characteristics that are favourable for substantial industry growth. Prawns are a core restaurant menu item and Barramundi provides a consistent high quality iconic “white fish” offering. Recent expansion of prawn farming in Queensland has seen an increase in production over the past year with value growing 55% from \$80.4 million in 2018–19 to \$124.6 million in 2019–20 (Schofield, 2021). This increase is expected to continue over the next few years. Oyster and abalone farming sectors continue to show steady growth and are important contributors to regional economies in NSW, Tasmania, South Australia and Victoria. The diversification by the large Atlantic Salmon

companies into prawns Yellowtail Kingfish and Barramundi demonstrates that these sectors have good investment potential.

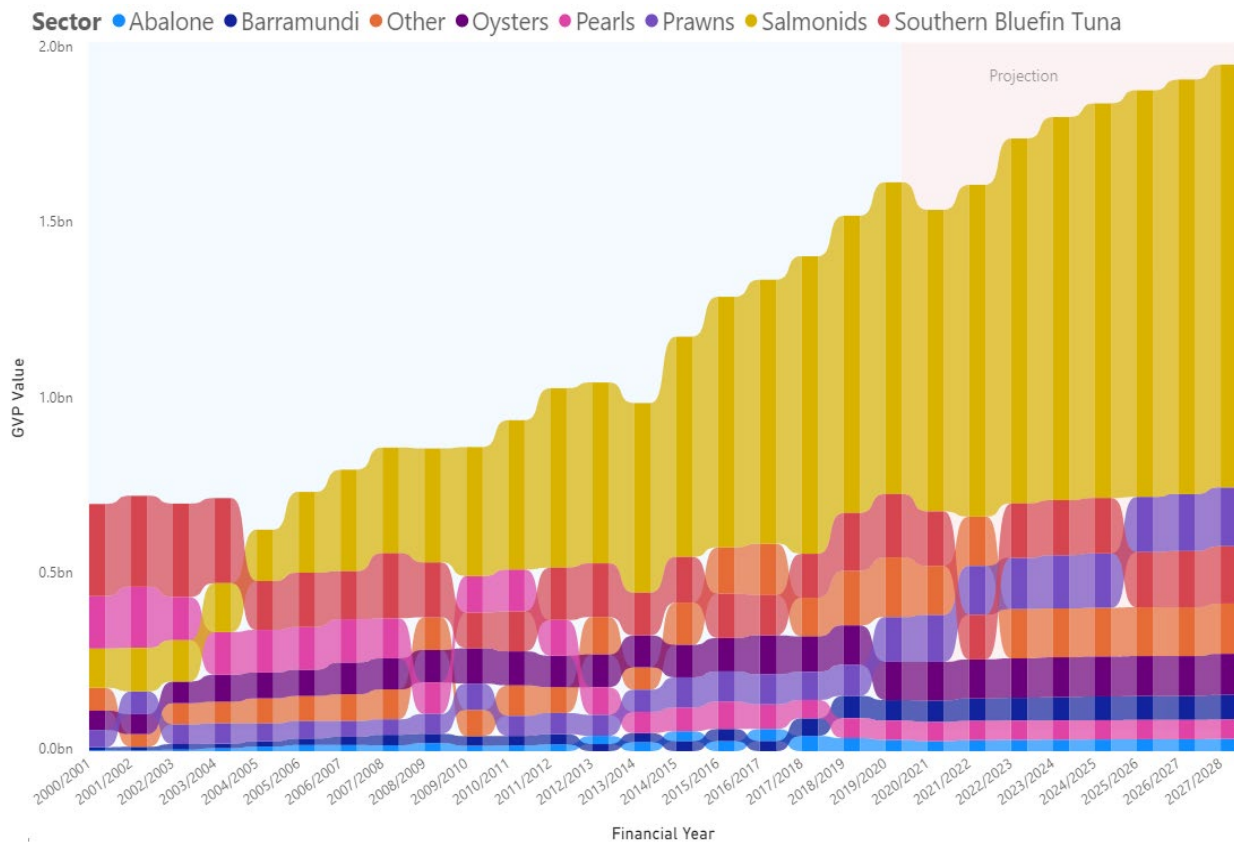


Figure 5. Value (GVP) of Australian aquaculture from each industry sector. Values to 2019-20 from FRDC including most recent production reports. Projections based upon ABARES industry growth estimates (Mobsby et al., 2021).

There is also growing optimism for the prospects of new aquaculture opportunities including seaweed farming and shellfish developments in Western Australia. New commercial seaweed farming ventures have recently commenced in Tasmania and South Australia and a recent Agrifutures Australia funded study predicts that the industry could become a \$1.4 billion aquaculture sector by 2040 (Kelly, 2020). A world first tropical spiny lobster aquaculture farm, Ornatas (<https://ornatas.com.au/>), based on closed lifecycle has commenced commercial hatchery production in Queensland with plans for additional grow out in Northwest Western Australia. Investments in shellfish farming in Western Australia provide optimism for greater production of mussels, Western Rock Oysters, Akoya Pearl Oysters for consumption, along with the development of Tropical Rock Oyster farming in northern regions.

FRDC expects that the Australian aquaculture industry will exceed the \$2 billion target of the National Aquaculture Strategy 2017 with increasing growth of some established sectors (salmon, oysters, abalone), the recovery of some sectors (pearls, Southern Bluefin Tuna), growth projections from expanding sectors (prawns, Barramundi), and the emergence of new opportunities (seaweeds, shellfish). If an overall 12% improvement above the ABARES predictions (Mobsby et al., 2021) can be achieved the Australian aquaculture industry could be valued at \$2.17 billion in 2026-27 (Figure 2).

Opportunities and barriers to the expansion of the aquaculture sector: including ability to access capital and investment.

Australian aquaculture focuses on premium products that generate significant economic value. Aquaculture is a primary industry positioned within Australia's food and agribusiness industry that is identified as a sector of competitive strength and strategic priority (FIAL, 2019). While Atlantic Salmon farming industry is already the largest primary industry in Tasmania, other aquaculture sectors (e.g., Barramundi and prawn farming) are now, relative to other agrifood industries, emerging to become significant contributors to the value of Australian agriculture. For sustainable growth opportunities for the established, emerging and new sectors of the Australian aquaculture industry to be achieved, there are challenges that need to be accommodated, including:

- Evolving relationships with stakeholders and within industry sectors as mergers and acquisitions occur creating larger companies creating a greater proportion of sector production.
- The industry needing to become world competitive through ongoing reduction of costs and increasing efficiency.
- Creating and demonstrating sustainability throughout the supply chain as this is now the price of entry into the market that has greater scrutiny from consumers, who demand increased requirements for sustainability credentials that assess the environmental footprint of production.
- Growing visibility as sectors expand production and the need for increased transparency and accountability to allay community concerns about the industry and its practices.
- Adapting to increasing environmental pressures such as climate change, water scarcity and pollution.
- Adopting opportunities presented through growth of circular economies that do more with less to make the most of the available resources.
- Acknowledging the rise of plant-based protein and cell cultured seafood products.

OPPORTUNITIES

Food Innovation Australia Limited (FIAL, 2019) have reported that if Australia were to restructure its protein production mix to match projected global protein consumption in 2025 and correspondingly focus more on higher-value protein categories such as aquaculture, the country's food production value could be as high as \$122 billion. This is \$55 billion higher than if producers were to follow a business-as-usual trajectory.

Observation 2

The Australian government assist transformation of Australia's agrifood production system through recognising the potential that support for the Australian aquaculture industry can achieve towards meeting the target of growing Australian agriculture to \$100 billion by 2030.

Northern Australia

Northern Australia offers significant potential to further expand aquaculture production across many species and regions with vast areas of land suitable for land-based aquaculture (Irving et al., 2018). The CRC for Northern Australia funded a Northern Australia Aquaculture Situational Analysis (Cobcroft et al., 2020) which provided a detailed investigation of the potential and barriers to growth of the industry in this region. The report describes potential GVP primarily from expansion of prawn

and Barramundi farming of between \$535 million and \$1.34 billion pa under the most likely scenarios investigated.

The opportunity presented by expansion of aquaculture in Northern Australia can only be achieved if several barriers to growth are addressed. The major barriers relate to remoteness and harsh environmental conditions creating the following issues:

- Remoteness of farms and low population makes it difficult for aquaculture ventures to attract and retain skilled labour.
- Lack of local infrastructure, services, and poor connectivity
- Harsh environmental conditions (i.e., heat, cyclone, large tides, crocodiles)
- High costs of accessing and purchasing key inputs.

Recommendation 1

The Australian government and industry stakeholders implement the recommendations on development of aquaculture across Northern Australia, in particular, the recommendations of the Northern Australia Aquaculture Situational Analysis (Cobcroft et al., 2020).

Observation 3

The Australian government and industry stakeholders note the recommendations presented by the Joint Select Committee on Northern Australia report: Scaling Up – Inquiry into Opportunities for Expanding Aquaculture in Northern Australia (Anon. 2017b).

[Access to sites for sustainable industry growth](#)

Across Australia there are sites available to increase national aquaculture production. Some recent industry expansion has been achieved through refurbishment of underutilised sites (prawn and Barramundi farm expansions) in addition to development of new farming locations. As acknowledged in the National Aquaculture Strategy 2017 (Anon., 2017c), regulatory burden upon aquaculture operators can be significantly reduced through the establishment of designated aquaculture zones that include agreed preliminary environmental and planning approvals enabling industry to establish aquaculture operations without having to undergo lengthy, complex, and expensive individual approval processes. This process provides 'investment ready' areas of land or water reducing the time and complexity to establish commercial aquaculture operations. In addition, Governments in some jurisdictions (South Australia, Queensland) operate a one-stop-shop approach to servicing aquaculture development approvals, involving consultation with all relevant departments. Ideally an additional benefit of this approach is that regulators can manage the types of aquaculture enterprises that occupy the zones and evaluate cumulative impacts.

Several jurisdictions have identified suitable aquaculture development area (ADA) to promote and grow sustainable aquaculture. In South Australia there are 10 designated ADAs that allow for production of a range of species. Each zone has a policy that describes where, what species and how much of a particular type of aquaculture development can occur within the zone boundaries. Primary Industries and Regions South Australia recently opened a public call for aquaculture developments within more than 5,000 hectares of water across five growing areas. In Tasmania, 14 Marine Farming Development Plans set out areas where marine farming can occur ('zones'). The Plans specify which types of marine farming (i.e., finfish, shellfish) that can take place

within each zone and contain management controls developed to mitigate and manage potential impacts of farming within the zone. In Queensland, six land-based marine ADAs totalling over 7,000 hectares have been identified to promote and grow a sustainable aquaculture industry. Another ADA is currently being considered. In Western Australia, the following three aquaculture development zones have been established:

- The Kimberley ADA - 2,000 hectares that has the capacity to sustainably produce around 20,000 tonnes pa of marine fish.
- The Mid West ADA - 3,000 hectares that has the capacity to support sustainable production of around 48,000 tonnes pa of marine finfish.
- Albany ADA for the culture of marine shellfish such as edible oysters and mussels.

Although ADAs have been created, the regulatory pathways and approval processes need to be further streamlined to improve occupancy by commercial enterprises within these areas that have been identified to grow sustainable aquaculture industries. FRDC is also aware that some aquaculture sectors consider that some ADAs are located in areas where the business case for aquaculture is difficult to make.

Recommendation 2

The Australian government and industry stakeholders recognise that scientific evidence is needed to set realistic harmonised regulatory requirements, and improve the approval pathway for aquaculture development taking into account land and aquatic use planning.

Off-shore Aquaculture

Australian aquaculture industries are becoming constrained by the availability of suitable near shore production sites with increasing community concerns about environmental impact and farm operations (noise, vessel traffic, visual impact) in the coastal zone making expansion of aquaculture challenging. Consequently, developing production systems suited to more offshore locations presents an enormous opportunity for Australia to use its ocean domain to continue to grow marine aquaculture. However, there is a lack of knowledge about operating in this more exposed environment that requires more robust infrastructure and poses different challenges for servicing (maintenance, energy supply, feeding, animal husbandry, supply chain logistics and biosecurity). Some of these challenges have begun to be addressed through the Blue Economy Cooperative Research Centre (<https://blueeconomycrc.com.au/>) that brings together national and international expertise in aquaculture, marine renewable energy and marine engineering.

To fully realise this opportunity, offshore aquaculture growth requires agreement on regulation of aquaculture in Commonwealth waters (National Aquaculture Strategy 2017). A clear regulatory framework for undertaking aquaculture in Commonwealth waters is needed to attract the large investments required for offshore opportunities to be realised.

Recommendation 3

The Australian government develop a clear planning and regulatory framework for undertaking aquaculture in Commonwealth waters.

Changing consumer expectations

To grow value, the Australian aquaculture industry must understand and align production with evolving consumer preferences that are increasingly demanding more information on environmental

credentials and traceability. Increasingly the Australian public and consumers now expect that the seafood they buy is produced in a manner that aligns with their values. The ability to access origin data behind a product will be an expectation and the attachment of a service that provides this information to a product item will become the norm (Global Aquaculture Alliance, 2019). The Australian aquaculture industry and supply chains need to respond to these consumer and community drivers that are increasingly demanding evidence of environmental, animal welfare and social performance.

Involvement of all steps of the supply chain from the producer to the consumer is critical to achieve change and progress towards a sustainable aquaculture industry supported by the Australian public and consumers. To achieve sustainable growth the aquaculture industry can capitalise upon inherent advantages that allow it to provide product choices that focus on health, sustainability, nutrition and convenience.

The opportunity and challenge for the Australian aquaculture industry is to demonstrate and communicate that future growth of a sustainable industry is achieved through ethically managed production systems that target minimal environmental impact and meet consumer expectations of traceability throughout the value chain, resulting in assurance that aquaculture products are the best environmental and social choice for seafood.

These changing consumer and public demands present a challenge and an opportunity for aquaculture sectors to create close connectivity to build strong trust between aquaculture producers, consumers and the Australian community. Science, technology, and communications systems are available that can be adopted by the Australian aquaculture industry to deliver these consumer expectations.

A threat that needs to be addressed is consumer disruption from social media influencers that can pose reputational risks to markets can reduce community confidence and support for the aquaculture industry based upon inaccurate information.

Recommendation 4

The Australian government and industry stakeholders support innovations that increase traceability along the supply chain to confirm quality, safety and sustainability credentials of aquaculture products, and provide the capacity for investigation and enforcement of seafood fraud.

Domestic market

The strong domestic food market offers opportunities for Australian aquaculture to provide a diverse range of healthy, nutritious products that meet consumer needs. Growth of the Australian aquaculture industry will present challenges to increase market share and price as production increases. Like other seafood products, those produced from aquaculture face resistance from Australian consumers, many of whom do not like the smell or touch, and are not confident in selecting and cooking seafood. These constraining factors continue to present a challenge to growing the domestic market for seafood products, including those produced by aquaculture.

Export markets

There is a perception that Australian aquaculture products will experience a strong demand from Asia as populations grow and incomes rise. To date these opportunities to grow export revenue have only been realised by exports of Southern Bluefin Tuna, farmed abalone, cultured pearls and recent

increases in volumes of Atlantic Salmon with exports growing to 25% of production (20,000 tonnes) since 2013 (Mobsby *et al.*, 2021).

As production from the aquaculture industry expands, it is perceived that Australia's reputation for clean, safe and trusted seafood products will be the foundation for growth in the more affluent international markets of the Asia Pacific region, where "brand Australia" has value. Consequently, to support growth of export markets for aquaculture products, Australia must promote and maintain a strong external-facing brand and continue to support the regulatory systems that give "brand Australia" credibility in international markets.

Indigenous participation in aquaculture

The National Aquaculture Strategy 2017 (Anon., 2017c) identified the need for a stronger level of recognition of the rights and interests of Aboriginal and Torres Strait Islander peoples in the management and development of aquaculture in Australia. Recently there have been examples of growing participation of Indigenous corporations in aquaculture, including:

- Granting of seaweed farming licences to the Narungga Nation Aboriginal Corporation (NNAC) on Yorke Peninsula, South Australia. NNAC will be working in partnership with CH4 Global to commercialise cultured seaweeds.
- In South Australia, the Far West Coast Aboriginal Corporation together with the Stehr Group established the Indigenous-owned Southern Bluefin Tuna farming enterprise Wanna Mar Stehr.
- Farming of Tropical blacklip oysters is being investigated in the Northern Territory by Yagbani Aboriginal Corporation, South Goulburn Island and Anindilyakwa Land Council, Groote Eylandt.
- Tropical rock oyster farming is also being investigated in Western Australia by the Murujuga Aboriginal Corporation that has partnered with Pilbara Development Commission, Maxima Pearling Company, and the City of Karratha.
- Tasmanian Seafoods Pty Ltd working in co-operation with Indigenous communities to develop hatchery production and sea ranching of Sea cucumber in Northern Australia.
- Emama Nguda Aboriginal Corporation in Derby, Western Australia is commercialising the breeding of the northern Australian giant freshwater prawn, Cherabin.

Aquaculture provides opportunities for enterprises for coastal Indigenous communities with the Indigenous Land and Sea Corporation increasingly seeking to support economic participation in these opportunities.

Recommendation 5

In supporting growth of aquaculture in Australia, it is recommended that this be pursued in a manner that delivers significant economic and social benefits to Indigenous Australians.

BARRIERS

Access to capital

Historically, the Australian aquaculture industry has difficulty attracting investment from private equity groups due to the lack of scale of operations that allow economies of scale derived cost savings and consequent returns on investment to be achieved. The industry is comprised of a number of sectors segments containing several types of producer business models and levels of vertical and horizontal integration.

A unique challenge faced by investors considering the aquaculture industry is that as operations of some sectors occur on water that is leased rather than owned, there is little or no real property right attached to the producing assets. This presents a challenge for investors to evaluate the attractiveness of the Australian aquaculture industry. In addition, aquaculture is capital intensive requiring investment in production infrastructure and working capital and requires further investment as production grows. This restricts new entrants as established operators are best positioned to attract new investors due to their production records, knowledge, and ability to mitigate risks.

Recently this situation has begun to change with investment in aquaculture increasing as demonstrated by the growing number of ASX listed aquaculture companies (13 listed) (Figure 6) and private equity investments in shellfish farming, Aquafeeds and seaweed ventures. There has also been investments by Tasmanian Atlantic Salmon farming companies in other emerging aquaculture sectors (i.e., Tassal’s substantial expansion into prawn farming, Petuna/Sealord investment in Barramundi farming and Huon Aquaculture Company interest in Yellowtail Kingfish farming within the Mid-West ADZ, Western Australia). These enterprises bring vertical integration, market power and established supply chains.

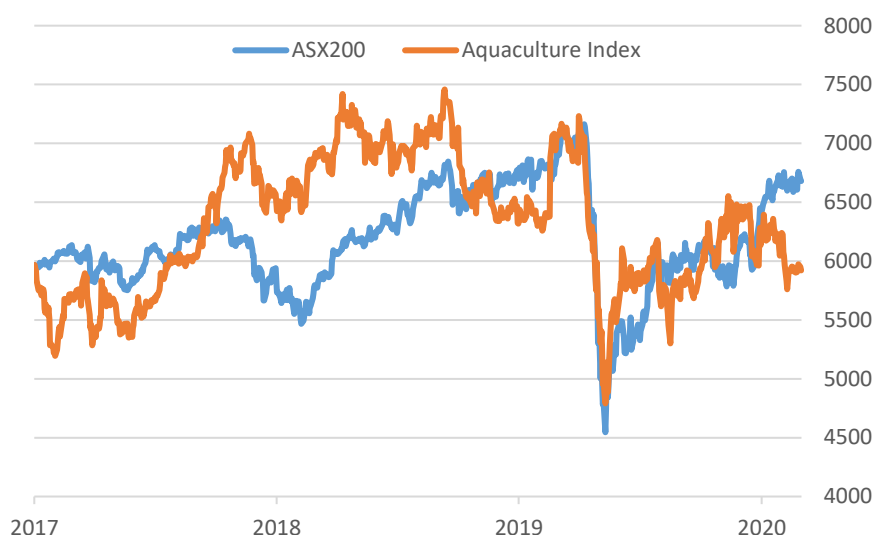


Figure 6. Performance of aquaculture companies listed on the Australian Stock Exchange (2017-present) compared to the top 200 listed companies. The Aquaculture Index is created using the average market capitalisation of the ASX traded aquaculture companies. The data is normalised for comparative purposes against ASX200.

Achieving scale of production

The National Aquaculture Strategy 2017 (Anon., 2017c) highlighted that achieving the necessary scale of operation was a barrier to growth of the industry. This included the ability of emerging companies to, to put in place logistics to get product to markets, maintain product quality and develop a recognised brand name. Stakeholders identified vertical integration as one successful business model for improving market access and protecting brand image.

Operators in some sectors of the Australian aquaculture industry face challenges for undifferentiated products that receive low margins in competitive markets. Some segments of the

industry remain relatively immature, fragmented and somewhat inefficient. This suggests that significant opportunities exist for these segments or companies that can overcome the adverse effects of these conditions. Recently there has been evidence of increasing scale of operations with increasing consolidation within sectors (oyster, prawn, Barramundi) and entry of corporations leading to larger entities. This change has been accompanied by modernisation of old farming locations and investment in new farming technologies to increase efficiency and productivity. As a result of this “evolution” it is likely that there will be increased production and value from some sectors of the Australian aquaculture industry in the next few years as evidenced by the increased growth from prawn farming in Queensland.

In addition to achieving scale of operations, developers need to be able to obtain a permit within a reasonable amount of time. Minimising the time to market for developments needs regional scale collaboration, while partnerships between stakeholders are critical for accelerating the speed and scale of progress (see above recommendation 2 - Access to sites for sustainable industry growth).

Infrastructure

There is a lack of high-quality infrastructure in some regional or remote areas including roads, ports, electricity and freight logistics. These are required by aquaculture industries that rely upon getting fresh product to market quickly. Appropriate infrastructure to maintain the supply chain from aquaculture ventures in Northern Australia (cold storage, road, and air freight service) will improve access to markets and lower transaction costs for businesses so that they can increase productivity and profitability needed to create new jobs and revenue in regional areas (Cobcroft et al., 2020).

Recommendation 6

Co-ordinated access to and incentivisation of capital across all levels of government to improve supply chain infrastructure for fisheries and aquaculture (e.g., cold chain infrastructure) and to support the adoption of new technology. This will enable the sector to be more efficient across the entire supply chain and reduce costs.

Inquiry into growing Australian agriculture to \$100 billion by 2030. Submission 11 - FRDC. 2019.

(https://www.aph.gov.au/Parliamentary_Business/Committees/House/Standing_Committee_on_Agriculture_and_Water_Resources/Agriculturegrowth/Submissions)

Country of Origin Labelling

Some aquaculture sectors (e.g., farmed Barramundi and prawns) are significantly disadvantaged by current food labelling practices that do not require food service establishments to identify the origin of the seafood sold to customers. This can only be overcome through an Australian Government Legislative response to extend mandatory Country of Origin Labelling (CoOL) to food service. CoOL would provide both an informed choice to Australian consumers and a market advantage to Australian aquaculture products as many consumers will purchase locally produced product if they have the CoOL information provided to them. This is anticipated to yield economic benefits to the Australian aquaculture (and broader seafood) industry and improve consumer confidence in the provenance and environmental credentials of the seafood being offered.

Recommendation 7

The FSANZ Food Standards Code 2.2.3 should mandate the use of the Australian Fish Names Standard to support expanded country of origin labelling (<https://fish.gov.au/-/media/fish-frdc/corporate-documents/submissions/cool-submission-from-frdc-april-2014.ashx>).

Demonstrating sustainability

The trajectory for aquaculture to achieve the goal of sustainability is no different than any other form of food production; that is limit, counteract, or isolate its pollution on the localised environment, and accelerate the efficiency of natural resource use” (McNeven, 2020).

Sustainability is not just a trend, it is a movement that can make or break aquaculture. Cost of carbon emissions, nutrient discharge and other effects on the local and global ecosystems will be more important in the future (PWC, 2017). Being proactive in anticipating and responding to these issues means the Australian aquaculture industry accepts ownership of its sustainability and companies are increasingly integrating sustainability values as part of their core business model. To ensure sustainable growth, aquaculture production and ecosystem protection must be linked at every level (i.e., good science, management, and farm practice). Perhaps the most attractive and most challenging benefit to achieve, is to facilitate growth, new revenue streams and customer loyalty. For example, “ecological salmon” is a trend that is catching on, and one that can create new revenue streams if successful (PWC, 2021).

Banks and the investment community are beginning to consider sustainability in their assessments of seafood businesses, while Australian and multinational companies are increasingly including sustainability performance criteria into their supply chain contracts. This highlights the increasing importance of assessing the implications of sustainability performance on business profitability, and potential implications for future access to finance.

The Australian aquaculture industry has opportunities to further improve sustainability as the linear economy is slowly replaced by a circular economy with three central principles:

1. To restore natural systems by protecting and actively improving the environment.
2. Minimise waste and pollution by designing products and services in a new way.
3. To keep products and materials in use for as long as possible.

These principals will require innovation to provide solutions that can be adopted within commercial aquaculture operations to meet greater sustainability ambitions. They can be achieved through innovations that increase production, the use of novel ingredients and by-products for feed, optimised resource use through new technology and big data, and increased collection and recycling of nutrients (PWC, 2021).

Research institutions, industry and regulators must continue to narrow the gap between scientific evidence and policy making by supporting R&D that provides science-based decision-making tools for efficient planning and sustainable management of the Australian aquaculture industry.

Recommendation 8

The Australian government support the aquaculture industry to achieve greater sustainability through moving towards a future regenerative or “circular economy” that utilises all wastes produced within aquaculture systems and creates benefits beyond profit.

Aquatic biosecurity

The intensified production and high trade volumes of aquatic animals and their products can be a significant pathway for the spread of aquatic animal diseases. Australia is facing unprecedented biosecurity challenges as pests and diseases are spreading around the world at a much higher rate than ever before, primarily driven by increasing trade and tourism. Globally, a trend in aquaculture is

that every three to five years a previously unreported pathogen that causes a new and unknown disease will emerge and spread rapidly crossing national borders, causing major production losses (FAO, 2020). Due to the inter-connectedness of aquatic systems, preventing the introduction of diseases and parasites is of foremost importance for the Australian aquaculture industry. Effective biosecurity is by far the most cost-effective approach to minimise impacts of aquatic diseases and parasites. Additionally, there is recognition of the priority status of biosecurity amongst aquaculture industry stakeholders to ensure both animal health and welfare, and to underpin access to both domestic and international markets.

The introduction of White Spot Disease into prawn farms in SE Queensland in 2016 is attributed to a breakdown in border biosecurity. The proliferation of major diseases in overseas producing nations farming similar species to those farmed in Australia creates persistent biosecurity threats. Consequently, Australian aquaculture sectors are striving for evidence-based policy changes that reduce the disease risk posed by imports (i.e., uncooked frozen, fresh, and chilled products). This situation highlights the need for maintaining biosecurity and aquatic animal health capability, in both industry and government institutions at a national level. The priorities to progress these needs will be included within the soon to be completed AQUAPLAN 2021-26 (<https://www.agriculture.gov.au/animal/aquatic/aquaplan>) developed by Department of Agriculture, Water and the Environment (DAWE) in consultation with industry stakeholders.

Recommendation 9

The Australian government and industry stakeholders work to implement the areas of need identified in AQUAPLAN 2021-26 (in development phase).

Aquatic Animal Health and welfare

Aquatic animal diseases and parasites are one of the most serious constraints to the expansion and development of sustainable aquaculture (FAO, 2019). Infectious microbial diseases continue to impose major yield-limiting effects on global aquaculture production with the overall impact exceeding \$6bn per annum (Steniford, 2017). The Australian aquaculture industry also faces significant aquatic disease and parasite issues including Pilchard orthomyxovirus (Atlantic Salmon), Pacific Oyster Mortality Syndrome, QX and winter mortality (oysters), white spot disease (prawns), external parasites (Yellowtail Kingfish, Barramundi, Murray cod), and most recently the re-emergence in Victoria of abalone viral ganglioneuritis (AVG).

The Australian aquaculture industry must ensure the use of the highest standards of humane culture and harvest practices throughout the industry. Improved aquatic animal health and welfare translates to improved productivity and profitability, reduced environmental impacts, and greater consumer and community acceptance. Appropriate strategic and tactical R&D, better resourced aquatic diagnostic services, and development of aquatic veterinarian and research capabilities are needed to support the growing Australian aquaculture industry to improve health and welfare of aquatic species cultured under commercial conditions (see FRDC's Aquatic Animal Welfare information <https://www.frdc.com.au/issues/aquatic-animal-welfare>).

Access to veterinary medicines

Veterinary medicines play a valuable role in ensuring animal health, welfare and maximising the quality and yield of primary produce (economic sustainability) but must be used safely to reduce risks to consumers, ensure market access and avoid potential for environmental impacts. However,

there is limited availability of safe and effective veterinary medicines to treat existing and emerging aquatic diseases and parasites that threaten the Australian seafood industry.

FRDC provided a submission to the independent review of the agricultural and veterinary chemicals regulatory system that highlighted that the current regulatory framework is suited to sectors that require high volumes of these chemical products and is not well suited to sectors such as aquaculture that use lower volumes, and consequently require an efficient application and approval process to obtain minor use permits (MUPs) for safe and effective use.

Observation 4

FRDC has previously provided a submission to the *Independent Review of the Agvet Chemicals Regulatory System. 2021.* (<https://haveyoursay.awe.gov.au/agvet-chemicals-regulatory-reform/widgets/330976/documents>)

Social license

Social license issues focused on the public perception of the sustainability of aquaculture production industries are a growing threat to industry expansion. Fortunately, the issue of social license has come to the fore in the Australian aquaculture sector at a time when companies are committing themselves to sustainability. The Australian aquaculture industry sees the incorporation of a commitment to obtaining and maintaining social license as a key driver for understanding and building industry-community relations, particularly if it can be part of the basis for a societally endorsed, sustainable aquaculture sector. One of the features of aquaculture that makes achieving social license more difficult than for other resource intensive sectors (mining, forestry) is the wide extent of competing users in the associated stakeholder network associated competing users including commercial fishing, recreational activity and tourism. This has relevance for how aquaculture industries negotiate social license with stakeholders that are demanding stronger regulatory oversight over aquaculture.

Building social license will require skills and resources to implement greater information sharing and proactive communications with communities and wider interest groups, beyond seafood consumers. Better investigation of, and communication regarding the real versus perceived impacts of aquaculture could aid in clarifying the debate about aquaculture and help to achieve positive environmental and reputational impact by actively promoting the industry as the most resource efficient and sustainable supplier of animal protein as measured by nutrient, water and land use, carbon production, and ecological interaction. This will be assisted by:

- Effective communication of science-based information that addresses stakeholder concerns to improve community and consumer understanding to enhance support for aquaculture; and
- Ongoing demonstration of the contribution of aquaculture to resilient communities when farming on public land or in the sea, thereby fulfilling social contracts which legitimise the aquaculture industry.

Need for Industry cohesion

The Australian aquaculture industry operates across jurisdictions with different regulatory systems, cultures, a diverse range of species with different biological characteristics and environmental tolerances (tropical, temperate, sea water, freshwater) requiring different farming systems (ponds, raceways, sea-cages, recirculating water systems) in different locations (onshore, coastal, estuarine). Within a sector (e.g. prawn or Barramundi farming) operators may range from family businesses to small-medium enterprises to public listed companies. This diversity creates challenges to

collaboration, and presenting a united representation to governments seeking support to address key barriers and fully achieve the development opportunities that the industry presents to particularly regional Australia.

Climate change

Australian aquatic environments are observing the impact of climate change as populations of marine organisms undergo changes in density and geographic distribution. A dramatic example is the significant reduction in the giant kelp (*Macrocystis*) forests on the east coast of Tasmania over the past 20 years. This has been accompanied by a southward range extension of the long-spined sea urchin (*Centrostephanus*) capable of forming large ‘urchin barrens’ through overgrazing, which are devoid of important fishery species (rock lobster and abalone). It has also become increasingly evident that climate change arising from global warming, may alter aquaculture production strategies due to the occurrence of saline water intrusion, stress due to changing water temperature, and ocean acidification (D’Abramo & Slater, 2019). Inevitable changes in physical and biological conditions will need to be confronted by the ability to make changes in management practices (site, species) including the use of more suitable organisms from selective breeding programs (Teletchea, 2020). The Australian aquaculture industry will inevitably need to confront these environmental changes.

Recommendation 10

The Australian Government continue to co-invest through the Council of Rural Research and Development Corporation’s Climate Initiative to enable aquaculture as part of a broader agrisystem to continue to thrive irrespective of a changing climate.

The ability for businesses to access and commercialise new innovations to expand aquaculture.

Although a minnow in the global aquaculture industry, Australia has an impressive record in innovation, specifically:

- Southern Bluefin Tuna fishermen in Port Lincoln developed the world’s first successful tuna farms that have been adopted to farm other tuna species in the Mediterranean, Japan, Mexico and USA.
- In Tasmania the Institute for Marine and Antarctic Studies pioneered the closing of the lifecycle of several spiny lobster species and developed hatchery culture technology that has enabled Ornatus (<https://ornatas.com.au/>) to establish the world’s first spiny lobster aquaculture farm in Queensland.
- The longline and basket systems developed by innovative Australian oyster farmers have been commercialised by Australian companies (i.e. Seapa, BST, Hexcyl, Zapco) that are manufacturing and exporting this technology to farmers around the globe. Recently digital oyster farm management systems (i.e., Smartoysters, Oystercloud, MiShell) have also been developed that are transforming oyster farming and are also being adopted internationally.
- AQ1 Systems (<http://www.aq1systems.com/products.html>) develop intelligent feeding control systems and fish sizing technology that is used in fish and shrimp aquaculture globally.
- Innovations in the Tasmanian salmon farming industry have included: development of “fortress” pens to minimise seal interactions; advanced vaccines to improve fish health and minimise use of veterinary medicines; in camera, sensor and feeding systems to allow remote monitoring to optimise productivity from centralised control rooms located in Hobart and novel ROV net cleaning systems that have been adopted worldwide.
- Over many years Australian abalone farmers have continued to trail different tank designs and over recent years have settled upon a unique “slab” tank system that combines low water depth and high flow to maintain water quality and husbandry operations.

- Prawn farming research has led to commercialisation and global adoption of the novel microbial biomass feed ingredient Novacq™ (<https://www.ridley.com.au/investors/novacq/>) that improves health and growth of prawns globally while advances in disease identification, genetics and data analysis has been commercialised (<https://www.genics.com.au>) and is now being used by most Australian prawn farmers and others in 30 countries.

These examples demonstrate the important role of innovation in securing long term productivity growth and prosperity of Australian aquaculture.

Innovation is complementary to, but separate from, production aquaculture. Essentially innovation is about doing things faster, cheaper and better and provides the opportunity for aquaculture to become more profitable, lower impact and lower risk. New technologies are increasingly more affordable and accessible and the cost of new technology and the time taken from breakthrough to mass market is falling rapidly, making new technology more viable and widely used within the aquaculture industry (PWC, 2017). Innovations being developed and implemented allow aquaculture operators to digitise the real world to measure and analyse production systems. These innovations include:

- Sensor technology and 24/7 wireless connectivity to provide continuous monitoring of the environment, and fish behaviour, physiology, health and welfare.
- Artificial intelligence (i.e., machine learning, computer vision and predictive analytics) for data driven decision-making to optimise production, and increase transparency and traceability for industry, regulators and the community.
- Underwater communication, vehicle positioning and camera systems for 3D vision
- Mechanisation, automation, robotics, visual recognition, drones and autonomous underwater vehicles (AUVs)

Costs of labour, transport, energy, food safety compliance and environmental management in Australia far exceed those of our international competitors. Due to these high costs, Australia must be competitive using available technology and innovations to achieve efficiencies (e.g., reduce labour demands, input efficiencies, production gains, survival, time to market) to reduce production costs and farm better and smarter. Australian aquaculture companies will increasingly need to adopt technological innovations to become more productive and scale to thrive. To become the largest Australian aquaculture industry, Atlantic Salmon farming companies have adopted many global technological innovations or have adapted others to address local farming conditions. Sectors that are now accelerating growth (i.e., prawn, Barramundi, oyster and abalone farming) are increasingly incorporating innovative aquaculture technologies to achieve production efficiencies and sustainability targets.

Within the global aquaculture industry there is now “line of sight” between developments in automation and applications that will reduce production costs and improve product quality for consumers. These innovations will also change the face of labour intensive processes within the aquaculture industry by removing repetitive tasks, reducing human error and improving safety and well-being of workers. The world has entered the fourth industrial revolution “Industry 4.0” that brings increasing digitalisation for interconnection of products, value chains and business models within the full life cycle of the product value chain. An ‘aquaculture 4.0’ will be based on systems with highly connected processes and controls, such as the internet of things, artificial intelligence, machine learning, cybernetics and the principles of the circular economy. These innovations have the possibility to further improve the efficiencies of management practices, product quality, including making production systems more sustainable within a climate changing environment, achieving a close to zero footprint and consolidating aquaculture as carbon-neutral industry. To

increase engagement with aquaculture innovation that is advancing globally, the Australian R&D sector and industry could:

- Establish collaborative links with overseas companies and research agencies to collaborate, access current knowledge, solve common problems, and allow rapid adoption of technologies needed to grow offshore and onshore aquaculture.
- Place greater focus on extension as part of the RD&E framework for implementing and adopting innovation and new technology on-farm. Build relationships necessary to drive effective technology development, adoption, and support in the sector promote innovation and collaboration within the sector.
- Develop producer networks to share best practice and experiences with the use of technological solutions to industry challenges.

In the exploration of opportunities for industry growth, it is vital to recognise the importance of system-level innovation. Convergent thinking underpinning *Agricultural Innovation – A National Approach to Grow Australia’s Future* (Ernst and Young, 2019) and the Council of Rural RDC’s *Vision 2050* (Anon. 2018) reinforces a need for integrated national systems thinking and leadership, bringing various influences together in a consistent and coherent way. This logic also underpins the draft National Agriculture Innovation Policy Statement and its five underpinning pillars of reform which seek to operate systemically to drive growth across Australia’s agrisystem.

Recent initiatives including establishment of Agricultural Innovation Australia (<https://www.aginnovationaustralia.com.au/>) and the cross-RDC Climate Initiative (<http://www.ruralrdc.com.au/news/rdc-climate-initiative/>) are examples offering ability integrative system-level thinking and planning and leverage the Australian R&D ecosystem to capitalise on new knowledge and expertise in research and innovation.

Recommendation 11

The Australian government apply a system level approach in the development and application of policy and investment settings to encourage aquaculture growth while also integrating needs of other users of the aquatic landscape.

Recommendation 12

Recognising the significant impact of the FRDC’s historical investment to enable aquaculture development, and ongoing need for coordination of RD&E to enable continued sustainable growth, it is recommended that the FRDC be afforded increased authority to drive strategic planning, coordination, and investment in RD&E.

To capitalise upon these substantial challenges and opportunities, the Australian government will need to continue working in partnership with jurisdictions, research agencies and industry, and embrace some aspirational goals to guide sustainable industry growth for the Australian aquaculture industry including those presented in the National Aquaculture Strategy 2017 that extends to until 2027.

Recommendation 13

The Australian government and industry stakeholders continue implementation of the remainder of the National Aquaculture Strategy 2017 by establishing and resourcing a body tasked to drive this strategy to achieve national aquaculture industry development goals. Ideally this body should combine a balance of expertise and knowledge and operate as a meaningful collaboration to actively progress the National Aquaculture Strategy through to 2027 together with addressing key recommendations from this inquiry.

The FRDC thanks the Standing Committee on Agriculture and Water Resources for the opportunity to comment on this issue. The FRDC also thanks our stakeholders who have contributed comments to this submission.

REFERENCES

- Data for FRDC tables and figures is located here <https://frdc.com.au/en/services/seafood-production-and-trade-databases/gross-value-production-report>
- Anon. 2016. National Aquaculture Council submission to the Productivity Commission Inquiry (2016) into the Regulation of Australian Marine Fisheries and Aquaculture Sectors.
https://www.pc.gov.au/data/assets/pdf_file/0010/197137/sub002-fisheries-aquaculture.pdf
- Anon. 2017a. Innovation and Science Australia 2017, Australia 2030: prosperity through innovation, Australian Government, Canberra.
- Anon. 2017b. Joint Select Committee on Northern Australia report: Scaling Up – Inquiry into Opportunities for Expanding Aquaculture in Northern Australia.
- Anon. 2017c. Australian Government, Department of Agriculture and Water Resources (DAWR). 2017. National Aquaculture Strategy 2017, Canberra, (August 2017). CC BY 4.0.
<https://www.agriculture.gov.au/fisheries/aquaculture/national-aquaculture-strategy>
- Anon. 2017d. Australian Government response to the Joint Select Committee on Northern Australia report: Scaling Up – Inquiry into Opportunities for Expanding Aquaculture in Northern Australia.
- Anon. 2018. Rural R&D Corporations. Vision 2050 – New thinking about rural innovation in Australia.
<http://www.ruralrdc.com.au/wp-content/uploads/2018/12/Vision-2050-Paper-December-2018.pdf>
- Cobcroft, J., Bell, R., Fitzgerald, J., Deidrich, A., Jerry, D. 2020. Northern Australia aquaculture situational analysis. CRC for Developing Northern Australia Project A.1.1718119 (May 2020).
- D’Abramo, L.R., Slater, M.J. 2019. Climate change: Response and role of global aquaculture. *J World Aquaculture Society*. 50:710–714. DOI: 10.1111/jwas.12643
- Ernst and Young. 2019. Agricultural Innovation - A National Approach to Grow Australia’s Future.
<https://www.agriculture.gov.au/sites/default/files/sitecollectiondocuments/agriculture-food/innovation/full-report-agricultural-innovation.PDF>
- Food and Agriculture Organisation (FAO). 2018. The State of World Fisheries and Aquaculture, 2018 - Meeting the sustainable development goals, Rome.
- Food and Agriculture Organisation (FAO). 2020. The State of World Fisheries and Aquaculture 2020. Sustainability in action. Rome.
<https://doi.org/10.4060/ca9229en>
- Food Innovation Australia Limited (FIAL). 2019. Protein Market: Size of the prize analysis for Australia. <https://workdrive.zohopublic.com.au/external/4xHhCwTPeA-7DLiON>
- Global Aquaculture Alliance (GAA). 2019.
<https://www.aquaculturealliance.org/advocate/transparency-technology-puts-aquaculture-on-the-front-foot/>
- Hicks, C., Cohen, P., Graham, N., Nash, K., Allison, E., D’Lima, C., Mills, D., Roscher, M., Thilsted, S., Thorne-Lyman, A., MacNeil, A. 2019. Harnessing global fisheries to tackle micronutrient deficiencies. *Nature*, 574: 95–98. <https://www.nature.com/articles/s41586-019-1592-6#Abs1>
- Irving, S., Coman, G., Musson, D., Doshi, A., Stokes, C. 2018. Aquaculture viability. A technical report to the Australian Government from the CSIRO Northern Australia Water Resource Assessment, part of the National Water Infrastructure Development Fund: Water Resources Assessments. CSIRO, Australia. 126p.
- Kelly, J. 2020. Seaweed Industry Blueprint – A Blueprint for Growth. Agrifutures Australia Publication No. 20-072 Project No. PRJ-012324

- Mobsby, D., Steven, A.H., Curtotti, R., Dylewski, M. 2021. Australian fisheries and aquaculture. Outlook to 2025–26. Research by the Australian Bureau of Agricultural and Resource Economics and Sciences, Annual Fisheries Outlook. March 2021
- M^cNeven, A. 2020. The path to sustainability for the increasingly important aquaculture based source of global food production. In: Boyd, C. E., D'Abramo, L.R., Glencross, B.D., Huyben, D.C., Juarez, L.M., Lockwood, G.S., McNeven, A.A, Tacon, A.G.J., Teletchea, F., Tomasso, J.R., Tucker, C.S., Valenti, W.C. 2020. Review article. Achieving sustainable aquaculture: Historical and current perspectives and future needs and challenges. *Journal of the World Aquaculture Society*, 51 (3), pp. 578-633. <https://doi.org/10.1111/jwas.12714>
- O'Shea, T., Jones, R., Markham, A., Norell, E., Scott, J., Theuerkauf, S., Waters, T. 2019. Towards a Blue Revolution: Catalysing private investment in sustainable aquaculture production systems. The Nature Conservancy and Encourage Capital, Arlington, Virginia, USA.
- Price Waterhouse Cooper (PWC). 2017. Seafood Barometer 2017, Sustainable growth towards 2050. pp100. <https://www.pwc.no/no/publikasjoner/pwc-seafood-barometer-2017.pdf>
- Price Waterhouse Cooper (PWC). 2021. Seafood Barometer 2021, Sustainable growth towards 2050 pp54. <https://www.pwc.no/no/publikasjoner/pwc-seafood-barometer-2017.pdf>
- Teletchea, F. 2020. The role of domestication to help enhance sustainable fish aquaculture production. In: Boyd, C. E., D'Abramo, L.R., Glencross, B.D., Huyben, D.C., Juarez, L.M., Lockwood, G.S., McNeven, A.A, Tacon, A.G.J., Teletchea, F., Tomasso, J.R., Tucker, C.S., Valenti, W.C. 2020. Review article. Achieving sustainable aquaculture: Historical and current perspectives and future needs and challenges. *Journal of the World Aquaculture Society*, 51 (3), pp. 578-633. <https://doi.org/10.1111/jwas.12714>
- Schofield, R. 2021. Ross Lobbegeiger report to farmers - Aquaculture production summary for Queensland 2019-20. Fisheries Queensland, Department of Agriculture and Fisheries.
- Stentiford, G. 2017. Solving the \$6 billion per year global aquaculture disease problem. <https://marinescience.blog.gov.uk/2017/02/02/solving-the-6-billion-per-year-global-aquaculture-disease-problem/>
- Steven, A.H., Mobsby, D., Curtotti, R. 2020. Australian fisheries and aquaculture statistics 2018, Fisheries Research and Development Corporation project 2019-093, ABARES, Canberra, April. CC BY 4.0. <https://doi.org/10.25814/5de0959d55bab>.
- Tlusty, M., Tyedmers, P., Ziegler, F., Jonell, M., Henriksson, P.J.G., Newton, R., Little, D., Fry, J., Love, D., Ling Cao. 2018. Commentary: comparing efficiency in aquatic and terrestrial animal production systems. *Environmental Research Letters*, Volume 13, Number 12.
- United Nations (UN). 2019. United Nations, Department of Economic and Social Affairs, Population Division. *World Population Prospects 2019: Highlights (ST/ESA/SER.A/423)*.
- World Bank. 2013. *Fish to 2030 Prospects for Fisheries and Aquaculture*. World Bank Report Number 83177-GLB.

Appendix 1. FRDC research project reports for Australian aquaculture sectors.

Australian Abalone Growers Association Industry Partnership Agreement

<https://www.frdc.com.au/frdc-stakeholders/industry-partnership-agreements/aaga>

Australian Barramundi Farmers Association Industry Partnership Agreement

<https://www.frdc.com.au/frdc-stakeholders/industry-partnership-agreements/abfa>

Australian Prawn Farmers Association Industry Partnership Agreement

<https://www.frdc.com.au/frdc-stakeholders/industry-partnership-agreements/apfa>

Australian Southern Bluefin Tuna Industry Association Industry Partnership Agreement

<https://www.frdc.com.au/frdc-stakeholders/industry-partnership-agreements/asbtia>

Oysters Australia Industry Partnership Agreement

<https://www.frdc.com.au/frdc-stakeholders/industry-partnership-agreements/oysters-australia>

Tasmanian Salmon Growers Association Industry Partnership Agreement

<https://www.frdc.com.au/frdc-stakeholders/industry-partnership-agreements/tsga>

Appendix 2. FRDC submissions related to the Australian aquaculture industry.

Independent review of the agvet chemicals regulatory system. 2021. FRDC Submission.

<https://haveyoursay.awe.gov.au/agvet-chemicals-regulatory-reform/widgets/330976/documents>

Fin Fish Farming in Tasmania Inquiry. 2020. FRDC Submission.

<https://www.parliament.tas.gov.au/ctee/council/Submissions/FIN%20FISH/Submissions%201%20-%20125/96%20Fisheries%20Research%20and%20Development%20Corporation.pdf>

Inquiry into growing Australian agriculture to \$100 billion by 2030. Submission 11 - FRDC. 2019.

https://www.aph.gov.au/Parliamentary_Business/Committees/House/Standing_Committee_on_Agriculture_and_Water_Resources/Agriculturegrowth/Submissions

Productivity Commission Inquiry into the regulation of Australian Marine Fisheries and Aquaculture Sectors. FRDC Indigenous Reference Group Submission. 2016.

https://www.pc.gov.au/_data/assets/pdf_file/0003/199056/sub057-fisheries-aquaculture.pdf

Inquiry into the regulation of fin-fish aquaculture industry in Tasmania. Submission 8 – FRDC. 2015.

https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Environment_and_Communications/Fin-Fish/Submissions

House of representatives inquiry into fisheries and aquaculture science. 2012. Submission 19 – FRDC.

https://www.aph.gov.au/parliamentary_business/committees/house_of_representatives_committees?url=arff/fisheries/subs.htm

Submission to the country of origin food labelling enquiry - May 2014

<https://fish.gov.au/-/media/fish-frdc/corporate-documents/submissions/cool-submission-from-frdc-april-2014.ashx>