Circular economy opportunities for fisheries and aquaculture in Australia

30 September 2022

FRDC Project No. 2020-078

UTS Institute for Sustainable Futures
UTS Climate, Society and Environment Research Centre
FRDC

This publication (and any information sourced from it) should be attributed to:

Cunningham, R., Barclay, K., Jacobs, B., Sharpe, S., McClean, N., 2022. *Circular Economy Opportunities for the Fisheries and Aquaculture Sector in Australia,* FRDC Report 2020-078, Sydney Australia.

ISBN 978-0-9953662-6-8

Research team

- Doctor Rebecca Cunningham
- Professor Kate Barclay
- Associate Professor Brent Jacobs
- Doctor Samantha Sharpe
- Doctor Nicholas McClean

About the authors

ISF is an independent research institute within the University of Technology Sydney. We conduct transdisciplinary, project-based research in line with our vision of creating positive change towards sustainable futures.

Contents

Figures

Acknowledgements

The authors acknowledge the significant and valued input from the members of the project's Steering Committee, who contributed a broad range of expertise on circular economy practices and the fisheries and aquaculture sector in Australia.

We would also like to thank the industry stakeholders who participated in our project workshop and/or agreed to be interviewed. Many of the participants run their own businesses, and we are aware that their time and resources are precious and limited. We truly appreciate the generosity and openness of all participants, and their patience with regards to all communication needing to be virtual/online due to COVID-19 pandemic travel restrictions.

A special thank you to Dr Carolyn Stewardson who worked closely with us as FRDC project manager.

Abbreviations

AFMA	Australian Fisheries Management Authority
APCO	Australian Packaging Covenant Organisation
CE	Circular economy
EMF	Ellen MacArthur Foundation
FRDC	Fisheries Research and Development Corporation
ISF	Institute for Sustainable Futures
NSW	New South Wales
SA	South Australia
SC	Steering Committee
SME	Small to medium enterprise
TAS	Tasmania
UTS	University of Technology Sydney
WA	Western Australia

Executive summary

Background

In 2020 the Fisheries Research and Development Corporation (FRDC) funded the first circular economy (CE) project for the Australian seafood sector, in partnership with the University of Technology Sydney (UTS). From the start, the aim was to understand current CE activities, opportunities and barriers in the fisheries and aquaculture sector in Australia through extensive stakeholder engagement. This report shares the outcomes of this collaborative research project.

It is widely acknowledged that current resource use worldwide presents a major challenge to the sustainability and resilience of many industries. In CE, however, circular value chains allow for the efficient management of waste losses and maximise resource recovery. CE mimics certain cycles in nature in which there is no unnecessary waste. It does this in several ways, including by keeping products in use for longer, intensifying resource use (increasing the resource consumption to production ratio), and recycling materials at end-of-life. CE also incorporates 'regenerative development,' which is the concept that the earth's resources could restore and enhance – rather than deplete – natural capital as they cycle as materials through the economy.

For fisheries and aquaculture, CE offers a more holistic and far-reaching vision of sustainability than the conventional focus on preventing overfishing and avoiding pollution. CE encompasses those too, but also involves thinking about the impacts of all plastics, metals, fuels, gases and other materials in supply chain activities.

CE in a fisheries and aquaculture context means using all parts of the creatures harvested in aquaculture (including tails, guts and frames) for human or animal consumption, or as fertiliser to grow more food. It means minimising the waste materials that end up as landfill, or as harmful gas or water emissions. It means using vessels, equipment and gear for longer, and making sure materials can be recycled at the end of their useful lives. It means decarbonising the energy and materials used along every link in the supply chain.

A clear example of how circularity can work in the industry is 'integrated multi-trophic aquaculture,' a system in which the excrement from one organism (such as prawns) becomes food for another species in the ecosystem (such as algae).

The economic opportunities of circularity are widely acknowledged. The World Economic Forum estimates that the global adoption of CE principles would deliver significant cost savings and generate new value in the economy of up to US$4.5 trillion by 2030 (World Economic Forum, 2022). One estimate puts the economic benefits to Australia of adopting CE at AU$1.9 trillion by 2041 (PWC, 2021). However, current knowledge gaps constrain how CE may develop, at what scale it makes sense to close resource loops, and the strategies, policy mix and incentives needed to promote circularity.

Importantly, CE opportunities in the fisheries and aquaculture sector are often linked to other land-based sectors (such as reusing fish/shell waste in agriculture or high-value pharmaceutical applications). While fish/shell waste is currently a burden and can cost up to US$150/tonne to dispose of in Australia, it could be repurposed as fertiliser due to the high phosphorus concentration in fish skeletons and clam or abalone shells. This could, in turn, buffer Australia from future fertiliser price fluctuations and supply disruptions (and reduce the geopolitical risks associated with our food system being dependent on imported fertiliser).

For fisheries and aquaculture, CE presents new and practical solutions to existing challenges. It can tackle waste issues through the creation of new value chains for waste, and by substituting or recycling plastics. This has a three-pronged positive impact: increased resource efficiency, healthier aquatic ecosystems, and the creation of added economy-wide value and new employment.

Robust overarching frameworks to guide this kind of 'CE thinking' do already exist, for example, the Ellen MacArthur Foundation's ReSOLVE framework (Ellen MacArthur Foundation, 2015a), and the 10Rs framework (Potting et al. 2017). However, these have not yet been broadly applied within wider food innovation debates (Pagotto and Halog, 2015), and the opportunities for implementation within the seafood sector are still emerging (such as using wine production waste in feed for abalone, or repurposing mussel shells as fertiliser).

There is thus an urgent need to understand the industry context, opportunities and potential benefits of CE innovations, and to identify strategic approaches to sectoral circularity at scale.

Objectives

The objectives of this project are to:

1. Develop increased knowledge of how the concept of circular economy can be applied to the fishing and aquaculture sector, including downstream activities such as post-harvest processing and packaging.
2. Develop increased knowledge of how circular practices being implemented in other sectors and industries might be relevant to the fishing and aquaculture sectors, and thus viable for fishing and aquaculture businesses to adopt. This includes opportunities for fisheries/aquaculture industries to develop circular linkages with other marine and land-based sectors.
3. Identify opportunities and areas for exploration in the short-, medium- and long-term to progress a circular economy for fisheries and aquaculture.
4. Identify barriers to adopting circularity within the fisheries/aquaculture sector, and known strategies for addressing those barriers.

Methodology

This project was designed to use a mixed method approach. We applied internationally recognised CE principles from the wider body of CE literature, such as the 10Rs (Potting et al. 2017). We also drew extensively on the frameworks created by UK-based charity and leading proponent of CE, the Ellen MacArthur Foundation (Ellen MacArthur Foundation, 2015a; 2015b), and followed their guidelines for operationalising CE through the ReSOLVE framework (for further details, please see the report's methodology section).

Phase 1: Co-design partnership formation and confirmation

UTS worked closely with the FDRC and a project Steering Committee (SC) to develop the project design. The SC includes representatives from government, the private sector, civil society groups from the fisheries and aquaculture sector, and leaders of CE initiatives. UTS researchers liaised with the SC for the duration of the project.

Phase 2: Literature review of circular economy research and innovations

A desktop review of CE-related literature identified a range of relevant past and current research, applications, innovations and examples of CE in practice. This review was used to inform subsequent stakeholder workshops to disseminate these findings to industry. The review is organised into three topics:

1. International CE applications and best practice in i) other sectors, and ii) within fisheries/aquaculture
2. Australian CE applications in other sectors

3. The extent of CE adoption and active innovation in Australian fisheries and aquaculture.

Phase 3: Systems mapping workshop

Informed by the research findings of Phases 1 and 2, a systems mapping workshop was conducted online in July 2021. At this workshop, stakeholders from the fisheries and aquaculture sector, members of the Steering Committee, and the project research team collaboratively mapped the input and output flows of materials along the supply chain (fish production, processing, transport and logistics, wholesale and retail to consumers) across six production systems:

1. Wildcatch: Trawl and net
2. Wildcatch: Trap and line; hand gathering
3. Wildcatch: Recreational
4. Aquaculture: Sea cage
5. Aquaculture: Pond
6. Aquaculture: Estuarine shellfish

Drawing on CE and systems thinking expertise, and applying previously published frameworks, the team has developed a tailored CE framework for these six Australian fisheries and aquaculture production systems.

This framework ensures consideration of CE at both the project and program levels (using the Ellen MacArthur Foundation's CE principles) as well as in strategic action planning (using the Foundation's ReSOLVE framework for practical change). The production systems framework is nested within and connected to other industry sectors (e.g. agriculture) to help identify potential objectives, benefits, targets, amplification and implementation pathways for CE in the fisheries and aquaculture sector.

The workshop also identified appropriate case studies from across production systems that were further investigated in Phase 4.

Phase 4: Case studies – deep dives into best practice and adoption of CE

Based on engagement with partners and the systems mapping workshop (Phases 1 & 3), five domains for case studies were selected:

1. Plastic
2. Organic waste
3. Water/waste water
4. Energy
5. Collaborative consumption

From September to December 2021, semi-structured interviews were carried out across Australia, balancing location, sub-sectors, industries, degree of existing CE applications, and opportunities for CE integration. The interviews aimed to explore best practice and opportunities for the implementation of CE principles in the fishing and aquaculture sector.

The interviews focused on:

- Applicability of CE principles to current practices, including existing practices that support circularity but are as yet unrecognised (e.g. by-catch mitigation, which is analogous to REFUSE in the Ellen MacArthur Foundation's hierarchy of CE principles).
- Opportunities and barriers to building circularity as revealed by each case study – whether for the individual business, fishery or sector. Consideration was also paid to the financial, supply chain (i.e. availability of materials), social and geographical factors that enable or

inhibit circularity within the sector (or *between* fisheries/aquaculture and other marine or land-based sectors).

- Strategies for advancing and amplifying circularity (scaling up, scaling out and scaling deep) in light of known opportunities/barriers.

Findings from the interviews were collated and thematically coded, analysed and reported. The main objective of the semi-structured interviews was to develop a series of case study ‘industry vignettes,’ with outputs from this phase incorporated into both this report and the stand-alone case study communication materials.

Results/key findings

This research and consultation project has found that there are many CE activities occurring throughout the sector at a range of scales. However, there are significant barriers to overcome to fully realise the opportunities that CE presents. One finding is that the scale of the enterprise plays a role in the ability of any business to absorb elements of the supply chain and optimise the reprocessing of their waste streams.

Those businesses working on developing new and niche products may require additional collaborations to meet their circular goals. There is also a balance to be struck in terms of gathering the appropriate volumes of waste or reuse materials for a business to be economically viable, while ensuring that the transport and storage (e.g. freezing) of those materials does not invalidate a company’s existing carbon footprint.

Implications for relevant stakeholders

We explore the implications of our research for fishing and aquaculture industries using the concept of ‘territoriality’ (Tapia et al., 2021). This is a useful lens to understand opportunities and barriers to CE in the geographically dispersed, regional/remote sector, and pays attention to the following six factors:

1. Land-based factors, including physical endowments of materials

In relation to land-based factors and the physical endowments of materials, it may be possible to generate sufficiently large resource volumes for circular activities (such as recycling) if the fisheries and aquaculture industry is closely connected to terrestrial enterprises. This connectivity requires purposeful planning to be effective. One example shared with us of the negative consequences of insufficient planning is where a fishing co-operative planned to share water with a neighbouring agricultural enterprise. These plans became untenable following the development of water and electrical infrastructure for a residential housing estate adjacent to the co-operative’s site.

2. Agglomeration factors for resources, knowledge, collaboration and markets

Large organisations within the fisheries and aquaculture sector may have the internal capacity to absorb some elements of CE through vertical integration. By contrast, small to medium enterprises (SMEs) often have more limited capacity for vertical integration, and require deeper collaboration along value-chains to achieve CE goals. However, for the establishment of effective CE, agglomeration of resources (such as stockpiling materials, or creating larger centralised companies) is not always required. Global supply chains can often hide significant carbon emissions (e.g. cold chain, transport and logistics), while local supply chains incorporating CE collaborations at a smaller regional scale may be more flexible and better adapted to local needs.

In some instances, scaling up is possible, particularly where financial capital and volumes of material are available. In other situations, the nature of the activity may demand an upper limit to match CE goals. For instance, Farmer Meets Foodie provides a platform to connect growers/fishers directly to consumers, removing the need for long transport links. The focus on local supply and connection to growers is key to its business model. While this model could be replicated in other locations, the challenge is that if this social enterprise were to grow, it would begin to replicate the business models of larger seafood markets and lose its unique point of difference.

3. Access to and availability of physical infrastructure

Some challenges are intractable, such as the difficulties of working across long distances in Australia, and – for some parts of the sector – operating in remote locations. Due to the regional nature of the sector, a significant challenge is ensuring appropriate infrastructure is available in these widely dispersed and often remote locations. Establishing sites for onshore processing close to the point of capture (e.g. in the Gulf of Carpentaria) would allow for more efficient utilisation of organic waste.

4. Access to state-of-the-art technologies

There is already a wide range of technological innovation within this sector, and there are opportunities to harness this for CE. In terms of accessing these technologies, SMEs and newer enterprises face specific challenges that are not unique to this sector, but apply more generally. This means there is an opportunity for cross-sectoral collaboration to pool knowledge and overcome some of these barriers.

5. Knowledge and practical know-how

Our research found that, in many cases, CE is not deeply embedded in core business goals. Instead, it is often external drivers – such as the rising costs of waste disposal, fuels, electricity and water – that encourage businesses to explore circular opportunities, in the pursuit of ongoing financial viability. The good news is that this has led to many CE activities throughout the sector, at a range of scales and across production systems. Yet a key finding of this project is that the fisheries and aquaculture sector currently sees 'sustainability' only in terms of not depleting fish stocks or reducing pollution (which is, of course, essential). The challenge and opportunity is to encourage the industry to also see 'circularity' as key to operating in ways that are environmentally, socially *and* fiscally responsible.

6. Governance and institutional arrangements

There is a real opportunity to enhance current governance and institutional arrangements within the sector. Existing regulatory frameworks for circularity are, in many respects, insufficient. Additional regulation and support is especially urgent in order to reduce the wide range of plastics currently used in the Australian seafood system, and to establish firm plastics recycling protocols.

Keywords

Circular economy for fisheries and aquaculture, Sustainable supply chains, Innovation, Fisheries and aquaculture sustainability

Recommendations

Our recommendations cover a range of institutions within different business sectors and located across several geographical regions. For this reason we do not rank the recommendations numerically, but instead have indicated the priority level for action.

Recommended action	Responsibility	Priority
Create incentives and capacity for seafood industries to recycle more through **existing government initiatives that support recycling infrastructure** and **manufacturing innovation** (especially plastics and metals).	Seafood Industry Australia (SIA); other industry organisations; recycling/manufacturing initiative agencies	High
Develop regulatory frameworks that mandate the use **of plastic types that can be recycled within Australia** at a reasonable cost to businesses.	Commonwealth, State and Territory governments	High
Investigate methods to **make recycling of plastics that have been in contact with seafood easier** (e.g. autoclaving).	FRDC	Medium
Support the development **of compostable alternatives to plastic** in packaging for feed/bait bags and food retail.	Multiple institutions	High
Develop **cross-sectoral collaborations that can facilitate CE in fisheries and aquaculture**, such as: - establishing agglomeration of organic waste projects with farming and/or municipal waste collection organisations - recycling or replacing soft plastics in collaboration with the food retail sector - recycling plastics in pipes, nets and ropes in partnership with the farming sector**.**	Multiple institutions	High
Investigate development of **financial support and grant opportunities for SMEs** to jumpstart or scale up CE activities.	Regional development bodies; Commonwealth bodies	High
Survey the **regulatory factors that are obstacles or drivers for CE** in fisheries and aquaculture, and make recommendations for change.	FRDC	High
Investigate possibilities for changing fisheries and aquaculture regulatory and policy frameworks to **introduce CE into existing visions of ecologically sustainable development**. Ideas for action include: - placing more emphasis on regeneration in aquaculture, and regeneration offsets for fisheries - adding materials cycles (reuse, recycling, organic waste) to existing principles for protecting ecosystems in fishing and aquaculture.	FRDC; State, Territory and Commonwealth fisheries management agencies; industry organisations	Medium
Build awareness about and capacity for CE within the fisheries and aquaculture industry.	FRDC	High
Commission business research to support fisheries and aquaculture businesses **in developing new ideas and testing the feasibility of different CE initiatives.**	FRDC	High

Introduction

Project objectives

This report describes FRDC-commissioned and supported research by UTS to document the establishment of a circular economy (CE) in the Australian fisheries and aquaculture sector. The project has four aims:

1. To increase knowledge of how the concept of CE might be applied in the fishing and aquaculture sector, including in downstream activities (such as post-harvest processing and packaging).
2. To increase knowledge of how circular practices being applied in other sectors and industries relate to the fishing and aquaculture sector, and could be adopted by businesses. This includes exploring opportunities for fisheries/aquaculture to develop circular linkages with other marine and land-based sectors.
3. To identify opportunities and areas for exploration in the short-, medium- and long-term in order to progress a circular economy for fisheries and aquaculture.
4. To identify barriers to adopting circularity within the fisheries/aquaculture sector and known strategies for addressing those barriers.

Circular economy concepts

It is widely acknowledged that current resource use worldwide presents a major challenge to the sustainability and resilience of many industries. In CE, however, circular value chains allow for the efficient management of waste losses and maximise resource recovery.

A circular economy mimics certain cycles in nature in which there is no unnecessary waste. It does this in several ways. Firstly, by extending product life cycles (through reuse, refurbishment and remanufacturing). Secondly, by improving the efficiency of existing resource use (by increasing the resource consumption to production ratio, and by supporting business models founded on sharing or co-leasing rather than owning equipment/infrastructure). Thirdly, by recycling materials at end-of-life.

The transformation from a linear to a circular economy also needs to incorporate ‘regenerative development,’ which is the concept that the earth’s resources could restore and enhance – rather than deplete – natural capital as they cycle as materials through the economy.

For fisheries and aquaculture, CE presents new and practical solutions to existing challenges. It can tackle waste issues through the creation of new value chains for waste, and by substituting or recycling plastics. This has a three-pronged positive impact: increased resource efficiency, healthier aquatic ecosystems, and the creation of added economy-wide value and new employment. CE offers a more holistic and far-reaching vision of sustainability than the conventional focus on preventing overfishing and avoiding pollution. CE encompasses those too, but also involves thinking about the impacts of all plastics, metals, fuels, gases and other materials in supply chain activities (Figures 3, 13, 14).

CE in a fisheries and aquaculture context means using all parts of the creatures harvested in aquaculture (including tails, shells, guts and frames) for human or animal consumption, or as fertiliser to grow more food. It means minimising the waste materials that end up as landfill, or as harmful gas or water emissions. It means using vessels, equipment and gear for longer, and making sure materials can be recycled at the end of their useful lives. It means decarbonising the energy and materials used along every link in the supply chain.

The economic opportunities of circularity are widely acknowledged. The World Economic Forum estimates that the global adoption of CE principles would deliver significant cost savings and generate new value in the economy of up to US$4.5 trillion by 2030 (World Economic Forum, 2022). One estimate puts the economic benefits to Australia of adopting CE at AU$1.9 trillion by 2041 (PWC, 2021). However, current knowledge gaps constrain how CE may develop, at what scale it makes sense to close resource loops, and the strategies, policy mix and incentives needed to promote circularity.

This project thus addresses the urgent need to understand the industry context, opportunities and potential benefits of CE innovations, and to identify strategic approaches to sectoral circularity at scale.

The UK-based Ellen MacArthur Foundation (EMF) has been at the forefront of developing and advocating for the idea of a circular economy within industry, public policy and global government (Ellen MacArthur Foundation, 2015a).

The Ellen MacArthur Foundation defines a circular economy as “an industrial economy that is restorative or regenerative by intention and design” (2013: 14). CE makes the distinction between technological and biological cycles, and is thus a new economic model designed to decouple continued economic development from finite resource consumption (Webster, 2015).

In CE, toxic and non-recyclable chemicals and materials are designed out of products until they no longer circulate, with the remaining safe and recyclable materials moving through the economy in two cycles: a biological cycle, and a technical cycle.

In the biological cycle, discarded materials can ultimately be composted and returned to the biosphere.

In the technical cycle (which includes materials such as polymers, alloys and other human-made materials), products are designed for longevity, upgrading, refurbishment, remanufacturing and recycling.

These two cycles are represented in the EMF’s ‘butterfly diagram’ of CE systems (see Figure 1).

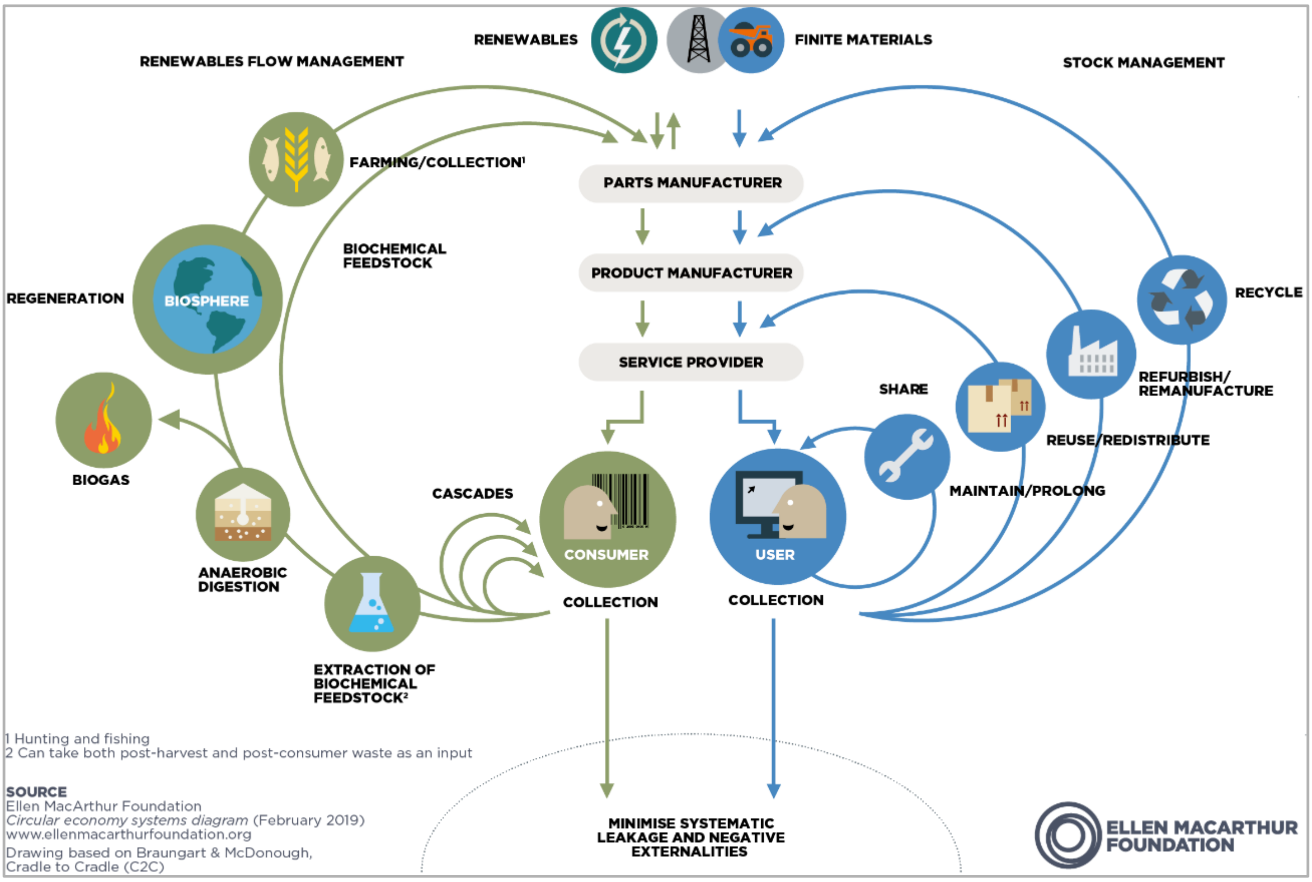

Figure 1. Circular economy systems diagram

Source: Ellen MacArthur Foundation (2019)

The EMF's definition of CE also highlights the importance of restorative and regenerative processes. The aim of CE is for industrial practices to do no harm: to restore and ideally to regenerate natural environments and resources (as opposed to depleting them). The full spectrum of actions that lead to circularity are covered in the EMF's ReSOLVE framework, which stands for: regenerate, share, optimise, loop, virtualise and exchange (see Figure 2).

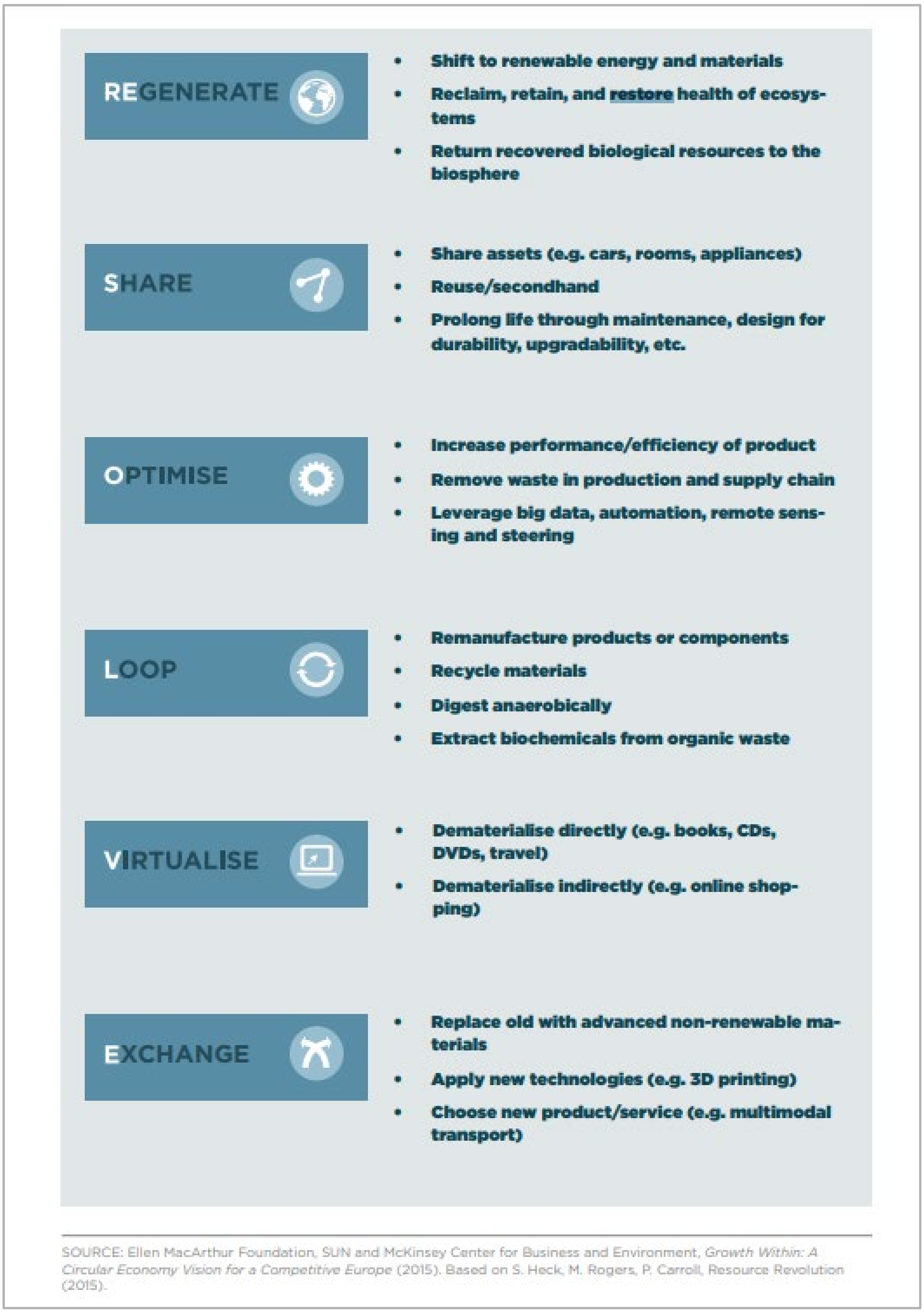

Figure 2. The ReSOLVE framework for a circular economy

Source: Ellen MacArthur Foundation et al. (2015a)

The concept of a bioeconomy has many overlaps with CE. Bioeconomy refers to any sector of the economy that creates value chains by using biomaterial (made from renewable biological resources) or by repurposing waste products from agricultural, aquatic and forestry sources (EEA, 2018). The re-use of biological waste can certainly contribute to CE. Yet a shift to using or producing biomaterials is not always sustainable in itself, as it can lead to the overexploitation of natural resources or disturbances in nutrient cycling. Certain biomaterials (such as bioplastics) may also not be fully biodegradable or recyclable (EEA, 2018).

Opportunities for CE are well-defined in some specific or niche industry sectors and geographical contexts. In general, however, there are significant knowledge gaps across every industry in terms of identifying and operationalising CE opportunities, identifying the scale at which it makes sense to close resource loops, and the business models, policy mix and incentives that have been proven to promote circularity.

Circular economy in seafood industries

For fisheries and aquaculture, CE offers a more holistic and far-reaching vision of sustainability than the conventional focus on preventing overfishing and avoiding pollution. CE encompasses those too, but also involves thinking about the impacts of all plastics, metals, fuels, gases and other materials in supply chain activities.

CE in a fisheries and aquaculture context means using all parts of the marine creatures harvested in aquaculture (including guts, tails and frames), either for human or animal consumption, or as fertiliser to grow more food. It means minimising the waste materials that end up as landfill or as harmful gas or water emissions. It means using vessels, equipment and gear for longer, and making sure materials can be recycled at the end of their useful lives. It means decarbonising the energy and materials used along every link in the supply chain (Figure 3).

A clear example of how circularity can work in the industry is ‘integrated multi-trophic aquaculture,’ a system in which the excrement from one organism (such as prawns) becomes food for another species in the ecosystem (such as algae).

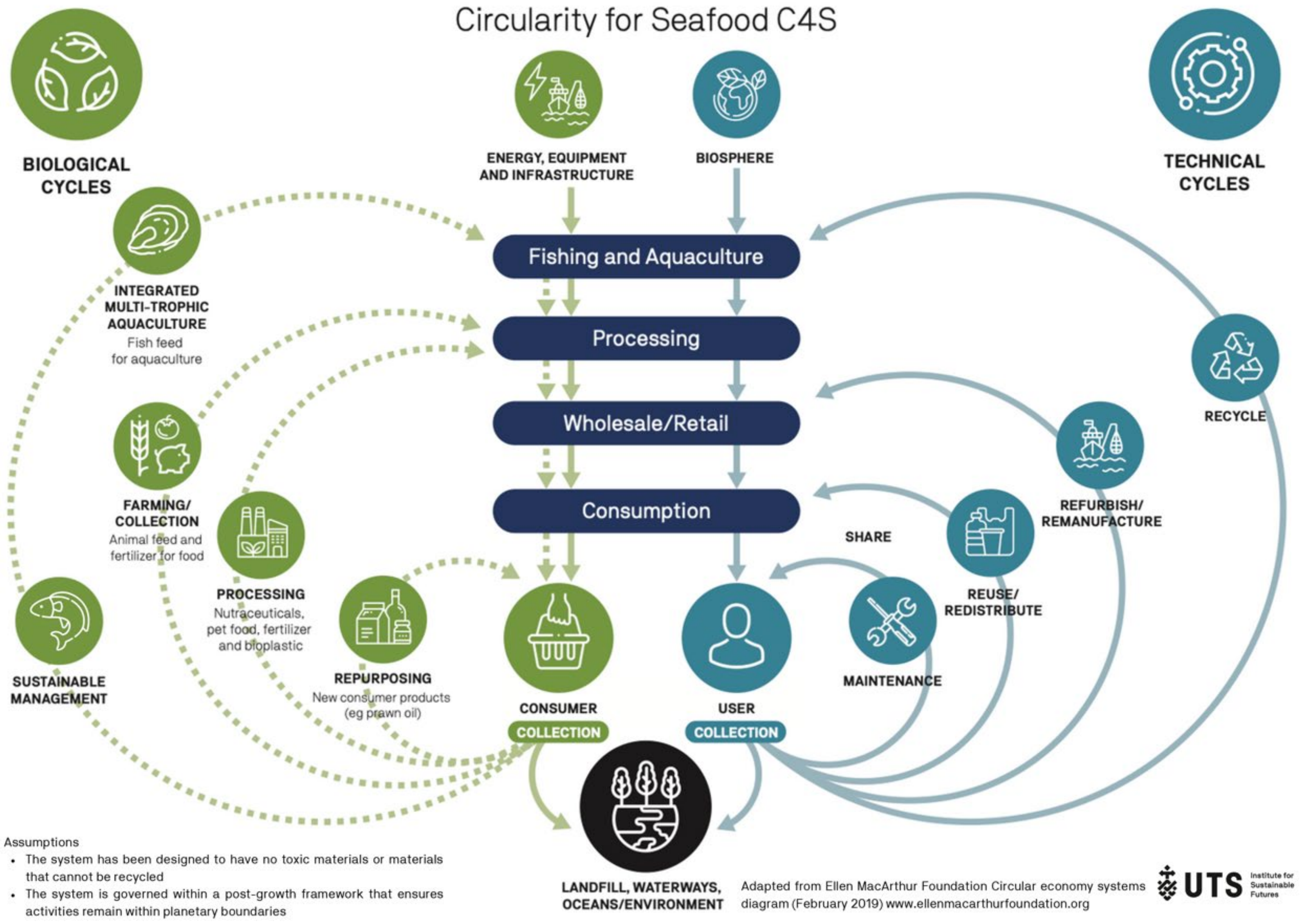

Figure 3. Circularity for Seafood (C4S) infographic

Image source: this project.

Existing CE frameworks, such as the EMF's ReSOLVE (Ellen MacArthur Foundation, 2015a) and 10Rs frameworks (Potting et al., 2017), have not yet been broadly applied within wider food system innovation debates (Pagotto and Halog, 2015) nor to the fisheries/aquaculture sector. This means that the opportunities for CE implementation within the seafood industry are still emerging (examples include replacing fish feed for abalone with wine production waste, or repurposing mussel shells as fertiliser).

Circular economy policy context in Australia

In Australia, CE is currently most prominent in waste policy at local, regional and national levels of government, especially for plastics, organic waste and packaging. There is some use of direct government regulation to reduce this waste (e.g. requirements for plastics recycling, product stewardship, or food waste).

Many of the government-led waste initiatives involve encouraging the private sector to move towards circularity, and there has been increasing private sector interest in CE. In 2018, the Australian Government's Department of the Environment and Energy launched a National Waste Policy (DEE, 2018) incorporating five principles of CE to improve waste management:

- Avoid waste
- Improve resource recovery
- Increase use of recycled material and build demand and markets for recycled products
- Manage material flows better to benefit human health, the environment and the economy
- Share information to support innovation, guide investment and enable informed consumer decisions.

In 2019, the Australian Government's National Waste Policy Action Plan (DEE, 2019) created even stronger incentives for a circular economy. Some of the key directions include regulating the export of waste glass, plastic, tyres and paper, increasing capacity for recycling domestically, and building demand for recycled products.

The Commonwealth, State and Territory governments are investing AU$600 million in recycling infrastructure, including initiatives to improve recycling infrastructure in rural and remote locations (DAWE, 2021c).

Two related Commonwealth initiatives are the Recycling Modernisation Fund (DAWE, 2021b) and the Modern Manufacturing Strategy (DAWE, 2021b; 2021c) to fund and support recycling and clean energy projects. The Modern Manufacturing Strategy (worth AU$1.5 billion) identifies recycling as a national manufacturing priority (DAWE, 2021b; 2021c).

The Australian Government's Sustainable Procurement Policy also creates incentives for CE. This policy has improved Commonwealth procurement rules so that sustainability criteria – including the use of recycled materials – must be considered as part of any 'value for money' assessment when purchasing goods and services (DAWE, 2021b).

In CE, resources are viewed as flowing in circles of use and reuse. Within existing Australian fisheries policy, the view of sustainability is more linear, with a focus on protecting biodiversity and ecosystems by preventing overfishing. CE principles – like actively regenerating environments or reusing/recycling waste created in fishing and seafood value chains – are not yet represented in the Australian fisheries or aquaculture policy arena. There are only a few isolated examples of CE principles being included in aquaculture policy (e.g. reusing some forms of aquaculture waste as a valuable input to food systems).

According to the Commonwealth Government's Fisheries Policy Statement, "[o]ur fisheries are managed in a manner consistent with the principles of Ecologically Sustainable Development, with no overfishing and the recovery of overfished stocks" (DAWE, 2021a: 2). Ecologically

Sustainable Development also takes into account social and economic factors, and the policy promotes principles of equitable resource-sharing among professional, recreational and Indigenous fishers.

While this is commendable, the language of the policy does not encourage circular, renewable stewardship of fish stocks, but simply institutes and defines property rights and quota management in common fisheries, with the goal of “maximizing the net economic return to the Australian community” (DAWE, 2021a: 2).

A full review of all relevant State and Territory fisheries policy is beyond the scope of this report, but, in general, State and Territory fisheries policy takes a similar approach to Commonwealth policy.

For instance, the objectives of the NSW Fisheries Management Act (1994) “are to conserve, develop and share the fishery resources of the State for the benefit of present and future generations” (Barclay et al., 2020: 47). The highest-priority objective is to protect marine ecologies and biodiversity. Secondary objectives include promoting viable fishing industries, resource sharing among user groups, and creating social and economic benefits for the wider NSW community (Barclay et al., 2020).

As is the case in Commonwealth fisheries policy, recent NSW fisheries policy establishes property rights for fisheries resources through quota management (Barclay et al., 2020), and institutes Harvest Strategies (NSW DPI, 2021). The latter is a method for pre-determining the steps to be taken to address any stock declines that may occur. Circularity principles to encourage reducing/reusing/recycling waste from the sector are absent. Marine environments are not discussed in terms of regenerative practices.

In existing Australian aquaculture policy, Ecologically Sustainable Development is a stated goal. Both production and economic growth are key policy goals in aquaculture, which is in contrast to fisheries policy (where growth in production is generally not a goal because of concerns about overfishing). The National Aquaculture Strategy (DAWR, 2017) sets the objective of doubling the value of the aquaculture industry to AU$2 billion by 2027, in line with the development of what is called the broader ‘blue economy.’

Environmental regulation related to aquaculture is generally a State and Territory responsibility, enforced through processes of development approval, evaluating land-clearing applications, and preventing polluted waste water discharges.

CE is not centrally positioned in the National Aquaculture Strategy (DAWR, 2017) as a potential solution to environmental risks in aquaculture, and the world ‘circular’ is not used in the document. The strategy takes a mostly linear approach to preventing environmental damage from aquaculture activities, focusing predominantly on the risks of water pollution, disease spreading from aquaculture farms, and biosecurity risks from imports (including aquaculture feed).

The strategy does, however, showcase as best practice some circular economy activities within the sector. One example used is regenerative aquaculture, where species (such as native shellfish) are used to remediate degraded marine environments. Another example is Aboriginal communities in South Australia using ‘integrated multitrophic aquaculture,’ where waste from one aquatic species is used to feed another.

Circular economy policy example: plastic waste

The unique properties of plastics (produced from fossil fuels) means that they are used extensively in many parts of seafood supply chains. Plastic waste enters ocean ecosystems and persists in the environment, causing all kinds of environmental problems.

Disposing of plastics is becoming more firmly regulated and very costly to businesses. However, plastic waste continues to pose a major challenge to the establishment of circularity in the fishing industry because biosecurity and food safety concerns constrain its reuse. Many businesses are actively seeking to eliminate plastic waste and to explore the use of alternative materials.

In 2021, the Australian Government Department of Industry, Science, Energy and Resources commissioned CSIRO to develop a CE roadmap for plastics, glass, paper and tyres, and also to create a National Plastics Plan (Schandl et al., 2020; DAWE, 2021c). The plan includes actions to prevent plastic waste problems at the source.

Initiatives in these frameworks that are relevant to the seafood industry include efforts to eliminate the use of plastic packaging that is not compostable, and eliminating the use of expanded polystyrene in food and beverage packaging.

These approaches create incentives to encourage industry to make voluntary changes, rather than using regulation to force change. For instance, the Australian Government states that it is “working with industry to fast-track phase outs of problematic plastic materials” (DAWE, 2021c: 5).

One form of regulation that the Commonwealth is working on in concert with States and Territories is aligning regulation to ban single-use plastics where practical. The Australian Government has also committed to banning exports of certain types of plastics to reduce global plastic waste (DAWE, 2021c: 7). Some States and Territories have also implemented regulation of plastic waste (see Figure 4).

Figure 4. Scorecards for State action on plastic pollution

Image source: World Wildlife Foundation 2019 scorecards, as presented in Schandl et al. (2020).

Non-regulatory action on CE includes Australian Government commitments to (DAWE, 2021c):

- Establish a National Circular Economy Hub by the end of 2021
- Review the National Environment Protection (Used Packaging Materials) Measure 2011 and the Australian Packaging Covenant to see how well the co-regulatory arrangements are working to reduce the environmental impacts of packaging
- Work with Boomerang Alliance (an Australian NGO) to eliminate single-use plastics from popular beach areas, and support businesses to switch to alternative products.

The Australian Government has also proposed to work on “regional solutions” to identify and assess plastics collection processes for remote and regional areas “through partnerships,” but without specifying funding arrangements (DAWE, 2021c: 7).

The National Plastics Plan (DAWE, 2021c) lays out a series of proposed actions for industry:

- Transition towards easier-to-recycle plastics, such as Polyethylene Terephthalate (PET), High-Density Polyethylene (HDPE), Low-Density Polyethylene (LDPE) and Polypropylene (PP)
- Encourage the design of easier-to-recycle products
- Move towards all packaging being reusable, recyclable or compostable
- Phase out problematic and unnecessary single-use plastic
- Commit to increasing the use of recycled content through the Australian Packaging Covenant Organisation’s (APCO) Member Pledge program
- Work across the plastics recycling supply chain to develop nationally consistent performance standards for material recovery facilities to deliver clean feedstock for remanufacturing.

Method

Our research project used a mixed method approach (comprising an in-depth literature review, a systems mapping workshop, and semi-structured qualitative interviews to inform case studies). The four key phases were:

- Phase 1: Co-design partnership formation and confirmation
- Phase 2: Literature review of circular economy material
- Phase 3: Systems mapping workshop
- Phase 4: Case studies – deep dives into best practice and adoption of CE in the sector

The methods we chose to use are qualitative. CE in fisheries and aquaculture, and in Australian food production in general, is still in its infancy. As a result, quantitative data related to circularity in these contexts does not yet exist, and it was beyond the scope of this project to generate that kind of data from scratch.

A concurrent FRDC project on plastics in fisheries and aquaculture (FRDC 2020-084) will generate useful quantitative data in the near future, as will other emerging research projects, such as an AgriFutures Australia project on developing a national waste management strategy for primary industries (PRO-015140).

Circular economy frameworks

This study used a systems approach that drew on the Ellen MacArthur Foundation's key international guidelines: the ReSOLVE framework for CE, which is operationalised through the 10Rs (a set of practical steps for change) (Ellen MacArthur Foundation, 2015a; 2015b; Potting et al., 2017). This ensured that we incorporated best practice CE at both the level of strategic action planning (ReSOLVE) and at the project and program level (the 10Rs).

This systems approach also helped the project team to identify potential objectives, targets and implementation pathways for CE in the fisheries and aquaculture sector.

The 10Rs framework (see Figure 5) was used throughout the data collection and during the workshop feedback session, with the following aims:

- To guide the investigation of international best practice, leadership, case studies and policies by making sure that a hierarchy of increasing circularity is established and evaluated in the findings (Phases 2 and 4)
- To engage internal stakeholders in identifying current/planned CE initiatives – both formal and informal – using the '10Rs CE worksheet' developed for this project (see Figure 5) (Phases 2 and 4)
- To categorise the data collected from internal stakeholders to be shared in the workshop, and to identify current CE projects/programs and initiatives, as well as gaps, challenges and opportunities.

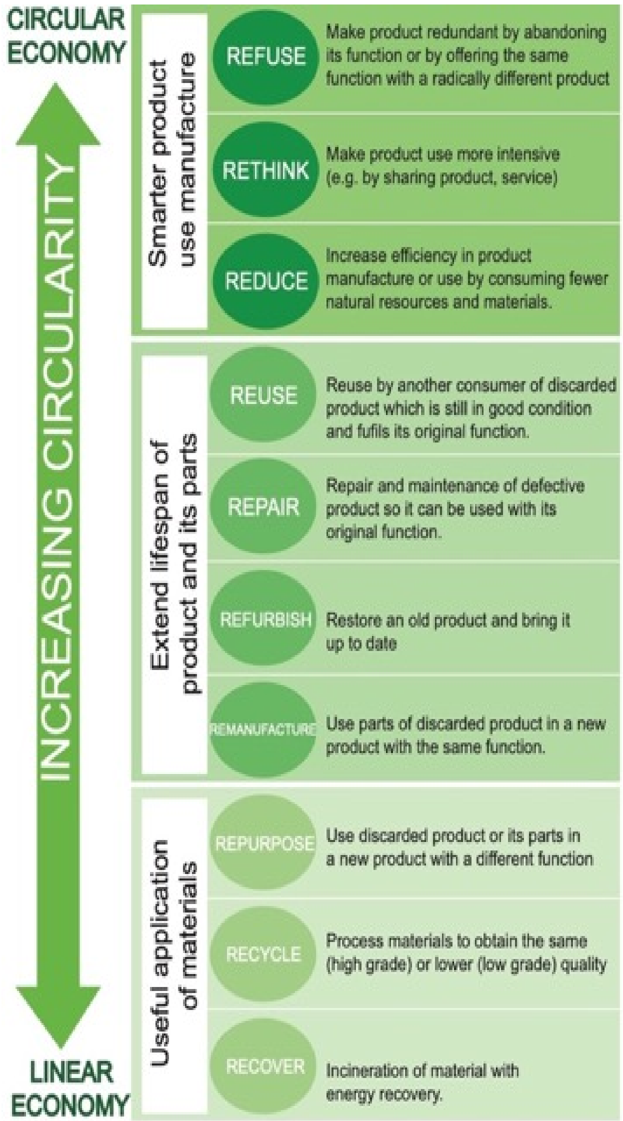

Figure 5. The 10Rs framework.

Source: Potting et al. (2017)

The 10Rs framework

Our methodology takes as its starting point the Ellen MacArthur Foundation's definition of a circular economy as "an industrial economy that is restorative or regenerative by intention and design" (2013b: 14).

CE is an alternative material-flow model that is cyclical. It is designed to replace the traditional linear model, which is based on an extract-produce-use-dispose approach. The cyclical CE model instead emphasises product, component and material reuse; remanufacturing; refurbishment; repair; cascading; and upgrading. It creates a cradle-to-cradle life cycle for the entire value chain. The aspiration for CE is to create no waste, only secondary raw materials produced and reused in cycles.

CE requires substantial transformations in design, production, consumption, use, waste and reuse practices. There are several guidelines outlining concrete steps for change, including the EMF's 10Rs framework adopted by the EU. This requires consideration of all ten of the following factors: Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle and Recover (Potting et al., 2017).

As an economy moves closer to being circular, it progresses up this hierarchy, from Recover all the way up to Refuse. Each step is a positive one, with the final goal being full circularity (Ellen MacArthur Foundation, 2015a).

The EMF's ReSOLVE framework is complementary to the 10Rs. While the 10Rs identify the hierarchy of circularity in individual projects/programs or initiatives, ReSOLVE provides system-wide insights into how regeneration, sharing, optimisation, loops, virtualisation and material exchange can be facilitated at a sectoral scale (see Figure 6).

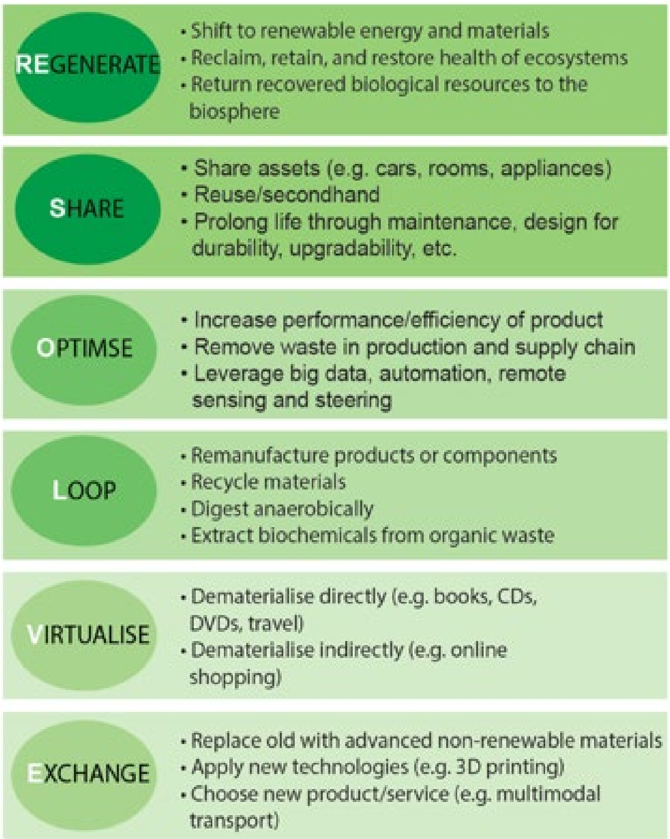

Figure 6. ReSOLVE framework for CE

Source: Ellen MacArthur Foundation (2015a)

The ReSOLVE framework

CE rests on three key principles:

1. Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows

2. Optimise resource yields by circulating products, components and materials at the highest utility at all times, in both technical and biological cycles

3. Foster system effectiveness by revealing and designing out negative externalities, such as water, air, soil and noise pollution; climate change; toxins; congestion; and negative health effects related to resource use.

These three principles of the circular economy can be translated into a set of six business actions: Regenerate, Share, Optimise, Loop, Virtualise and Exchange. Together, these form the ReSOLVE framework.

Each of the six actions represents a circular business opportunity.

These actions all increase the utilisation of physical assets, prolong their life, and shift resource use from finite to renewable sources. Each action reinforces and accelerates the other actions in the framework.

We used the ReSOLVE framework throughout the data analysis phase and in the workshop event to identify stakeholder goals and objectives for achieving CE. This helped us to set the following goals:

- To categorise and confirm existing projects and initiatives that incorporate CE principles, and to identify gaps in current/planned CE initiatives
- To clarify the role of various actors in CE, and to identify opportunities and barriers within organisations of varying size and complexity
- To facilitate defining the overall scope, targets, objectives, implementation pathways and circular strategies for achieving CE.

Integrating these two frameworks (the 10Rs and ReSOLVE) was a unique way of meeting the project's objectives. It helped to guide the development of a working definition of CE for the fisheries and aquaculture industry. It also allowed us to consider CE at different scales (local initiatives, sectoral planning and policy/governance), and informed our four-phase research design.

Phase 1: Co-design partnership formation and confirmation

UTS worked closely with the FDRC and a project Steering Committee (SC) to co-develop the project design. The SC included representatives from government, the private sector, civil society groups from within the fisheries/aquaculture sector, and leaders of CE initiatives. UTS researchers liaised with the SC for the project's duration.

The co-design partnership phase brought together a range of sectoral stakeholders into the Steering Committee (SC) to guide the project. This included representation from the following organisations:

- ANU
- Austral Fisheries
- CSIRO
- Fish Matter
- Lifecycles
- National Marine Mammals Advisory Committee
- Indigenous Reference Group (Fisheries Research Development Corporation)
- Great Barrier Reef Marine Park Authorities Ecosystems Advisory Committee
- GBRMPA Indigenous Reef Advisory Committee
- NSW Aboriginal Fishing Advisory Council
- NSW Circular
- NSW Seafood Industries Advisory Council
- NSW Fisheries Research Advisory Body
- Tassal
- The University of Adelaide
- Venus Shell Systems

The SC was directly involved in each of the phases. They provided key literature for the review, participated in the systems mapping workshop, and co-developed the five case studies. SC members also assisted by providing key contacts for interviews within sectors for the final phase of the project.

Please see Appendix 1 for the terms of reference for the SC.

Phase 2: Literature review of circular economy material

A desktop review of the existing literature on CE identified a range of relevant research, applications, innovations and examples of best practice. This was used to inform the stakeholder systems mapping workshop, where these findings were disseminated to industry representatives.

In this section, we describe the literature review process, including how we identified primary domains and keywords, and how we conducted keyword searches of select articles in Scopus (a peer-reviewed academic literature database).

The three key domains we initially defined were:

1. International CE applications and best practice in i) other sectors, and ii) within fisheries/aquaculture
2. Australian CE applications in other sectors
3. The extent of CE adoption and active innovation in Australian fisheries and aquaculture.

Table 1: Domain and keywords for literature review

Domain	Keywords
International CE applications and best practice	Circular economy
Australian CE applications in other sectors	Circular economy, Australia
Australian CE applications in fisheries and aquaculture	Circular economy, climate change, marine systems, Australia, resource-efficiency, bioeconomy, recycling, reuse, materials, plastics, fuel, pharmaceuticals, barriers, adaptive management, fisheries, regenerative fisheries and aquaculture, regenerative fisheries, supply chains

Technical reports and articles that were published more than ten years ago were excluded, though it should be noted that many of the more recent CE publications build on long-standing concepts and projects from the fields of industrial ecology and resource conservation.

We conducted our search using the Scopus database of academic literature. We initially searched for keywords in the titles, keywords and abstracts of publications. This allowed us to identify a broad range of literature, and then to evaluate and hone our selection according to relevance.

There was a high number of publications identified within the broad domain of CE internationally (10,896), and fewer for CE in Australia (68) – please see Appendix 2 for the literature search details and numbers of references found in each domain by search terms. Searches specifically for CE in Australian fisheries and aquaculture yielded no results in the literature, so we used related terms (such as 'adaptive management' and 'supply chains') to find relevant publications. It is noteworthy for the purposes of this study that there were no searchable publications on CE in the Australian seafood sector as of 2021.

One challenge we faced was that some of the most relevant studies were still in the process of being finalised while this literature review was being undertaken (for instance, the FRDC project 2020-084: *An audit of plastic use in the fishing and aquaculture sectors*, which is still in progress).

The final list of analysed literature was generated from abstract and keyword searches of the Australian CE literature and the international CE literature, with a focus on key concepts (such as CE business models, CE applications that could be used in the fisheries and aquaculture sector, and the bioeconomy).

Phase 3: Systems mapping workshop

A systems mapping workshop was conducted online in July 2021, informed by the findings from Phases 1 and 2.

There were 36 participants in this workshop, including members of the Steering Committee. These participants were from fishing and aquaculture companies, seafood retail and trading businesses, fisheries and aquaculture industry organisations, fishery co-operatives, recreational fishing bodies, research and consulting organisations, and the Marine Stewardship Council. Project investigators acted as facilitators for the workshop and managed the Zoom breakout rooms.

This workshop mapped the input and output flows of materials along the supply chain (fish production, processing, transport and logistics, wholesale/retail, and consumption) across six production systems:

- Wildcatch: Trawl and net
- Wildcatch: Trap and line, hand gathering
- Wildcatch: Recreational
- Aquaculture: Sea cage
- Aquaculture: Pond
- Aquaculture: Estuarine shellfish

Drawing on systems thinking expertise, and applying best practice CE frameworks, the team developed a tailored CE framework for these six Australian fisheries and aquaculture production systems.

This framework ensures consideration of CE at both the project and program levels (using the Ellen MacArthur Foundation's 10Rs steps for change) as well as in strategic action planning (using the Foundation's ReSOLVE framework) (Ellen MacArthur Foundation, 2015a; 2015b).

The tailored production systems framework is nested within, and connected to, other industry sectors (e.g. agriculture) to help identify potential objectives, benefits, targets, amplification and implementation pathways for CE in the Australian fisheries and aquaculture sector.

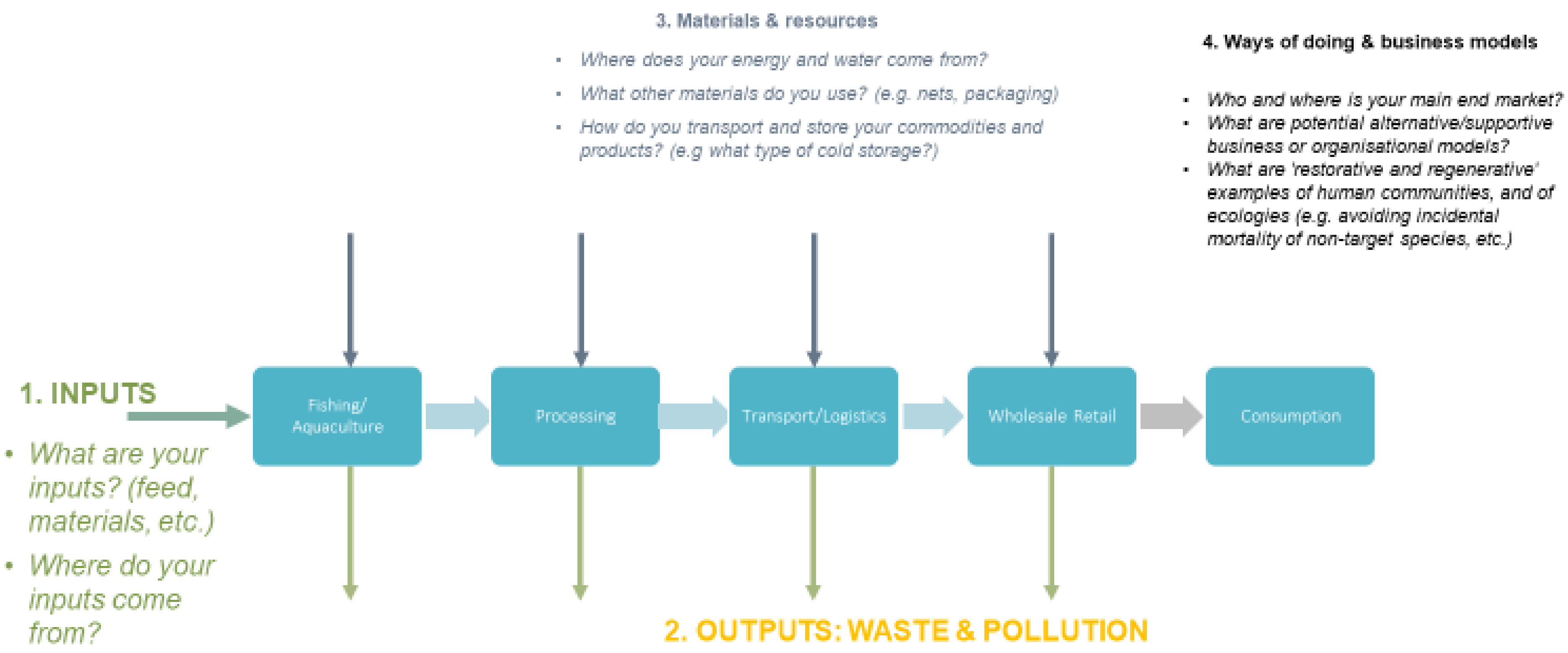

Figure 7. Supply chain template for stakeholder workshop (used to map inputs and outputs of materials, and existing/future CE business models)

Please note: Figures 7 and 8 are discussion stimulus graphics, not input-output graphics. For this reason, they do not contain all the details a CE input-output graphic would normally include (e.g. types of materials, energy, waste types and emissions). Please see Figures 13 and 14 for our detailed infographics that include input-output flows.

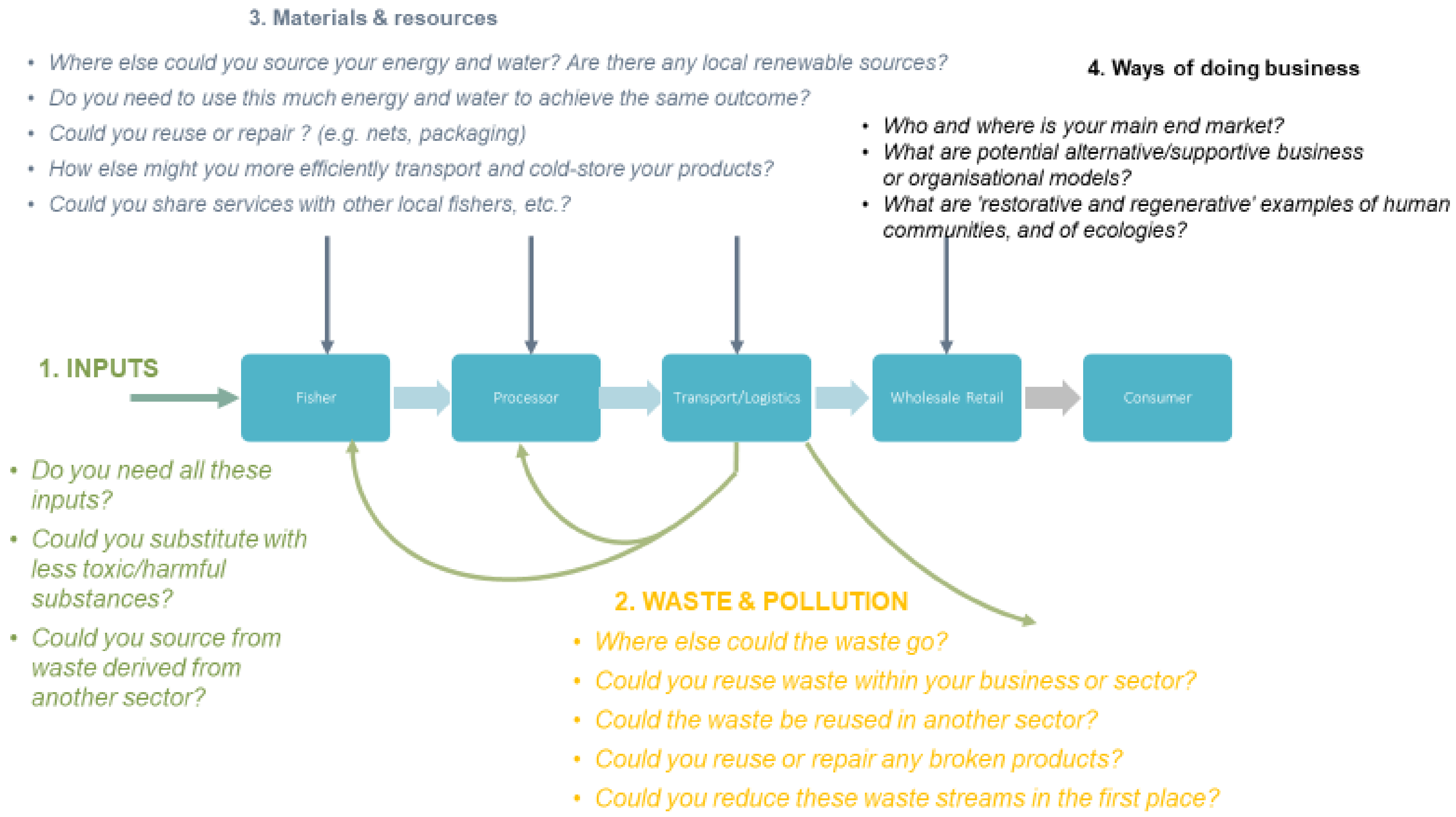

Figure 8. Supply chain template for stakeholder workshop (identifying opportunities and barriers to CE)

At the workshop, a systems mapping activity was undertaken, with input from the SC, project investigators, and additional experts from within the Australian seafood sector. The workshop participants also helped to identify appropriate case studies from across production systems that were further investigated in Phase 4.

Phase 4: Case studies – deep dives into best practice and adoption of CE

The suitability of potential case studies for inclusion in this project was assessed according to the criteria detailed in Table 2.

Table 2: Criteria and categories to guide the selection of suitable case studies

Criteria	Category
Scale of circularity	Individual business Two or more value-chain nodes Regional initiative
Hierarchy of principals	Design out waste Keep materials in use Regenerate natural environment
Environmental impacts addressed	Material inputs Waste and pollution Biodiversity
Degree of regeneration	Sustainable (harm minimisation) Restorative (recover/reuse materials) Regenerative (enhance environment)
Technology readiness status	Research Development Deployment Scale-up
Opportunity	Short-term (1-2 years) Medium-term (3-5 years) Long-term (>5 years)
Barriers	Political Economic Social Technological Environmental Legal
Scalability	Fishery Region State Nation

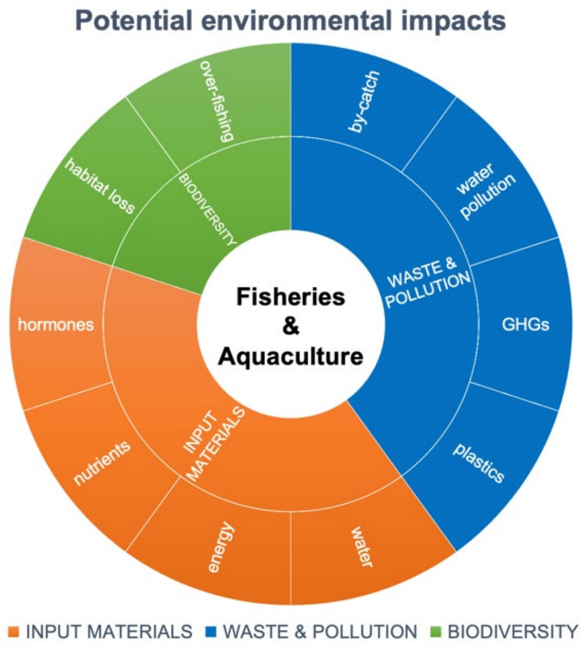

Figure 9. Fisheries and aquaculture input materials; waste and pollution; biodiversity

The justification of the CE categories presented in Table 2 is as follows:

Scale of circularity

Individual businesses can only go so far on their own towards CE (e.g. through production efficiency). A true CE requires a functioning market for circular activities, and value chain collaboration.

Hierarchy of CE principles

In ascending order of priority (according to the EMF [2015]), CE seeks to:

1. Design out waste and pollution (once products are designed, it is hard to reverse damage)

2. Keep products and materials in use (reuse, repair, remanufacture/recycle)

3. Regenerate the natural environment (going beyond ‘protect’ to ‘restore’)

Environmental impacts addressed

There is a wide range of potential environmental impacts caused by processes in the sector that circular systems seek to address.

Figure 10. Transition stages in CE

Source: Mukheibir, Jazbec & Turner (2020)

Degree of regeneration

Sustainability initiatives often seek to protect natural systems from further harm, yet this may now be insufficient given the environmental challenges the planet is facing. As Mukheibir, Jazbec and Turner write, “[W]e need to consider restoring the material balance and then to actively go further with regenerative actions that will ensure the planet’s health, resilience and ability to adapt” (2020: 4).

We selected the following five domains for case studies of CE best practice: plastic, organic waste, energy, collaborative consumption, and water/waste water (see Figure 11).

This selection was informed by the above criteria, insights from the systems mapping workshop with stakeholders, and discussions with Steering Committee members and FRDC staff. More details about case study selection are included in Appendix 3.

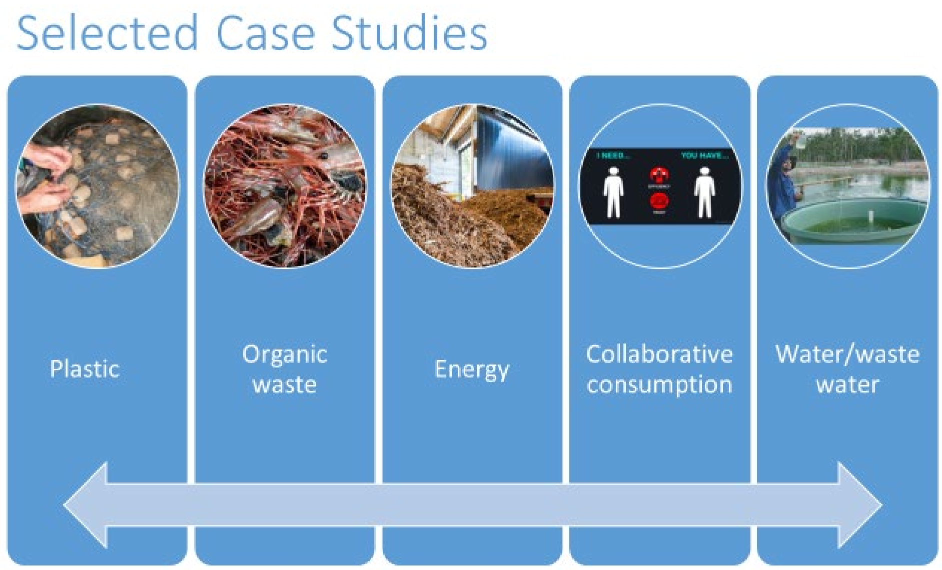

Figure 11. Five case study domains

From September to December 2021, we also carried out semi-structured interviews with stakeholders to inform our selection and development of case studies (up to five interviews per case study).

We selected interviewees from a diverse range of geographical locations in Australia, sub-sectors and industries. We also tried to make selections based on both existing CE initiatives and potential opportunities for CE in the fisheries/aquaculture sector. The goal was to showcase CE best practice, as well as to capture some of the challenges faced by businesses or sectors trying to incorporate CE principles.

We used a snowballing technique to engage the desired number of businesses (n=35) in the interviews. This number was considered sufficient as our aim was not to achieve statistical representation (which is beyond the scope of this project), but simply to explore CE successes and challenges within a sample of organisations and businesses in the sector.

Table 3: Organisations interviewed by the project team to inform the case studies

All Fish for Dogs	A Culture	Australian Barramundi Farmers' Association
Australian Oysters	Ballina Fishermen's Co-operative Ltd	Blue Harvest
CARAPAC	Coast4C	Dinko Tuna
Disruptive Packaging	Farmer Meets Foodie	Great Wrap
Grounded Packaging	Huon Salmon	Jumbunna UTS
Kansom	Lakes Entrance Fishermen's Co-operative Ltd.	Mainstream Aquaculture
Malanda Seafood	Mobius Farms	Murray Cod Australia
NSW DPI	NSW Shellfish Committee	Ocean2Earth
Oceanwatch	Oz Fish	Seaweedery
Spresser	Tailor Made Fish Farms	Tassal
TomKat Line Fishing	Tricep	UTS Seafood Safety Group
Venus Shell Systems	Wallis Lake Fishermen's Co-operative Ltd.	

The interviews focused on:

- Applicability of CE principles to current practices (including existing practices that supported circularity but were as yet unrecognised)
- Opportunities and barriers to build circularity within the case study business, fishery or sector (with a focus on financial, supply chain, social and geographical factors that enable or inhibit circularity within the sector), and between the fisheries/aquaculture sector and other marine or land-based sectors
- Strategies for advancing and amplifying circularity (scaling up, scaling out and scaling deep) in light of the known opportunities/barriers to CE.

The interview guide can be found in Appendix 4. The main objective of the semi-structured interviews was to develop a series of ‘industry vignettes,’ which are incorporated into this report as well as the stand-alone case study communication materials.

Research findings and discussion

This section shares and discusses the findings from Phases 2, 3 and 4 of this research project (the literature review, the systems mapping workshop, and the identification and creation of relevant case studies through semi-structured interviews with stakeholders).

Literature review

Our review highlighted that there is very little literature examining the application of CE within the fisheries and aquaculture sector in Australia. Globally, the CE literature is also sparse for the seafood sector.

For this reason, we also included literature on CE concepts and processes in other sectors (including CE business models, innovation processes, and the impacts of geography on CE opportunities and challenges).

In our review, we focused on:

- CE applications in specific sectors
- CE applications in specific business models
- 'Territoriality' (Tapia et al., 2021) as a concept that helps to explain opportunities and obstacles to CE in the Australian fisheries and aquaculture sector.

Opportunities for CE are well-defined in some specific or niche sectors and geographical contexts, but in general there are some significant knowledge gaps. These include identifying and operationalising CE opportunities, and the business models, policy mix and incentives that work to promote circularity.

Product loops and scale

In terms of the challenge of identifying at what scale it makes sense to close product loops, Stahel and Clift (2016) refer to three product loop scales in CE.

Loop 1 focuses on product reuse through second-hand sales, or private and commercial reuse (such as reusing or refilling containers, etc). Loop 2 focuses on product repair and remanufacturing to meet new uses. Loop 3 focuses on residual products and materials, reprocessing for new products, or energy recovery.

Loop 1 and Loop 3 have strong local and regional scales (especially for biological materials). For Loop 2, the scale can vary depending on the product and the repair/remanufacturing involved.

Tapia et al. (2021)'s concept of 'territoriality' (the geographical location of a business and regional/remote scale of a sector) is useful to isolate six factors that impact CE opportunities and implementation in the Australian seafood industry:

1. Land-based factors, including physical endowments of materials
2. Agglomeration factors (for resources, knowledge, collaboration and markets)
3. Access to and availability of physical infrastructure
4. Access to and availability of state-of-the-art technologies
5. Access to knowledge and know-how
6. Governance and institutional arrangements.

Points 1 and 2 (above) define CE opportunities; points 3 and 4 enable CE in practice; and points 5 and 6 allow for system-wide circular clusters and transformations.

CE economic opportunities and business models

In terms of economy-wide opportunities, CE can promote economic diversity and growth across many sectors (including waste and recycling management, transport and logistics, manufacturing and remanufacturing, and infrastructure).

There are also a range of indirect benefits of CE to the economy. Knowledge and expertise related to CE are valuable and can be exported. CE creates new incentives for innovation in the manufacturing sector (e.g. product design for reuse) and in the recycling industry (e.g. more accurate technology for collection and separation), as well as in logistics. CE also stimulates new business activity within the remanufacturing sector (such as repair and reuse of electronic products) (Lacy et al., 2014).

From an individual business perspective, there are many economic benefits to CE. A circular approach allows businesses to mitigate the risk of rising resource costs by taking ownership of their products and extending their life cycles.

Recycling and reuse activities give businesses more control over the full material cycle of their products, and this can offset their need to hedge against the future price volatility of resources (Ellen MacArthur Foundation, 2015a). The complex systems required for effective recycling and reuse are still, however, a barrier for many businesses. This will continue to be the case while disposing of materials and products in landfill is relatively cheap, but it's a promising sign that increased waste levies and overall waste policy are incentivising reuse.

In the literature, the main criticism of CE is that it does not adequately engage with the bigger issue of the unsustainable growth in demand for resources. Critics point to the fact that it is theoretically impossible to continually reuse and recycle materials without some losses or environmental impacts. Materials recycling, for instance, needs large energy inputs (Allwood, 2014). This suggests that there is an upper limit in terms of the efficiency of resource cycling and recycling.

A truly sustainable model of CE must also focus on reducing the *demand* for resources, and acknowledge the natural limits to resources. This is particularly relevant within the food and fibre sectors. To date, CE thinking has focused less on reducing demand, and more on new consumption models (such as product service systems, where services are supplied instead of a product).

There are very limited examples of product service systems in fisheries and aquaculture, but there are opportunities in the existing seafood supply chain (particularly in processing, storage, packaging and transport).

The shift towards CE in fisheries and aquaculture will also require significant input from industrial design and marketing experts, in order to understand and change industrial practices and consumer behaviours.

There will be strong local and regional dimensions to circular activities in the fisheries and aquaculture sector, as cycling products will be geographically bounded (Korhonen et al., 2018). In the broader CE literature, the full implications of this are underexplored (Merli et al., 2018; Bahers and Durand, 2017).

Business models define the way a firm does business, and determine whether CE opportunities can be operationalised. A business model dictates how an organisation creates value (by exploiting materials, knowledge, technology, partnerships); how it delivers value (offering products, processes or services to customers, society and/or the environment); and how it captures value (through various revenue models).

Robust CE business models support activities that boost resource productivity. They promote resource use efficiency across the supply chain, including in how consumers access, use and reuse products and services.

For CE to thrive in the wider economy, there is an urgent need for radical new business models. A positive sign is that these are growing in number (Bocken et al., 2016).

In the literature, there are many suggestions of how to categorise these emerging business models (Bocken et al., 2016; Bocken et al., 2014; Bakker et al., 2014; Giessdoerfer et al., 2020; Henry et al., 2020). Geissdoerfer et al. (2020: 7) draw on an extensive literature review of the field to define circular business models as follows:

> [B]usiness models that are cycling, extending, intensifying, and/or dematerialising material and energy loops to reduce the resource inputs into and the waste and emission leakage out of an organisational system. This comprises recycling measures (cycling), use phase extensions (extending), a more intense use phase (intensifying), and the substitution of products by service and software solutions (dematerialising).

Figure 12 highlights these four broad sets of CE business models.

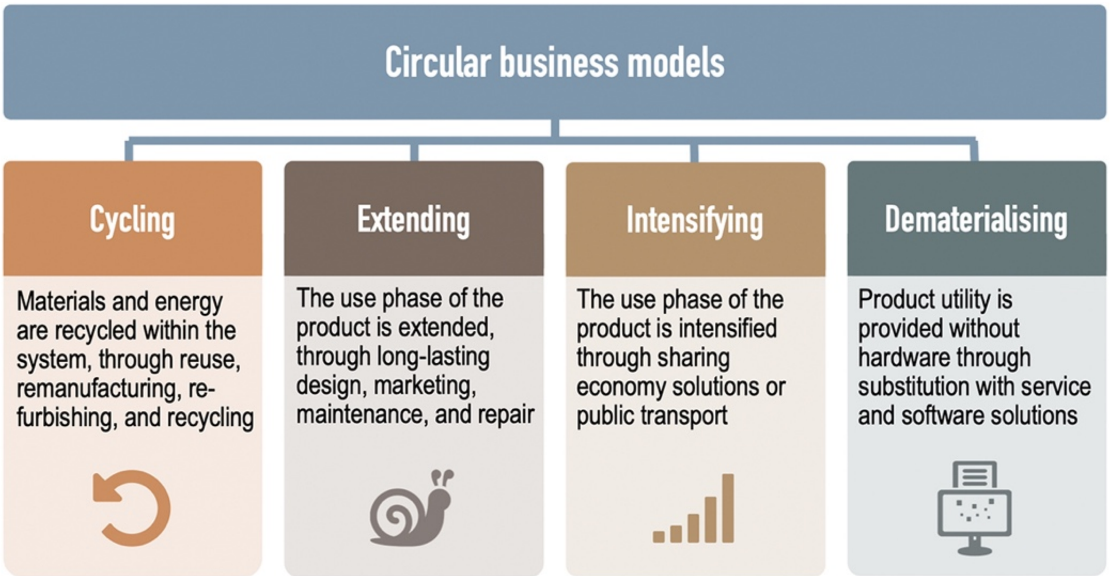

Figure 12. Circular economy business models

Source: Giessdoerfer et al. (2020)

Innovation and the circular economy

Innovation is crucial for any business to remain competitive. In CE, innovation is even more important because businesses participating in circularity also need to be 'open' in their innovation processes (Sharpe et al., 2017).

The existence of innovation ecosystems – dynamic and co-evolving communities of actors (e.g. companies, research centres and institutes, and government agencies at varying levels of jurisdiction) who drive innovation through close collaboration – are critical for the adoption of CE (Moodie et al., 2018; Tapia et al., 2021).

CE innovation ecosystems are more than just industrial clusters. The co-creation and sharing of CE knowledge is not just industry-specific. It needs to bridge local, regional and global knowledge systems and bring together stakeholders across many scales. For this reason, sophisticated collaboration skills are necessary in the circular economy, so that businesses and organisations can come together to negotiate and pool resources, and facilitate interactions up and down the supply chain (Sharpe et al., 2017).

Current applications

Applications of CE principles to date have focused mostly on recycling activities, even though recycling only represents a fraction of the wider CE economic potential.

An overall gap in the literature is concrete evidence of how CE applications can be scaled up to significantly transform production and consumption systems. There is very little literature on how overarching economic and social systems can be changed to promote CE. In existing policy domains, CE has mainly evolved as a targeted solution to waste issues (De Schoenmakere et al., 2017). More research is needed to demonstrate and measure the wider environmental benefits of CE, beyond waste reduction.

In the fisheries and aquaculture sector, the CE applications that have been documented focus mostly on recycling materials (such as fishing nets and other equipment).

There are some examples of cycling business models (as per Figure 12), where fisheries waste products are transformed into new products: fish waste can be turned into pet food or other fish products (such as prawn oil); or used to make dietary supplements of omega-3 oils. There are a few examples of fish and aquatic residues being converted into biogas and agricultural fertilisers (De Schoenmakere et al., 2018). In these examples, the co-location of activities was critical to their success.

The European Environment Agency has identified mechanisms for best practice at the business, consumer and policy level to help drive uptake of CE principles (De Schoenmakere and Gillabel, 2017).

At the business level, key mechanisms are:

- functionality/performance as a source of value creation
- location of production and use being closely linked
- user needs and wants driving the product's role
- internal incentives (within the business model) to close product loops and life cycles.

At the consumer level, key mechanisms are:

- consumer satisfaction
- a local-first attitude
- accessibility
- product end-of-life incentives for reuse

At the policy level, key mechanisms are:

- building a skilled workforce
- regulated, safe and healthy services
- product end-of-life incentives for reuse at a holistic level.

Table 4 presents an annotated bibliography of key publications on CE identified through our literature review (using Scopus).

Table 4: Annotated bibliography of key CE publications identified in the literature review

1.	Fleming, A., Hobday, A. J., Farmery, A., van Putten, E. I., Pecl, G. T., Green, B. S., & Lim-Camacho, L. (2014). Climate change risks and adaptation options across Australian seafood supply chains–A preliminary assessment. *Climate Risk Management*, 1, 39-50. https://doi.org/10.1016/j.crm.2013.12.003 Examines potential impacts of climate change across seafood supply chains. Through semi-structured interviews with stakeholders, the authors examine perceptions of where climate change impacts and adaptations currently occur, or may occur in the future, across supply chains for several species: southern rock lobster, tropical rock lobster, prawns (fisheries); and oysters and prawns (aquaculture). Climate change impacts were understood by stakeholders, and supply chain disruptions were evident, but adaptation was focused mainly on production. A risk-based approach was recommended for adaptation planning for Australia's seafood sector.
2.	Lim-Camacho, L., Hobday, A.J., Bustamante, R.H., Farmery, A., Fleming, A., Frusher, S., Green, B.S., Norman-López, A., Pecl, G.T., Plagányi, É.E. and Schrobback, P. (2015). Facing the wave of change: stakeholder perspectives on climate adaptation for Australian seafood supply chains. *Regional Environmental Change*, 15, 595-606. https://doi.org/10.1007/s10113-014-0670-4 Explores Australian seafood industry stakeholder perspectives on potential options for adaptation along seafood supply chains (wildcatch and aquaculture) based on future potential scenarios. Adaptation strategies focused on the production end of the supply chain. Suggested chain-wide adaptation strategies may be generally beneficial (increasing product promotion, strengthening relationships within the supply chain, innovation to encourage resource use efficiencies), and adaptation strategies that target one stage of the chain may affect other stages, requiring holistic approaches.
3.	KPMG Economics. (2020). *Potential economic payoff of a circular economy*. KPMG https://assets.kpmg/content/dam/kpmg/au/pdf/2020/potential-economic-pay-off-circular-economy-australia-2020.pdf Investigates the potential benefits of a circular economy in Australia represented by eight different CE opportunities: (1) nutrient recovery and recycling, (2) biogas from organic waste, (3) water use efficiency, (4) food waste (Food), (5) electrification of transport, (6) car sharing (Transport), (7) compact dwellings, (8) Energy-efficient buildings (Built Environment). The report considers a broad range of sectors and industries, and concludes there are substantial pay-offs of CE beyond environmental benefits. Analysis does not separate fisheries from the agriculture, forestry and fish sector.
4.	European Commission, Directorate-General for Research and Innovation. (2015). *Sustainable agriculture, forestry and fisheries in the bioeconomy: a challenge for Europe*. 4th SCAR foresight exercise. Publications Office. https://data.europa.eu/doi/10.2777/51435 Explores current and future implications of the development of a sustainable European bioeconomy (defined as the production of renewable resources and their conversion into food, feed, bio-based products and bioenergy). Highlights internal contradictions within primary production sectors and possible conflicts among sectors. The report helps to set the research and innovation agenda, establish priorities, and provide ground for policies.
5.	Geissdoerfer, M., Pieroni, M. P., Pigosso, D. C. & Soufani, K. (2020). Circular business models: A review. *Journal of Cleaner Production*, 277, 123741. https://doi.org/10.1016/j.jclepro.2020.123741

	Literature review of circular business models and circular business model innovation to provide: (1) an overview of the history of the concepts of circular business models and circular business model innovation, (2) an overview and synthesis of definitions of circular business models and circular business model innovation, and (3) an overview and synthesis of conceptual frameworks for circular business models and circular business model innovation.
6.	Bocken, N. M., De Pauw, I., Bakker, C. & van Der Grinten, B. (2016). Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering*, 33(5), 308-320. https://doi.org/10.1080/21681015.2016.1172124 Addresses the question: what are the product design and business model strategies for companies that want to move to a circular economy model? Develops a framework of strategies to guide designers and business strategists to transition from a linear to a circular economy through slowing, closing and narrowing resource loops. Provides a list of product design strategies, business model strategies, and examples for key decision-makers in businesses to move to CE. This framework also opens up a future research agenda for the circular economy. Suggests future research needs to include elements such as supply chains, enabling technologies, and infrastructure with strategies tested through development of case studies.
7.	Tapia, C., Bianchi, M., Pallaske, G. & Bassi, A. M. (2021). Towards a territorial definition of a circular economy: exploring the role of territorial factors in closed-loop systems. *European Planning Studies*, 29(8), 1438-1457. https://doi.org/10.1080/09654313.2020.1867511 Reviews territorial (geographical) factors shaping closed-loop systems. Considers six categories of territorial factors: (1) Land-based factors emphasise the significance of physical endowment to satisfy the growing demand for secondary and biotic materials in a circular economy; (2) agglomeration factors are important determinants of a circular economy, as these provide circular businesses with the necessary access to resources, knowledge and collaboration, as well as viable markets. Some of the latter functions are enabled by (3) hard territorial factors, in particular by accessibility and connectivity infrastructures, as well as by (4) access to state-of-the-art technologies. Softer territorial factors, including (5) knowledge and (6) governance and institutional arrangements, support collaboration between companies, consumers and public institutions. Agglomeration and land-based factors contribute to defining the framework conditions of circular transformations; the harder territorial factors enable the circular economy in practice; and the softer factors (knowledge, awareness, governance and settings) catalyse circular transformations.
8.	De Schoenmakere, M. & Gillabel, J. (2017). *Circular by Design*: *Products in the Circular Economy*. Report prepared for the European Environment Agency (6). ISSN 1977-8449 https://www.eea.europa.eu/publications/circular-by-design Contributes to the framing, implementation and evaluation of circular economy policy in Europe, and to capacity building among stakeholders. Highlights the importance of product-related aspects (such as eco-design, innovation incentives, business models and production-consumption trends), with a focus on the systemic drivers of product design and use, and their implications for the governance of the transition to a circular economy. Report concludes that transition CE requires better knowledge of the links between products, underlying business models, and the societal infrastructure and governance determining their life cycles. Suggests dedicated monitoring to identify key mechanisms and trends, and that one-size-fits-all solutions should be avoided.
9.	De Schoenmakere, M., Hoogeveen, Y., Gillabel, J. & Manshoven, S. (2018). *The circular economy and the bioeconomy: partners in sustainability*. Report prepared for the European Environment Agency (8/2018). ISBN: 978-92-9213-974-2 https://www.eea.europa.eu/publications/circular-economy-and-bioeconomy

	Explores possible synergies, tensions, gaps and trade-offs between the bioeconomy and circular economy. The authors suggest that by shifting from agriculture to alternative (aquatic) sources of biomass and more effectively using biowaste and residues, the resource base could be extended without the need for additional land for biomass production. The report discusses the roles in CE of consumers (consumption patterns, waste separation); innovations (biorefineries, 3D printing with bioplastics, valorising residues and food waste, and biowaste treatment); policies (to reduce environmental pressures along the entire value chain); and technology (to drive system innovation, support consumer behaviour change and manage waste).

Systems mapping workshop

Stakeholders mapped the input and output flows of materials along the supply chain (production, processing, transport and logistics, wholesale/retail, and consumption) for six production systems in Australian fisheries:

1. Wildcatch: Trawl and net
2. Wildcatch: Trap and line, hand gathering
3. Wildcatch: Recreational
4. Aquaculture: Sea cage
5. Aquaculture: Pond
6. Aquaculture: Estuarine shellfish

Much of the information is common to multiple systems, particularly within the major categories of wildcatch and aquaculture. For example, the use of energy in producing ice, and inputs of plastic in retail packaging, appear in most system descriptions.

Accordingly, the next section will provide detailed information about wildcatch (see Figure 13) and aquaculture (see Figure 14) as generic archetypes. It will then focus on describing where the six systems vary from these archetypes. The general supply chain elements (such as processing, wholesale/retail and consumption) are similar across all six systems, so these will be discussed in general terms, followed by a discussion of existing opportunities and barriers.

In each system, there are inputs (such as organics, plastics, water, energy, chemicals and metals) at each point of the supply chain. There are also outflows from each point of the supply chain. Some of these outputs are currently being reprocessed and recycled, but a significant amount of these materials is being deposited in landfill.

It should be noted that there are elements not captured within these maps. These include governance, policy (including by-catch reduction; access rights and quotas; fisheries management; and human resources), processes such as workforce issues and product provenance (e.g. where the seafood comes from), infrastructure, and transport and logistics.

Due to the extended lifespan of infrastructure (e.g. wharves, moorings, buildings, roads, etc.), these are considered external to the six production systems. However, the sector should consider implementing sustainable procurement practices for new builds, and end-of-life materials recycling for existing infrastructure.

The implementation of CE principles in transport and logistics is beyond the scope of this project. Transport and logistics in the fisheries and aquaculture sector currently rely heavily on the use of fossil fuels across the value chain in each production system. For example, fishing fleets depend on the use of diesel as fuel; wholesale and retail depend on the use of forklifts, trucks, trains, airfreight and shipping; and customers/consumers drive to and from the point of sale, or to the fishing site (in recreational fishing).

Overview of production systems

In this section, the similarities and differences between these six production systems in Australian fisheries will be compared, followed by a discussion of specific barriers and opportunities for CE in each production system, as identified by workshop participants.

Within the three wildcatch production systems, the ‘fishing’ component of the supply chain differs for each system, but the processing, wholesale/retail and consumption nodes of the chains are mostly similar. Figure 13 maps the inputs, processes, outputs and circular activities currently occurring within these systems, according to the workshop findings.

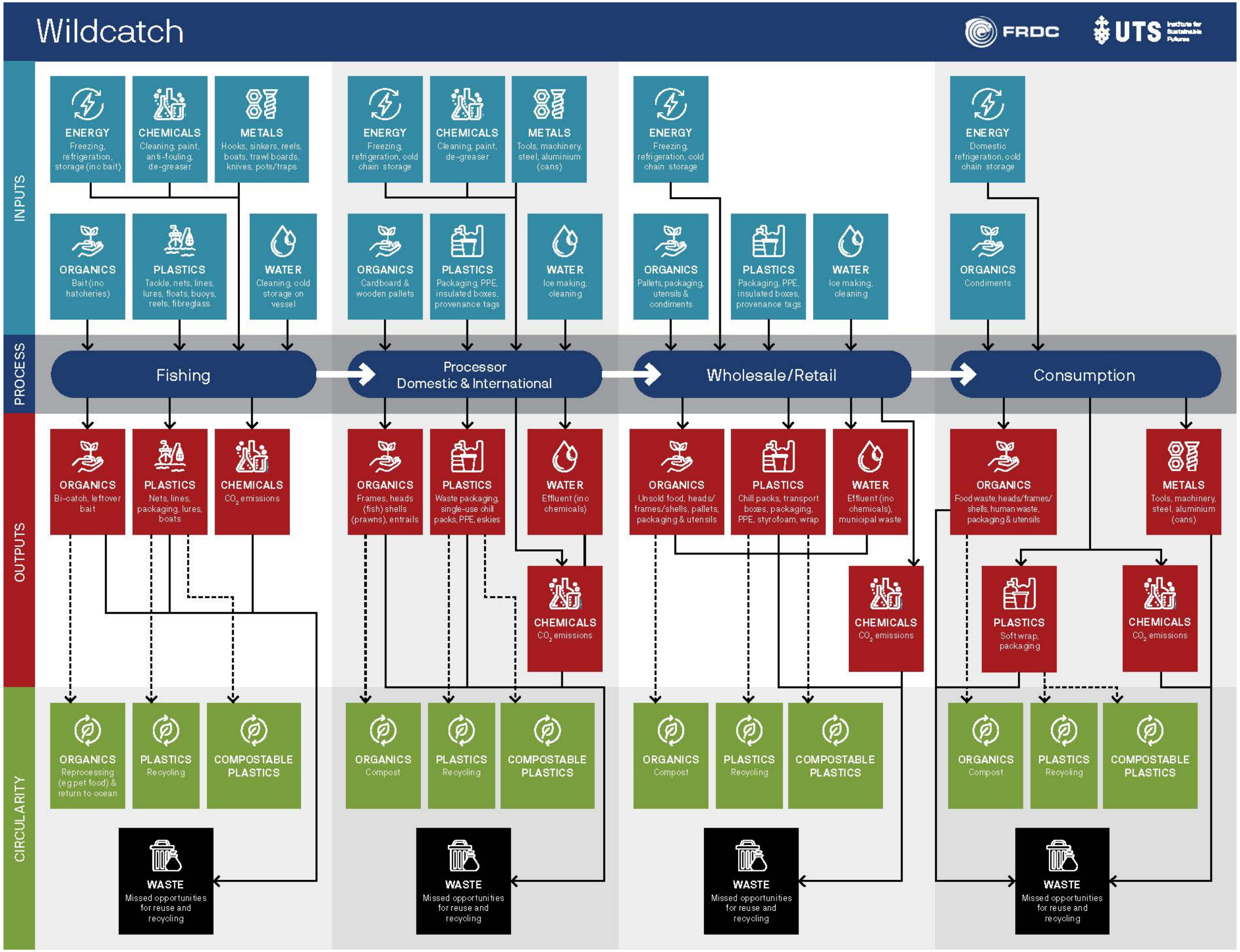

Figure 13. Wildcatch fisheries input-output flow diagram

Within the three aquaculture production systems, there is considerable variation in the production component of the supply chain across each system: sea cage, pond and estuarine shellfish. However, the processing, wholesale/retail and consumption nodes of the chains are similar (and resemble wildcatch supply chains too).

Figure 14 maps the inputs, processes, outputs and circular activities currently occurring within aquaculture systems, according to the workshop findings.

Aside from inputs such as small boats (which are similar across the sector), there are additional inputs unique to aquaculture production systems. Most require the breeding of hatchlings (all three production types) and animal feed (sea cage and pond). Fish feed is primarily provided by three companies in Australia (Skretting, Ridley and BioMar).

Aquaculture systems produce several organic outputs, including sludge (from ponds), and culled or deceased animals. In wildcatch production systems, these outputs are absorbed naturally into the local marine or estuarine systems (e.g. becoming food for scavengers or other creatures). However, nutrient leakage from some aquaculture production systems (e.g. from sea cages) is a challenge, as animal wastes may exceed the local environment's capacity for absorption.

Within both wildcatch and aquaculture production systems, there are differences in seafood products (e.g. whole, filleted, fresh, frozen, local consumption, export, or a combination of several of these processes).

For the export/import trade, most products are shipped frozen (e.g. prawns). However, some specialty lines and high-value products are transported unfrozen or live by airfreight (e.g. fingerlings, fresh chilled salmon, lobsters and abalone).

Certain products – such as prawns – follow complex and geographically dispersed value chains. They may be grown or harvested in Australia, exported to Vietnam for processing, and then returned to Australia for sale. Prawns are sometimes also used as feed in aquaculture. This blurring of the division between domestic and exported products changes the opportunities for circularity in relation to food processing and packaging outputs.

Figure 14. Aquaculture input-output flow diagram

The following sections provide more detailed insights into these production and value chain systems, as generated by participants in the systems mapping workshop. We share them here to add contextual depth to the diagrams in Figures 13 and 14.

Production system – wildcatch: trawl and net

Within the fishing component of the wildcatch trawl and net supply chain, there is considerable reliance on non-renewable energy. This is true for all production systems where boat/vessel usage occurs, as biofuels are currently not commercially available. When working close to shore, there is potential for electrification of small boat outboard motors, through the use of batteries and electric motors.

However, workshop participants noted that diesel is preferable for powering larger vessels (such as deep-water fishing fleets), and there are currently no fuel alternatives for long trips. Opportunities are emerging for the sector to connect with technology providers experimenting with hydrogen fuel cells and other technologies ('green' fuels) to decarbonise the transport component of fishing.

At end-of-life, some vessels are traded overseas, and there may be opportunities to recycle steel boats.

Plastic is used throughout the supply chain, and across production systems. Plastic in some fishing nets and ropes is currently repurposed by Aboriginal and Torres Strait Islander communities into arts and crafts, recycled into sunglasses and tents, or used in 3D printing materials. However, these are generally small, niche initiatives that do not reuse or recycle the full supply of plastic nets and ropes at end-of-life.

Production system – wildcatch: trap and line, hand gathering

The vessels and ropes used for trap and line fishing are similar to those used in other production systems, but fishing line is an additional plastic product used. Within the fishing component of the value chain, there are certain materials used (e.g. pots, and traps made from metal wire) that may require alternative reuse pathways; further investigation is required.

Production system – wildcatch: recreational

In this system, hatchery activities are common (e.g. for stock enhancement, or prawn hatcheries for bait). Most of the materials used for fishing (e.g. rods, reels, nets, lines and lures) are similar to those used in commercial fishing. However, a major difference in recreational fishing is the tailoring of products for individual use (such as single-use plastic packaging for small quantities of hooks or bait). This results in larger ratios of plastic packaging to usable product; this packaging often ends up in landfill (through municipal waste streams).

Indigenous cultural fishing may also occur within the recreational production system.

A broad range of materials is used within recreational fishing: fibreglass, carbon, resins, monofilament, dyneema, spectre, high-density glass (as a sinker alternative), metals and chemicals (e.g. chemical coatings on metals, spearfishing gear, cleaning chemicals), paints, resins, plastics (e.g. packaging, wetsuits, dive gear), powered personal vessels (there are different emissions for different boat types, e.g. petrol and oil-powered; electric and hydrogen-powered), and electronics (e.g. sounders, batteries, phones).

Recreational fishing differs from commercial systems in that many fishers employ catch-and-release techniques, which may incorporate additional materials (such as brag mats, boga grips, etc.).

Production system – aquaculture: estuarine shellfish

A range of materials is required in this system, and may include those used in hatcheries.

There are unique organic inputs, such as spat. Additional inputs include oyster rack systems and oyster-catching slats, mussel ropes, wet storage tanks, and depuration tanks.

Hardwood and plastic sheaving are used, as well as a range of plastic tanks, pumps and tubs. Other oyster-cultivation gear includes floating bags, baskets, trays and tumblers.

Production system – aquaculture: sea cage

This system breeds fish and then grows them using sea cages. It requires infrastructure similar to pond aquaculture at the breeding stage, as the fish often live on land for almost half their life before moving to the sea cage.

Shore-based fish hatcheries are required for kingfish, barramundi and salmon. These require separate facilities, which creates additional water disposal, feed and plastic waste issues. For feeding, metal bins are required to transport feed to the cages.

Sea cages are made from nets, with kingfish in particular requiring netting to provide protection from avian predators across the entire pontoon. Other cage systems use plastic and/or steel stanchions for predator protection.

Other materials used in sea cage aquaculture include polyethylene pipe rings for floating cages, plastic sea cables, plastic buoys, and metal and plastic walkways for cage access (for feeding and maintenance).

Production system – aquaculture: pond

For pond aquaculture, many of the inputs are similar to the terrestrial component of sea cage aquaculture. Some systems use concrete tanks, while others may grow fish or prawns in bund-walled earthen dams.

In this system, tanks and ponds can be either indoors or outdoors. Energy is required for temperature control of the water to ensure optimum development and yield of the animals. Additionally, aeration requiring energy inputs (electricity) is a necessity in many of these production environments.

Aquaculture feedbags are often plastic, and are tied together with mesh on pallets. Some feed comes in paper bags. Monitoring equipment is needed for weight checks (e.g. nets and scales); these are used, maintained and replaced on a regular basis.

When maintaining the ponds/tanks between batches of fish, chains are dragged along the bottom to refresh the pond. There is an inevitable build-up of organic materials (nutrients/feed) on the bottom of the pond. Ponds must be pumped out regularly to prevent this organic build-up, and additional equipment is needed to clean and remove sludge from ponds.

Processing

Where possible, processing is carried out locally to save on transport costs and reduce related carbon emissions. However, this is not always possible, due to the regional and remote nature of many fisheries and aquaculture operations, the availability of the workforce at point-of-catch, and the economic cost of local Australian-based labour. As such, product is often sent overseas (e.g. to Vietnam and Taiwan) for processing and then returned to Australia for sale.

Workshop participants discussed instances where additional processing was undertaken within Australia for discrete products, such as collagen from skin (from hoki), finings being used for wine-making, and the extraction of carotenoids and development of biodegradable plastics from prawn shells. These were considered to be emerging market opportunities, and are often still in the research and development stage, rather than being current commercial opportunities.

Regarding energy production, some processing facilities have installed rooftop PV-solar, where building designs allow for this. Solar energy was described as “not the main game” by participants, in terms of decarbonising their industry, although it is appreciated as a cost-reduction exercise for many businesses.

For recreational fishing, processing may occur on the boat, onshore, at the boat ramp, or in the fisher's place of residence. This situation creates highly distributed waste flows of organic materials that may be problematic for the establishment of CE. Fishers may also use a range of methods to preserve the catch (such as cryovac, fillet/freeze, hot- or cold-smoking, or dehydration), and these may involve additional materials as inflows. Some organic waste from fish processing may be used as berley in fish catching.

Within the estuarine shellfish system, processed hessian bags and plastic woven bags are often used for live product. Vacuum packs, foam and cling wrap are used after shucking. Mussel and oyster shells are reprocessed into fining for wineries, into shell grit for chicken feed, as construction material in reef restoration, as soil conditioner/fertiliser, and as a lime/cement additive. Yet a significant proportion of waste still ends up in landfill, as the process of decontamination for biosecurity is energy-intensive and thus often economically prohibitive.

For kingfish, salmon and barramundi, gases (e.g. nitrogen) are used in processing. While most processing happens onshore (e.g. Tasmanian salmon), some processing happens on international factory ships (in wildcatch contexts). Organic waste from seafood processing ends up in various destinations (e.g. burley blocks for fishing; blood-and-bone fertiliser; and gills, covers and tails may go to landfill or be used in organic mulch production).

Wholesale/retail

Plastic packaging is an issue throughout the sector, and particularly at the wholesale/retail point in the supply chains. At early stages in production and processing, hard plastics are used extensively. Towards the retail end of the chain, soft plastics predominate.

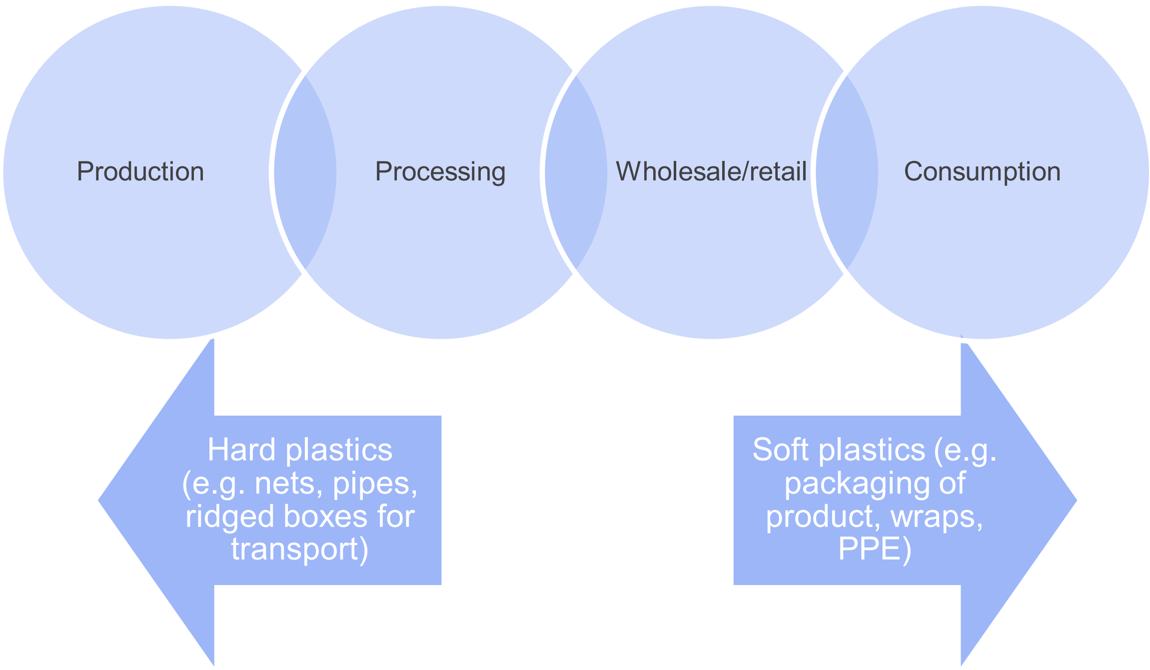

Figure 15. Different plastic types used along the seafood supply chain

Workshop participants reported an industry-wide need (and desire) for more information about the properties of each type of plastic used in supply chains and production systems. There are currently many different types of plastic used in the sector, and there is an opportunity for the industry to agree to using fewer plastic types and ensuring those plastics can be recycled.

Once seafood products come into contact with soft plastics, it is difficult to recycle them. There may be an opportunity to focus on introducing new soft organic products at this point in the supply chain.

Of the hard plastics, styrofoam is still widely used within the sector for the transport of fresh and frozen product. In some contexts where there are larger fish markets (e.g. Sydney Fish Market), there has been investment in local recycling. However, many styrofoam packaging products are deposited in landfill at this point in the supply chain, as recycling is not cost-effective for smaller operators.

There has been some experimentation with alternative insulated packaging (e.g. woolpack), but for small operators the cost per unit is too high compared to styrofoam or polyethylene (PE)-coated paperboard. PE-coated paperboard is useful for packaging food because it is waterproof (a required property), but it is difficult to recycle at end-of-life.

At the point of wholesale/retail, large amounts of waste water may be generated, and water and energy are used extensively for ice-making and cleaning. Where possible, on-site waste water treatment facilities have been installed. However, due to the chemical composition of the waste water, this opportunity is limited, as it can cause problems for the local council's water treatment processes, requiring additional filtering or chemical treatment.

While there is no wholesale/retail element within recreational fishing, the catch is often shared within social and cultural groups. It was noted that there may be some nefarious activities whereby products from the recreational production system are sold through wholesale/retail markets.

Consumption

At the point of consumption, participants identified further plastic inputs (e.g. soy sauce containers, tartare sauce packets, and plastic trays for oysters or sashimi) for which there are currently no opportunities for recycling.

Organic waste from seafood consumption in households may go to domestic pets or domestic garden compost, but most of this waste (e.g. heads, frames, shells) ends up in municipal waste streams and is deposited in landfill. Within restaurant/food and beverage operations, there are growing opportunities for reuse, such as the OzFish program (which collects oyster shells for use in reef restoration). However, this program does not cover all waste streams, and does not operate in all jurisdictions.

For recreational fishing, organic waste is produced at the consumption point in the supply chain. Since the people involved at point-of-capture are often those involved in primary consumption, materials from along the supply chain will also often be disposed of in the home (rather than in a place of business). This means that CE opportunities are reliant on municipal waste collection and processing.

CE opportunities and barriers identified by workshop participants

Opportunities

This section lists opportunities for CE identified by participants in the systems mapping workshop.

- **Plastic alternatives**
  - Investment in plastic alternatives, such as compostable starch-based or other organic-based (and potentially recycled) materials. When exploring plastic alternatives, it is important to consider the life cycle impact to ensure less harm.

- Move away from plastic transport bags to bulk bins. From a health and safety perspective, these can be heavy (>50kg). This kind of action will depend on the destination of the product; it was noted that hessian bags are currently preferred to plastic nets for some products (e.g. shellfish). In each case, these alternatives must be compostable at end-of-life.
- For the processing part of the supply chain, there are some alternatives to plastic (e.g. woolpack, designed by Planet Protectors). However, these are still a niche product and relatively expensive compared to styrofoam boxes.
- Within wholesale/retail and consumption points in the supply chain, food service packaging is changing (e.g. from plastic to bamboo or sugarcane cardboard). There is an opportunity for these products to be developed in Australia (participants reported these are currently sourced and processed in China). There are existing examples from overseas (such as the Responsible Plastic Management program in the U.K.) that may assist in this transition.
- Legislation drove the food service plastic packaging ban; there is an opportunity for something similar in the fisheries sector to drive out soft plastics and develop bioplastic alternatives.
- Awareness of the opportunities presented by bioplastics is low among the seafood industry and seafood consumers (the researchers note that if compostable packaging goes to landfill, it can generate more CO2 than plastic would have, so disposal practices must be considered alongside any development of alternatives to plastic packaging).

- **Plastic consolidation and recycling**
  - There is an opportunity for further recycling of nylon.
  - Within estuarine shellfish aquaculture, there are opportunities to consolidate different plastic streams. It was noted in the workshop that there are 4 to 5 main plastic suppliers. A feasibility study of recycling oyster baskets in South Australia noted that mixed-waste plastic (containers, ties) used in the sector is a challenge for existing recycling technologies. At present, it is not possible to deal with mixed-waste plastic in an appropriate way. This problem is further compounded by the difficulties of recycling plastic that has been in contact with seafood products (for biosecurity reasons).
  - Plastic stanchions are being chipped and sold to the recycled plastics market; there is further opportunity to increase these activities. Polyethylene pipe rings, for instance, are recycled for use in irrigation/drainage infrastructure.
- **Organic uses**
  - An increasing amount of waste from seafood processing is going to animal feed. There is an existing but small market for heads of salmon and smaller offcuts to be used in the animal feed sector (e.g. pet food).
  - There are increasing opportunities to use organic waste (such as tails and cores of fish) in pet treats.
  - This waste can be converted into nutritional high-value products or higher-value uses (e.g. sauces and soups for human consumption), which could connect into and/or expand the existing pet market to capture all co-product. For example, in Japan, abalone guts are a delicacy; after seeing this opportunity, seafood-processing company Kansom developed the world's first abalone sauce. When transforming a waste product into a high-value product, there can be challenges; for instance, it can be difficult to market these products if there is no existing demand.

- **Energy alternatives**
  - There is an opportunity to use heat from hydrogen power for internal heating.
  - There is a potential opportunity to use bioenergy. For example, pallets of wood can be used in furnaces to offset the cost of energy needed for freezing and ice creation.
  - Pond aquaculture facilities can use geothermal heat for ponds, rather than using power from the grid.
  - Solar power can be used for a range of land-based seafood activities.
- **Collaboration**
  - There is an opportunity for more collaboration and sharing of resources (e.g. sharing of boats, or food-sharing within the community). Fishing co-operatives are strongly supported in NSW, allowing fishers to share the costs associated with landing, marketing and transporting fish. There is an opportunity to use co-ops as sites for waste collection too, in order to build the volume of waste materials to a level that makes them viable for recycling or other circular activities. In South Australia, one waste collector travels directly to individual tuna farms with a plastic shredder to collect and process materials.
  - There is an opportunity to include more detail in existing case studies (e.g. the tuna sector, or processing of rock lobsters) in terms of reporting the rate of recycling or refilling of containers that are specific to that production system (such as tuna bags). Further information may come from the FRDC-funded project 2020-084: *An audit of plastic use in the fishing and aquaculture sectors*.
  - There are opportunities for developing collaborative consumption in shellfish aquaculture. Currently, grading machinery in some areas is being shared. There may be an opportunity to develop grants that allow for growers working in the same estuary to apply for shared mechanical resources. There are also opportunities for shared resources in wet storage (on a co-operative basis).
- **Learning**
  - There are opportunities to learn from the current regenerative or circular practices within Indigenous cultural fishing.
  - There is an opportunity for sharing knowledge between recreational and commercial fishers and seafood processors, principally around food preparation and consumption (e.g. principles of full-use of fish and filleting). Resources could also be shared. For example, there is an opportunity to use commercial fish waste as berley or bait within the recreational fishing system.
  - Since hatcheries are important for bait production, there is an opportunity to engage these operators in wider-scale circular opportunities to agglomerate materials. Hatchery businesses use potentially recyclable materials such as PVC pipes, ponds/tubs and netting, operate using freshwater/recycled water that could contain valuable nutrients, and have packaging from feed and medicines that could be designed out or recycled.
  - Within the estuarine shellfish production system, there was a shift from using treated timber to using plastics 20 to 30 years ago. These materials have a long useful life, so the 'first wave' of those plastics arriving at end-of-life is only now beginning. There is an opportunity to look to similar industries in France, Europe or New Zealand to learn from their experiences in recycling oyster/mussel-production plastics.

- **Uses for oyster and mussel shells**
  - Oceanwatch and Oz Fish have existing programs where shells are collected. They are either taken back to oyster farms, or to local reefs for reef restoration activities.
  - There have been examples of trials where shell waste is transformed into fertiliser. This requires not only that all protein is burned off (as in the above example of shell repurposing), but also that shells are ground down. An emerging use for this product is in soil conditioner (for purchase by home gardeners/high-end gardeners). However, this is currently a niche market with limited opportunities for distribution (e.g. local garden centres).
- **Packaging developments/plastic alternatives**
  - Developing alternative packaging for oysters and mussels is a challenge because it must be water-resistant. Compostable alternatives are more expensive, and not always appropriate for transporting wet product. There are some compostable options, but they come with a plastic lid. There is an opportunity for further biodegradable/compostable options to enter the market at a competitive price.
- **Waste water**
  - Waste water from pond aquaculture and hatcheries may be suitable for use in agricultural irrigation (it has good nutrient load but low salt content).
- **Extraction of bioactive compounds from fisheries waste**
  - Further research is needed into this promising field (e.g. extracting enzymes from waste from toothfish, a species that thrives in low temperatures and thus has unusual enzymes).
  - There is current research into mapping the genomes of various fish (e.g. DNA Zoo); there may be further opportunities for research and commercialising.

Barriers

The barriers to CE reported by workshop participants have been grouped according to a PESTLE analysis of factors (Political, Economic, Social, Technological, Legal and Environmental).

In this instance, political, legal and regulatory factors have been combined.

- **Political, legal and regulatory factors**
  - There is a risk there will be future CE-supportive regulation without consideration of price points. The regionality of materials may also be a problem (e.g. in transport), as different States and Territories may have different regulations.
  - The development and ownership of intellectual property can be a challenge when collaborating and working with funders.
  - Within the recreational fishing production system, the opportunity to use commercial fish waste as berley or bait is currently prevented by regulation at the State level. The Australian Fisheries Management Forum (AFMF) may be a pathway to overcome this barrier, with input from State and Territory governments.
  - Additional trials for reprocessing oyster shells have been hampered by the difficulty of finding appropriate sites given current biosecurity regulations.
  - Biosecurity concerns are a significant barrier to reprocessing organic waste (e.g. proteins from the waste of one species cannot be used to feed the same species – to avoid cannibalism –

but *can* be fed to other species). There are other biosecurity barriers too (for instance, feed for salmon in Australia may not be able to include waste from other fish industries, e.g. tuna from Thailand).

- **Economic factors**
  - When it comes to reprocessing, there are considerable logistical barriers to getting minimum quantities together to be economically viable. There are also high costs to recycling.
  - Upfront capital costs, and investment costs without appropriate incentives, make CE-related changes to these production systems difficult, especially for small businesses.
  - New markets will be needed for any new products that utilise waste (e.g. high-end restaurants could showcase and support new high-value products).
  - Labour costs and lack of expertise in CE is an issue for the Australian seafood sector.
  - The demand for recycled plastic products (e.g. plastic pellets) is currently higher than supply. There is a considerable cost difference between packaging types; and no existing like-for-like high-performance option (e.g. to replace styrofoam boxes).
  - There are cost considerations for any proposals to do more processing locally. It was reported that many prawns farmed in aquaculture in Australia are first frozen, then sent to Vietnam for processing. The prawns are thawed, processed and re-frozen/chilled, then either sent back to Australia for consumption, or shipped elsewhere. There is often not enough product volume to make local processing cost-efficient, and Australian labour costs are high.
  - It was noted that high-value waste repurposing products (such as abalone sauce) may be more suitable for overseas rather than local markets.
  - Scale is an issue for the cost-effective use of fish waste for animal feed (as fishmeal); large volumes of waste are needed in order for this to be economically viable.
  - The cost of electricity is a considerable barrier to storing organic waste until there are appropriate volumes for reprocessing. Currently, power bills for freezing are huge (e.g. >AU$800,000 per year). Some companies use solar power, but this is not uniform throughout the sector and solar does not always meet energy needs. Further research is required.
- **Social factors**
  - Current practice in the sector is to only consider resources that are tangible. Yet the fisheries sector contains a wealth of intangible resources, including knowledge and know-how. There is a need for appropriate engagement with communities and businesses to create networks and platforms for knowledge-sharing.
  - There is a push towards restructuring the entire industry, which could lead to a loss of knowledge at the local level.
  - Australia's dietary culture constitutes a challenge to circularity in seafood sectors, in that Australians tend to eat a lot of terrestrial animal protein (chicken, pork, beef, lamb).
- **Technological factors**
  - There are no high-performance like-for-like products available to transition away from using some kinds of plastic.
  - There is a lack of viable alternatives to diesel available for powering fishing boats.

- **Environmental factors**
  - There are considerable barriers to recycling soft plastics due to biosecurity reasons.
  - There is a need for bespoke alternatives to soft plastics used in seafood packaging. These plastic alternatives need to last in chilled or frozen conditions for 3 to 4 years, but still be able to break down when composted. Participants from the workshop reported that these products do not yet exist.
  - When dealing with end-of-life nets and ropes, there can be challenges due to biofouling and the difficult and costly nature of this work. Stockpiles of these used nets and ropes can attract rodents and snakes, and can become dangerous fuel loads when there is bushfire risk.
  - In Australia, there is currently no clear market for nets and ropes at end-of-life at the volume required to be feasible (artworks and sunglasses made from this material are niche activities). There is also a lack of information and advice on best practice for this kind of reuse within the industry.

Case studies – deep dives into best practice and adoption of CE

The initial phases of this research project revealed that CE (as a concept) is not widely used or understood within the Australian fisheries and aquaculture sector. We felt that case studies of CE applications being adopted within the sector would help to provide context and share useful information about best practice.

To develop these case studies, we carried out semi-structured interviews with participants who were recruited because they were involved in an activity that could be characterised as circular (even if this was not necessarily the terminology they used to describe that activity).

A thematic analysis of these interviews highlighted several CE drivers, barriers and opportunities for the sector. Additional factors (such as geography and key CE themes) were considered and applied.

This resulted in several themes, including regulatory drivers, barriers, geography and circular economy activities. Sub-themes include opportunities for finance, access to partners, service provision, scale and sustainability goals.

This section presents a discussion of the themes as they arose in the case study interviews, and excerpts from the interviews to illustrate those themes.

Drivers

For circularity to be enacted, there is a range of drivers for businesses. One powerful driver is government regulation or legislation. The Australian Government's recent National Waste Policy (DEE, 2018; DEE, 2019) has increased the need for businesses to think about waste streams and end-of-life considerations for all materials. With waste water management, there are State-based regulations that specify the nutrient loads of waste water released back into ecosystems, or for use in agriculture.

For some businesses in the fisheries/aquaculture sector – particularly those with sustainability principles at their core – there was a strong driver for CE within the **organisational mission.**

> *When they said it can be recycled and it has a value, I thought: here's an opportunity to set up, pilot it on a product that – what's the worse than can happen? We clean up a few beaches, and if it doesn't work out, then no livelihoods have been damaged in the process and dependency [hasn't been] created because of the waste resource. (Interview #5)*
>
> *Yeah, and working out how we can incorporate it into what we are doing so that we're not just a selling platform – you know, not Amazon or anything like that. Something that's making the world a better place. (Interview #12)*
>
> *There are a lot better ways to recover all the intrinsic value that fish has, not just from the financial value but from that sheer effort that has gone in to raise that animal…I think we're coming to the conclusion that, as a leader in aquaculture in Australia and globally, we need to do better at these sort[s] of things. Not just look at that prime product, but look at everything we do. (Interview #6)*

For more mature organisations, the shift to CE is beginning to appear in their **business plans**, and builds upon previous sustainability pathways. For others, there is the issue of having a **social licence to operate**.

> *A lot of it is financial driven. It's not all altruistic. A lot of it is [be]cause we're either spending money or we could make money. There's also that view of being – we're a big part of these communities, and we need to show that we're doing the right thing. (Interview #6)*

In other instances, circularity initiatives grew from wider organisational missions to **move away from fossil fuels**, to **avoid plastic waste**, and to **minimise waste** within the sector.

These goals directly influence the behaviour of these businesses in terms of whether they choose to a) design out waste; b) keep materials in use; c) regenerate ecosystems (the three key pillars to CE). Independent businesses within the sector are beginning to move towards the **electrification of their transport fleet**. Further research is needed (e.g. feasibility studies and a cost/benefit analysis) regarding the proposal to switch smaller boats with outboard motors to electric power.

Cost reduction regulation and the cost of disposal were also strong drivers as these costs rising across Australia). Some businesses are exploring reprocessing organic waste as **fertiliser or pet food**, while others are working on initiatives to keep the **majority of organic waste products suitable for human consumption**.

> *We've always believed in nose-to-tail eating for fish, so – where possible, with freight obviously, and room and capacity to store – we've always kept wings from all our fish. We don't waste any wings. We try and keep the majority of the frames, whether it be for crab pot bait for ourself or others – for eating, [or for] crab pot bait in the shop. We're reef fishing at the moment, which makes it easier. [It's] only an hour and a half from the boat to us. We don't need freight companies. We have our own seafood trailer. We're not paying 50 cents a kilo fees, so we can keep that little bit more. We're only fishing for three days, so it makes it easier. We keep the head, the wing, the frames, the fillet, so there's no wastage. (Interview #22)*

> *We know a few businesses that are on the land that are big processors, where they're next to the ocean, the boats come in, they're processing in their shops. Therefore, they have the wastage, the boat doesn't. They have the staff, the storage, the facilities to store that and then sell it on to people who do dry dog treats and fertiliser. We had actually talked –because we only have a little boat in our off-season, not the big boat – we had actually talked about doing fertiliser on our farms. We had 115 acres – or have 115 acres until next month, when we're selling. It was to do fishermen's fertiliser. (Interview #22)*

Higher electricity bills were noted as a driver for using **solar energy**.

In some instances, however, the electricity demand for businesses is larger than solar can achieve alone (without the business being categorised as an energy producer).

> *97 kilowatts of [solar] panel[s] on my roof…the maximum we could get without being called an energy producer…When our ice machine and our freezers are working, we use 105 kilowatts. We're always using electricity...I think my bill used to be $16,000, $18,000 a month, and now I pay something like $7,500 a month since I put the solar on. (Interview #14)*

The **cost of water** also drives business innovation in finding alternatives. These may include changing water-use practices and introducing water-efficient hoses for washing.

However, there are some challenges associated with changing these behaviours, and balancing food health risks with water use.

> *…we're a high-end user of water. I've introduced water-saving nozzles…We ice the floor probably three or four times a day because you get fish or fish slobber or whatever on the floor, you can't let it lay there for too long. We introduced a chemical cleaning to reduce the amount of water that they use…I'm constantly having to replace them [water-saving hoses] because the fishermen come in and cut them off because they want water. They want it quickly and they [want to] be gone…Water is a big a cost here and so is replacing hoses…I've tried all ways of reducing the water [use]…The danger that we have is if we reduce the amount of water, we increase the risk of food contamination. We [are] stuck [between] a rock and a hard place – reducing that water will create a bigger problem. (Interview #14)*

The **cost of fuel** was also a consideration for many businesses.

> *It's more so making sure your boat runs efficiently. So your motor's now, like, for your fuel, [be]cause obviously you don't want a fuel-guzzling boat that's [going to] use more fuel – that affects your bottom dollar. But also for environmental reasons and reliability with the four-stroke outboards, instead of the two-stroke. Things like that. At the moment, we're only running very small boats, so we don't even use much fuel anymore, so the footprint is quite small. We're working very close, so we're not going those big distances anymore, because we don't [have] to sustain having, you know, six people catching the fish; it's just my partner. (Interview #22)*

For many of the businesses we interviewed, there was active consideration of the **waste hierarchy** (fertiliser versus higher-value product).

For example, if a business could sell organic waste for 30c per kilogram (for fertiliser) or $30 per kilogram (for pet food), the business would obviously opt for the higher-value product.

A further driver is the **volume of waste material** available for reuse and resale, particularly when businesses are already operating at scale. Many businesses are **unsure about market readiness**.

> *It's a bit of a chicken-and-egg thing. We don't [want to] go and commit to freeze-drying 40 or 50 tonnes of this stuff if we don't have the confirmed market at the back end. Also, we're getting told, "Well, we need the product to get to market." It's one of those ones that, as a business, we've been really hesitant to make that commitment to go and dry 40 tonnes of this stuff, which would cost hundreds of thousands of dollars to dry, if we don't have the market. …In that same space, we've been exploring other products that would come out of that process that would go through exactly the same freeze-drying process. (Interview #6)*

Due to the way aquaculture works, there will always be volumes of organic waste from large-scale aquaculture. However, as one business noted, there is an **associated risk of incentivising overfishing**, or targeting specific species for the pet food market.

> *Does any of this drive overfishing? That's something we had to look at very carefully. For example, [with] fishing, you say – well, what value do they get from this? And is [this] going to subsidise bigger fishing nets? Because that's not what we want. Also, is it going to subsidise bad practices?...So you have to be very careful with that. And most market-based mechanisms…provide incentives and effectively make people feel a bit properly appreciated…it's not just charity [that is] important. You've got to strike that balance, really…When people are looking at trying to increase the value of the fish catches, then we know that incentivises their fishing. If it can be associated with better regulations, I'm thinking, great – but it can be a problem. (Interview #5)*

" We've always believed in nose-to-tail eating for fish, so – where possible, with freight obviously, and room and capacity to store – we've always kept wings from all our fish. We don't waste any wings. We try and keep the majority of the frames, whether it be for crab pot bait for ourself or others – for eating, [or for] crab pot bait in the shop.

Figure 16. Example of large-scale aquaculture

Image credit: Tassal (sourced from abc.net.au)

Barriers

The businesses we interviewed identified a range of political, economic, social, technological, legal and environmental barriers to CE in the Australian fisheries and aquaculture sector.

While legislation can be an important driver of CE initiatives (as outlined in the previous section), it can also sometimes be a barrier to CE.

A survey of all relevant State, Territory and Commonwealth regulation relevant to each production system and every point of the supply chain is beyond the scope of this project. **One of our recommendations is that a *separate* survey of relevant regulation is needed.** This survey should also consider whether there is any potential to adjust or tweak existing regulations to enable – rather than obstruct – CE initiatives.

Our interviewees identified the following types of regulation as being potential barriers to the widespread adoption of CE:

1) food safety regulation related to ingredients in aquaculture feed

2) food safety regulation related to materials used in food production and packaging

3) environmental protection regulation designed to reduce the risk of biological contaminants in recycled or reused plastics

4) fisheries management regulations

5) regulations linked to renewable energy (including the amount of renewable energy that can be produced before an organisation is tipped into the category of being an 'energy producer')

6) trade regulations for imports and exports.

Regulation governing organic waste reuse and plastics recycling is particularly complex, as there are differing requirements around Australia, and varying definitions of biosecurity risks, biofouling, and acceptable waste products for reuse.

For example, businesses that make fertiliser from aquaculture organic waste have more complex rules to follow (and regulatory approvals to obtain) if they source waste from more than one supplier, because of the risk of transferring disease.

> *[T]he biosecurity of three different fish companies sending it all to that one site, it's really tricky. (Interview #6)*

One organisation noted that the Environmental Protection Agency (EPA)'s rules had been a significant barrier, in particular in terms of **gaining appropriate licences to process waste.** Even once this licence was obtained, there were further challenges in finding appropriate sites for the organic waste to be processed.

> *Well, the EPA has been a barrier but we've crossed it. The costings are fairly high there, but more of the barrier probably – at the moment – is getting sites and stuff like that. We've already proved it works, but that was a long two-and-a-half years since. Yeah, financially, we're not getting a good enough return on what we've done. We're finding it hard to crack in the market [be]cause we need to be a little bit expensive because of all our other costs, and that's really affecting us at the moment. The retail mark-up in Australia is pretty horrendous. (Interview #26)*

Regulations regarding **biofouling** and **recycling plastic waste** can also act as barriers to CE.

> *Our largest HDPE [high-density polyethylene] supplier is now taking back all of our HDPE pipe when it's done. So they will recycle it and reuse it again, but that's probably the anomaly in the whole thing…we're constrained in what we can do and where we can send stuff because of biosecurity rules as well. If something's really heavily fouled at one place, it might not necessarily be able to go somewhere else. There's a lot of those regulations and stuff that do limit some of these movements. It can be a bit challenging as well. (Interview #6)*

> *On an average pen, there's about 14 kilometres of rope. We end up with a lot of rope. That's one where, again, we've tried to go back to the suppliers and said, "Okay, what's your end-of-life plan?" The best we've got is, "Well, you could put it in a container and send it back to us, if you like," which is obviously not economically viable for us. That one's an ongoing challenge…[I]t's purely the cost at this stage. Most of the rope goes just to landfill once it's reached the end of its life. We can't send it back to anywhere, and [we can't] have it go back into the water…We've tried, with a few of our nets, to send them on to other people, but, again, we need to ensure that [they never go] back into the water, which can be challenging. (Interview #6)*

Figure 17. Example of pelletised reprocessed hard plastic

Image credit: Getty Images

In the innovation space, there can be challenges when **regulation cannot keep pace with new products or ideas** (for instance, feeding insects to fish).

[As] an emerging industry, some of those regulations are just either non-existent or, for example, there's nothing in the pet food standards or anything that says whether you're allowed to include insects or not. I think we've got a lot of catching up to do just in that regard…[With] pet foods, obviously, [there is] less regulat[ion] [than with] human food… [T]alking to, say, the CEO of Clean Seas – he's like, "We can't just feed fish to fish." I'm going, "You're allowed to feed fish larvae to fish?" He's like, "Well, yeah." I'm like, "Has that been validated?...What are the health safety concerns? Can we test them out?" (Interview #25)

> “ We downsized to focus on the shop. We get a lot more recognition and appreciation in our local community for that. People want to know where their seafood is coming from, and who’s caught it, and that trust is there.

The **regulatory landscape was also perceived to be in a state of flux**, which made it difficult – particularly for SMEs – to stay up to date with current legislation and certification demands.

As individual fishers, we don’t have a peak body that will act for us. I suppose it’s a bit hard, too, in the fact that everybody might operate differently, so how would they police the umbrella of everybody in that certification? We’re definitely out on our own. We do feel strangled by the government, because we’re meeting the rules and regulations that have been in place for a long time, with minimum and maximum sizes, pro seasons, boat sizes, license requirements, but they keep [moving] the goalposts. We kept going up in boats because when they brought the green zones in, we needed bigger boats to travel further…[F]or bigger boats, you need to fish longer because you’ve got bigger fuel costs, you need more fish to then cover your break-even point and pay for the crew. Then my partner was just never home, so when we got to the top, and we had the biggest boat – the newest boat in the fleet – he was just never home because the crew just couldn’t manage their money. When you’re responsible for six people that are broke, you’ve got to go back to work. You’re just living to pay the bills and keep going. We had no work/life balance. It made it hard, so we got rid of that. (Interview #22)

[T]he fishing…it would either be declining in catches, or seasonal catches, or price. It doesn’t matter, you know: it costs the same amount of money to catch that fish, and if you’re getting a low price, there’s no margin in it…China was then being very fussy with the colour of the fish. Then COVID happened, and they’re even fussier. It’s ridiculous. We downsized to focus on the shop. We get a lot more recognition and appreciation in our local community for that. People want to know where their seafood is coming from, and who’s caught it, and that trust is there. (Interview #22)

In addition, some SMEs noted that they felt a **lack of support from the industry** itself.

[A]s a wild fisher, I wasn’t getting support, and then Seafood Industry Australia has now been created, but they’re heavily funded by aquaculture...We can’t afford $1,000 [in annual membership]. I don’t see the value in it. I just find that we are being strangled, and the only sector that’s booming is aquaculture. (Interview #22)

Accessing appropriate finance is a considerable barrier for many businesses wanting to implement CE. This was particularly obvious for SMEs, where the desire for change exists (e.g. to move to solar energy, or expand the scale of a small or niche operation). However, **access to appropriate grants and incentives is limited**.

The capital cost of doing everything internally would just kill us, and I think we’ve learnt from bitter experience that, at some point, we need to stick to our knitting. We’re not a freight company. We’ve tried to expand into other realms, and perhaps realised after the event that that’s not where our *expertise lies, and it takes a while to get there…We do little things…It all comes down to where we get the best bang for our buck, I think, with a lot of this stuff. (Interview #6)*

We feel like we're doing something that really does warrant some government investment… We've got to go out there now and we've got to fund purchases of land, or lease of land. We've got to fund [the] EPA license. We have to fund…packing sheds, all of that stuff. Realistically, we're probably looking at $2 [or] $3 million investment, if not more – and that's something we're [going to] have to fund off our own back if we really [want to] keep operating this business, otherwise…that'll be the end of this. (Interview #26)

Regarding packaging, a significant barrier is that there is **no high-performing like-for-like product** to switch to at comparable cost.

[W]e get boxes sent up to us as freight…[T]hey come from a large seafood business. They've got a pre-printed poly[styrene] box and they're all cracked and broken – and they end up in the bin. I'm thinking, that's a massive company that would have all these things ticked, but they don't have that ticked. They can't expect us to have it done if they can't change it either. They have the money, the profit, the manpower to change that if they wanted to. I know there [are] things happening with Kool-boxes [KoolPaks] in the pipeline, but costs would be the main factor. The compostable bags – [those] I'd like to use. I see a fish shop in Melbourne used them, but again, it would be cost and quantity. I'm not sure if it would be cost-effective having a plastic bag that would be compostable. I don't even know if people here compost. You could be changing all these things in your business, [and] then people [are] still putting it in the bin. (Interview #4)

The most significant barrier, you know, [is] price point for us...[our KoolPak product is] obviously dearer. You know, maybe four or five times dearer than the poly-box. Soon to be banned, [the poly-box] is. But then, you start to pull it down into context. You get 38 polystyrene boxes on a pallet that size. You get 120 to 140 of ours on a pallet, flat-packed. The new packaging has a higher payload. You've got reuse, you don't have a single-use plastic bag, you have to buy or be responsible for [it]. (Interview #4)

You've got a difficult [item] to recycle and then landfill is expensive, so I hear. So many people [are] going, you know, when we put our poly-boxes in a skip, we don't get that many in, and the skips fall, and it's expensive to take it to the tip and it's like—in our box, obviously you could get some cash back. (Interview #4)

“ The compostable bags – [those] I'd like to use. I see a fish shop in Melbourne used them, but again, it would be cost and quantity. I'm not sure if it would be cost-effective having a plastic bag that would be compostable. I don't even know if people here compost. You could be changing all these things in your business, [and] then people [are] still putting it in the bin.

When businesses are working at the cutting edge of innovation, and implementing CE-focused business models, **doing things differently can be a barrier to collaborating with partners**.

It's difficult for my shareholders to understand, but I think that you become quite broad, and there's many strings to your bow then – but I think that can sometimes be difficult to manage. But it doesn't mean you have to execute everything in parallel, equally. Sometimes things are established as a concept and are drawn out over time. Markets have to be tested, and that sort of thing, but I think that diversification is something that we might have learnt – during the COVID period – is…important [to] the resilience of a company. It also is an opportunity, at this stage, to be across a number of marine industries, and I think each of the products and projects and arms – some may drop off, some may accelerate into their own new company spin-offs and that sort of thing – but I think that we actually found a niche of opportunity…We're trying things, and R&D is a big part of *our work at the moment, and that will fluctuate over time. Some years, you start focusing on sales only, and other times it's like, "Oh, well, that's all flowing now, let's look at the next project that we had in line." (Interview #15)*

The **cost of products that can be manufactured locally and sustainably** (e.g. soldier fly larvae for aquaculture) can be a barrier to the growth of an innovative and potentially sustainable market. Product costs interact with economies of scale.

That comes back to…the cost of production. The cost of fishmeal is low, but growing. The cost of soy protein – even though we import, I think, almost all of it into Australia, maybe 700,000 tonnes a year – that's still quite cheap, still only $2 or $3 a kilo, whereas insect protein in Australia is still probably north of that $20 a kilo. That's the main impediment…do you promise the world scale before you can get sales? Or do you try and get sales before you can really generate that scale? (Interview #25)

The seasonal nature of the sector (particularly for wildcatch) and regional nature of many operations also means that there can be **challenges in finding a suitable workforce**.

There's no training facilities to bring new people in. There's been a lot of people that have wanted to do that as a business, but haven't been able to do it. Then there's the conflict in the industry that the wrong people would be training them, so they would be not [suitable to] our business. They've been taught the lazy way, or whatever. There's definitely staff like that. It's the cost. We kept changing boats, so we got to the biggest boat. We then sold that one and went to a smaller boat, which was faster. It was meant to be a 10-year plan but that was the most expensive…Insurance alone was $20,000 [to] $30,000 a year. That's somebody's wage. (Interview #22)

Interviewees noted **the need to educate consumers about seafood seasonality**, as there is often a demand for the same fish to be on the menu year-round. For fresh product, this isn't feasible, particularly for small local producers.

Restaurants…[have got to] be able to get regular supply of that fish. I was in the retail shop yesterday, dealing with a local restaurateur who came in – and he was looking for swordfish…Swordfish are not in season. They haven't been in season for a number of months, but on his menu board, he's got a special swordfish. People go, "Oh, we can get swordfish and he's got it – oh, it's fresh. Yeah. Yes. It's fresh. It's been freshly defrosted for you at convenience… (Interview #14)

Geography

The fisheries and aquaculture sector in Australia is mostly regional and remote in nature (see Figure 17).

There are certainly things that we are continuing to look at, but, again, the logistics of doing a lot of things at the bottom of the world makes it really difficult. (Interview #6)

This creates significant challenges regarding access to volumes of the material, as well as access to an appropriate workforce. An alternative is to transport materials to a central location, however, this increases the carbon footprint of that product (due to fossil fuel use in the transport and logistics sector) as well as cost to individual businesses.

It's that the freight charge kills you before you get started… We have no shortage of product that is now seen as waste that has a hell of a lot of value, and it's just finding how we can get that value and get it to a market in a cost-effective way… The challenge for us is making the economics of it stand up for them as well as us. We're talking thousands of tons of this stuff. Again, the logistics of it just makes it expensive. (Interview #6)

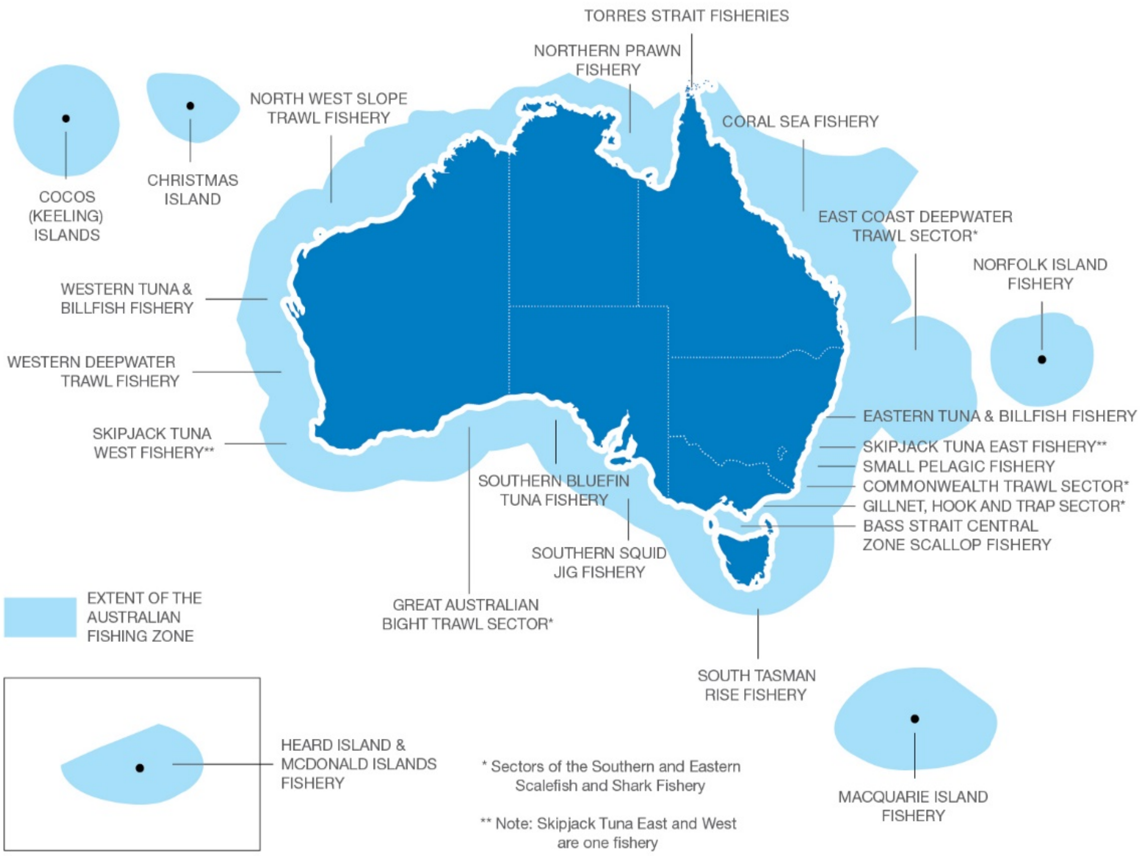

Figure 18. Australian Fishing Zone and Commonwealth Fisheries (light blue)

Source: Australian Fisheries Management Authority (AFMA).

CE hierarchy analysis

The hierarchy of CE principles are 1. Design out waste and pollution (once products are designed, it is hard to reverse the damage), 2. Keep products and materials in use (reuse, repair, remanufacture, recycle), and ultimately, 3. Regenerate the natural environment (going beyond ‘protect’ to restore). (Ellen MacArthur Foundation, 2015a; 2015b; Potting et al., 2017)

Participants reported that they mostly work in the ‘Reuse’ space. Additional support could go to design and regeneration.

Within the plastics case study, participants talked about reuse – where possible – through plastic recycling and ‘designing out’ (avoiding plastic use in packaging and developing biodegradable/compostable alternatives).

Within the organic waste case study, participants talked about reuse through alternative uses for waste – both high-value (e.g. pet food, nutraceuticals) and lower-value (e.g. fertiliser) products.

For water, the focus was on ‘designing out’ waste by improving water reticulation systems.

In the energy case study, the focus was on ‘designing out’ fossil fuel use by shifting to renewables.

Figure 19: Small-scale rooftop solar installation

Image credit: Getty Images

Opportunities

There are significant opportunities to increase circular activities within the sector. The policy context and various schemes that support recycling and CE in manufacturing could, for instance, be applied within the fisheries and aquaculture sector.

In our case study interviews, businesses reported that they need better funding opportunities.

- SMEs noted there were no small (less than AU$100,000) grants that would allow them to innovate, try something new, or scale up incrementally or in stages.

There are specific opportunities and suggested actions to promote CE in each case study domain, as listed below.

Plastic

- Support SMEs working in plastic recycling and the development of alternate materials.
- Explore scientific solutions to cleaning/mitigating biofouling (caused by microbes) that don't depend on the use of toxic chemicals. This allows for continuing use of those materials, or for safe and efficient recycling. Autoclave sterilisation techniques could be explored.
- Restrict (through regulation) the types of plastics used in the industry to those that can be recycled domestically at a reasonable cost.

Organic waste

- Support SMEs and large-scale organisations to develop market opportunities for waste products. These could include niche products (such as prawn oil) or nutraceuticals, as well as new products (such as soil conditioners).
- Explore the large market opportunity for this waste to be used in organic fertiliser
- **Water/waste water**

- Create funding incentives for water reticulation improvements and water-efficiency innovations and infrastructure.
- Create targeted incentives to encourage the installation of high-flow, water-sensitive taps along the supply chain (e.g. gurneys/pressure washers).

Collaborative consumption

- Develop networks within the sector to encourage more collaboration and co-sharing of equipment where possible (e.g. grading machinery in estuarine aquaculture).
- Create funding incentives for fishery co-operatives to install solar power.
- Create funding incentives for fishery co-operatives to install new digital IT systems to manage and monitor organic inputs.

Energy

- Create targeted funding incentives for solar installation/renewable energy options.
- Encourage the sector to move to renewable fuels for fishing vessels.

> “ Our ethics are really around creating vibrant sustainable communities, but also environmental values of reducing carbon emissions.

Scale of circularity

Individual businesses can only go so far on their own in taking steps towards circularity (e.g. through improving production efficiencies). A true circular economy requires a functioning market, and collaboration across every point in the value chain.

As businesses shift towards circularity, they often encounter **problems linked to the limited scale of circularity in the wider industry**.

> *We'd like to expand down throughout Queensland, and we've had a lot of interest in south-east Queensland and northern New South Wales…We had massive growth in the last couple of months with the home deliveries, but it got to the point where it was not sustainable for us to be doing those deliveries. We're just changing the model now, pulling back from us doing deliveries, and have to rebuild it a bit with these other delivery providers…We could have a big warehouse and buy everything off the producers and resell it, but that's just the same as what everyone else is doing. It's not changing things for the producers. I mean, it might mean people – if we do it more localised – would still get the local food, but you run that risk of – you see, if you try and grow it too quickly like that, it's just [going to] end up with everything going to Brisbane and back…You know, social enterprise is you're putting the money back into the business…our ethics are really around creating vibrant sustainable communities, but also environmental values of reducing carbon emissions. (Interview #12)*

For some businesses, **the goal is to have complete ownership and control of CE processes**.

> *The vision is to have it all in-house. Make the bioplastic, process it, turn it into film, distribute the film. Even providing compost solutions if there aren't local composting solutions. (Interview #17)*

For others, there is **a desire to work with the right partners and supply chain collaborators**, although they are not always easy to find.

> *Finding somebody who's willing to work with us, and who's willing to spread some of the financial pain in the initial period – rather than wanting just to see us as a supplier, as opposed to a partner in it. (Interview #6)*

Degree of regeneration

Given the scale of global environmental challenges, sustainability measures (protecting natural systems from further harm) are no longer enough. We need to consider actively *restoring* natural systems, and – ideally – *regenerating* them to safeguard the planet's health.

Restorative solutions focus on resource recovery to mitigate the impact of all material inputs and outputs on an ecosystem. This shift from protecting to restoring – and ultimately regenerating – natural environments may require new business models.

Figure 20: Oyster aquaculture (various locations in NSW)

Images credit: Andy Myers

Many workshop participants and interviewees, however, noted that the act of fishing itself cannot really be done in a way that is 'regenerative.' They remarked that this is perhaps the most challenging aspect of CE for the sector. The regeneration of fishing grounds is only possible through doing *less* fishing, yet this is the core activity on which the sector's economic viability depends.

One way to address this challenge would be for fisheries and aquaculture businesses to participate in regenerative community- or habitat-nurturing activities as 'offsets' (as with carbon emission offsets).

It was noted that some organisations are already excelling in this space, such as Goolwa Pipi Co in South Australia. The organisation supports projects that regenerate local communities. It has also decided to actively reduce the scale of its harvesting, allowing the natural resource to recover.

Aquaculture, like terrestrial farming, can more easily be done regeneratively. A positive example is advocacy by oyster farmers to encourage local governments and communities to reduce land-based pollution that impacts water quality. Filter-feeder shellfish aquaculture (such as oyster and mussel farming) in itself improves local water quality.

Kelp aquaculture has the potential to contribute to the development of a viable bioplastics industry in Australia, but only if it's carefully farmed, with consideration of all possible impacts on the local ecosystem (high-input farming methods should be avoided).

Technology readiness

In developing the case studies (based on our semi-structured interviews with stakeholders), we evaluated CE activities in terms of their Technology Readiness Levels (TRLs), using the following categories:

1. Research
2. Development (feasibility, trials, proof of concept, etc.)
3. Deployment (within the production system or sector)
4. Scale (including the ability to scale up from small to large/commercial).

CE within the sector is still hampered by uncertainty. For instance, even with CE activities that are well-established (e.g. transforming organic fisheries waste into pet food), there are still unknowns regarding the availability of products long-term, and how market dynamics will affect businesses.

Many stakeholders noted that **CE is still a relatively new concept for many in the industry**, and that Australian seafood businesses are not yet mature in terms of their CE knowledge and expertise.

> *[I]f you look at the industry in the other major aquaculture countries – like Norway and Scotland and Canada – they're a lot more mature or established than we are here [in Australia]. We're very much in the development stage and expansion stage at the moment. We don't have the build-up in support of other businesses, contractors, companies that they do over there. (Interview #6)*

"[I]f you look at the industry in the other major aquaculture countries – like Norway and Scotland and Canada – they're a lot more mature or established than we are here [in Australia]. We're very much in the development stage and expansion stage at the moment. We don't have the build-up in support of other businesses, contractors, companies that they do over there.

Case study industry vignettes

We have developed a series of 'industry vignettes' to showcase current CE initiatives within the five case study domains. These vignettes are intended to be accessible and inspirational communication pieces that can be widely shared. We hope that they can support the practical adoption and expansion of CE across the fisheries and aquaculture sector. These are also available as a stand alone five-page communication piece.

CASE STUDY INDUSTRY VIGNETTES

Organic waste

FRDC UTS Institute for Sustainable Futures

Figure 21. Seaweedery prawn oil

Seaweedery

Organic waste is produced at every stage of seafood supply chains. Many businesses now view these organic materials as opportunities to apply circular economy principles to undervalued resources. Collecting, recycling and reprocessing materials like fish frames, shells and offcuts not only diverts organic waste from landfill, it creates new value chains for food products and fertilisers.

At Seaweedery, a chef and a sustainable packaging expert joined forces to reprocess seafood waste into high-value human food products. With the support of business accelerator Seafood for Good, and in collaboration with Austral Fisheries, Seaweedery is transforming prawn shells into high-value prawn oil for human consumption. Their business is based on the concept of a restaurant kitchen where nothing is wasted.

Figure 22. Pet treats made from fish waste

All Fish for Dogs

The founder of All Fish for Dogs (pet food treats made using fish waste) came up with the idea in 2015, after seeing first-hand – as a commercial fisher – the volumes of fishing waste and by-catch. The business was established using the funds from the sale of the founder's fishing licence, and now uses organic fish waste from across Australia.

Based in Mission Beach (Queensland), the company has overcome a range of logistical and packaging challenges linked to the transport of frozen fish from interstate. The fish waste is processed and dried into a range of dog treats (made from 100% fish, with no preservatives, additives or artificial colours).

Figure 23. Venus Shell Systems distillation process

Venus Shell Systems

Unlike many companies that are new to organic waste use, Venus Shell Systems was founded on circular economy principles. The business, based in the Shoalhaven region of NSW, produces unique traceable, premium-quality marine biomass (from seaweed).

New products – including biomaterials, cosmetics, dermatological care, food, nutraceuticals and pharmaceuticals – are created from this waste. Venus Shell Systems collects nutrient waste and carbon dioxide from wheat-processing to enhance seaweed biomass production. The business also processes aquaculture waste (such as mussel and oyster shells), and is expanding its portfolio of ingredients made from sustainable marine sources.

Figure 24. Ocean2Earth fish waste collection

Ocean2Earth

On the far-south coast of NSW, Ocean2Earth provides the local council with an alternative to sending fish waste to landfill. Drawing on previous experience in marine biology and gardening, the business founders began collecting and composting fish waste from boat ramp bins in Bermagui and Eden. This had the added benefit of reducing odours and waterway pollution.

The business has now expanded to collect over 300 tonnes annually of fish waste from the Bega Valley alone. The composting process also uses local timber mill waste. Ocean2Earth believe they have only just begun to scratch the surface of using organic materials that can be diverted from landfill for use as soil fertilisers or conditioners in agriculture, public parks and gardens.

Image sources:

Seaweedery (https://startsomegood.com/seaweedery); All Fish for Dogs (https://www.cleardog.com.au/category/dog-treats/fish-dog-treats/)

Venus Shell Systems (https://www.venusshellsystems.com.au/about-us/); Ocean2Earth (https://ocean2earth.com.au/)

Plastic

Plastics (produced from fossil fuels) are used extensively in seafood supply chains. Plastic waste enters ocean ecosystems and persists in the environment. Its disposal is increasingly firmly regulated and more expensive for businesses. Plastic waste poses a major challenge to the establishment of circularity in the fishing industry because biosecurity and food safety concerns limit reuse. Many businesses want to eliminate plastic waste and explore the use of alternative materials.

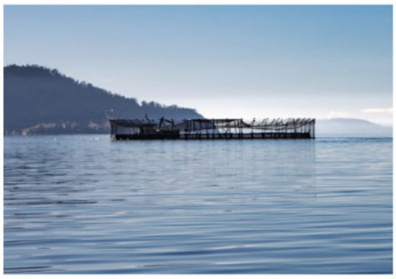

Figure 25. Aquaculture plastics

Tassal

In Tasmania, aquaculture business Tassal makes extensive use of hard and soft plastics in salmon farming. Hard plastics are used in feed pipes, stanchions, and the frames that make up salmon pens. These materials are recycled by Environex locally into second-life products.

Through membership in the Australian Packaging Covenant (APCO), Tassal is exploring similar opportunities for recycling more problematic types of plastic used in packaging (such as film and poly-boxes).

Figure 26. A KoolPak

Tom Kat Line Fish

In Queensland, Tom Kat Line Fish developed a solution to its needs in KoolPak, an innovative seafood packaging product that eliminates single use poly-boxes for transport to market of its tropical, wild-caught fish.

KoolPaks can be reused multiple times, are 100% recyclable, have superior thermal performance to polystyrene, and are strong, airline-approved and leak-proof. Each KoolPak incorporates near-field-communication (for chain of custody tracking), temperature sensing, and has an anti-microbial layer (for compliance with food safety regulations).

Figure 27. Compostable wrap

Great Wrap

A passion for finding alternatives to plastic film packaging led the company Great Wrap to produce the only Australian-made compostable wrap suitable for use in catering and pallet wrapping.

Their product is made from potato waste and a mix of other biopolymers, and is certified compostable (which means it must break down in a compost pile in under 180 days and leave behind zero toxins). The business is currently exploring the potential to replace potato waste with alternatives (like aquaculture-farmed kelp) to make their product even more sustainable.

Image sources:

Tassal (https://tassalgroup.com.au/wp-content/uploads/sites/2/2021/11/Tassal-Sustainability-Report-Final-Interactive_FINAL.pdf)

Tom Kat Line Fish (https://www.koolpakbox.com/)

Great Wrap (https://www.greatwrap.co/products/compostable-pallet-caps-pack-of-100)

Energy

The rising costs of energy and concerns about carbon emissions are driving change in energy use in the fishing industry. Some businesses have found unique renewable energy solutions to suit their individual needs.

Figure 28. Ballina Fisherman's Co-operative

Ballina Fisherman's Co-operative

At Ballina Fisherman's Co-operative the installation of roof top solar photovoltaic cells (PV) generates 97kW of electricity that substantially offsets the Co-op's energy use. The Co-op's electricity bill, mainly to run its ice machines and freezers, has fallen to about $7,500 per month, less than half the cost of power before the solar PV installation six years ago. While the Co-op cautions that the $140,000 spent to install the solar system may seem high, the savings mean these costs have been quickly recouped. Businesses seeking to copy Ballina Co-op's success need to be mindful that older buildings may not be suitable for rooftop installations, and there are limits on the amount of electricity that can be generated from grid connected systems before network access fees apply.

Figure 29. Murray Cod Australia aquaculture ponds

Murray Cod Australia

Like Ballina Co-op, aquaculture business, Murray Cod Australia, has also installed solar PV systems at two of its farms with plans to expand solar energy generation to other sites as capital becomes available. Energy is the second biggest cost of production after fish feed for this business. Through its annual carbon footprint audit, the business understands that electricity makes up about 75 per cent of its carbon emissions. However, because in aquaculture much of the power use is at night, solar-PV alone can't offset all of their electricity use. Rather than install expensive battery storage, the business chose to purchase certified green power from commercial electricity suppliers to ensure that they can realise their goal of being carbon-neutral within the next 12 to 18 months.

Figure 30. Tom Kat Line Fish employee

Tom Kat Line Fish

In far-north Queensland, line-fishing business Tom Kat Line Fish turned to solar and wind generation to supply its energy needs. The company requires energy 24 hours a day to run its operations, but in the tropics, high levels of cloud cover and seasonal rainfall can limit electricity generation from solar-PV systems. Tom Kat obtained council approval to install a direct-drive, high-torque wind turbine that harnesses energy from the trade winds. The 6-metre wide, 30-blade turbine is mounted atop a tall tower, and generates 8 or 9 kW of power per hour to supplement the company's energy needs when the solar power generated is insufficient.

Image sources:

Ballina Fisherman's Co-operative (https://ballinafishermenscoop.com.au)

Murray Cod Australiia (https://aquna.com/news-room/)

Tom Kat Line Fish (https://www.tomkatlinefish.com)

Water/waste water

Applications of CE in the fishing industry encourage efficient use of Australia's limited water resources, and a philosophy of responsible management of waste water from fish farming and processing.

Figure 31. Tom Kat Line Fishing dry-filleted fish

Tom Kat Line Fish

Reducing water use in fish processing while maintaining product quality is central to Tom Kat Line Fishing's operating principles. The company has implemented a dry-filleting process that is unique in Australia.

Fish are dry-filleted using ultraviolet light (to check for bones and scales) before the fillets are vacuum-sealed and blast-chilled to -40°C to lock in freshness. Paper towel rather than fresh water is used to clean work surfaces, which is later combined with fish frames from the filleting line for hydrolysing. The process complies with food safety standards, and the product compares favourably with traditionally produced chilled fillets in professional blind tastings.

Figure 32. Mainstream Aquaculture Group's aquifer

Mainstream Aquaculture Group

Mainstream Aquaculture Group's fish farming operation in Victoria has found a unique solution to supplying fresh barramundi to major urban markets while limiting reliance on municipal water supplies.

Twenty years ago, the business established an urban fish farm at Werribee, to supply the freshest produce to major markets in southern Australia and overseas. The business sustainably extracts water from a deep aquifer that is heated throughout the year by geothermal activity. The water is high in minerals, making it unsuitable as drinking water or for agricultural uses. However, the water's high-mineral content and warm temperature makes it ideal for producing barramundi in a cool climate, and reduces the company's use of urban water supplies and energy for heating.

Figure 33. Tailor Made Fish Farms aquaponics system

Tailor Made Fish Farms

Company concern about the overuse of natural resources (including wild fish stocks and fresh water supplies) led Tailor Made Fish Farms to develop a combined aquaculture and aquaponics production system. The aquaponics side uses waste water from the fish farm to grow vegetables hydroponically.

The waste water from fish production is supplemented with additional nutrients to ensure plant health and high yields. Vegetables (like tomatoes and lettuce) produced this way use only a fraction of the water of field-based crops, making them highly water-resource efficient. The business also runs a restaurant on-site that helps to reduce food miles from paddock (or pond) to fork.

Image sources:

Tom Kat Line Fish (https://www.tomkatlinefish.com)

Mainstream Aquaculture (http://www.mainstreamaquaculture.com/about-us/our-history/)

Tailor Made Fish Farms (https://www.tailormadefishfarms.com.au/)

Collaborative consumption

Applying circular economy principles not only depends on a ready source of materials for recovery and reuse. It also calls for an ethos that integrates circularity into business operations, and a willingness to work with like-minded businesses and consumers.

Figure 34. Farmer Meets Foodie online platform

Farmer Meets Foodie

The establishment of a virtual marketplace has allowed Farmer Meets Foodie to take advantage of a growing trend that links sustainable seafood producers directly to consumers.

The far-north Queensland company was founded due to concern that seafood and farm produce often travels long distances from the place of harvest to centralised urban markets, and then out to consumers (creating significant carbon emissions). They established an online platform and partnered with three seafood businesses to market their produce in 'virtual shopfronts.' This approach suits smaller-scale businesses looking for local distribution, or higher-value products (where transport costs represent a smaller proportion of product value). The seafood products are delivered directly to consumers, ensuring freshness, reducing food miles and providing a fair return to producers.

Figure 35. Fishing boats at harbour

Commercial fishing co-operatives

Commercial fishing co-operatives are common within the NSW fishing industry, and play an important role in the circular economy by sharing services. Co-ops provide local commercial fishers with fuel, ice, gas, cold storage, mooring facilities, transport and marketing. Co-op sustainable procurement policies and circular practices can positively influence the network of members.

Many co-ops organise training delivered through OceanWatch's national SeaNet environmental extension service. This provides advice to members on environmental responsibility and biodiversity conservation, species protection, by-catch reduction, and introduction of sustainable/circular technologies and practices. Some co-ops have implemented new digital data/IT systems to assist members in monitoring progress on key performance indicators of business sustainability and circularity.

Image sources:

Farmer Meets Foodie (https://www.farmermeetsfoodie.com.au/index.php?);

Trip Advisor (https://media-cdn.tripadvisor.com/media/photo-s/10/31/f7/45/the-yamba-boat-harbour.jpg)

Implications

In this section, we explore the implications of our research findings for the fishing and aquaculture industry through the lens of 'territoriality' (Tapia et al., 2021). We chose this lens in recognition of the wide geographical range and location of seafood businesses in Australia, and the regional (or remote) nature of the sector.

The concept of territoriality involves paying attention to the following six factors in understanding CE opportunities or barriers:

1. Land-based factors, including physical endowments of materials

In relation to land-based factors and the physical endowments of materials, it may be possible to generate sufficiently large resource volumes for circular activities (such as recycling) if the fisheries and aquaculture industry is closely connected to terrestrial enterprises.

This connectivity requires purposeful planning to be effective. One example shared with us of the negative consequences of insufficient planning is where a fishing co-operative planned to share water with a neighbouring agricultural enterprise. These plans became untenable following the development of water and electrical infrastructure for a residential housing estate adjacent to the co-operative's site.

2. Agglomeration factors for resources, knowledge, collaboration and markets

Large organisations within the fisheries and aquaculture sector may have the internal capacity to absorb some elements of CE through vertical integration.

By contrast, SMEs often have more limited capacity for vertical integration, and require deeper collaboration along value-chains to achieve CE goals.

However, for the establishment of effective CE, agglomeration of resources (such as stockpiling materials, or creating larger centralised companies) is not always required. Global supply chains can often hide significant carbon emissions (e.g. cold chain, transport and logistics), while local supply chains incorporating CE collaborations at a smaller regional scale may be more flexible and better adapted to local needs.

In some instances, scaling up is possible, particularly where financial capital and volumes of material are available. In other situations, the nature of the activity may demand an upper limit to match CE goals. For instance, Farmer Meets Foodie provides a platform to connect growers/fishers directly to consumers, removing the need for long transport links. The focus on local supply and connection to growers is key to its business model. While this model could be replicated in other locations, the challenge is that if this social enterprise were to scale up, it would begin to replicate the business models of larger seafood markets and lose its unique point of difference.

3. Access to and availability of physical infrastructure

Some challenges are intractable, such as the difficulties of working across long distances in Australia, and – for some parts of the sector – operating in remote locations. Due to the regional nature of the sector, a significant challenge is ensuring appropriate infrastructure is available in these widely dispersed and often remote locations. Establishing sites for onshore processing close to the point of capture (e.g. in the Gulf of Carpentaria) would allow for more efficient utilisation of organic waste.

4. Access to state-of-the-art technologies

There is already a wide range of technological innovation within this sector, and there are opportunities to harness this for CE. In terms of accessing these technologies, SMEs and newer enterprises face specific challenges that are not unique to this sector, but apply more generally. This means there is an opportunity for cross-sectoral collaboration to pool knowledge and overcome some of these barriers.

5. Knowledge and practical know-how

Our research has shown that, in many cases, CE is not deeply embedded in core business goals.

Instead, it is often external drivers – such as the rising costs of waste disposal, fuels, electricity and water – that encourage businesses to explore circular opportunities, in the pursuit of ongoing financial viability. The good news is that this has led to many CE activities throughout the sector, at a range of scales and across production systems.

However, a key finding of this project is that the fisheries and aquaculture sector currently sees ‘sustainability’ only in terms of not depleting fish stocks or reducing pollution (which is, of course, essential). The challenge and opportunity is to encourage the industry to also see ‘circularity’ as key to operating in ways that are environmentally, socially *and* fiscally responsible.

6. Governance and institutional arrangements

There is a real opportunity to enhance current governance and institutional arrangements within the sector. Existing regulatory frameworks for circularity are, in many respects, insufficient. Additional regulation and support is especially urgent in order to reduce the wide range of plastics currently used in the Australian seafood system, and to establish firm plastics recycling protocols.

Recommendations

Our recommendations cover different geographical regions and business sectors, and assign responsibilities to organisations at varying points in the value chain, so he have not ranked the recommendations numerically. We have indicated the priority level (medium/high) for each recommendation.

Recommended action	Responsibility	Priority
Facilitate **more recycling by** seafood industries through **existing government initiatives in supporting recycling infrastructure** and **manufacturing innovation** (especially plastics and metal).	Seafood Industry Australia, other industry organisations, recycling/manufacturing initiative agencies	High
Develop regulatory frameworks that allow for the use **only of plastic types that can be recycled within Australia** at a reasonable cost to businesses.	Commonwealth, State and Territory governments	High
Investigate innovative methods for **recycling plastics that have been in contact with seafood** (e.g. autoclaving).	FRDC	Medium
Support the development **of compostable alternatives to plastic** in packaging for feed/bait bags and food retail.	Multiple institutions	High
Develop **cross-sectoral collaborations that can facilitate CE in fisheries and aquaculture** (e.g. agglomeration of organic waste with farming and municipal waste collection systems; recycling or replacing soft plastics in partnership with the food retail sector; or recycling plastics in pipes, nets and ropes for use in the farming sector).	Multiple institutions	High
Develop better **grants and financial support opportunities for SMEs** to jumpstart or scale up CE activities.	Regional development bodies, Commonwealth bodies	High
Survey the **regulatory factors that are obstacles or drivers of CE** in fisheries and aquaculture, and make recommendations for change.	FRDC	High
Investigate possibilities for changing seafood industry regulatory and policy frameworks to **introduce CE into existing visions of ecologically sustainable development**. This could include more emphasis on reuse and regeneration in aquaculture, or regeneration offsets for fisheries.	FRDC, State, Territory and Commonwealth fisheries management agencies, industry organisations	Medium
Build awareness about and capacity for CE within the fisheries and aquaculture sector.	FRDC	High
Commission business research to support the fisheries and aquaculture sector in **generating new ideas and investigating the feasibility of different CE initiatives**.	FRDC	High

Extension and adoption

Target audiences

Target audiences include government (e.g. AFMA and State agency managers, especially where State-specific case studies or key opportunities exist), the private sector (e.g. Sydney Fish Market, Tassal, Venus Shell Systems), civil society groups (e.g. recreational fishers), and leaders of CE initiatives (e.g. Planning Institute of Australia, World Wildlife Foundation [WWF]).

Key messages

Key messages include:

- How circular practices are being applied in other sectors and industries
- How circular economic principals may be adopted by the fishing and aquaculture sector in Australia (including by forming linkages with other marine and land-based sectors)
- Current barriers and opportunities to adopting circularity within the fisheries/aquaculture sector, and known strategies for overcoming those barriers.

Methods of extension and adoption

During the active research phases of this project, information was delivered to the target audiences through consultations with the Steering Committee (SC) and in the systems mapping workshop. The final research outputs (including this report, which includes systems mapping diagrams and case study 'industry vignettes') are designed to be used to promote CE extension and adoption by fishery managers, and industry and community stakeholders in the fisheries and aquaculture sector.

The SC has provided valuable guidance throughout the project, from the research design phase onwards, and will act as a useful conduit to extend the project outputs. We incorporated the advice of the SC on how best to design our research outputs to maximise their positive impact on target audiences.

The research outcomes will also be widely shared with the CE and fisheries/aquaculture research communities through relevant national/international conference papers and presentations, and by publishing our findings in high-quality, peer-reviewed journals.

Action Plan

1. **Written report** delivered in draft form for feedback; final version incorporates findings from all four phases of the research.
2. **Systems mapping infographics** developed of the circular economy opportunities across the Australian fisheries and aquaculture supply chains, and creation of a seafood-specific CE 'butterfly' diagram.
3. **Case study 'industry vignettes'** developed as widely accessible, stand-alone pieces to be shared with a broad industry audience.
4. **Presentation deck** delivered to FRDC, with the option of a webinar with FRDC and other stakeholders at project completion.
5. **Conference papers** and **peer-reviewed journal articles** created from research outputs and submitted for publication.

During the active research phases of the project

Method	Responsibility	Completion date
Presentations to Steering Committee	Principal and co-investigators	Throughout the project, whenever opportunities arise.

Use preliminary research findings to guide the design of the systems mapping workshop with stakeholders	Principal and co-investigators	June 2021

After the completion of the project

Method	Responsibility	Completion date
Presentation to Ocean Decade Australia	Principal and co-investigators	Late 2022 (investigators to liaise with Jas Chambers of Ocean Decade Australia regarding setting a date for presentation).
Presentation to High Level Panel for a Sustainable Ocean Economy webinar series	Principal and co-investigators	Late 2022 (investigators to liaise with Russell Reichelt about organising this presentation).
Report and communication materials shared with Steering Committee, and with all stakeholders who participated (or expressed interest) in the project	Principal and co-investigators	October 2022
Report and communication materials made available online (FRDC website, UTS:ISF website)	Principal and co-investigators, FRDC	October 2022
Public dissemination of research findings via *The Conversation* or similar outlet	Principal and co-investigators	Q4 2022
Industry dissemination via FRDC communications, including a 'story board'.	FRDC, Kate Barclay	Q4 2022
Conference presentations and journal publications	Principal and co-investigators	Kate Barclay presented to Seafood Directions in September 2022. Samantha Sharpe to present at a CE conference in 2023 (e.g. Big Plate: Produce Lifetimes and the Environment) Investigators to submit a paper on the project to a peer-reviewed marine policy or resource management journal in 2023

Evaluation

- Development of a diverse and inclusive national Steering Committee (SC) with a wide range of experience across both the seafood industry and circular economy theory/principles/practice
- Successful stakeholder engagement – this enabled the identification of five case study domains, each containing success stories and 'industry ready' opportunities
- Creation of systems mapping infographics that clearly demonstrate the opportunities for CE to be implemented within the sector
- Systems mapping infographics have been widely shared and promoted (as measured by website hits, requests for report, requests for further information/presentations)
- Materials/outputs for improving awareness of CE opportunities widely disseminated within the industry through the SC and key stakeholders (nature of materials to be shared identified by SC).
- Materials/outputs for engaging local seafood producers and related supply chain stakeholders widely disseminated (e.g. case study 'industry vignettes')
- Materials/outputs widely shared and accessed (as measured by website hits and requests for further information).

Project coverage

FRDC has agreed to explore media leveraging opportunities with UTS in October 2022.

Project materials developed

In addition to this report, three sets of communication materials have been developed, all of which are included in this report and also available as stand-alone pieces to be used in targeted outreach.

- ‘Butterfly’ infographic of Circularity for Seafood (C4S) (Figure 3)
- Systems mapping infographics of input and output flows (Figure 13 for wildcatch fisheries; Figure 14 for aquaculture)
- A series of case study ‘industry vignettes,’ grouped according to five identified case study domains (plastic, organic waste, energy, collaborative consumption, and water/waste water).

Appendices

- Steering Committee terms of reference
- Literature searches
- Case study profiles
- Interview guide

Appendix 1: Steering Committee terms of reference

A Steering Committee is being established for the project to allow broader stakeholder input into the direction of the project. The purpose of the Steering Committee is to:

1. Provide strategic advice and input into the implementation of the research project
2. Ensure that the outputs of the research project will be relevant
3. Assist with access to stakeholder networks for participation in the research, and dissemination of the findings.

About the project

In collaboration with the Fisheries Research and Development Corporation (FRDC), researchers from the University of Technology Sydney (UTS) will co-design and conduct research to:

1. Develop increased knowledge of how the concept of circular economy relates to fishing and aquaculture, including both upstream and downstream activities (such as post-harvest processing and packaging).
2. Develop increased knowledge of how circular practices being applied in other sectors and industries relate to the fishing and aquaculture sectors and could be adopted by fishing and aquaculture businesses. This includes opportunities for fisheries/aquaculture industries to develop circular linkages with other marine and land-based sectors.
3. Identify opportunities that are available and areas for exploration in the short, medium and longer term to progress a circular economy for fisheries and aquaculture.
4. Identify barriers to adopting circularity within the fisheries/aquaculture sector, and known strategies for addressing those barriers.

The project will run from March 2021 until March 2022. The research will proceed in four phases:

1. **Partnership formation** (March – May 2021)

   Formation of the Steering Committee in collaboration with the FRDC.

2. **Literature review** (April - May)

   A literature review will identify a range of relevant past and current research, applications and examples of CE. The review findings will be incorporated into the final report, inform the stakeholder workshop, and be disseminated to industry.

   The review will focus on:

   a) International CE application and best practice in i) other sectors and ii) within fisheries/aquaculture
   b) Australian CE applications in other sectors that may be applicable to fisheries /aquaculture
   c) Extent of CE adoption and active innovation in Australian fisheries and aquaculture.

3. **Systems mapping workshop** (July 2021)

   Based on the findings from Phases 1 and 2, we will design and facilitate a face-to-face or virtual participatory workshop with sectoral stakeholders. In this workshop, we will collaboratively map key fishing and aquaculture sector supply chains against circular economy principles (using the ReSOLVE framework).

   The workshop with the SC will also identify appropriate case studies from across the system to investigate further in Phase 4.

4. **Case studies** (August-December 2021)

   Based on engagement with partners and system analysis (Phases 1 & 3), five case studies will be selected. Semi-structured interviews (up to 5 in each case study) will be carried out in case study sites across Australia, balancing: location, sub-sectors, industries, degree of existing CE applications, and opportunity for CE integration. The goal of these case studies is to showcase best practice and opportunities for the implementation of CE principles in the fishing and aquaculture sector.

   The interviews will focus on:

a) Applicability of CE principles to current practices, including existing practices that support circularity but are as yet unrecognised as such (e.g. by-catch mitigation, which is analogous to REFUSE in the Ellen MacArthur Foundation [2015a]'s CE frameworks).

b) Opportunities and barriers to building circularity within the case study business, fishery or sector. This will consider the financial, supply chain (i.e. availability of materials), social and geographical factors that enable or inhibit circularity (both within the sector and *between* fisheries/aquaculture and other marine or land-based sectors).

c) Strategies for advancing and amplifying circularity (scaling up, scaling out and scaling deep) in light of known opportunities/barriers.

Findings from the interviews will be collated and thematically coded, analysed and reported. The main objective of the semi-structured interviews is to develop a series of learning vignettes with outputs from this phase being incorporated into both the short report as well as individual case study communication materials

The project outputs will include an in-depth report, stand-alone case study 'industry vignettes' (included in the report and available to be widely disseminated to businesses throughout the sector), and possible conference presentations and/or papers in peer-reviewed scientific journals, as agreed in consultation with the client.

Steering Committee members

Associate Professor Stephan Schnierer  	*Southern Cross University* *School of Environment, Science and Engineering* *Faculty of Science and Engineering* Stephan has extensive knowledge and experience in the areas of Indigenous Environmental Management, Indigenous Resource Rights, Traditional Ecological Knowledge, Intellectual Property Rights, International and National Environmental Policy. He is a member of several governmental advisory committees, including the National Marine Mammals Advisory Committee, the Indigenous Reference Group (Fisheries Research Development Corporation), the Great Barrier Reef Marine Park Authorities Ecosystems Advisory Committee, the GBRMPA Indigenous Reef Advisory Committee, the NSW Aboriginal Fishing Advisory Council, the NSW Seafood Industries Advisory Council, and the NSW Fisheries Research Advisory Body. He was also recently appointed to the Fisheries Council of South Australia. Stephan previously chaired the NSW Indigenous Fisheries Advisory Committee and advises the NSW Department of Aboriginal Affairs and the NSW Aboriginal Land Council on a range of environmental issues. Stephan is also an adviser to the United Nations Convention on Biological Diversity Secretariat. He is a member of a number of international expert panels relating to Indigenous rights in biodiversity. Stephan is currently undertaking research on Indigenous cultural fishing in NSW funded by Fisheries Research Development Corporation.
Dr Jodie Bricout 	*The University of Adelaide* *School of Civil, Environmental and Mining Engineering* *Faculty of Engineering, Computer and Mathematical Sciences* Jodie is a globally recognised expert in the circular economy and life cycle thinking. She brings two decades' worth of experience working with industry, research and policymakers in Australia, Dubai and Europe. While undertaking a PhD with the University of Adelaide, Jodie is also circular economy manager at leading consultancy Lifecycles, co-founder of the groundbreaking not-for-profit Loop Circular Economy Platform, and Board Member of NSW Circular. During her 13 years in France, she helped dozens of businesses seize the benefits of circular approaches; contributed to shaping state, federal and European policy; and collaborated with 100 of the planet's leading corporations, emerging innovators, governments, cities, and higher-learning institutions in the Ellen MacArthur Foundation's CE100 program. Since returning to Australia in 2016, Jodie has engaged with hundreds of professionals to adapt European best practice to the unique needs of our country. She has also been engaged by two states, a capital city, two groups of 8 universities, and more to develop circular economy projects and strategies.

	Circular approaches aim to engineer production and consumption systems in which infrastructure, assets and products are designed to last longer, be shared, repaired, repurposed and remanufactured. While there are a range of strategies available, lower-value strategies (e.g. recycling) can tend to dominate both policy frameworks and business operations. There is a need to develop new quantitative metrics and decision-support tools to promote and facilitate uptake of higher-value circular strategies, such as reuse and remanufacturing. Jodie's research will develop an analytical framework to support the application of higher-value approaches in the circular economy for government and business.
Dr Christopher Cvitanovic 	*Australian National University* and *CSIRO* In its broadest sense, Chris's research is focused on improving the uptake and impact of scientific research among different end-users, to facilitate evidence-informed decision-making for sustainable ocean futures. He does so by collaborating closely with researchers from other disciplines (e.g. economists, psychologists and ecologists) and actors from other sectors (e.g. policymakers, industry leaders and non-governmental organisations) to ensure a transdisciplinary approach in his work. Chris is currently leading (or has led) research projects throughout Australia, in the EU, the U.S. and the South Pacific. He is focused on improving knowledge exchange among marine scientists and decision-makers to enable evidence-informed decision-making processes. He approaches this topic in a number of ways. First, by seeking to identify and better understand the strategies that can facilitate improved knowledge exchange, to optimise their implementation and match specific strategies to contexts. This work has included a focus on knowledge brokers (Cvitanovic et al., 2017), boundary organisations (Cvitanovic et al., 2018a) and processes of knowledge co-production (Norström, Cvitanovic et al., 2020). Second, this research seeks to improve the ways in which knowledge exchange processes are evaluated (Posner and Cvitanovic, 2019) so as to improve our capacity to learn from existing efforts, and provide guiding principles for future initiatives aimed at linking marine science to policy and practice (e.g. Figure 1 in Cvitanovic and Hobday, 2018). A key focus throughout all of this research has been identifying the institutional changes that are needed (by research organisations, government agencies and research funders) to better support a more dynamic relationship between marine science, policy and practice.

Dr Pia Winberg 	*CEO of PhycoHealth* and *Venus Shell Systems* Pia has worked across both sustainable marine industry development and academia for the past 20 years and has a background in marine systems ecology. Her main research interest is in marine food production systems that are sustainably integrated with the coastal and marine environment. Pia's published research efforts therefore span aquaculture and sustainable estuarine systems. She has developed a focus on the development of seaweed cultivation systems for Australia. Australia is well-placed to contribute to the value-adding of seaweed metabolites, species diversity in culture, and quality control systems from production to processing. Pia has developed pilot-scale, integrated marine aquaculture systems with private industry, conducts research and development in collaboration with the aquaculture industries in three states, and has been a key driver of seaweed networks, research and development in Australia and internationally. She believes that marine-farming opportunities in the ocean – if sensitively and ecologically incorporated into the ecosystem – are a necessary way forward to achieving sustainable food production technology for the future. A core aspect of this is the potential for seaweed cultivation for a range of markets, ranging from food, health and medical products, agricultural and aquaculture applications. Pia has been the Director of the Shoalhaven Marine and Freshwater Centre at the University of Wollongong (from 2008-2013), and is now CEO of Venus Shell Systems (VSS) Pty Ltd. VSS is a new Australian company taking the science of marine biological systems through to production of high-quality marine biomass. She is also CEO of PhycoHealth Pty Ltd., a company delivering a range of consumer products with evidence-based health and nutritional properties.
Dr Ingrid van Putten 	*CSIRO Research Scientist* Ingrid is a research scientist with the ecosystems modelling team at the CSIRO Oceans and Atmosphere in Hobart, Australia. Her background is in economics and environmental studies. She has a particular interest in applying behavioral economics to help address fisheries and natural resource management problems. In her past research, she has focused on understanding social and economic decision-making by marine resource users (whether they are commercial fishers, recreational fishers, the aquaculture industry, or tourists) and comprehending their interactions with the biophysical marine environment. Ingrid uses empirical approaches (such as interviews and different survey techniques) as well as different modelling tools and approaches (e.g. Bayesian and network analysis). Combining real data and models to represent resource-user behavior and interactions at the appropriate level of complexity is a powerful tool to help plan appropriate management interventions. Overall, she hopes to improve the management of important marine systems and ensure their long-term viability.

Duncan Leadbitter 	*Director of Fish Matter* Fish Matter is a small fisheries and natural resource consultancy that works globally on standards, fisheries management improvement, advice on sustainable seafood, evaluating fisheries, and marine conservation planning. See www.fishmatter.com.au
Angela Williamson 	*Tassal Group – Senior Manager Responsible Business* Leading strategic communications, government relations, sustainability reporting, partnerships and engagement to support responsible salmon and prawn farming and to ensure Tassal Group is responsive to our people and communities.
David Carter 	*Austral Fisheries CEO* EO David Carter is the worthy recipient of the Marine Stewardship Council's 'Lifetime Achievement Award.' David has dedicated his entire working career (over 40 years!) to advancing and promoting the seafood industry. His particular focus has been on sustainable, science-based fisheries management and preserving the natural environment. In this time, David has seen Austral Fisheries become MSC-certified for its key fisheries, he's fought against illegal toothfish poachers, he's seen the introduction of Australia's premium-branded products (Glacier 51 Toothfish and Skull Island Prawns), and he's led Austral to becoming the world's first carbon-neutral seafood business.

Roles and responsibilities of the Steering Committee

Roles and responsibilities of the Steering Committee might include:

- Providing advice on high-level research design and scope
- Identifying appropriate case studies and research participants
- Providing advice on the appropriateness of outputs, and suggestions for improving research outputs
- Assisting with the communication and dissemination of the research outputs to target audiences.

UTS-ISF and the FRDC will consider the input of the Steering Committee and will endeavour to incorporate their recommendations (where appropriate and within project scope) into the research.

UTS-ISF will be responsible for co-ordinating meetings; distributing meeting agendas, documentation and minutes; incorporating the advice of the Steering Committee into the research project; and updating the Steering Committee on the project's progress towards its objectives.

Meetings

The Steering Committee will have three meetings throughout the project's duration, with the following objectives:

1. **Initiation meeting (week of 17 May 2021)**
   a) Introduce the project and the Steering Committee
   b) Agree upon Terms of Reference
   c) Share project plans and timelines
   d) Discuss plans for project outputs.
2. **Systems mapping stakeholder workshop (July 2021)**
   a) Discuss literature review findings and data collection to date, receive input/feedback from Steering Committee on draft literature review
   b) Provide input to systems mapping activities and infographics, including identifying possible case studies.
3. **Final meeting (April 2022)**
   a) Discuss empirical findings from the case studies and receive input/feedback from Steering Committee on findings and outputs.

These meetings will be two hours in duration and will require a minimum of five Steering Committee members to proceed. Videoconference will initially be used to conduct the Steering Committee meetings. As the COVID-19 situation unfolds, in-person attendance might be possible and encouraged at a later stage.

Each meeting will have a Chair (Professor Kate Barclay) and Secretariat (Dr Rebecca Cunningham). The Chair will facilitate meetings, and maintain alignment to project objectives and the roles and responsibilities of the Steering Committee. The Secretariat will distribute the agendas, meeting invitations and meeting minutes.

The Steering Committee may be requested to consider additional correspondence out-of-session; however, the project team will endeavour to minimise requests that use up members' time.

If members are unable to attend a meeting, it is possible to send a proxy. This will ensure that the committee will be able to reach quorum and the project can stay within the outlined research timelines.

Appendix 2: Literature search results

TIER LOGIC	TIER #	SEARCH #	SEARCH Terms	Returns
International CE	Tier 1	1	Circular economy	10896
Australia CE	Tier 2	2	Circular economy, Australia	68
Australia CE Fisheries	Tier 3	3	Circular economy, Climate change, Marine systems, Australia, Resource-efficiency, Bioeconomy	0
Australia CE Fisheries	Tier 3	4	Circular economy, Climate change, Marine systems, Australia, recycling, reuse	0
Australia CE Fisheries	Tier 3	5	Circular economy, Climate change, Marine systems, Australia, materials,	0
Australia CE Fisheries	Tier 3	6	Circular economy, Climate change, Marine systems, Australia, materials, plastics	0
Australia CE Fisheries	Tier 3	7	Circular economy, Climate change, Marine systems, Australia, materials, fuel	0
Australia CE Fisheries	Tier 3	8	Circular economy, Climate change, Marine systems, Australia, pharmaceuticals	0
Australia CE Fisheries	Tier 3	9	Circular economy, Climate change, Marine systems, Australia, barriers	0
Australia CE Fisheries	Tier 3	10	"Adaptive Management", Marine systems, Australia	59
Australia CE Fisheries	Tier 3	11	"Adaptive Management", fisheries, Australia	78
Australia CE Fisheries	Tier 3	12	"Regenerative fisheries & aquaculture" Marine systems, Australia	0
Australia CE Fisheries	Tier 3	13	Regenerative fisheries, Marine systems, Australia	0
Australia CE Fisheries	Tier 3	14	Supply chains, fisheries, Australia	16

Appendix 3: Case study profiles

This appendix outlines the case study methodology, especially the plan for selection of case studies.

Figure 21. Small-scale fishing gear, NSW

Figure 22. Oysters on plastic trays, Sydney Fish Market

Image Credit for fishing nets: Kate Barclay. Source of oysters image: https://en.wikivoyage.org/wiki/Sydney#/media/File:Oysters_at_Sydney_Fish_Market.jpg

Plastic

This case study explores how existing organisations are repurposing hard and soft plastics waste from along the fisheries and aquaculture supply chain. Existing examples of scalable technologies include recycling fishing nets and buoys, PVC pipes and stanchions from sea cages (e.g. Environex, Geoff Pilgrim Transport); the use of recycled fisheries plastics in fashion (e.g. Sepia swimwear, World Wildlife Fund sunglasses, Dresden); and the development of bioplastics (e.g. Coast4C).

Soft plastics are used in bags for feed in aquaculture, bait bags for some forms of commercial fishing and in recreational fishing. They are also used for all kinds of seafood packaging at the consumption end of supply chains.

The literature review and stakeholder workshop did not uncover examples of recycling being conducted for these kinds of soft plastics, but single-use plastics are being phased out in food service, so alternative products (bamboo, cardboard, as well as bioplastics) are being explored. Responsible Plastics Management UK & Ireland may have useful lessons.

Hierarchy of CE principles: Design out waste; keeping products and materials in use

Jurisdiction of case study examples: TAS, SA, NSW, WA

Application: Australia-wide

Production systems: Aquaculture: pond; Aquaculture: sea cage; Aquaculture: estuarine; Wildcatch: trawl and net; Wildcatch: Pole, line and hand; Wildcatch: Recreational

Figure 24. Raw prawn heads

Figure 23. Fish oil capsules

Image source fish oil capsules: https://www.nutraceuticalbusinessreview.com/news/article_page/Combining_the_advantages_of_probiotics_and_omega-3_in_a_single_softgel/154600. Image source prawn heads: https://shrimpmeal.wordpress.com/tables/composition-of-shrimp-waste-meal/

Organic waste

Organic waste will be separated into upcycling and downcycling categories. Existing examples of downcycling organic waste includes use in the agricultural industry, fish food industry and in pet food (e.g. Huon Salmon, Bio Supplies, Mobius Farms and All Fish for Dogs).

We define organic waste as ‘upcycling’ when organic waste products are being reused in products for human consumption. Existing examples include niche food products such as prawn oil (Seaweedery), abalone sauce (Kansom) and seaweed (Venus Shell Systems), as well as emerging markets for nutraceuticals use (e.g. carotenoids) being developed by Mantzaris Fisheries Pty Ltd. and Venus Shell Systems.

Hierarchy of CE principles: Keeping products and materials in use

Jurisdiction of case study examples: NSW, WA, QLD, TAS

Application: Australia-wide

Production systems: Aquaculture: pond; Aquaculture: sea cage; Aquaculture: estuarine; Wildcatch: trawl and net; Wildcatch: Pole, line and hand

Figure 25. Wood material in chip form for bio energy

Image credit: Don Erhardt. Source: https://news.ubc.ca/2019/08/19/innovative-ubc-heat-and-power-facility-boosted-by-federal-investment/

Energy

Transport and refrigeration are key elements of the fisheries and aquaculture supply chain. However, both of these sectors face challenges when incorporating circular economy principles.

Although some small-scale hydrogen vehicles are now available on the market, the high buy-in cost is prohibitive for many users. Biofuels may become available in coming years, but at present there are not relevant market drivers in place to encourage the use of biofuels for land/sea/air vehicles.

Coldchain refrigeration and the high energy requirements of ice-making further impact the transport/logistics and wholesale/retail nodes of the supply chain. This case study gives examples of where novel applications of renewable energy use and biofuels provided new opportunities for producers (e.g. Geralton Fishing Association).

Hierarchy of CE principles: Design out waste

Jurisdiction of case study examples: WA

Application: Australia-wide

Production systems: Aquaculture: pond; Aquaculture: sea cage; Aquaculture: estuarine; Wildcatch: trawl and net; Wildcatch: Pole, line and hand; Wildcatch: Recreational

Figure 26. Sharing economy infographic

Image credit: The Collaborative Lab. Source: https://www.political-intelligence.com/fr/the-brussels-digital-week-sharing-economy-is-it-the-economy-of-the-future-for-brussels/

Collaborative consumption

Within the fisheries and aquaculture sector, there are instances where collaborative consumption has allowed for the sharing of resources between otherwise competing enterprises.

Fisheries Co-operatives, in general, are a form of collaborative consumption whereby groups of fishers share wharf and offloading infrastructure, including ice-making and refrigeration facilities, and so on. In the Taree Co-operative, we have been told that small-scale estuarine fishers are sharing some machinery.

Hierarchy of CE principles: Keeping products and materials in use; regeneration

Jurisdiction of case study examples: NSW, SA

Application: Australia-wide

Production systems: Wildcatch: commercial fishing

Figure 27. Prawn farming water use

Image source: https://www.globalseafood.org/advocate/inland-prawn-farming-trial-in-australia/

Water/waste water

Within pond aquaculture, recycling and reusing water is an integral part of keeping businesses profitable and ensuring compliance with regulatory requirements.

Across all production systems, water is not only a key input but often a waste product at the processing and wholesale/retail nodes of the supply chain. This case study investigates best practice examples of how water can be best utilised (e.g. Sydney Fish Market; Tailor Made Fish Farms, where nutrient-rich pond water is used for hydroponic vegetable horticulture; Marron and red claw crayfish).

Hierarchy of CE principles: Keeping products and materials in use; regeneration

Jurisdiction of case study examples: NSW, TAS, NT

Application: Australia-wide

Production systems: Aquaculture: pond; Seafood processing

Appendix 4: Interview guide

Fisheries Research and Development Corporation (FRDC)

Circular economy opportunities for fisheries and aquaculture in Australia

Interview guide

About your business

1. Please tell me about your business, in particular *[insert circular economy element]*
    a. What production system does this CE activity operate within?
    b. Where in the supply chain does the business operate?
        i. Within Australia
        ii. Operate overseas
    c. Who are your collaborators?
        i. What is the immediate link ahead and behind you?
        ii. *(SCALE)* Is the circularity happening within your business or are you using/providing resources to other businesses?
            - *Individual business*
            - *2+ sectors in a value chain*
            - *Regional/jurisdictional, etc.*
2. How long have you been operating in your business?
    a. How long have you been doing CE activities?
        i. What is the status of your CE enterprise?
            - *Research*
            - *Development*
            - *Deployment*
            - *Scale-up*
3. What is the size of your operation?
    a. Number of employees
    b. Multiple sites

About your CE activity

1. What drove you to move to circularity?
    a. Financial
    b. Political
    c. Social conscience
    d. Other
2. What changes have you made to encourage circularity – how have you made this work?
3. Are there other elements of your business that have taken on circularity?
4. What are the barriers you see for your business, in particular this CE work?
    - Political
    - Economic
    - Social
    - Technical
    - Environmental
    - Legal
5. Do you ever think about where your business is influencing and impacting the sector in this regard?
    - *Design out waste*
    - *Keep in use*
    - *Regenerate*

    a. What is the degree of regeneration?
        - *Sustainable (do less harm)*
        - *Restorative (recover, reuse, etc.)*

            - *Regenerative (enhance environments)*

6. What are the opportunities you see for your business, in particular, this CE opportunity?
    a. What is the timescale?
        - 1-2 years
        - 3-5 years
        - 5+ years
7. You mentioned that your CE activity is currently X – do you see your business expanding this CE activity?
        - *Within fishery*
        - *Regional*
        - *State*
        - *National*
8. Where do you look for information about CE?
9. Do you share information about CE?
10. Do you know anybody else we should speak to about CE in your industry?

References

Allwood, J.M. (2014). Squaring the circular economy: the role of recycling within a hierarchy of material management strategies. In: Worrell, E. & Reuter, M.A. (Eds.) *Handbook of recycling*. Elsevier. Pp. 445-477.

Bahers, J-B., Durand, M. & Beraud, H. (2017). What territoriality for the circular economy? Interpretation of local typologies in waste management. *Flux* , 3-4 (109-110), 129-141. DOI:10.3917/stream1.109.0129

Bakker, C., Wang, F., Huisman, J. & Den Hollander, M. (2014). Products that go round: exploring product life extension through design. *Journal of Cleaner Production*, 69, 10-16.

Barclay, K., Davila, F., Kim, Y. & McClean, N. (2020). *Economic analysis & Social and Economic monitoring following the NSW Commercial Fisheries Business Adjustment Program*. Prepared for the NSW Department of Primary Industries. Retrieved from: https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/1256128/Economic-analysis-and-Social-and-Economic-monitoring-following-the-NSW-Commercial-Fisheries-Business-Adjustment-Program.pdf

Bocken, N. M., Short, S. W., Rana, P. & Evans, S. (2014). A literature and practice review to develop sustainable business model archetypes. *Journal of Cleaner Production,* 65, 42-56.

Bocken, N. M. P., de Pauw, I., Bakker, C., & van der Grinten, B. (2016). Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering, 33*(5), 308-320. doi:10.1080/21681015.2016.1172124

DAWE. (2021a). *Fisheries and the environment*. Australian Government Department of Agriculture, Water and the Environment (DAWE). Retrieved from: https://www.awe.gov.au/agriculture-land/fisheries/environment

DAWE. (2021b). *Investing in Australia's waste and recycling infrastructure*. Australian Government Department of Agriculture, Water and the Environment (DAWE). Retrieved from: https://www.awe.gov.au/environment/protection/waste/how-we-manage-waste/recycling-modernisation-fund

DAWE. (2021c). *National Plastics Plan 2021*. Australian Government Department of Agriculture, Water and the Environment (DAWE). Retrieved from: https://www.awe.gov.au/sites/default/files/documents/national-plastics-plan-2021.pdf

DAWR. (2017). *National Aquaculture Strategy*. Australian Government Department of Agriculture and Water Resources (DAWR). Retrieved from: https://www.agriculture.gov.au/sites/default/files/sitecollectiondocuments/fisheries/aquaculture/national-aquaculture-strategy.pdf

DCCEEW (2021a). *Comparison of Modern Manufacturing and Recycling Modernisation Programs*. Australian Government Department of Climate Change, Energy, the Environment and Water. Retrieved from: https://www.awe.gov.au/environment/protection/waste/publications/rmf-mmi-comparison

DCCEEW. (2021b). *Sustainable Procurement*. Australian Government Department of Climate Change, Energy, the Environment and Water. Retrieved from: https://www.awe.gov.au/environment/protection/waste/sustainable-procurement

DEE. (2018). *2018 National Waste Policy: Less waste, more resources*. Australian Government Department of the Environment and Energy (DEE). Retrieved from: https://www.awe.gov.au/environment/protection/waste/publications/national-waste-policy-2018

DEE. (2019). *National Waste Policy Action Plan*. Australian Government Department of the Environment and Energy (DEE). Retrieved from: https://www.awe.gov.au/environment/protection/waste/publications/national-waste-policy-action-plan

De Schoenmakere, M. & Gillabel, J. (2017). Circular by Design: Products in the Circular Economy. Report prepared for the European Environment Agency, 6. ISSN 1977-8449. Retrieved from: https://www.eea.europa.eu/publications/circular-by-design

De Schoenmakere, M., Hoogeveen, Y., Gillabel, J. & Manshoven, S. (2018). *The circular economy and the bioeconomy: partners in sustainability*. Report prepared for the European

Environment Agency (8/2018). ISBN: 978-92-9213-974-2. Retrieved from: https://www.eea.europa.eu/publications/circular-economy-and-bioeconomy
Ellen MacArthur Foundation. (2013). Towards the Circular Economy. UK: Ellen MacArthur Foundation. Retrieved from: https://www.werktrends.nl/app/uploads/2015/06/Rapport_McKinsey-Towards_A_Circular_Economy.pdf
Ellen MacArthur Foundation. (2015a). *Delivering the circular economy – A toolkit for policymakers*. Retrieved from: https://emf.thirdlight.com/link/kewgovk138d6-k5kszv/@/preview/1?o
Ellen MacArthur Foundation. (2015b). Growth Within: A Circular Economy Vision for a Competitive Europe. Ellen MacArthur Foundation, SUN & McKinsey Center for Business and Environment. Retrieved from: https://www.mckinsey.com/capabilities/sustainability/our-insights/growth-within-a-circular-economy-vision-for-a-competitive-europe
Ellen MacArthur Foundation. (2019). Circular economy system diagram. Retrieved from: https://ellenmacarthurfoundation.org/circular-economy-diagram
Geissdoerfer, M., Pieroni, M. P. P., Pigosso, D. C. A., & Soufani, K. (2020). Circular business models: A review. *Journal of Cleaner Production, 277*, 123741. doi:https://doi.org/10.1016/j.jclepro.2020.123741
Henry, M., Bauwens, T., Hekkert, M. & Kirchherr, J. (2020). A typology of circular start-ups: An Analysis of 128 circular business models. *Journal of Cleaner Production,* 245: 118528.
Korhonen, J., Honkasalo, A. & Seppälä, J. (2018). Circular Economy: The Concept and its Limitations. *Ecological Economics*, 143: 37-46.
Lacy, P., Rosenberg, D., Drewell, Q. & Rutqvist, J. (2014) 5 Business Models that are Driving the Circular Economy. Retrieved from: http://www.fastcoexist.com/1681904/5-Business-Models-That-Are-Driving-the-Circular-Economy
Merli, R., Preziosi, M. & Acampora, A. (2018). How do scholars approach the circular economy? A systematic literature review. *Journal of Cleaner Production*, 178: 703-722.
Moodie, T.R., Alakerttula, J., Ruokonen, H. & Leino, J. (2018) *Developing and Managing Innovation Ecosystems in the Circular Economy*, Nordregio, August. Retrieved from: http://doi.org/10.30689/PB2018:4.2001-3876
Mukheibir, P., Jazbec, M., & Turner, A. (2020). *Transitioning the water industry with circular economy*. Prepared for the Water Services Association of Australia, Institute for Sustainable Futures, University of Technology Sydney. Retrieved from: https://www.uts.edu.au/sites/default/files/2021-03/Transitioning%20the%20water%20industry%20with%20the%20circular%20economy%20FINAL%2012102020.pdf
NSW DPI. (2021). Government of New South Wales Department of Primary Industries (NSW DPI). Retrieved from : https://www.dpi.nsw.gov.au/fishing/harvest-strategies/policy-and-guidelines
Pagotto, M. & Halog, A. (2016). Towards a Circular Economy in Australian Agri-food Industry: An Application of Input-Output Oriented Approaches for Analyzing Resource Efficiency and Competitiveness Potential." *Journal of Industrial Ecology,* 20(5): 1176-1186.
Potting, J., Hekkert, M., Worrell, E., & Hanemaaijer, A. (2017). *Circular economy: Measuring innovation in the product chain*. Retrieved from: https://www.pbl.nl/sites/default/files/downloads/pbl-2016-circular-economy-measuring-innovation-in-product-chains-2544.pdf
PWC (2021) *Building back better - the opportunity of transitioning to a circular economy*. Retrieved from: https://www.pwc.com.au/assurance/esg/building-a-more-circular-australia.pdf
Schandl, H., King, S., Walton, A, Kaksonen, A.H., Tapsuan, S. & Baynes, T.M. (2020). Circular economy roadmap for plastics, glass, paper and tyres. CSIRO, Australia.
Sharpe, S., Delaney, C. & Cunningham, R. (2019). Forced Innovation: Business preparedness and recovery after extreme weather events, Research Report for the OEH Adaptive Communities Node. Sydney: University of Technology Sydney.
Stahel, W. and R. Clift (2016). Stocks and Flows in the Performance Economy. In: Clift, R. & Druckman, A. (Eds.) *Taking Stock of Industrial Ecology*. Cham: Springer. pp.137-158.
Tapia, C., Bianchi, M., Pallaske, G., & Bassi, A., M. (2021). Towards a territorial definition of a circular economy: exploring the role of territorial factos in closed-loop systems. *European Planning Studies, 29*(8), 1438-1457. doi:10.1080/09654313.2020.1867511

Webster, K. (2015). The Circular Economy: A Wealth of Flows. Ellen MacArthur Foundation Publishing.
World Economic Forum (2022). *Circular economy and value chains*. Retrieved from: https://www.weforum.org/communities/circular-economy-and-value-chains#:~:text=The%20Circular%20Economy%20Challenge&text=The%20circular%20economy%2C%20which%20promotes,in%20economic%20benefits%20to%202030

“

We’ve always believed in nose-to-tail eating for fish, so – where possible, with freight obviously, and room and capacity to store – we’ve always kept wings from all our fish. We don’t waste any wings. We try and keep the majority of the frames, whether it be for crab pot bait for outselves or others – for eating, [or for] crab pot bait in the shop.

UTS Institute for Sustainable Futures

UTS Climate, Society and Environment Research Centre

FRDC