Australian Government

Fisheries Research and Development Corporation

# FRDC Submission to House Standing Committee on Agriculture Inquiry:

## Strengthening and Safeguarding Food Security in Australia

Submitted to the Committee Secretary
House of Representatives Standing Committee on Agriculture
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# Glossary

| | |
|---|---|
| ABARES | Australian Bureau of Agricultural and Resource Economics and Sciences |
| BOM | Australian Bureau of Meteorology |
| CE | Circular economy |
| CRC | Cooperative research centre |
| CSIRO | Australian research agency |
| EEZ | Exclusive economic zone |
| F&A | Fisheries and Aquaculture sectors |
| FAO | Food and Agriculture Organisation of the United Nations |
| FIFO | Fly in, fly out |
| FRDC | Fisheries Research and Development Corporation |
| FTE | Full time equivalent |
| GDP | Gross domestic product |
| GHG | Greenhouse gases |
| GVP | Gross value of production |
| IPCC | Intergovernmental Panel on Climate Change |
| MMT | Million metric tonnes |
| NALAC | National Agricultural Workforce Strategy |
| RD&E | Research, Development, And Extension |
| RTO | Registered training organisation |
| SST | Sea surface temperature |
| TPA | Tonnes per annum |

## Executive Summary

The Fisheries Research and Development Corporation (FRDC) appreciates the opportunity to provide a submission in response to this Inquiry.

Strengthening and safeguarding food security is complex – particularly in the common property resource context within the marine environment. Consequently, this submission is necessarily complex, to ensure that unique aquatic environment considerations are adequately addressed within the Terms of Reference.

Key points:

- Seafood is a nutritious core food, providing quality protein, omega-3 long-chain fatty acids, selenium, zinc, vitamins, and iodine. Seafood consumption can reduce risk of cardiovascular disease, support healthier ageing and longevity, better pregnancy and birth outcomes, reduced risk of depression, type 2 diabetes, and some cancers.
- Commercial seafood production and supply (including imports) dominates (91%) seafood consumption. Recreational and Indigenous customary harvests contribute significant volumes to private consumption subject to species and local community preferences. Quantifying recreational and Indigenous harvest is difficult and costly using current means (e.g. fisher surveys). However, such information is vital to understand overall utilisation of fish stocks, and contribution to food security.
- Australia's fishers operate in a vast marine economic zone, and its fishers and aquafarmers have access to extensive near shore, offshore or terrestrial areas. But there are many competing users for the fishery and site access rights, including marine parks, mining businesses, oil and gas businesses, renewable energy farms, and coastal communities.
- Trade-offs need to be made to ensure food and nutrition security is improved, while optimising local seafood sources and human capital, de-risking biosecurity, and minimising impacts on ecosystems.
- Increased food security for the wild catch sector will flow from allocating strong, secure rights to fisheries resources. For the aquaculture sector it will flow from allowing development to occur with an acceptable impact (where risk appetite does not preclude development).
- Australian food security for seafood closely correlates to natural resource access on which the industry depends. The opportunity to address environmental threats provides a win-win: healthier ecosystems result in healthier fisheries, and improve wellbeing of human communities through increased seafood production and other associated benefits.
- To Aboriginal and Torres Strait Islander fishers for whom fishing is a vital customary activity, food security equates with continuing the recent improvements in their rights to access to traditional fishing areas. A similar equation exists for recreational fishers.
- It is important to note that as lower-value fisheries resources are utilised more optimally in a commercial context, one un-intended consequence can be reduced access to those low-cost species by more vulnerable demographics in other sectors.
- In seeking to optimise food security outcomes, there is opportunity to incorporate the knowledge of Traditional Owners. This knowledge gap has been recognised as an issue affecting not only Australian but also global food security

- Costs of labour, transport, energy, food safety compliance and environmental management in Australia far exceed those of our international competitors. Australia must be competitive using available tangible and intangible inputs and technologies to achieve efficiencies and acceptable economic returns.
- Human capacity is the key input to the future success and food security of Australia's seafood community. The main food security risk relates to accessibility of wildcatch crews. Australia's immigration and industrial relations laws will determine the availability of substitute crews in Australia and therefore the level of security related to seafood.
- Continued access to key inputs such as labour, power, access to financial capital, capital assets and maintenance, healthy supporting ecosystems, feed and breeding capability/access to spat and fingerlings will be critical to ensuring seafood security.
- Accelerating data inter-operability in an agriculture, fisheries and forestry context will be critical to support improved traceability; QA compliance; and ensure that Australia has a digitally enabled production and processing sector and a strong agrifood tech sector.
- Biosecurity presents a significant ongoing threat from a food security perspective.
- Climate change affects fishing and aquaculture through three main physical attributes - temperature, water chemistry, and currents, and interactions between these attributes.
- Seafood security is directly impacted as fishers face the largest near term and most direct impact of climate change. Over the long term, changes in ecosystem services will also indirectly impact the marine resource and therefore seafood security.
- There is currently no mechanism to account for shellfish or seaweed/algal biomass as carbon sinks, but it is expected that the Carbon Credits (Carbon Farming Initiative— Tidal Restoration of Blue Carbon Ecosystems) Methodology Determination will be the first of an expanding range of potential blue carbon methodologies to enable carbon from seaweeds and marine plants to be captured and accounted as Australian Carbon Credit Units.
- Increased circularity will help safeguard food security, addressing waste challenges through the creation of new value chains. This provides co-benefits of resource efficiency, creation of added value and new employment, and contributions to and regeneration of healthy aquatic and terrestrial ecosystems.
- While there are many examples within the Australian seafood industry of voluntary measures to reduce plastic use, baseline data is needed to determine where to focus reduction efforts, to establish targets, to track improvements, and to support benchmarking within the Australian industry and beyond, including international.
- SafeFish identify several knowledge gaps that exist in relation to micro- and nanoplastics and potential impact on human health. Further research is required to understand their impact and effects more thoroughly.

In response to this inquiry the FRDC provide the following recommendations:

- Australia needs to address current and potential future gaps in food security and improve production as part of reducing reliance on imports.
- Importantly, many changes needed for long-term food security (summarised in this submission) require multidisciplinary research planning and implementation, so Australia needs to implement key strategies to prepare for critical and emerging issues.

- There is a need for increased support and investment into the Australian Agrifood Data Exchange, which will play a key role in showing trade partners that Australia is committed to data-enabled produce traceability; QA compliance; and that Australia has a digitally enabled production and processing sector and a strong agrifood tech sector. This will strengthen existing and create new national/international partnerships to benefit government, researchers, producers, processors, retailers, and freight.
- National goals are identified to focus research, development, and extension activities, consistent with recommendations within the National Marine Science Plan:
    1. Manage Australia's fisheries and aquaculture sectors in a risk-based manner that will ensure that they are publicly acknowledged as ecologically sustainable
    2. Improve secure access to, and equitable allocation of, fisheries and aquaculture resources within an increasingly crowded marine landscape
    3. Maximise benefits and value from fisheries resources (productivity, profitability, health and wellbeing) and increase aquaculture production
    4. Streamline governance and regulatory systems
    5. Maintain and improve the health of habitats and environments on which fisheries and aquaculture rely
    6. Improve management of aquatic animal health and biosecurity.

## Introduction

*What is Food Security?*

Food security refers to the availability of food, and whether people have the resources and opportunity to gain reliable access to it[i]. Australia has agreed as a nation to Sustainable Development Goal (SDG) 2: 'End hunger, achieve food security and improved nutrition and promote sustainable agriculture'. Australia's report in SDG 2: [Zero hunger | Sustainable Development Goals (sdgdata.gov.au)](). Other Sustainable Development Goals of relevance to food security include SDG1 (No Poverty), SDG 12 (Responsible Consumption and Production), and 14 (Life Below Water).

In 2010, an expert review (PMSEIC, 2010) recommended greater priority be given to food security, and related value chain capacity, human engagement, and innovation. A National Food Plan then set a goal to improve food security, especially for disadvantaged Australians (DAFF, 2013).

Australia ranks highly among food secure nations, alongside Canada, Germany, and France (ABARES, 2020). In parts of Australia, ~20% of people experience food insecurity (Indigenous, unemployed, single-parents, rental households, low-income earners, young people and remote communities). Others are susceptible including the frail, those lacking transport, substance abusers, and some culturally diverse groups. The bulk of food consumed in Australia is grown and produced here – around 10% is imported.

Recent research (CSIRO, 2022) identifies an additional $35 billion opportunity for Australia by 2030 - to combine our export capability, high food security, and novel technologies to boost food supply in a world of 9.7 billion consumers in 2050. Seafood is forecast to contribute $1.5 billion to added national productivity.

*Seafood snapshot*

Seafood[ii] comes from the Fisheries and Aquaculture (F&A) sectors – and is unlike all other food supply systems. Seafood is hundreds of perishable aquatic animal and plant species from diverse production sources, processed into multiple formats, then consumed as human food. It also creates many inedible industrial by-products – health supplements, cosmetics, animal feed, fertilisers etc.

From hunting (~400 wild species) and farming (~40 aquaculture species) sources, seafood comprises finfish, molluscs, crustaceans, and plants from local and overseas producers. Seafood, both for food availability and nutritional security, provides three billion people with nearly 20% of their animal protein [iii]. As the global population rises, seafood consumption has doubled in the last 50 years and is likely to double again by 2050. Rising demand drives up pressure on marine resources and, if not well managed, threatens the health of aquatic ecosystems. Many global wildcatch supply chains are not well managed - around one third of global seafood today is lost or wasted[iv].

Capture fisheries (i.e., wild catch) are critical to seafood volume and diversity. Since 1980, global farmed seafood has grown (7.5% p.a.) to dominant supply and demonstrate its crucial role in food security.

Middle-class consumerism drives seafood demand growth. Consumers choose seafood in their diet because it is diverse, delicious, nutritious, and healthy (e.g., diabetes, cancer, cognitive function).

Australia faces a choice regarding its seafood supply. Trade-offs need to be made to ensure food and nutrition security is improved, while optimising local seafood sources and human capital, de-risking biosecurity, and minimising impacts on ecosystems.

- As a global producer, Australia is a top five nation for fishery sustainability and supply chain integrity. Our local and overseas customers enjoy safe, attractive, diverse seafood at competitive prices in retail or food service outlets. Imports contribute 72% of our seafood meals.
- Around 50% of our local sustainable capture fishery resources are unharvested, and undervalued (FRDC projects 2016-224, 2016-056). More recent research (Smith, et al., 2021) indicated that potential production could be more than double the current national catch (an increase over current catches of about 124%), but potential increases vary considerably among species/fisheries as well as within Federal, State and Territory jurisdictions. And while the best global technologies and skilled fishing crews are available off the shelf, many fishers are subscale, lacking long term human and financial capital.

In seeking to optimise food security outcomes, there is also an opportunity to incorporate the knowledge of traditional owners. This knowledge gap has been recognised as an issue affecting not only Australian but also global food security discussions (Viyayan, et al., (3) 213 2022 )

The Fisheries Research and Development Corporation (FRDC) welcomes the opportunity to contribute to the inquiry relating to the adequacy of Australia's food security measures and response preparedness.

## A. National production, consumption, and export of seafood

### 1. Seafood Supply and Trends

*Production from all sources[v]*

Australians consume aquatic animals and plants from three sources:

1. **Wild catch fisheries** - accessed by commercial, recreational, and Indigenous customary fishers in commonwealth, state, or territory fisheries,
2. **Aquaculture production** – accessed under license predominantly by commercial operators on state or territory hatchery, farming, or ranching sites (land based, estuarine, near shore marine, or offshore marine),
3. **Imported seafood** – landed as seafood and related products in multiple formats including fresh, chilled, frozen, cooked, canned, dried or salted, smoked, prepared or preserved, or fats or oils.

Food from aquatic sources is broadly referred to as 'seafood' but the term 'Seafood' applies to those products that are produced and/or processed for commercial sale only. It is illegal in all Australian jurisdictions to commercially sell aquatic plants and animals drawn from recreational activities, and under restricted conditions in some jurisdictions when harvested for customary purposes. This submission is focussed on Seafood for commercial sale.

Commercial seafood production and supply (including imports) dominates (91%) seafood consumption. Recreational and Indigenous customary harvests contribute significant volumes to private consumption subject to species and local community preferences. Quantifying recreational and Indigenous harvest is difficult and costly using current means (e.g. fisher surveys). However such information is vital to understand sustainability of fish stocks in populations targeted by all sectors (e.g. barramundi) and therefore may have a large (but unpredictable) impact on food security.

Figure 1. Supply seafood to Australians 2020

| Australian Consumption of Aquatic Animals and Plants 2020 | | F&A Industry Production by Sector | | | |
|---|---|---|---|---|---|
| | | Commercial Seafood (Retail + food service) | Recreational (Private consumption) | Customary (Indigenous consumption) | Total |
| Source of Supply | Wild catch (Harvest tns) | 179,261 | 30,000[vi] | 2,000[vii] | 211,261 |
| | Aquaculture (Harvest tns) | 106,139 | negligible | negligible | 106,139 |
| | **Total domestic production** (Harvest tns) | **285,400** | **30,000** | **2,000** | **317,400** |
| | Less: Exports (Seafood tns) | 42,363 | n/a | n/a | 42,000 |
| | Plus: Imports (Seafood tns) | 207,127 | n/a | n/a | 207,000 |
| | **Total domestic supply** (Seafood tns) | **334,615** | 30,000 | 2,000 | **366,615** |
| | Estimated domestic consumption Kg/person (Seafood + Harvest kg) | 12.4 | n/a | n/a | 13.6 |

Source: ABARES, FRDC, Ridge Partners n/a=not applicable Note that harvest tonnes is wet weight, whereas seafood tonnes is product weight. They are not additive.

Trade is crucial to global food security. Australia differs from most other developed countries in that a significant proportion of local premium product (e.g., rock lobster, premium tuna species, and abalone) is exported while imports largely consist of lower value products (e.g., canned fish, frozen fillets). In general terms, imports fill the gap when domestic consumption exceeds domestic production. It is not just the volume of trade that is crucial to seafood security; it is also the integrity of domestic seafood production and supply, a key market touch point valued by both local and overseas consumers. Internationally Seafood provides 17% of animal protein production and 7% of all proteins in 2019 (FAO, 2022, p.86). Importantly for developing countries, they dominate the international trade in seafood, that supports their goal of poverty alleviation.

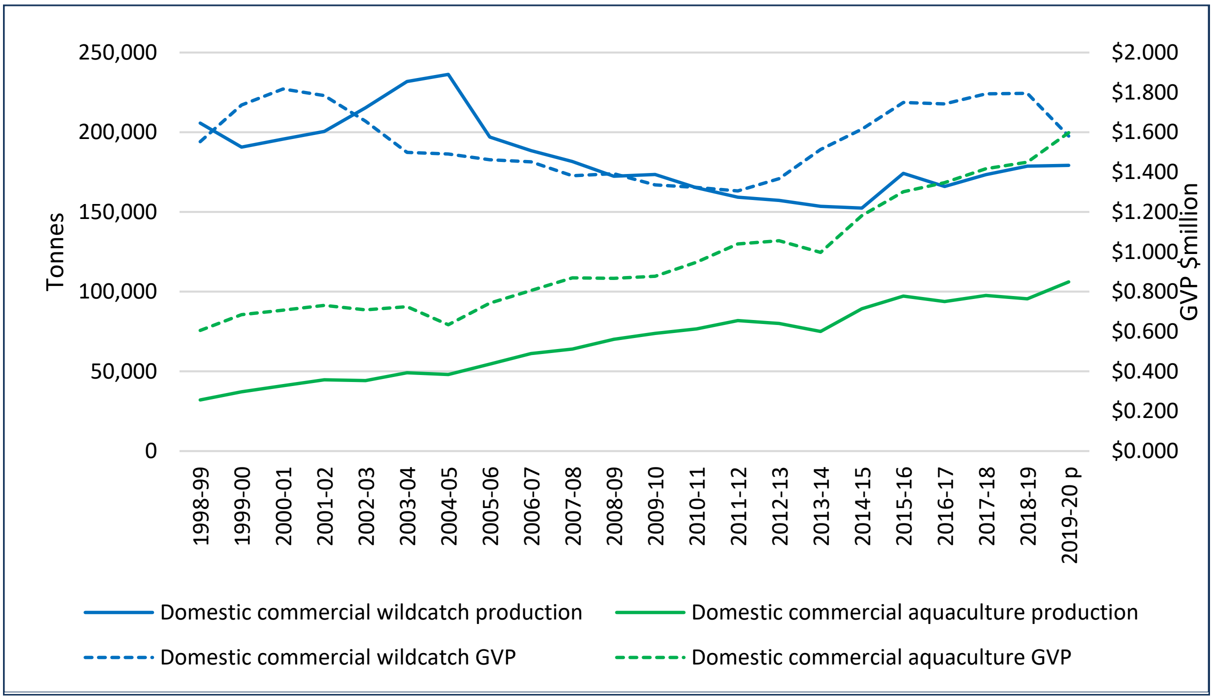
Since 2000, Australian seafood production has increased from 228,000 tonnes to 285,000, a gain of 25%. Over that period wildcatch seafood has been relatively stable and aquaculture seafood has increased 185% to 106,000 tonnes (Figure 2).

Wildcatch fisheries contribute a far greater diversity of seafood to Australian and overseas consumers than the aquaculture sector, and often at affordable prices. This is evident where high volume wild catch fisheries use low cost catching methods like trawling and purse seine to deliver sustainable fresh volumes of affordable seafood to Australia's large urban seafood markets in Sydney and Melbourne.

Two drivers greatly influence Australian harvest volumes and trade flows: the growth in aquaculture production, and the US$/$A exchange rate, discussed in Figures 2 and 3.

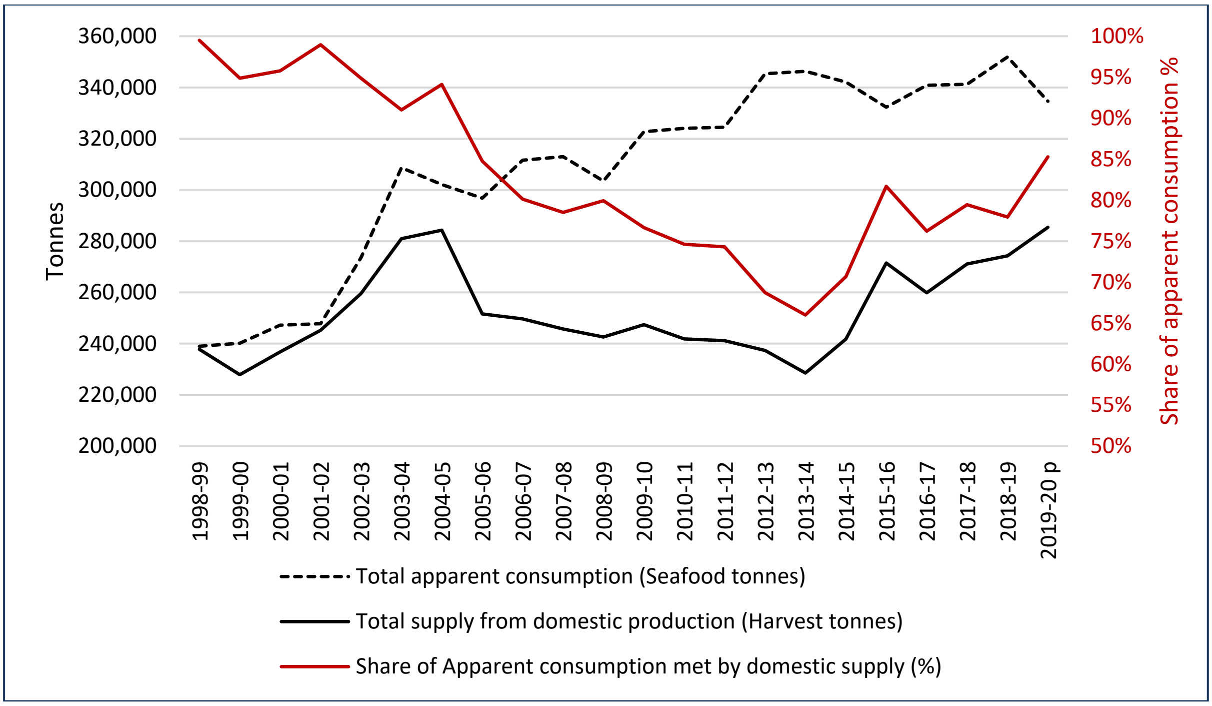
The growth in local aquaculture has boosted both production volume and value (nominal), and therefore improved domestic food security. Figure 2 confirms that farmed seafood GVP has recently surpassed wildcatch GVP. The proportion of the value of Australian seafood production attributed to aquaculture 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 2. Domestic Aquaculture and Wildcatch Seafood Production Trends 1999-2019 (ABARES)




Both Figure 2 and Figure 3 confirm the impact of a key exchange rate breakpoint in 2013-2014 - the $A fell from US$1.09 to below US$0.80, and now sits at ~US$0.67. As a result, domestic wildcatch and aquaculture producers become increasingly competitive against imports in domestic markets, and far more price competitive in overseas export markets.

Figure 3. Domestic Commercial Seafood Supply and Consumption Trends 1999 – 2019 (ABARES)

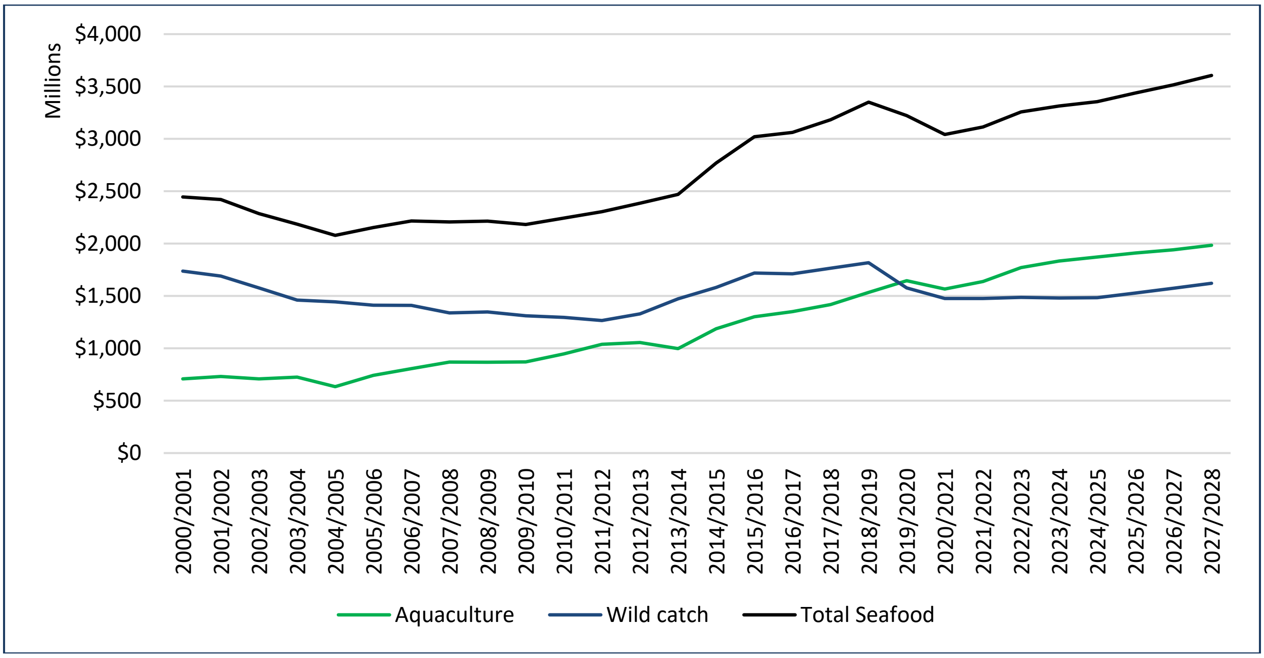


A recent pre-Covid-19 study (Agrifutures ACIL, 2019) highlighted the rising seafood demand from Asian incomes and populations for Australia's clean, safe, and trusted seafood products. The pandemic had a large, if temporary, impact in some seafood trade flows – for example Australia's imported prawn volumes fell 23% (SIA Export Plan p93).

A review of Covid-19 impacts to fishing and aquaculture (FRDC 2016-128) on the Australian seafood industry found impacts have been asymmetric. Economically significant sectors that relied on one or two export markets have been badly affected, while other sectors supplying domestic markets have generally prospered. Businesses, irrespective of sector, that have been both willing and able to be innovative and agile have also benefited. The businesses most negatively impacted were live export and dine-in food service, due to their reliance either on international air freight or on people moving about in their communities

The latest GVP forecast https://www.frdc.com.au/seafood-production-and-trade-databases suggests aquaculture will continue to expand to 2027 while wildcatch remains stable (see Figure 4). In real terms (i.e., adjusted for inflation, 2022 A$) the key growth aquaculture species over the forecast period are Salmonids (up 154%), Prawns (up 134%), and Abalone (up 95%) all of which have strong and or emerging export market opportunities.

Figure 4. Australian Seafood GVP Actual and Forecast to 2027




Peak body Seafood Industry Australia (SIA, 2022) notes that by 2030, global seafood consumption will increase by 20%. The proven health benefits and sustainability credentials of seafood, rising consumption in Asia, growing aquaculture sector, and an increase in frozen formats are driving factors for this expected increase. Asia will account for 70% of the projected growth in seafood to 2030.

The F&A community's *[Fish Forever - A shared 2030 vision for Australia's fishing and aquaculture community]* highlights the crucial contribution to food security and human well-being, that fishing and aquaculture can and will make to grow and prosper as part of an increasingly vital Blue Economy.

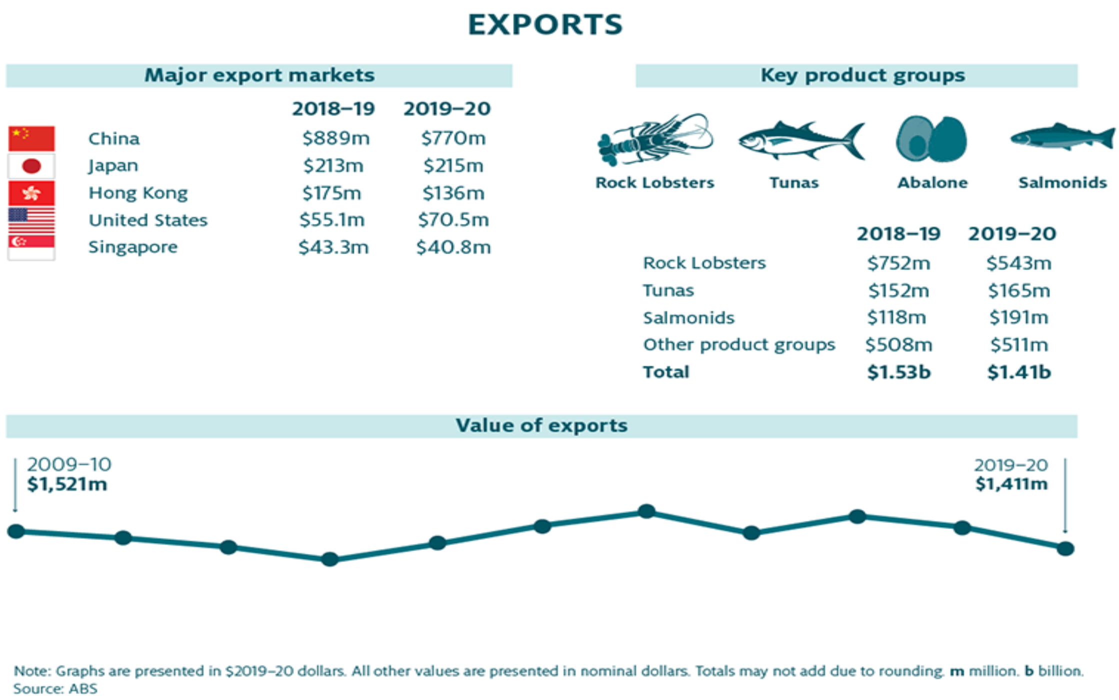
*Seafood Exports*

Much of Australia's seafood exports target the food services sector in Asia, mainly by air freight. As Covid-induced disruptions recede, ABARES forecasts near-term growth in seafood export values, which will return to a 0.4% p.a. growth trend. Over the medium term, transport logistic pressures will ease, as international travel and tourism increases.

Figure 5 shows (note the graph is in real 2019-20 dollars) the early impact of the Covid-19 export contraction, which ultimately reduced Australian seafood exports by 14%. Major falls occurred for wildcatch species Rock lobster and Abalone, while farmed Salmon exports achieved a significant gain in that year.

Some key seafood sectors that are heavily reliant on export trade to China (e.g., Rock lobster, Abalone) have faced severe trade restrictions over the last five years. They have variously moved to diversify their markets with some success. The shift towards online consumer sales, both domestically and internationally, observed during the pandemic is expected to continue over the outlook period. Recent meetings between Australian and Chinese leaders may see trade tensions resolved and export volume expand again.

Figure 5. Australia's Seafood Export Markets 2018-19 to 2019-20




The national Ag2030 Plan aims to create a $100 billion agriculture and fisheries industry by 2030. The whole-of-industry 2030 Seafood Industry Export Strategy aims to increase seafood exports by $747 million to $2 billion by 2030.

## 2. Seafood Risk and Food Security

Australian food security in relation to seafood is closely correlated to access to the natural resources on which the industry depends. Wildcatch seafood production in Australia is challenging due to the relatively low productivity of marine resources and fisheries in our EEZ. Therefore, the nature of access to food-producing areas for seafood production and other purposes is crucial. Whereas increased food security for the wildcatch sector will flow from allocating strong, secure rights to fisheries resources, for the aquaculture sector it will flow from allowing development to occur with an acceptable level of impact that is not set at such a low level of risk that development is precluded.

Security of supply ensues from recognition that fishing, and aquaculture play a preeminent part in providing food to the 96%[viii] of Australians who prefer to purchase seafood. To Aboriginal and Torres Strait Islander fishers for whom fishing is a vital customary activity, food security equates with continuing the recent improvements in their rights to access to traditional fishing areas. A similar equation exists for recreational fishers. It is important to note the tensions that exist between competing users of fisheries resources from a food security context. That is, as lower-value fisheries resources are utilised more optimally in a commercial context, one un-intended consequence can be reduced access to those low-cost species by more vulnerable demographics in other sectors.

Food security also flows from consumers' diet (i.e., utilisation), not only what is available and accessible. Family members, medical experts, and media influence food choice. Many Australians make poor choices that result in increased obesity, type 2 diabetes and cardiovascular diseases. It is also important to note that poor diet isn't always a product of choice; particularly so for people in lower socio-economic circumstances, for which protective foods are more costly and out of reach.

The physical flows of seafood along supply chains described above, creates seafood insecurity risks for consumers. But a complete perspective of food security must include the diverse controllable and uncontrollable risks that impact (direct and indirect) all aspects of the Australian Seafood Industry. This risk assessment has most recently been reviewed (at four levels) by SafeFish (SafeFish, 2022 May), as presented in Figure 6. Recent research led by AgriFutures also discusses factors disrupting logistics across agriculture, fisheries and forestry during the COVID pandemic, and recommendations to improve resilience.

Figure 6. Seafood Industry Risk Register (SafeFish 2022)

**Critical Risks**

1. Increased presence, virulence & challenging risk management of VIBRIO
2. Inadequate adaptation to CLIMATE CHANGE IMPACTS
3. Arbitrary trade sanctions, delisting and loss of products, GEOPOLITICAL UNCERTAINTY
4. Increased harmful algae blooms, low awareness of BIOTOXINS, CIGUATERA
5. Industry not adopting TRACEABILITY & AUTHENTICITY technology, increased FOOD FRAUD

**High Risks**

6. FAILURE TO ADAPT / GAPS IN REGULATORY FRAMEWORK for changing food safety threats
7. Increased illnesses by growing READY-TO-EAT product & delivery of seafood: LISTERIA & SALMONELLA
8. LABOUR shortages, LIMITED TECHNICAL CAPABILITIES & CAPACITY, limited SUCCESSION
9. LOSS OF TRUST IN INDUSTRY / SOCIAL LICENSE TO OPERATE: Loss of community support, NGO pressure

10. OVER RELIANCE ON HIGH VALUE MARKETS: China, high end food service
11. Inadequate labelling and awareness of SEAFOOD ALERGENS
12. Growing BIOSECURITY threats and barriers
13. Enhanced concerns re HEAVY METALS in seafood
14. Inadequate management of COLD CHAINS with growing delivery & supply chain disruptions
15. Banning of existing practices due to ANIMAL WELFARE (trawling, live product, feeding or killing methods)

**Medium Risks**

16. LOSS OF REPUTATION / PROFITS due to poor quality imports and price disparities
17. Increased illness with PARASITES IN FISH due to raw consumption
18. Low levels of PREPAREDNESS FOR INCIDENT RESPONSE in industry
19. AG-VET CHEMICAL REASSESSMENTS by export markets impacting trade
20. Increased presence of HUMAN DERIVED POLLUTANTS IN FISH: plastics, chemicals, pharmaceuticals
21. AUSTRALIAN BRAND IMPACTED by incidents, regulations, fraud, grey channels
22. OVERUSE OF CHEMICALS & ANTIBIOTICS due to increase demand
23. REDUCED GOVERNMENT SUPPORT / SPEND: resources focused on other priorities e.g., Covid 19
24. REDUCED SEAFOOD CONSUMPTION due to inflation
25. INCREASED FISHING PIRACY due to global economic pressures

**Low Risks**

26. LOSS OF SENSITIVE DATA / DISRUPTIONS due to inadequate cybersecurity
27. CATASTROPHIC EVENTS in fishing area leading to large scale contamination or depletion of resources
28. Lack of preparedness in industry for IMPACT OF NEW TECHNOLOGIES: cell cultures, drones, 3D printing
29. ACCESS TO SUITABLE WATER due to changes in zoning and marine parks, recreation, etc.
30. LACK OF FOOD SAFETY knowledge
31. GEOPOLITICAL IMPACT OF TRADE BLOCKS
32. LOSS OF PREDICTABILITY WITHIN RISK MODELS due to the pace of environmental change

## 3. Drivers and Inhibitors of Australia's seafood security

In global terms, Australia is a small seafood producer and exporter. We benefit from proximity to expanding Asian consumer markets, premium native species, and respected and trusted seafood production systems. Within our control are strong food security drivers and potential productivity gains (e.g., making use of underutilised species). But there are also many food security inhibitors that threaten to impair production and supply capability and diminish seafood security. Sources for this figure include (Agrifutures ACIL, 2019) and (NMSC, 2015)

Figure 7. Seafood Security - Drivers and Inhibitors

| DRIVERS | INHIBITORS |
|---|---|
| • Upside potential for growth and diversification in local sustainable seafood production, both wildcatch and aquaculture<br>• Significant opportunities exist for Indigenous, social, and economic benefit from improved access to marine resources<br>• Ongoing strong and rising human demand for seafood protein especially in export markets<br>• Effective, efficient, and mature fishery and environmental management capacity (in top 4 globally), anchored in industry-agency collaboration<br>• Aquatic products expected to face large real price increases relative to global food sources - and the greatest growth is expected in our region<br>• Increased productivity from Australia's underutilised fisheries and species in both wildcatch and aquaculture<br>• Expanding aquaculture to leverage Australia's comparative advantage in climatic and marine access and biosecurity, and boost economic scale<br>• New technologies that boost both industry and on-farm productivity<br>• Increasing public interest in seafood tourism and engaging producers, especially expanding aquaculture<br>• Regulator clarity on novel foods, including cultured food technologies<br>• New data and technologies in the hands of emerging fishers and farmers | • High reliance (72%) on imports to meet consumer demand, especially processed commodities (frozen fillets, prawns, and canned seafood<br>• Uncontrolled events (regional conflicts, pandemics, etc) that directly impact Australian supply and trade chains and level of food security<br>• Increased public scrutiny of resource management, uncertain fishery / farm site access, and social license<br>• Small fishery scale, but large geographic, ecological and political footprint<br>• Import competition from low-cost overseas producers<br>• Imported infectious disease threat – to healthy aquatic stocks, to natural resources, to international competitiveness, and to market access<br>• Seafood safety and production issues - pathogens, biotoxins, contamination, longer more complex supply chains, and emerging international regulations<br>• Lack of seafood product differentiation across markets<br>• Uncontrolled impact of extreme weather events and climate change<br>• Competition with other Marine Parks and users for access to coastal and aquatic resources<br>• Access to capital for expansion and productivity<br>• Declining habitat condition and extent<br>• Changing community values |

## B. Access to key Inputs – fuel, fertiliser, labour, and impact on production costs

### 1. Seafood's binary production system

Seafood provision occurs via two primary systems - wildcatch fisheries and aquaculture - each with unique input needs, risks, and costs structures. Some inputs are common to both systems (e.g., labour, repairs and maintenance, downstream packaging, cold chain, distribution, and logistics), but most are system specific.

The scale, scope and economic impact of key fishing inputs also varies greatly subject to the species produced, the aquatic environment (e.g., fishing in Australian Antarctic waters for toothfish, compared to trevally fishing in NSW waters for the Sydney Fish Market) and therefore the production/harvest method (trawl, net, line, trap, etc). Farms face similar diversity of method (inshore oyster lines, earthen ponds, tanks, marine cages, raceways), but less species diversity. In turn, the risk to seafood security for each enterprise mirrors this great species and method diversity for inputs to production.

With this diversity in mind, the following discussion summarises the risks and options related to production inputs, and options to strengthen and safeguard seafood security.

Seafood industry operators incur the following capital and operating inputs:

*Fisheries*

- Vessel/s – fishing/process/storage plant and equipment, winches, trade tools, etc
- Mobile plant – vehicles, forklifts, compressors, etc
- Skipper and crew labour
- Fuel, oil and maintenance consumables for vessels (net of diesel fuel rebate)
- Vessel provisions
- Bait
- Fishing equipment, purchase and repairs (nets, pots, lines, etc.)
- Repairs & maintenance capacity - ongoing (slipping, painting, overhaul motor)
- Safety and security
- Insurance
- Industry fees
- Office & business administration (communication, stationery, accountancy fees)
- Leasing
- Packaging and ice

*Aquaculture*

- Farm/hatchery – production/process/storage plant and equipment, trade tools, etc
- Mobile plant – vehicles, forklifts, compressors, etc
- Labour from employees and casuals
- Electricity, gas, and maintenance consumables (net of diesel fuel rebate)
- Fry, fingerlings, spat, wild-caught juvenile tuna, etc

- Animal feed for hatchery and growout
- Aquatic animal health facility and agvet chemicals and equipment
- Repairs & maintenance capacity
- Safety and security
- Insurance
- Industry fees
- Office & business administration (communication, stationery, accountancy fees)
- Leasing
- Packaging and ice.

Costs of labour, transport, energy, food safety compliance and environmental management in Australia far exceed those of our international competitors (see FRDC's submission on Aquaculture, p.22). Australia must be competitive using available tangible and intangible inputs and technologies to achieve efficiencies and acceptable economic returns.

## 2. Key Inputs

For Australia's wildcatch fishers, the key inputs are labour (employees and crew), power (fuel, electricity and gas), capital assets/repairs and maintenance, and are also the largest input costs. In the large Northern Prawn Fishery, these three cost categories account for around 75% of input costs.[ix]. Similar data is not published for the bulk of wildcatch fisheries.

For Australia's aquaculture farmers the key inputs are power, labour, animal feed, capital assets/repairs and maintenance, breeding capability and supply of spat/fingerlings. However, the order of the key risks varies greatly, for example if you are growing oysters or barramundi in the marine water column, compared to prawns or abalone in a tank or raceway.

### a. Human capacity

Human capacity is the key input to the future success and food security of Australia's seafood community. The main food security risk relates to accessibility of wildcatch crews.

*Crews and employees*

Fishery labour comprises small single owner operators on day-trip fishing, through to large corporate vessels with crews of 8-10 people at sea for weeks. Most large vessel operators draw crew members (other than the master and senior crew) from both Australian sources and overseas FIFO crews. The bulk of the wildcatch harvest workforce (other than owners and skippers) is remunerated based on a harvest success rate, detailed in share-of-catch contracts (i.e., crew are contractors, not employees). Crew costs tend to move in line with total seafood receipts because crew are paid a proportion of catch receipts.

Smaller fishers mostly sell their catch to local fishing cooperatives or portside buyer and therefore do not employ onshore labour. Larger fishers typically maintain integrated offshore mothership and onshore supply chains that employ inhouse staff, technical specialists, and processing teams.

In the aquaculture sector, small farms are mostly owner operated with some full or part time employees, during busy harvest periods. Larger farmers retain permanent employees and technical specialists and hire contractors as the value of the 'crop' increase and at harvest and processing time. It is increasingly difficult (especially for wildcatch fishers) to attract competent people willing to work away from home in weather-dependent, potentially dangerous seasonal marine activity for extended periods. Therefore, overseas crews are increasingly critical to wildcatch operators. Aquaculture sites are onshore, less remote, less seasonal, and less exposed to uncontrollable operational risks than wildcatch fishers, so permanent labour is more accessible.

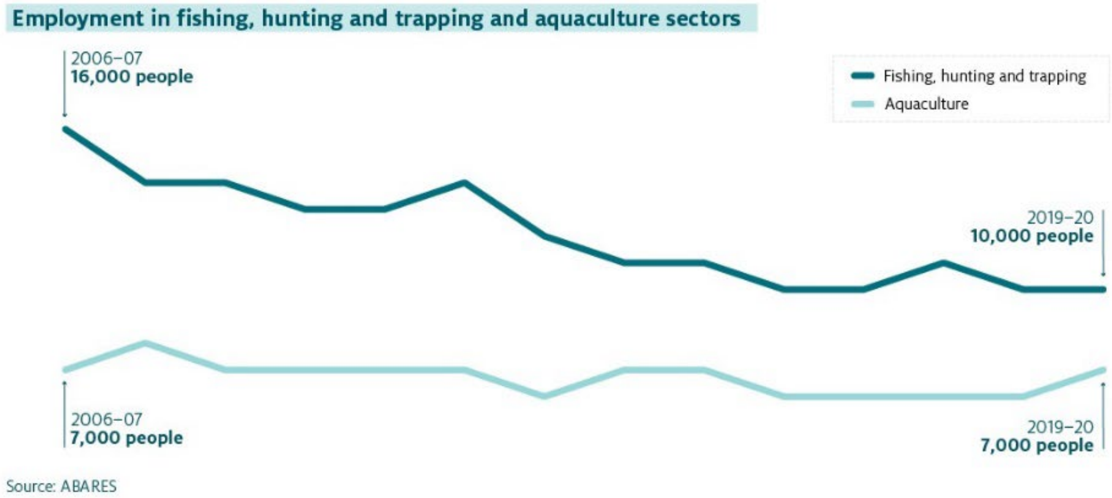
Figure 8 illustrates F&A employment from production to wholesaling at the 2016 Census by jurisdiction.

Figure 8. Employment in commercial fishing and aquaculture sectors - Census 2016 (ABARES)

| Seafood Industry | NSW | Vic. | Qld | SA | WA | Ras. | NT | ACT | Total Aust. |
|---|---|---|---|---|---|---|---|---|---|
| Aquaculture (general) | 84 | 142 | 118 | 156 | 92 | 139 | 8 | 0 | 737 |
| Onshore aquaculture | 106 | 104 | 334 | 152 | 74 | 120 | 17 | 0 | 913 |
| Offshore longline & rack aqua | 453 | 19 | 103 | 220 | 77 | 532 | 3 | 0 | 1,406 |
| Offshore caged aquaculture | 32 | 29 | 11 | 40 | 11 | 794 | 0 | 0 | 912 |
| **Aquaculture** | **675** | **294** | **566** | **568** | **254** | **1585** | **28** | **0** | **3,968** |
| Rock lobster & crab potting | 42 | 66 | 81 | 189 | 544 | 164 | 12 | 0 | 1,106 |
| Prawn fishing | 64 | 0 | 167 | 76 | 61 | 0 | 14 | 0 | 392 |
| Line fishing | 6 | 7 | 12 | 18 | 4 | 3 | 0 | 0 | 58 |
| Fish trawling, sein, & net | 11 | 11 | 28 | 22 | 3 | 0 | 0 | 0 | 80 |
| Fishing, hunting, & trapping | 260 | 196 | 276 | 89 | 99 | 45 | 18 | 7 | 997 |
| Other fishing | 673 | 299 | 710 | 574 | 380 | 316 | 173 | 0 | 3,144 |
| **Wildcatch Fishing** | **1,056** | **579** | **1,274** | **968** | **1,091** | **528** | **217** | **7** | **5,777** |
| **TOTAL F&A** | **1,731** | **873** | **1,840** | **1,536** | **1,345** | **2,113** | **245** | **7** | **9,745** |
| Seafood processing | 202 | 173 | 221 | 321 | 266 | 349 | 5 | 0 | 1,536 |
| Fish and seafood wholesaling | 668 | 625 | 604 | 191 | 258 | 109 | 16 | 7 | 2,477 |
| **Process & wholesaling** | **870** | **798** | **825** | **512** | **524** | **458** | **21** | **7** | **4,013** |
| **GRAND TOTAL Seafood** | **2,606** | **1,667** | **2,668** | **2047** | **1,875** | **2,586** | **282** | **18** | **13,755** |

Figure 9 present the latest seafood production employment trend data from ABARES. These trend data do not include finfish and seafood wholesaling and processing. Comparison between figures 6 and 7 highlights the complexity of estimating employment (including contractors in share-of-catch crews in the seafood industry along its complex value chain).

Figure 9. Employment Trends in Fishing and Aquaculture 2006-2020




Australia's immigration and industrial relations laws will determine the availability of substitute crews in Australia and therefore the level of security related to seafood.

The Australian peak seafood industry body Seafood Industry Australia (SIA) says the industry had a shortage of skilled and available workforce for at least the past decade. Workers are also aging and lacking the flexibility and resilience to respond to current challenges. While foreign labour is essential in the Australian industry, industry leaders need to promote industry's relevance and importance to the Australian community and Australian labour force and promote industry as a career pathway (SIA, 2020). The organisation believes there are four barriers to be overcome:

- Community perception and availability of workers
- Industry safety culture
- Limited retention of skilled and experienced workers
- Accessible and flexible training packages.

A thriving, skilled and effective fishing sector requires a commitment to training, and the availability of career paths. SIA notes the use of technology, and identifying the worker, can feed into better promotion of career paths and job vacancies.

National data from Vocational and Educational Training (VET) enrolments (NALAC, 2020, p. 135) records a decline in pre-pandemic seafood Industry enrolments from 1,420 in 2015 to 1,006 in 2019 in line with falls in other industries (meat processing, food and beverage, forestry, agriculture).

A new digital platform being developed by SIA (under development) will encourage, and empower, online solutions for engagement, learning and inductions, by bringing together information, applications, and safety (NALAC, 2020). The research also highlighted a lack of connection between new workers and a long-term career pathways, and found the seafood industry lacks accessible entry-level certification. A 'blue card' is being considered as an option, which, if delivered through the app, could deliver training packages and content to create a culture of care and professionalism on entry into the sector. A similar 'white card'

card in the building industry has had widespread success. Industry programs aim to attract, support, motivate and retain people in the seafood sector - and thus provide long-term 'on-the-boat' and 'beyond-the-boat' career path opportunities.

*Leadership*

The human capacity section (2a) summarises tangible metrics related to human participation in the seafood supply chain, at today's production scale. However, the 2030 Seafood Industry Export Strategy expects aquaculture to expand rapidly to 2027. There is a risk that growth will be constrained unless industry and agencies invest in human capacity along the supply chain. The SIA identifies leadership and unity in purpose as the key human input in four of its top five priorities, as follows:

- Work with all levels of government and industry to leverage available export expertise and support,
- Effectively identify and respond to trade opportunities,
- Enable access to export market resources, communication, and intelligence, and make them easier to use,
- Build the number and capacity of exporters across the industry.

### b. Energy – fuel, electricity, gas

Energy is a major input to fishing and aquaculture. Fishing vessels are mobile seasonal hunting platforms (very small to very large) that typically travel large marine distances and use large volumes of fuel (electric vessels are only just becoming available for the inshore fleet). Once on site, the type of gear (e.g., trawl, purse seine net, long line) used for target species will then determine the rate of and mix of energy (diesel, gas, electrical) usage. Diesel fuel price and availability is still therefore a major risk to domestic and global wildcatch seafood scarcity. FRDC have a project that is exploring alternative energy sources with the focus being on renewable zero carbon emissions fuels like methanol (https://www.frdc.com.au/project/2021-089 .

Aquaculture enables large volumes of seafood production from relatively small fixed-site locations powered by grid electricity, or renewables. There is minimal use of diesel. The FRDC is investing in the acceleration of renewable energy solutions into aquaculture.

### c. Vessels, equipment, and infrastructure

Fishing and aquaculture enterprises work with highly perishable food inputs. Their return on investment can only be maximised if seafood quantity and quality is captured and retained all the way along the supply chain to the consumer. This requires specialised harvest and cool chain equipment onsite, as well as periodic access to public or specialised proprietary infrastructure (e.g., port facilities, diesel supply, large fresh water holding vessels for salmon gill bathing to overcome pests and diseases).

For larger scale wildcatch and marine aquaculture fishers and farmers, there is limited manufacture of marine vessels in Australia. The fact that few vessels are being imported suggests the average age of the fleet is increasing. Repairs and maintenance costs for vessels are high due to the corrosive marine location, which is exasperated with prolonged exposure.

For terrestrial aquaculture the required plant, equipment and infrastructure is largely manufactured in Australia, with specialised pieces of equipment imported.

### d. Fish feed

The need and volume of bait used in wildcatch fisheries varies by target species, but generally there is limited importation of bait for commercial fisheries, and most of that can be sourced locally if required.

The availability of highly specialised animal feeds is a major driver for the growth of aquaculture – fish meal and soy ingredients are key ingredients in many feeds. Some species feed from the natural water column (e.g., oysters) at minimal direct cost; others such as farmed tuna draw feed supplies from proximate Australian Sardine fisheries in the Great Australian Bight; while many (Salmon, Prawn and Abalone) farms must import the bulk of their specialised fish feed diets from overseas processors. Environmental sustainability may be an issue where feed is applied in the water column (and not in a closed pond or tank).

## 3. Other inputs

### a. Financial Capital

Historically, the Australian fisheries and aquaculture industry had 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.

This is now changing, certainly for aquaculture. In the last month Australia's largest aquaculture business has been acquired by a private Canadian firm (Cooke Seafoods) that is a global leader in aquaculture production and marketing. This is the most recent in several new aquaculture development announcements. Another current initiative is the expansion, driven by local private investors of the prawn farming industry from 5,000 tpa to an estimated 17,000 tpa within a decade.

Investors perceive 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. This aligns with the SIA Seafood Export Strategy 2030. Thirteen aquaculture companies were listed on the stock exchange until the recent sale to Cooke[x]. The sector's ability to demonstrate a clear and derisked pathway from enterprise scale to consumer market has been the trigger for expansion.

Financiers and the investment community now integrate sustainability into their assessments of seafood businesses. This is a fundamental prerequisite, not a trend to be achieved.

### b. Healthy supporting ecosystems

Healthy aquatic habitats provide critical support to the benefits received from recreational, commercial, and Indigenous fisheries, and so are critical to food security. Aquatic habitats can be described in many ways including:

- the natural materials that comprise the habitat (e.g., rocks, coral, gravel, sand, and mud),

- the type of vegetation present (e.g., macrophytes, snags, seaweeds, seagrasses, mangroves, and saltmarsh),
- the shape and nature of the habitat (e.g., pools and riffles, billabongs, reefs), or
- the overall ecosystem (e.g., wetlands, floodplains, streams, estuaries, lakes, beaches).

There is a growing and concerning body of evidence highlighting decline in aquatic ecosystems and habitats that sustain fisheries nationally. The 2021 State of the Environment Report describes a trend of continued loss of mangrove habitats, declines in saltmarsh extent, extensive losses of seagrasses, macroalgae, coral reef bleaching, and loss of shellfish reefs. In the case of shellfish reefs, studies report loss of >90% of Australia's historical extent, making them our most threatened ocean ecosystem.

The opportunity to address environmental threats provides a win-win: healthier ecosystems result in healthier fisheries, and so improve wellbeing of human communities through increased seafood production and other associated benefits.

There are some good examples of government, community and the private sector working together to restore aquatic ecosystems, including shellfish reef restoration projects led by The Nature Conservancy, re-snagging waterways, seagrass and mangrove restoration works led by OzFish Unlimited. However, there is a need for efforts to be dramatically upscaled in order to arrest and reverse current declining trends. This will require the continued building of community capabilities to deliver on-ground restorative projects, establishment of new partnerships, and deployment of increased resourcing. The novel offsetting program OneFishTwoFish is an early example of how to deploy capital in novel ways to increase aquatic productivity. Increasing maturity in carbon and nature-based accounting and markets are likely to further incentivise investment into the restoration of natural aquatic systems.

### c. Access to resources and Social License

Australia's fishers operate in a vast marine economic zone, and its aquafarmers have access to extensive near shore, offshore or terrestrial farming areas. But there are many competing users for the fishery and site access rights, including marine parks, mining businesses, oil and gas businesses, renewable energy farms, and coastal communities.

Governments and fishery managers continue to progressively review and revise wild fishery access rights (harvest strategies, quotas, effort buybacks, etc) and prescribe de-risked fit-for-purpose aquaculture zones.

At the same time social license issues have emerged decisively, reflecting consumer and public perception of the sustainability of fishery and farm production. This is a growing threat to industry existence and expansion. However, in recent years seafood industry leadership (SIA and sectoral organisations) has collectively responded to collate and present the facts, implement seafood production performance standards, and professionally advocate on behalf of fishers and farmers. Community Trust in Australia's Rural Industries national surveys (Voconiq, 2022) suggest industry's professional approach is gaining traction with the public and seafood industry is seen as a respected user of resources.

### d. Supply chain disruption

Unforeseen global conflicts and wars have limited impact on the Australian fisheries and aquaculture industry. Diesel prices may have been impacted indirectly.

Aquatic animal disease is one of the most serious constraints to the expansion and development of sustainable aquaculture. Biosecurity has been challenging the aquaculture sector for the last three decades. The Australian aquaculture industry has experienced recent outbreaks of disease including White Spot Disease in prawns and Abalone Viral Ganglioneuritis disease in Victoria and Tasmania.

Globally, a trend in aquaculture is the emergence of novel, previously unknown diseases that cause major cross border production losses approximately every three to five years. The drivers for such trend include:

- Trade and movement of live animals and related products,
- Increased knowledge of pathogens that often lags aquaculture development,
- Lack of capacity in institutional and technical aquatic animal health management,
- Ecosystem changes arising from dynamic aquatic ecosystems, changing through both direct human activity (dams, community expansion, pollution, shipping, tourism, new species introductions, etc.) and non-human impacts (climate change, hurricanes, algal blooms, etc.).

### e. Data underpins food security

A digitally connected seafood sector is modelled to increase its GVP by 44% [xi]. In Australia, there is currently no trusted agrifood data exchange platform, nor catalogue that lists shareable but private datasets. Current systems are siloed, disparate, inefficient, and difficult to access which limits scalability. Additionally, sector-specific technology adoption and data interoperability persist.

FRDC is partnering in the Australian Agrifood Data Exchange (AAFDX) project with Meat and Livestock Australia (MLA), Department of Agriculture, Fisheries and Forestry (DAFF), Charles Sturt University (CSU), FRDC, Agriculture Victoria, Agrifutures, CSIRO, Food Innovation Australia Limited (FIAL), WA Department of Primary Industries and Regional Development (DPIRD), Department of Primary Industries and Regions South Australia (PIRSA), Food Agility CRC and AWI and with in-kind support by over 30 industry, research and government organisations to build foundational digital infrastructure to improve data availability and flow for regulation and compliance; foster industry transparency and innovation; and align Australia with leading agrifood-exporting nations.

An Australian Agrifood Data Exchange presents a significant number of opportunities as a solution to the challenges outlined in the previous sections, including:

- An opportunity to build foundational digital infrastructure to assist existing technologies and foster innovative future developments;
- An opportunity to increase the capacity for industry transparency and collaboration to optimise interactions between stakeholders in the value chain and create opportunities for collaborative action;
- An opportunity to keep Australia on track with leading agrifood-exporting nations to remain competitive in an increasingly digital global market;

- Enable the agrifood tech industry to access wider sources of data for accelerating innovation and product development and reach more customers through the AAFDX users and data marketplace services; and
- An opportunity to extract more complete value from investment in public data sets and research in agriculture.

The AAFDX will support export demand by showing trade partners that Australia is committed to data-enabled produce traceability; QA compliance; and that Australia has a digitally enabled production and processing sector and a strong agrifood tech sector. This will strengthen existing and create new national/international partnerships to benefit government, researchers, producers, processors, retailers, and freight. Long term benefits include:

- Export economy growth,
- Drought resilience,
- Regulatory compliance,
- Food security productivity improvement,
- Understanding food safety risks,
- Value creation opportunities,
- Reduced regulatory burden enabling market access,
- Ease in international market access,
- Improved transparency,
- Understand efficiency opportunities,
- Decrease operational and economic burden.

AAFDX project created four experiments to establish the use case for the data exchange as a reasonable potential solution to broad challenges across the agrifood sector and, as such, aimed to represent diverse and distinct problems, industries, geographies, and points along the value chain. The final experiments were:

1. Compliance - Addressing the cumulative burden of compliance for producers through to processors operating in the Victorian and NSW sheep sector (meat and wool),
2. Biosecurity - Strengthening biosecurity in the viticulture sector through standardised, accurate traceability data (Victoria and South Australia),
3. Benchmarking - Benchmarking to identify gaps and opportunities for improved performance pre harvest, in Western Australia's grain sector; and
4. Traceability - Timely quota accounting and pre-fishing information exchange for Western Rock Lobsters (Western Australia (WA)).

Australian Agrifood Data Exchange Phase 2: Experiment 4 (Cason, M., Lambardi, T., Australian Agrifood Data Exchange Phase 2: Experiment 4 – Traceability, IBM, Telstra and Meat and Livestock Australia, 2022.)

The delay in exchange and reconciliation of catch data by fishers and processors means that there is a delay in quota accounting that impacts planning due to a lack of timely information. Furthermore, with no access to pre-fishing data, processors are unable to plan logistics for efficient transportation. In addition, longer term ambitions of end-to-end product traceability are impossible to achieve without an exchange of data between inputs, production, and logistics. For example:

- A fishing company trades in Western Australia (WA) and is subject to numerous restrictions. The lack of effective data systems with real-time processing means the company must analyse requirements such as size limits and quotas post-catch. This results in extra work for the fishing company and a delay for the transport company. If the logistics operator attempts to predict transport requirements, there may be an over/under-estimation resulting in wastage and inefficiencies. Furthermore, once the product reaches the market, a consumer may be disincentivised to purchase it due to a lack of traceability data, i.e. questions about origin, freshness, safety, and sustainability.

The specific challenges that arise from the existing inability to leverage data (and how they could be remedied) are:

- Logistics inefficiencies (permissioned, near real-time exchange of pre-fishing information to processors);
- Sustainability challenges (increased trust stemming from data visibility across the production chain, or lack of trust with increased opacity);
- Supply-chain inefficiencies (leveraging traceability insights through data capture); and
- Planning frictions (near real-time exchange and reconciliation of catch data by fishers and processors and WA Department of Primary Industries and Regional Development.

Additionally, taking a leaf from the cloud revolution in the Information Technology (IT) sector where it lowered the barriers for access to state of the art IT systems, FRDC is partnering with the Australian Research Data Commons (ARDC) under their Translational Research Data Challenges initiative, to develop innovative digital infrastructure solutions to overcome data sharing trust barriers; enhance the discoverability and accessibility of data; solve existing and future challenges through evidence-based decisions; support stakeholder interaction and learning; and strengthen Australia's national food security through improved, data-driven production, consumption, and distribution of safe, traceable, and high-quality food.

## C. Impact of supply chain distribution on the cost and availability of seafood

### 1. Circularity in the Seafood Economy

The circular economy (CE) refers to the natural systems of energy and materials transfer that existed until the Industrial Revolution. Sunshine fuels plant growth, which travels up the food chain, waste and dead materials replenish the soil, energy lost along the way is sufficiently replenished by solar radiation through photosynthetic processes, and so on round and round.

Over the past few centuries, humans have increasingly relied on a linear model, in which energy and materials flow towards an unreclaimable waste end point, which challenges sustainability and the resilience of industries. It is well understood that waste occurs at every point of the food supply chain (Singh et al., 2022). With fisheries and aquaculture, this occurs in the form of bycatch or stock loss on farm during harvest and production, in the form of scales, bones, and viscera during processing, and in the form of food waste during transport and consumption. It is estimated that a third of all food produced on earth is wasted. In Australia this amounts to 7.6 million tonnes per year, equivalent to 312kg per person and costing $2,000 - $2,500 per household (FIAL, 2021). Another report (KPMG, 2020) estimated the real value (i.e., adjusted for inflation) of the benefit in 2047-48 to Australia from “reducing waste in the consumption of food” at $37.141 billion.

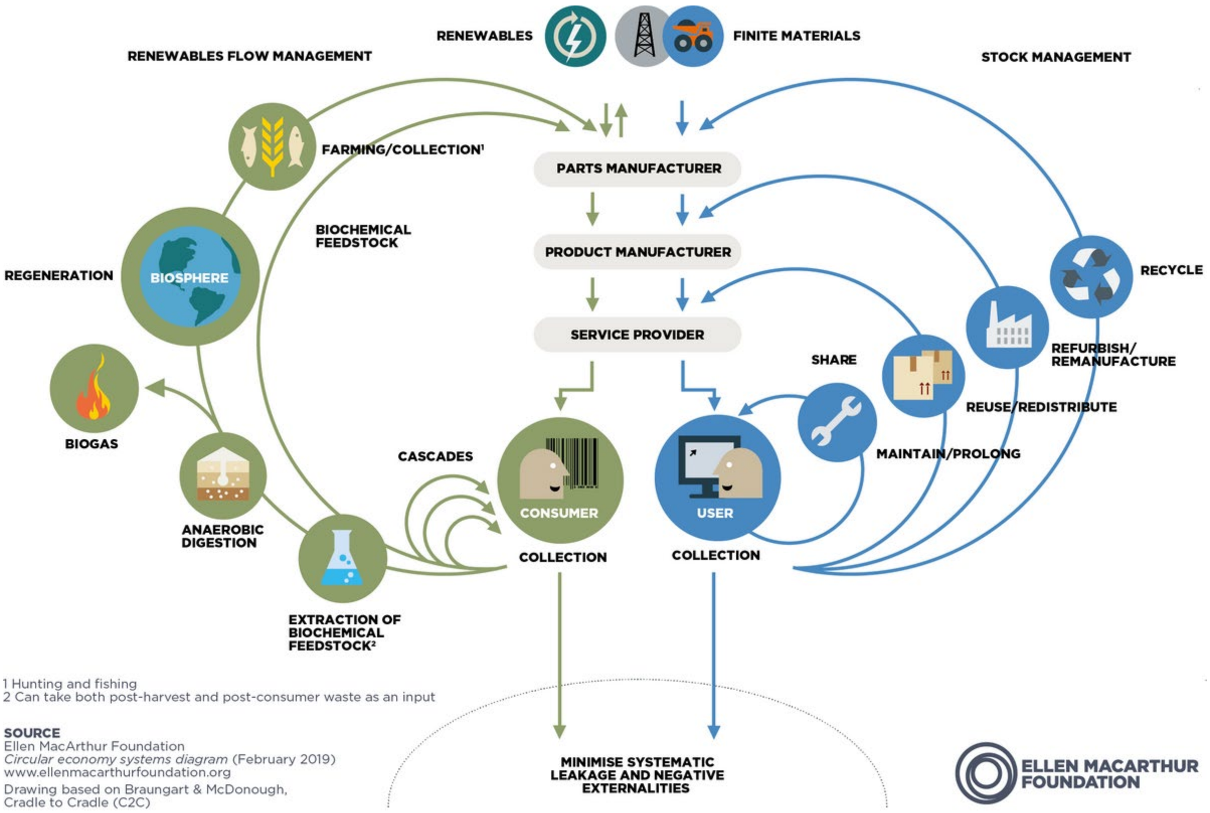
The CE goal is to rebuild capital lost through the linear model. Rebuildable capital can include everything from the money, skills, and connections we make to the natural resources we use. Circular value chains allow management of waste losses as well as waste threats to aquatic food production systems, maximisation of resource recovery and promotes regeneration within food production systems. CE mimics the cycles in nature in which there is no waste. Maximum value and utility of products and materials is maintained in CE through a combination of extending product lifetimes, increasing resource use intensity, and end-of-life material recycling. CE includes the principle of regenerative development; as resources cycle as materials through the economy they restore and enhance, rather than deplete, natural capital.

CE looks at materials as either renewable or finite through a model of biological and technical cycles (Figure 10 below). Fisheries and aquaculture might at first be viewed as an exclusively biological industry. As reproducing organisms, fish and other aquatic species are clearly a renewable resource which exists as part of a biological product cycle (fish eat wild food or manufactured feeds, are consumed, and many waste materials are composted). Fisheries and aquaculture also incorporate finite materials such as plastics and machinery, following technical product cycles. In technical product cycles, finite materials can be shared, maintained, reused or redistributed, refurbished or recycled (in order of energy consumption and system leakage).

For fisheries and aquaculture, CE adoption addresses waste challenges through the creation of new value chains for fish/shell waste and substitution or recycling of plastics along the supply chain. This provides co-benefits of resource efficiency, creation of added value and new employment, and contributions to and regeneration of healthy aquatic and terrestrial ecosystems. This latter point is of particular importance for supporting more resilient and productive food supplies from both aquatic and terrestrial ecosystem sources.

Critically, CE frameworks (e.g., Ellen Macarthur Foundation's 10R's and ReSOLVE) recognise that intersectoral collaboration is essential to ensure that systems and innovation designs can efficiently incorporate the logistical needs of both producers and new consumers of former waste products.

Figure 10. Circular Economy flows - biological and technical




An example in the Australian context is an emerging fertiliser product derived from marine, seafood processing, food manufacturing and timber by-products which meets Environmental Protection Agency and other product standards.  It is currently being tested as a soil enhancer for commercial land-based agriculture, with the potential to directly increase food security from land-based production by increasing intensity and resilience. Other opportunities for CE implementation within the sector are still emerging (e.g., replacement of fish-feed for abalone with wine production waste or repurposing mussel shells as high-nutrient fertiliser).

### *Australian Food Pact*

Australian Food Pact is a voluntary agreement brings together organisations in pre-competitive collaboration to make our food system more sustainable, resilient, and circular.

It is a multi-year commitment by the businesses who grow, make and sell our food to develop solutions and implement change at scale.

Voluntary agreements are a proven way of tackling food waste, they follow the food waste hierarchy – preventing food waste in the first place, donating good food, and supporting food chain transformation and innovation.

### *Focus for Research and Innovation*

There are three CE principles that variously anchor strategies to leverage the returns on investment in the CE:

1. Designing out waste and pollution,
2. Keeping products and materials in use,
3. Regenerating natural systems.

Each of these innovation pathways offers potential to mitigate the risks from food insecurity. The recent analysis undertaken by Food Innovation Australia Limited (FIAL) (presented below) addresses principles 1 and 2 regarding waste and recovery in the seafood supply chain.

FRDC is actively working in this space to map and quantify when and where waste occurs, and what the risks and opportunities are in terms of food availability, economics and environmental impacts (projects 2015-204, 2020-078). FRDC has recently invested in a CE program with other agricultural sectors and the Bega Valley Regional Circularity Cooperative to work with key innovators and local champions to trial and scale solutions and build communities of practice. The program will also build and use measurement tools to measure baselines and changes among businesses for circular economic maturity.

### a. Waste of Seafood

Global food loss and waste is a serious issue and is the focus of Sustainable Development Goal (SDG) Target 12.3, which aims to halve food wastage by 2030.

Proper handling, hygiene, and respect of the cold chain from harvest to consumption are crucial to preventing loss and waste and preserving quality. In most regions of the world, total fish loss and waste lies between 30-35% of harvest volume. Wastage rates have been estimated to be highest in advanced economies in North America and in Oceania, where about half of all fish caught is wasted at the consumption stage.

The World Resources Institute identifies five ways[xii] to accelerate loss reduction, improve efficiency of nutrition recovery, and maximise the value of seafood:

1. **What gets measured gets managed.** Collect and analyse seafood data - it is essential to know what is lost and from where
2. **Share data and lessons learned on seafood loss and waste -** Build the business case and research capacity to invest in waste
3. **Increase operational efficiency along seafood chains -** Processing, cool chain, human capital, technology application
4. **Create new products from seafood by products - human supplements, animal feeds, etc. -** Upscale to mainstream investment
5. **Build demand for underutilised fish parts, including nutritional waste -** Collaborate, educate, and engage consumers on social media

### *Australian Industry*

Recent research by FIAL[xiii] has found that the cost of food waste to the Australian economy is $36.6 billion a year (FIAL, 2021).

A national food waste stream of 17.8 MMT (million metric tonnes) arises from sources along the food value chain: primary production, processing, manufacturing, distribution, wholesale, and consumers (hospitality, households, and institutions).

The beneficial use or alternate outcome for this waste stream is variously anaerobic digestion, commercial composting, home/onsite composting, on-farm, disposal, waste to create energy, and as wastewater treatment. From the total stream of 17.8 MMT, 10.13 MMT (57%) is beneficially recovered, leaving an unrecovered food waste balance of 7.68 MMT (43%).

The FIAL study estimates the Fishing and Aquaculture Industry waste stream in 2021 to be 17,203 tonnes (0.1% of the national food stream). Just on 90% of this waste stream arises from Primary processing, with 10% due to product distribution.

Finfish processing creates around ¾ of all F&A waste: 74% of the beneficially recovered waste, and 75% of the unrecovered waste.

The F&A Industry breakout data is presented in Figure 11. A total of 7,782 tonnes (45%) of waste is beneficially recovered (blue shading). The unrecovered balance (green shading) of the industry waste is almost totally committed to landfill, with a minor fraction to commercial composting.

Figure 11. Fisheries 2021 National Waste Baseline

| **Value Chain Stage** 2021 (Tonnes) | **Animal Feed** | | | **Commercial Composting** | **Landfill** | | | **Total** |
|---|---|---|---|---|---|---|---|---|
| | Finfish | Crustaceans | Molluscs | | Finfish | Crustaceans | Molluscs | |
| Processing – Primary | 5,720 | 1,220 | 842 | 0 | 5,720 | 1,220 | 842 | 15,564 |
| Distribution | 0 | | | 328 | 1,095 | 61 | 155 | 1,639 |
| Subtotal | **5,720** | **1,220** | **842** | **328** | **6,815** | **1,281** | **997** | **17,203** |
| *% Contribution* | *73%* | *16%* | *11%* | *100%* | *75%* | *14%* | *11%* | |
| | | **7,782** | | **328** | | **9,093** | | **17,203** |
| | | **7,782** | | | **9,421** | | | **17,203** |

Source: FIAL https://www.fial.com.au/sharing-knowledge/food-waste and minor tonnage estimates by Ridge Partners

### *FRDC Investment*

Wild catch fisheries research has been underway for a decade to improve the utility of seafood processing waste. The early focus[xiv] was on understanding the scale of seafood waste, supply chain capability, waste minimisation through value adding the waste stream as profitable by-products, and especially for higher margin human consumption markets. The research estimated national seafood waste in 2013 was 59,000 tonnes, of which 31,131 (53%) was available for transformation through value adding. Comparing this with the findings presented in Figure 11, suggests that seafood waste streams have significantly reduced (or been confirmed to be a lesser volume) and are potentially much more efficient today.

Another waste utilisation pathway that FRDC has investigated in depth is that of underutilised wildcatch species, including optimisation of the use of bycatch (incidental catch to the main target species)[xv]. In Commonwealth fisheries the research found that 50-70% of available catch is not harvested (FRDC project 2016-056).

Underutilised fish species can be categorised under three headings (Stephens, 2018):

1. Fish caught but not used for human consumption. This may be due to their low market value, processing challenges, or being remotely harvested where infrastructure (processing or logistic) is not available. These fish are discarded at sea or used for low value fertiliser or bait,
2. Fish not caught even though quota is available or permits to harvest have been issued,
3. Fish neither caught nor included in current licensing arrangements yet might be caught in sustainable quantities.

Fish in commercial capture fisheries remain underutilised for a range of reasons, including:

- Diversity of seafood species that are edible, and targetable across Australia's exclusive economic zone and related jurisdictional fisheries,
- Diversity of market price (and net fisher return) for each of these species in consumer markets,
- Fishers' personal motivation for and assessed risk related to fishing activity in licensed waters,
- Fishing capacity and capability of each fisher enterprise and its ability to manage costs (e.g., fuel, wages) and maximise financial returns from fishing, today and over a sustainable future,
- Seasonal variations in the aquatic environment and related fisheries, which influence the availability of inhabiting species,
- Consumers' level of awareness of seafood species (provenance and credence, food safety, sustainability), which influences their demand for seafood, by location and season,
- Availability and price of seafood substitutes (farmed or imported seafood, and other non-seafood meal options) in consumer markets,
- Investors' risk-return expectations for seafood industry capital assets, including quota units.

This research found the economic impacts of species underutilisation are substantial – the added GVP available from fully harvesting a selection of 11 underutilised species in NSW waters was found to be $85 million per year.

A recent successful example of the potential to add value to a species is the Coorong Pipi fishery in South Australia. Shareholders and investors (including regional Indigenous communities) in Goolwa Pipi Company have transformed the humble pipi from a commodity bait product retailing at $6/kg in 2014 into a human seafood niche product retailing across sophisticated seafood markets in 2021 at $25/kg, and sales are booming.

### b. Waste of Energy

In Australia's National Greenhouse Accounts, emissions from the F&A sectors are currently included within the aggregated 'agriculture, forestry and fishing' segment. This segment is the third largest in Australia's inventory, and the 'fishing industry' data is overwhelmed within the large, aggregated datasets of these combined sectors and therefore often unintentionally overlooked.

Seafood consumers are increasingly wanting to know the story behind the products they're buying, including efforts by fishers and farmers to reduce their carbon footprint. Monitoring and engaging consumers and the public about emissions also creates a market benefit.

Measuring the F&A carbon footprint is a complicated task requiring an account of all the emissions generated directly and indirectly by the sectors. This includes:

- **Scope 1 emissions** – the largest source, dominated by fuel burnt (mostly diesel) for vessels directly to travel to and from fishing grounds and power harvest activity, purchased electricity, refrigeration emissions, and the emissions from services and products bought from external suppliers such as bait and aquaculture feed.
- **Scope 2 emissions** – relatively small source, relevant where fishing operations utilise considerable amounts of electricity for post-harvest, onshore processing, refrigeration, and packaging. This source is greatest for most aquaculture producers that use electricity.
- **Scope 3 emissions** - primarily derived from transportation of products (whole or processed), including bait fore line and trap fisheries, and storing and value adding seafood products in the supply chain (supermarkets, home consumption, restaurants, and food service).

Seaweed and algae farming is fast-emerging aquaculture sector (macro and microalgae) that offers food (animal and human) and human nutraceuticals. It also offers a fuel for energy production (biofuels), for habitat restoration (nutrient removal) and also for carbon sequestration ('blue carbon') potentially to create carbon 'credits'. In October 2021 the Clean Energy Regulator released a draft 'blue carbon' methodology under the Emissions Reduction Fund. There is currently no mechanism to account for shellfish or seaweed/algal biomass as carbon sinks, but it is expected that the *Carbon Credits (Carbon Farming Initiative— Tidal Restoration of Blue Carbon Ecosystems) Methodology Determination* will be the first of an expanding range of potential blue carbon methodologies to enable carbon from seaweeds and marine plants to be captured and accounted as Australian Carbon Credit Units.

A recent 2020 FRDC study[xvi] has measured the carbon emissions and energy use of Australia's largest F&A producers, which together constitute about 82% of Australia's domestic seafood production by gross value of production. This project is the first examination of the total carbon emissions of the Australian fishing and aquaculture sectors and component seafood production industries.

The study estimated the total emissions for Australian fishing and aquaculture to be approximately 1.5 MMT of $CO_2$-e - each kilogram of Australian seafood produced generates 6.5 kgs of $CO_2$-e. Aquaculture constitutes 59% of the Australian seafood industry's total emissions and wildcatch fishing contributes 41%. Greenhouse gas (GHG) emissions from aquaculture averaged 9.7 kgs of $CO_2$-e per kilogram of seafood produced compared to 4.4 kilograms $CO_2$-e per kilogram from wild-caught seafood.

The project recommends five actions for industry and agencies to improve GHG reporting methodologies for the fishing and aquaculture sectors.

1. It is recommended that FRDC continue to work agencies to determine best measures for obtaining and reporting data from the F&A sectors in national reporting schemes,
2. Empower data management and GHG decision making at the Industry Association level, such as electricity consumption for the Prawn and Barramundi farming industries,
3. Establishing a national baseline of measurement approaches, tools, and emissions reporting for the F&A sectors,
4. Commit industry to a timetable to develop a comprehensive national GHG baseline and ongoing annual reporting schedule, to provide:
    - A benchmark of emissions, and
    - Annual reporting against the benchmark and other relevant comparators
5. Develop communications networks of speciality information in related areas (e.g., carbon offsetting, blue carbon, waste management and CE issues), but also broader multi-sectoral streams to leverage the potential outcomes from these evolving areas of work.

### c. Waste of Plastics

A desktop study by Australia's OceanWatch in 2004[xvii] found the level of plastics used in the seafood industry was unknown. The report noted a major change underway in plastic use and the lack of baseline data to support plastic usage trends in the seafood industry. The report also noted that most stakeholders did not track these direct costs and could only provide rough guesses at the plastic volumes consumed and total costs incurred.

Waste has traditionally been the most visible and prominent aspect of the CE. For decades governments (local, regional, national) and some industries (food and groceries) have invested in waste reduction and management especially for plastics, organic waste, and packaging (e.g., requirements for plastics recycling, product stewardship, or food waste). However, these CE drivers have not yet been fully adopted across seafood harvest and supply chains. Waste policy has been broadly managed under the banner of Ecological Sustainable Development (ESD), and the adoption and regulation of ESD practices implemented variously according to state and territory priorities (per Figure 11).

In February 2016, the then Minister for Environment stated that the Federal Government would action a ban on plastic microbeads use in rinse-off personal care, cosmetic and cleaning products if the industry failed to implement a voluntary phase-out of their use by July 2017. In late 2017, the Department of Climate Change, Energy, the Environment and Water commissioned an independent assessment of microplastics in personal care and cosmetic products sold in supermarkets and pharmacies and found that approximately 94% of products were plastic free. A further study of microplastics in rinse-off products was commissioned in 2020, which found 99.3% of these products were free of microbeads and other non-soluble non-plastic polymers. Given these results, the Department have not initiated a formal ban. They have also implemented a monitoring and assurance protocol, which will include a further independent assessment of microbeads in the retail market as well as research on plastics entering the marine environment.

The Recycling and Waste Reduction Act 2020 was implemented in December 2020, incorporating an existing Product Stewardship Act of 2011. In addition, Australia took full responsibility for its plastic waste by banning the export of unprocessed waste materials including plastic, paper, and glass.

Figure 12. Scorecards for state action on plastic pollution (Source FRDC – UTS)

Taken action | Taken some action | Taken no action

| State action taken to ban: | NSW | VIC | ACT | QLD | WA | TAS | NT | SA |
|---|---|---|---|---|---|---|---|---|
| Plastic bags | Taken no action | Taken action | Taken action | Taken action | Taken action | Taken action | Taken action | Taken action |
| Microbeads (federal action) | Taken some action | Taken some action | Taken some action | Taken some action | Taken some action | Taken some action | Taken some action | Taken some action |
| Plastic & coffee cups | Taken no action | Taken no action | Taken some action | Taken no action | Taken some action | Taken no action | Taken no action | Taken some action |
| Plastic lids & coffee cup lids | Taken no action | Taken no action | Taken some action | Taken no action | Taken some action | Taken no action | Taken no action | Taken some action |
| Balloons and balloon sticks | Taken some action | Taken no action | Taken some action | Taken some action | Taken some action | Taken no action | Taken no action | Taken no action |
| Plastic plates | Taken no action | Taken no action | Taken some action | Taken no action | Taken some action | Taken no action | Taken no action | Taken some action |
| Plastic straws | Taken no action | Taken no action | Taken some action | Taken no action | Taken some action | Taken no action | Taken no action | Taken action |
| Plastic utensils | Taken no action | Taken no action | Taken some action | Taken no action | Taken some action | Taken no action | Taken no action | Taken action |
| Plastic containers | Taken no action | Taken no action | Taken some action | Taken no action | Taken some action | Taken no action | Taken no action | Taken some action |
| Plastic packaging eg. cling wrap, condiments | Taken no action | Taken no action | Taken some action | Taken no action | Taken some action | Taken no action | Taken no action | Taken no action |
| Plastic bottles (container deposit scheme) | Taken action | Taken no action | Taken action | Taken action | Taken action | Taken action | Taken action | Taken action |

Source FRDC – UTS (Cunningham, Barclay, Jacobs, Sharpe, & McClean, 2022)

In 2020 research[xviii] is currently underway to audit the plastic waste stream across Australian jurisdictions, including for bags, microbeads, coffee cups and lids, balloons, plates and utensils, containers, packaging, and bottles. The audit is needed to understand the volumes and types of plastics used by the Australian seafood industry, and waste management /reduction strategies including alternative materials.

While there are many examples within the Australian seafood industry of voluntary measures to reduce plastic use, baseline data is needed to determine where to focus reduction efforts, to establish targets, to track improvements, and to support benchmarking within the Australian industry and beyond, including international. Importantly, an audit will support business and industry decisions on practice change by contributing to information that allows comparison of material costs of current plastic use with alternatives.

#### *Microplastics in seafood*

Australia's SafeFish organisation (see discussion under Seafood safety in next section) maintains up-to-date advice for industry and stakeholders regarding broad concerns about microplastic contamination in food. With around 600 million tonnes of global plastic production forecast annually by 2025 (FRDC SafeFish, 2022 July) the number of plastic pollutants ending up in the marine environment is of increasing concern.

Two microplastic types are identified: Primary which are plastics manufactured to be of a microscopic size (typically used in facial-cleansers, cosmetics, as air-blasting scrubbers to clean surfaces, plastic powders used in moulding, or as vectors for drugs in medicines); and Secondary including tiny plastic fragments derived from the breakdown through prolonged ultraviolet light exposure of larger plastic debris both at sea and on land.

Microplastic accumulate in the gut of marine invertebrates (e.g., crustaceans and bivalves) and in sediment across the marine ecosystem. The risk of ingestion of microplastics by humans through eating contaminated seafood has been shown to be low as in most cases the product is eaten cleaned (with the gastrointestinal track removed). There is a higher risk from mussels, oysters and animals eaten whole.

Another area of potential concern for human exposure to microplastics, is the fact that these particles readily absorb other potential cancer forming chemicals from the environment such as polychlorinated bisphenyls (PCBs), dioxins, persistent organic pollutants (POPs), heavy metals, polycyclic aromatic hydrocarbons (PAHs), bisphenyl A, phthalates, and polybrominated diphenyl esters (PBDE).

A 2020 study of seafood in Australian markets examined microplastics in 25 species of fish and invertebrates. Microplastics were found in 44% of the animals studied (approximately 1800 organisms), with bivalve molluscs having the highest prevalence of contamination (56%). Microplastic loads were low relative to international reports, varying from 0.8 pieces per animal in crustaceans to 1.4 pieces per animal in bivalve molluscs. Microplastic load varied by state for finfish and bivalve molluscs.

In its published factsheet SafeFish concludes that there are still several knowledge gaps that exist in relation to micro- and nanoplastics and potential impact on human health. Further research is required to understand their impact and effects more thoroughly.

### d. Waste of Fresh Water and Water Use Efficiency

Clean water, both fresh and marine, is a primary resource in the Fishing and Aquaculture Industry. In 2020, a study (KPMG, 2020, p. 3) noted the depleting nature of fresh water was a strong economic and social driver to reduce water leakage and implement water recycling as a necessary step toward a CE. Action to implement such strategies across Australia's major urban centres would result in an economy wide boost to real annual GDP of $29.9 billion in 2047-48 with increased employment in that year of 4,510 FTEs. Unfortunately, this report does not consider the CE attributed for water used or recovered in the food industry or the seafood industry, and there is limited information available on wastewater within fishing and aquaculture sectors.

## 2. Health and Nutrition of seafood

The Australian Dietary Guidelines and Heart Foundation recommend eating one or two fish-based meals per week, but according to the last National Dietary Survey, only one in four of us reported eating fish at least once a week.

There is significant room to increase our consumption of local catch (and nutritional benefits), both from growing aquaculture production and better utilising our wild fisheries (Senior & Stewardson, 2019).

### a. Seafood and health

Seafood, including fish is a nutritious core food providing quality protein, omega-3 long chain fatty acids, selenium, zinc and vitamins A and D https://superseafood.com.au/. It is a major source of iodine in the Australian diet (especially saltwater species), an excellent source of fluoride, and fish with edible bones contribute significant amounts of calcium. From a health perspective, there are many reasons to recommend regular seafood consumption, summarised in an FRDC booklet https://www.frdc.com.au/sites/default/files/2021-07/Whats_so_healthy_booklet.PDF.

The most common is a reduced risk of cardiovascular disease but including seafood regularly is also associated with healthier ageing and longevity, better pregnancy and birth outcomes and reduced risk of depression, type 2 diabetes, and some cancers. International guidelines also consistently recommend consumption of at least two fish meals each week.

### b. Seafood consumption

It is a public health challenge to increase seafood consumption across the population, and especially in socially disadvantaged groups. The Dietary Guidelines for Australians recommend including around two serves of fish or seafood a week, which is around 230g raw/200g cooked.

The most recent survey of consumption by the Australian Bureau of Statistics (ABS) shows most Australians don't eat near that amount. In fact, as a nation the National Health and Medical Research Council (NHMRC) says we need to increase our seafood consumption by 40% to meet recommendations.

*How do we lift seafood consumption?*

Australian research has found the leading drivers of seafood consumption are health, taste, and convenience. The main barriers are price, availability, concerns about quality and a lack of confidence in selecting and preparing seafood (Christenson JK et al 2016).

Socioeconomic status (SES) also plays a role; people of higher SES are more likely to eat seafood and consume species with higher omega-3 fat levels (Farmery et al 2018).

*Is there enough seafood to support recommendations?*

According to the EAT-Lancet Commission on healthy diets from sustainable food systems (Willett et al 2019), 196g seafood per person a week is globally sustainable – roughly equivalent to the two serves a week widely recommended (200g). Its healthy reference diet for an intake of 2500 kcal/10,500kJ per day includes 28g of seafood a day, with a range of 0-100g to account for regions without access to seafood and higher amounts for added health benefits.

*New resources for health professionals*

In 2018 the FRDC commissioned resources to better equip health professionals to support their clients and communities to eat the recommended amounts of seafood and encourage them to choose Australian sustainable seafood. These resources are also useful for food industry professionals. The suite of resources includes an evidence review of seafood and health, an online brochure and a collection of family friendly recipes using Australian sustainable seafood species https://www.fishfiles.com.au/en/experts/healthprofessionals

### c. Seafood Sector Safety

SafeFish (https://www.safefish.com.au/) is a specialist Australian organisation that provides technical advice to support Australia's seafood trade and market access negotiations and helps to resolve barriers to trade. It is primarily funded by the FRDC and is the leading platform for dealing with food safety and trade and market access issues affecting Australian seafood.

Current work underway at SafeFish includes:

- Developing a food safety risk register for the seafood industry,
- Building on the national seafood risk register and developing specific sector risk registers/mitigation plans,
- Assisting the Seafood Trade Advisory Group (STAG)[xix] to develop an online 'Seafood exporters module'
- Raising the awareness of Ciguatera fish poisoning (CFP) with health professionals.
- Extension project if resources are available around Ready-to-eat seafood.

SafeFish collates technical advice and publishes it as factsheets for industry and stakeholder benefit. Factsheets currently available address seafood safety issues including E-coli, Paralytic shellfish poison, Listeria, Ciguatera, Hepatitis A, and Microplastics in seafood.

## D. Potential opportunities and threats of climate change on seafood production in Aust

### 1. Climate Change and Weather

Climate change[xx] poses both challenges and opportunities for Australia's wild fisheries and aquaculture sectors. These changes are a significant concern and impact at two levels, for:

- Fishers and the communities that depend on fisheries for their livelihoods, and
- Marine ecosystems also provide irreplaceable services including oxygen production, nutrient recycling, and climate regulation.

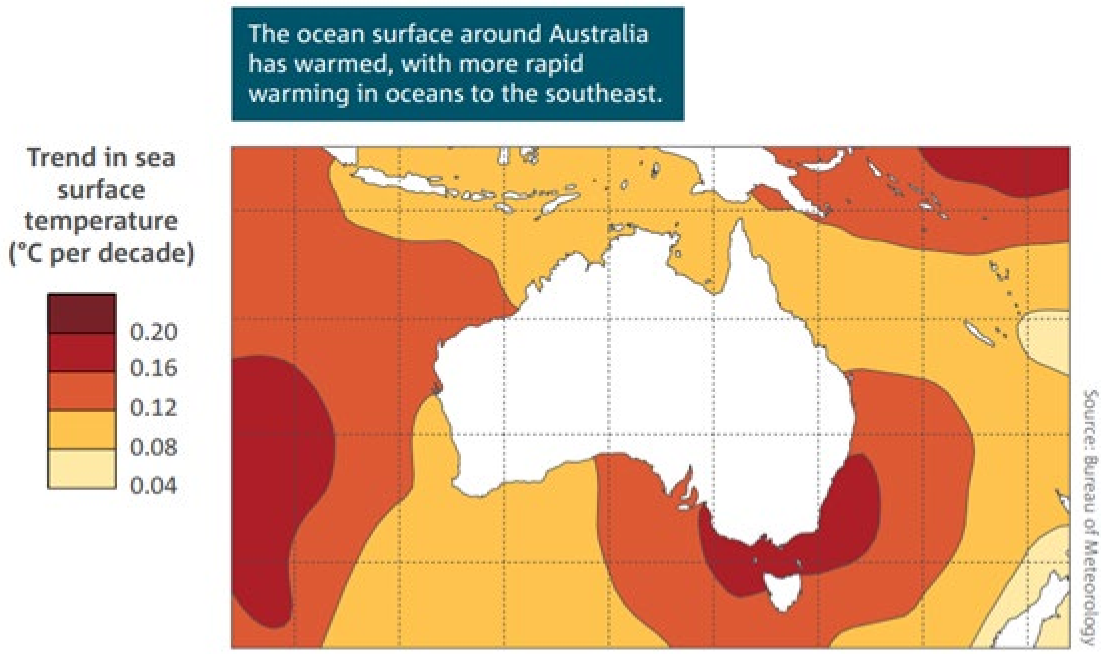
Seafood security is directly impacted as fishers face the largest near term and most direct impact of climate change. Over the long term, changes in ecosystem services will also indirectly impact the marine resource and therefore seafood security.

Climate change affects fishing and aquaculture through three main physical attributes - temperature, water chemistry, and currents, and interactions between these attributes.

#### a. Temperature

Research suggests wildcatch fisheries in south-eastern Australia are most at risk from warming marine environments.

Figure 13. Trends in sea surface temperatures in the Australian region from 1950 to 2017




Sea surface temperature increases are likely to affect many aspects of marine species' life history and demography, including larval development, growth rate, onset of reproductive seasons, timing of migrations or other movements, geographical distribution, and disease susceptibility.

All these changes have implications for marine and aquatic ecosystems, and the fishing and aquaculture communities that depend on them.

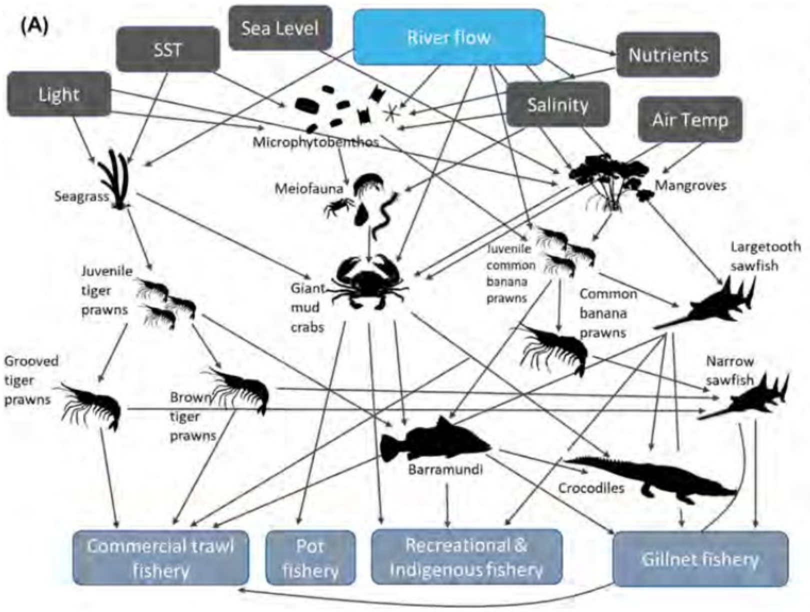
Changing oceanic temperatures have also contributed to increased frequency and intensity of marine heatwaves. The 2015 Tasman Sea marine heatwave was the longest and most intense recorded and was associated with several nearshore ecosystem events including new disease outbreaks in farmed shellfish, mortality of wild Abalone, and records of species normally associated with warmer ocean conditions.

A heatwave event on Australia's west coast in 2011 resulted in mass mortality of fauna including a 99% mortality rate for Roe's Abalone, and major reductions in recruitment of scallops, Western King Prawns, and Brown Tiger Prawns. Management responses included effort reductions and spatial and temporal closures.

Marine heatwaves are abrupt and marked increases in temperature, providing little opportunity for organisms to acclimate or adapt. Consequently, marine heatwaves will likely have strong, and even irreversible, ecosystem and evolutionary impacts.

Ecosystem impacts of marine heatwaves are particularly serious when habitat-forming taxa such as kelp or coral reefs are affected. One example is changes to freshwater river flows in northern Australia due to climate variability and development. Flows directly impacts seagrasses (the base of the food web in the tropics where phytoplankton biomass is extremely low) and mangrove forests (key nursery areas for many species of fish and crustaceans).

Figure 14. Linkages of Gulf of Carpentaria fisheries to river flows




Fresh water river flow is crucial in the life cycle, recruitment and mortality of Prawns (Northern Prawn Fishery) and other tropical species (e.g., mud Crab, Barramundi, Grunter, and Threadfin Salmon) of importance to commercial, recreational and Indigenous fisheries, and species with high conservation (e.g., Sawfish) and cultural value (FRDC 2018-079, 2022).

Marine heat waves have also been associated with increased occurrence of disease, incidence of harmful algal blooms, increasing the risk of Paralytic Shellfish Poisoning. Lengthy fisheries closures have resulted.

### b. Water chemistry

Atmospheric carbon dioxide ($CO_2$) levels are steadily increasing - present levels have not been exceeded during the past 420,000 years. In turn, atmospheric $CO_2$ levels increase dissolved $CO_2$ levels in oceans, changing water chemistry and causing acidification. Oceans around Australia are acidifying 10 times faster than at any point in the last 300 million years.

The impacts of ocean acidification for marine organisms are uncertain, but may include changes to species growth, physiology and reproduction, species composition, food web structure, nutrient availability and calcification rates for species that produce shells and exoskeletons from calcium carbonate (CSIRO BOM, 2022, p. 17).

The acidity of waters around Australia is increasing. Since the decade of 1880-1889 the average pH of surface waters around Australia and globally is estimated to have decreased by about 0.12, corresponding to about a 30% increase in acidity. Due to latitudinal differences in ocean chemistry, the oceans to the south of Australia are acidifying faster than those to the north.

### c. Ocean currents

Ocean boundary currents shape Australia’s marine ecosystems by redistributing heat, freshwater, nutrients, and organisms themselves along the coastline. The three major currents (East Australian Current, Indonesian Throughflow, and Leeuwin Current) shape and structure coastal our marine environments.

In turn these currents are shaped by global climate, particularly oscillations including the El Nino Southern Oscillation, Indian Ocean Dipole, and Southern Annular Mode.

Changes in oscillations drive ocean boundary currents and water exchange between inshore environments and the open oceans. These in turn affect nutrient supply and larval transport, with consequences for marine ecosystems. Fished species that rely on cross-shelf larval transport (e.g., Lobsters) are likely to be negatively affected by currents.

## 2. Predicting outcomes for Australian stocks and species

### a. Global stocks snapshot

The FAO (FAO, 2018, p. 76) has projected average changes in marine fishery catch potential by 2050 and 2100 relative to 2000. Various models have been used across a range of forecast climate change scenarios.

Figure 15 illustrates forecast fishery catch changes (%) averages and range around the average for selected leading global fishing economies and related Exclusive Economic Zones. The model employs the IPCCs most stringent pathway (RCP2.6 where $CO_2$ emissions start declining by 2020 and go to zero by 2100).

The selected EEZs are chosen to include the largest global fishing economies, and suppliers relevant to Australian food security.

The data illustrates the volatility of potential climate change impacts on fishery yield, and that many EEZ impacts are within a range where both negative and positive outcomes are likely.

Figure 15. FAO Forecast changes in fishery catch potential - selected EEZs

| Selected Economy EEZ | 2050 Mid Century | |
|---|---|---|
| | Average % | Range around the Average |
| Australia | -6.37 | 9.12 |
| Macquarie Island (Australia) | -15.15 | 8.74 |
| Canada - Pacific | +1.22 | 12.11 |
| Canada – East Coast and Arctic | +6.32 | 15.72 |
| Chile | +4.08 | 8.53 |
| China | -6.38 | 9.13 |
| Germany - North Sea | -24.29 | 45.60 |
| India | -10.30 | 23.92 |
| Indonesia - Eastern | -12.51 | 16.37 |
| Japan | -3.85 | 10.53 |
| New Zealand | -2.82 | 2.97 |
| Norway | +3.34 | 6.41 |
| Russian Federation | +60.31 | 73.74 |
| Thailand - Gulf of Thailand | -9.87 | 8.88 |
| USA – West Coast | -3.57 | 12.48 |
| USA – East Coast & Gulf of Mexico | -8.30 | 9.05 |
| USA - Alaska | +10.31 | 36.77 |
| Vietnam | -6.77 | 8.85 |

### b. Australian Species impacts

Climate change impacts on Australian marine and aquatic species will be highly variable - some seafood species and fisheries will gain, and others will lose. Ocean floor species (benthic, or demersal) are at greater risk than species that inhabit the water column (pelagic). Pelagic groups can move and will likely benefit from changed water-column properties and related dietary composition gains than demersal species.

Overall, temperate marine region ecosystems are probably at greater risk than those in the tropics. Tropical systems (e.g., Northern Prawn Fishery) will still be highly context dependent. In south-eastern Australia, the most valuable fisheries (Southern Rock Lobster, Blacklip Abalone, Greenlip Abalone) are likely to be sensitive to climate impacts, as are species including Black Bream, King George Whiting, Commercial Scallop, School Prawns, and Blue Grenadier.

Inland freshwater systems are highly exposed to climate-related impacts, particularly those relating to changes in rainfall patterns. Experts predict the southern Murray-Darling Basin habitats will experience stronger negative impacts, with more northern systems being relatively less affected, but the scale of scope of regional impacts from climate change and therefore food security, remain unclear.

In a fishery management sense, climate change can affect two main inputs in quota systems: 1) the setting of target and limit reference points and 2) the reliability of forward projections from management strategy evaluation models.

### c. Socio-economic impacts

Ecological effects of climate change will drive socio-economic impacts across fisheries and industry sectors. As these trends are now emerging, the full extent of near-term socio-economic impacts is still unknown.

Australian fishing businesses, supply chains, and regulators generally recognize they will have to modify practices in response to climate change (FAO, 2018, p. 354). Ecosystem models used to explore potential futures for Australian fisheries suggest some of the biggest challenges will be in the ability of human users to adapt their behaviours and in providing management that allows ecosystems the maximum potential to adapt to the environmental changes. Recreational and Indigenous customary fishers will also need to adapt to climate-related changes.

Overall, the management approaches generally used in Australian fisheries have the flexibility and potential to enable climate change adaptation to varying degrees.

Some ecological changes are already bringing human benefits (e.g., range extensions for an Octopus species) and recreational fishing for Yellowtail Kingfish and Snapper that are becoming more prevalent in Tasmanian waters. The FAO notes that if climate change opens opportunities to exploit new species or stocks (FAO, 2018, p. 353), because of changes in their spatial distribution, then access rights will need to consider the existing exploitation on these species elsewhere. The overall sustainability of the stock and its new distribution will need to be considered in deciding whether to grant new access rights or give access to these new areas by existing rights holders.

Others will be profoundly negative – and negative impacts are generally expected to predominate (e.g., rising sea levels and loss of kelp beds off Tasmania will reduce availability of culturally important maireener shells). Sea Urchin-mediated kelp loss is also affecting the productivity of the Southern Rock Lobster fishery.

The insurance and banking sectors are early indicators of assessable climate change impact on economic systems. Many insurers are now incorporating climate-risk considerations in their product offerings or reducing exposure to carbon-intensive industries. The high exposure of capture fishing (in particular) and aquaculture ventures means climate risks will directly impact insurance coverage, premiums, and investment risk.

As regions and industries most vulnerable to changing climate risk are identified finance markets are able and likely to rapidly reprice exposed assets, affecting insurers' investment portfolios and their own market valuations negatively. These adjustments will likely cause insurers to re-evaluate their investment strategies as the economy transitions towards decarbonisation, particularly in carbon-intensive investments.

There is also potential for Australia to develop its underutilised marine jurisdiction, to supply seafood to countries where production falls abruptly, for climate or other reasons. The National Marine Science Plan 2015 (NMSC, 2015, p. 19) notes that aquatic products are predicted to have some of the largest real price increases among the major global food sources—and the greatest growth is expected in our region.

### d. Mitigation and adaptation

Both mitigation of and adaptation to climate change are important to Australian fishing and aquaculture. The industry has significant opportunities to profitably engage with effective mitigation measures at scale, including through commercial production of various marine algae, and by adopting various measures to reduce its carbon footprint in line with increasing consumer interest in carbon neutrality.

The F&A Industry is already supporting private company initiatives that adapt and mitigate greenhouse gas emissions, including one of the largest prawn farms in Australia. The Pacific Reef Farm at Ayr is trialling, at scale, farmed algae production to provide environmental services and products including bioremediation of recirculating aquaculture waters used for prawn production[xxi].

In a recent FRDC-funded review of risks to fishing and aquaculture, researchers provided the following eight recommendations:

1. Management priority, based on short-term sensitivity, should be given to: (i) northern invertebrate fisheries, and (ii) finfish fisheries with areas of regime change (e.g., Tasman Sea)
2. Existing management strategies must be assessed in terms of their capacity to sustain long term ecological and resource management objectives
3. Flexible regulations and adaptive approaches are required to implement change as rapidly as needed in response to changing system state
4. Fisheries policy, management and assessment methods need to integrate the concept of regime shifts and extreme events for contextual management decision making
5. There needs to be greater recognition of non-static environmental conditions in fisheries operations and in the assessment and decision-making processes
6. A cross jurisdictional management of stocks is likely imperative
7. It will be increasingly necessary to acknowledge that not all fisheries and operators will have equal adaptive capacity
8. Integrated management needs to be central to fisheries management.

## 3. Research Focus

There are a wide range of investors in climate change RD&E, including the Department of Climate Change, Energy, the Environment and Water, CSIRO, the Australian Research Council, universities and the private sector.

At a national level, FRDC helps co-ordinate fisheries climate change R&D with government agencies, industry and stakeholders. FRDC's strategic imperatives are focused on enhancing adaptive capacity to foster mitigation actions, and to position our industries to take advantage of the impacts of climate change. FRDC's research into climate change spans over a decade.

Recent and current research projects align with the FRDC's R&D Plan 2020-25, as follows.

| Project Number | Title |
|---|---|

| | |
|---|---|
| 2022-007 | Trials of oceanographic data collection on commercial fishing vessels in SE Australia |
| 2021-104 | Applying the fisheries climate adaptation handbook to Australia's state fisheries |
| 2020-089 | Energy use and carbon emissions assessments in the Australian fishing and aquaculture sectors: Audit, self-assessment and guidance tools for footprint reduction |
| 2020-005 | Developing a cost-effective monitoring regime and stock assessment for Sand Flathead in Tasmania |
| 2019-144 | Cultivation trials of the red seaweed *Asparagopsis armata* and *A. taxiformis* |
| 2019-140 | Presentation at World Congress of Aquaculture and Fisheries (Xiamen, China) on Biosecurity and Aquatic Animal Health |
| 2019-099 | Climate driven shifts in benthic habitat composition as a potential demographic bottleneck for Western Rock lobster: understanding the role of recruitment habitats to better predict the under-size lobster population for fishery sustainability |
| 2019-032 | Seaweed production as a nutrient offset for Moreton Bay |
| 2019-015 | Understanding the relationship between commercial prawn species population dynamics, fishing patterns and climate in the Shark Bay World Heritage area in Western Australia |
| 2019-014 | Can DNA from routine plankton surveys be used to measure fish spawning areas and monitor changes in pelagic ecosystems? |
| 2019-013 | Modelling environmental changes and effects on wild-caught species in Queensland |
| 2019-010 | Revisiting biological parameters and information used in the assessment of Commonwealth fisheries: a reality check and work plan for future proofing |

Figure 16. Summary of Opportunities and Threats of climate change to Seafood Security

| OPPORTUNTIES from climate change | THREATS from climate change |
|---|---|
| • Develop and implement technologies on vessels and in farms that reduce carbon emissions,<br>• Communicate with consumers about the substantial and unique potential for wildcatch and farmed seafood industries to adapt to and mitigate climate change impacts on seafood diets<br>• Develop and increase local seafood production from our underutilised marine jurisdiction, and seafood species<br>• Support Australian aquaculture (including existing and potential fish and plant species) to expand seafood production and GHG mitigation services such as bioremediation of water effluent<br>• Monitor climate change impacts across our large EEZ to track and optimise fishery ranges for existing and new seafood species to capture optimum harvest yields<br>• Supply seafood to countries whose supply falls due to climate change<br>• Leverage Australia's climate change R&D and management capacity through closer international collaboration, and as a services export<br>• Engage fishers (seafood, recreational and customary) and managers early to support and motivate adaptive behaviours that defend against negative impacts and capture opportunities arising from climate change<br>• Assist all seafood fishers to understand their changing climate risk exposure (sectoral and in their enterprise) and to work with bankers and insurers to restructure capital and operational profiles accordingly<br>• Test the flexibility of Australian fishery management policy and people to adapt promptly to climate change risks and opportunities | • Seafood consumers are excessively exposed to imported seafood<br>• Environmental change may lead to species range contraction and closure of fisheries<br>• Loss of resilience to climate change impacts in habitat forming taxa (e.g., kelp, coral reefs)<br>• Increased occurrence of disease, incidence of harmful algal blooms, due to climate change<br>• Increased ocean acidification may change species growth, physiology and reproduction, species composition, food web structure, nutrient availability, and calcification rates<br>• Ocean current changes that drive adverse impacts on species that rely on cross-shelf larval transport (e.g., lobsters)<br>• Seafood that harvests ocean floor species (benthic, or demersal) are at greater risk than species that inhabit the water column (pelagic)<br>• temperate marine region ecosystems are probably at greater risk than those in the tropics<br>• In temperate Australia, valuable seafood fisheries (Southern Rock Lobster, Blacklip Abalone, Greenlip Abalone) are likely to be sensitive to climate impacts, as are multisector species including Black Bream, King George Whiting, Scallop, School Prawns, and Blue Grenadier.<br>• southern Murray-Darling Basin habitats will experience stronger negative impacts<br>• Rising sea levels will lead to localised flooding, loss of habitat and loss of seafood species – we need to know where and when this will arise |

## References

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[ii] FSANZ Definition – Seafood is all aquatic vertebrates or aquatic invertebrates intended for human consumption, but excluding amphibians, mammals, reptiles, and aquatic plants in any form, including whole fish, or part thereof, in raw or cooked form, or as a fish product.
[iii] https://sustainablefisheries-uw.org/seafood-101/what-does-the-world-eat/
[iv] https://www.frontiersin.org/articles/10.3389/fsufs.2021.611835/full
[v] https://www.frdc.com.au/gross-value-production
[vi] FRDC 2014-503.20 page 3
[vii] FRDC 2014-503 20 page 3
[viii] FRDC Response to the National Food Plan issues paper, Sept 2011 p23
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[x] FRDC submission to the Inquiry into the Australian Aquaculture Sector
[xi]
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[xiii] FIAL is an industry-led, not-for-profit organisation focused on growing the share of Australian food in the global marketplace.
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[xvi] FRDC 2020-089 Energy use and carbon emissions assessments in thew Australian fishing and aquaculture sectors; audit, self-assessment, and guidance tools for footprint reduction 2021
[xvii] FRDC 2004-410 Reducing plastics in the Australian seafood industry – a desktop feasibility study
[xviii] FRDC 2020-078 Circular economy opportunities for fisheries and aquaculture in Australia, September 2022; and 2020-084 An audit of plastic use in the fishing and aquaculture sectors.
[xix] STAG works with industry and government to resolve trade and market access barriers experienced by Australian seafood exporters. We also provide market intelligence services and resources to help Australian seafood exporters do business in their key markets. https://seafoodtradeadvisory.com/
[xx] https://www.frdc.com.au/climate-change-impacts-fishing-and-aquaculture
[xxi] https://www.pacificbio.com.au/