School of Management and Marketing

Improving Outcomes for Shell and Shucking By-Products in Australian Abalone Fisheries – A Supply Chain Perspective

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Declaration

To the best of my knowledge and belief, this thesis contains no material previously published by any other person except where due acknowledgement has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014. The proposed research study received human research ethics approval from the Curtin University Human Research Ethics Committee (EC00262), Approval Number #HRE2021-0714.

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ABSTRACT

Context: The Australian wild-harvest abalone industry consists of five fisheries in New South Wales, South Australia, Tasmania, Victoria, and Western Australia. These are economically significant fisheries (contributing ~AU$195 million annually to the Australian economy for at least 20 years) that have experienced persisting economic and environmental pressures for over a decade. Industry stakeholders have identified a potential to maximise their catch by seeking new revenue streams from processing waste (abalone viscera and shell); thereby addressing their economic concerns and sustainability imperatives. Concurrently, food waste is a pressing global issue that affects all stages of the supply chain. However, extant literature indicates that several data gaps exist at the supply chain-level concerning food waste quantification, understanding specific drivers of waste creation, and decision-making where improvements to waste management practices are concerned. Furthermore, these gaps remain underexplored where Australia's primary production and post-harvest processing segments are concerned. This research was conducted for the Abalone Council of Australia Ltd., the peak industry body for wild-harvest divers, quota owners, and processors, and therefore straddles practical industry needs and the application of supply chain theory to address food waste.

Literature Review and Theoretical Framework: This research was guided by a proposed theoretical framework that, in turn, was informed by core constructs drawn from the literature, including: food waste, supply chain analysis, circular economy principles, and economic feasibility. The theoretical framework was developed to address the two overarching research objectives which were to: (1) understand the volumes and drivers of food waste created in Australia's wild-harvest abalone industry by mapping and analysing its supply chains; and (2) to subsequently propose waste management interventions using circular economy principles and supply chain management theory. The two research objectives supported the two research questions.

Research Design: A pragmatic, qualitatively-dominant mixed methods approach (QUAL→quan) was adopted in this research. Overall, the research design consisted of four phases: an exploratory phase (desktop review), dominant qualitative phase

(Phase A), supplemental quantitative phase (Phase B), and a supply chain mapping phase (Phase C). In the exploratory phase, a desktop review was conducted to gather secondary data and more clearly define the research problem. Knowledge and data gaps identified from the desktop review guided the data collection instrument in Phase A. In Phase A, semi-structured interviews (*n*=16) were conducted with highly-experienced industry stakeholders and thematic analysis was conducted simultaneously (NVivo, Release 1.3 2020). The themes and knowledge of practices that were elicited in Phase A guided the selection of a subgroup of participants in Phase B. The subgroup provided responses that informed the mass flow analysis of by-products conducted in Phase B. Finally, in Phase C the qualitative and quantitative results were integrated by constructing current-state supply chain maps (*n*=10) for each state and abalone species.

Results: This research determined that there were varying opportunities for reducing waste volumes and improving by-product outcomes across the five abalone fisheries. It emerged that the motivations, strengths, interfirm relationships, existing firm structures, regulatory factors, current waste outcomes, and available volumes of by-product coalesce to form minimal or favourable conditions for reducing waste along each supply chain. Management interventions were subsequently proposed by devising future-state maps (*n*=2). The suggested interventions were aimed at reducing waste volumes and improving outcomes for by-products (e.g. from disposal to animal feed) based on circular economy principles. Food waste volumes were quantified along each wild-harvest abalone supply chain and these were mapped alongside product flows and other supply chain elements to produce a set of current-state maps (*n*=10). By constructing these evidence-based supply chain maps, it was possible to analyse the areas along the supply chains where food waste was highest (‘hotspots’), potential drivers of waste creation. It was also possible to subsequently propose management interventions based on circular economy principles and supply chain management theory. The suggested interventions were mapped on future-state maps (*n*=2) and were aimed at reducing waste volumes and improving outcomes for by-products (e.g. by diverting by-products from disposal to animal feed).

Significance: This research addresses both research and industry exigencies to quantify food waste volumes and understand the drivers for waste creation along an economically-significant agrifood supply chain; such that food waste outcomes can be improved. The research responds to the United Nations' Sustainable Development Goal 12.3 and Australia's National Food Waste Strategy to halve global and national levels of food waste, respectively, by 2030; and also yielded results that are important for Australia's wild-harvest abalone industry's decision-making process and supply chain design to better manage its food waste. From a theoretical perspective, supply chain mapping was demonstrated as a useful tool for identifying food waste 'hotspots' and initiating supply chain improvements to reduce food waste. Agrifood supply chain mapping and food waste theories were extended by devising and demonstrating a novel, mixed methods, and theory-based food waste mapping framework which builds on extant frameworks and models in the literature. Additionally, new knowledge was contributed by mapping and analysing Australian abalone supply chain structures, interfirm relationships, governance, processes, and product flows. The sustainability of wild abalone stocks has been well-documented in the literature, but from either fishery management or biosecurity perspectives. The sustainability of its supply chains from production, to processing, and distribution has received minimal attention and not on a national-scale. The theoretical framework proposed in this research may also have applicability to understanding and addressing food waste in other agrifood supply chain contexts, particularly heavily-regulated seafood industries.

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LIST OF ACRONYMS

Acronym/Abbreviation	Meaning
ABARES	Australian Bureau of Agricultural Economics and Sciences
ABS	Australian Bureau of Statistics
AU$	Australian dollar
AVG	Abalone viral ganglioneuritis
COVID-19	Coronavirus disease 2019
FAO	Food and Agriculture Organization of the United Nations
FIAL	Food Innovation Australia Limited
FLW	Food loss and waste
IQF	Individually quick frozen
NFSW	Australia's National Food Waste Strategy
NSW	New South Wales
QLD	Queensland
QUAL	Dominant qualitative component of the research, as per Janice Morse's shorthand notation (Onwuegbuzie and Collins 2007)
quan	Supplemental quantitative component of the research, as per Janice Morse's shorthand notation (Onwuegbuzie and Collins 2007)
RQ	Research question
SA	South Australia
SDG	United Nations' Sustainable Development Goals
SME	Small and medium-size enterprise
TACC	Total allowable commercial catch
TAS	Tasmania
VIC	Victoria
WA	Western Australia

GLOSSARY

Term	Definition
Abalone	Gastropod mollusc belonging to the Haliotidae family. Four species are commercially harvested from the wild in Australia: Blacklip abalone (*Haliotis rubra*), Brownlip abalone (*H. conicopra*), Greenlip abalone (*H. laevigata*), and Roe's abalone (*H. roei*).
Abalone fishery	Body of water where abalone have been harvested commercially from wild-stocks, as opposed to abalone farms.
Abalone receiver	Licensed individual or firm permitted by the state fishing authority to purchase and receive live abalone from quota owners and divers for the purposes of live tanking and distribution only. Receivers are not permitted to process abalone.
Actors	Firms, suppliers, customers, and other stakeholders involved in the supply chain.
Beach price	Industry-derived term that refers to the per-kilo price paid to divers or quota owners for abalone upon landing and before processing.
By-product	Parts shucked from the abalone meat, including shell, viscera, and blood.
Current-state map	Term adapted in this research from Value Stream Mapping; which refers to the visual model of a supply chain at a particular point in time as it is in reality, rather than how operations *should* work in an ideal situation. Contrasts a future-state map.
Eskies	Colloquial Australian term used to refer to portable ice box coolers.
Extended Value Stream Mapping	Specific mapping technique that adapts Value Stream Mapping to visually modelling whole supply chains, rather than single-firms only, according to Lean management principles.
Fishing zone	Body of water where wild abalone are permitted to be harvested, delineated by the state fishing authorities for stock management purposes.

Food waste	According to the NFWS (Commonwealth of Australia 2017, 8) food waste includes: • Solid or liquid food that is intended for human consumption and is generated across the entire supply and consumption chain; • Food that does not reach the consumer or reaches the consumer but is thrown away. This includes edible food, the parts of food that can be consumed but are disposed of, and inedible food, the parts of food that are not consumed because they are either unable to be consumed or are considered undesirable (such as seeds, bones, coffee grounds, skins, or peels); • Food that is imported into, and disposed of, in Australia; and • Food that is produced or manufactured for export but does not leave Australia.
Food waste hierarchy	Framework for managing waste that has been adapted from industrial ecology to an agrifood context, specifically where preventing, re-using, or recycling food waste is concerned; and is pervasive in food waste literature and practice.
Future-state map	Term adapted in this research from Extended Value Stream Mapping; which refers to the visual model of a current-state map which has been altered by management interventions.
Hotspot	Term used in research and practice to refer to areas in the supply chain where the high volumes of food waste are generated.
Lean thinking / Lean management	Supply chain management framework that has heavily influenced general supply chain management theory; and focuses on creating maximum customer value by eliminating non-value adding operational activities (Rother and Shook 2003; Womack 2006; Womack, Jones and Roos 1990).
Lease diver	An individual who is legally permitted to harvest abalone on behalf of quota owners. Lease divers either pay a lease fee to quota owners for the right to harvest abalone or are hired by quota owners as an employee or contractor to harvest abalone.
Management interventions	Suggested or implemented improvements to supply chain practices; which, in this research, relate specifically to improving food waste management to reduce or prevent food waste

Meat weight	Refers to the mass measurement of the shucked foot or meat of the abalone (grams, kilograms, or tonnes).
Mixed methods	A study which consists of qualitative and quantitative components (Burke Johnson, Onwuegbuzie and Turner 2007).
Processing	Includes the cleaning, shucking, freezing, cooking, and/or packaging of abalone post-harvest. Live abalone are not considered 'processed'.
Processor	Licensed individual or firm permitted by the state fishing authority to receive and process abalone.
Quota owner	Licensed individual or firm that pays the state fishing authority for rights to fish abalone; and is allocated rights to a specific portion of abalone TACC quota on an annual basis.
Shucking	Ubiquitous seafood industry term used to refer to the process of removing shells and viscera of molluscs (e.g. abalone, oysters, clams, mussels) from the meat.
Supply chain	A network of actors that transform raw materials into distributed goods by adding value to the materials that flow through the chain from upstream stages (e.g. primary production, processing, manufacturing) to downstream stages (e.g. retail, consumers) (Lambert 2008; Mangan, Lalwani and Calatayud 2021; Mentzer et al. 2001)
Supply chain analysis	A broad and common practice in supply chain management that involves modelling (i.e. supply chain mapping) and assessment of performance (Surie and Wagner 2008).
Supply chain mapping	A process that involves visually representing or modelling the structures, processes, relationships between actors, material flows, and governance that connect each stage of the supply chain; providing a 'blueprint' of sorts (Farris 2010; Gardner and Cooper 2003; Goldsby and García-Dastugue 2008).
Total allowable commercial catch (TACC) quota	Ubiquitous Australian commercial fishing term used to refer to portions of fish that are allocated by the state fishing authorities to licensed commercial quota owners for commercial harvest in each fishing zone; in this research TACC quotas refer to abalone quota.
Valorisation	Process of adding value to waste products or by-products.
Value Stream Mapping	Specific approach to visually mapping and improving single-firm operations devised by Lean thinking proponents such as Rother and Shook (2003) and Womack (2006).

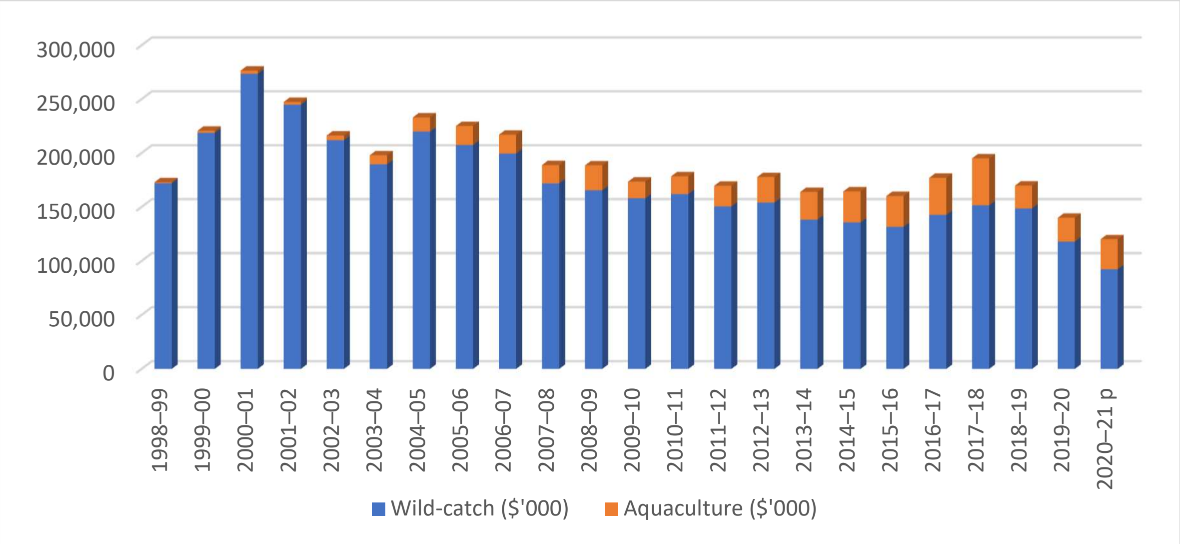
Viscera	Gut of the abalone.
Whole weight	Refers to the mass measurement of a whole abalone that has not been shucked, comprising the shell, meat, guts, and blood (grams, kilograms, or tonnes).

1 INTRODUCTION

This research is concerned with addressing two intersecting topics: the economic and environmental sustainability of Australian abalone fisheries; and food waste as a pressing global issue. This chapter contextualises the research by providing background on the Australian abalone supply chains; followed by an overview of food waste from global, national, and sectorial perspectives.

1.1 Overview of Australian Abalone Supply Chains

Globally and domestically, the Australian wild-harvest abalone industry is significant. Australia is the largest exporter of wild-caught abalone, which are highly sought-after in international markets, and accounts for approximately 35% of global wild abalone production (Curtotti et al. 2023; Hoshino et al. 2015). Domestically, wild-harvest abalone has been economically-significant in the Australian seafood sector for over 30 years (Bradshaw 2018; PIRSA 2012; Tuynman and Dylewski 2022); contributing an average of AU$192 million a year to the Australian economy for the past two decades (Stevens, Mobsby and Curtotti 2020). The Australian abalone industry consists of two categories: wild-harvest and aquaculture. Although aquaculture production is increasing, wild-harvest abalone continues to represent over 75% of Australian abalone production and value compared to aquaculture (see Figure 1).



N.B.: p = preliminary figures

Figure 1. Production values of Australian abalone from 1998-99 to 2020-21. Adapted from: Tuynman and Dylewski (2022).

Abalone are gastropod molluscs that have been fished commercially from wild-stocks in New South Wales, South Australian, Tasmanian, Victorian, and Western Australian fisheries since the 1960s (Mayfield et al. 2012). However, some indigenous Australian groups have a much longer history of harvesting and consuming wild abalone for ritual, trade, and survival (Cruse, Stewart and Norman 2005; Humphries and Lehman; Schnierer and Egan 2016). More recently, some species of abalone have been subject to cultivation and cross-breeding in open-water and land-based aquaculture settings in South Australia, Tasmania, Victoria, and Western Australia (Mayfield et al. 2012; Stevens, Mobsby and Curtotti 2021; Strain, Fabris and Jones 2021). This research focuses specifically on wild, commercially-harvested abalone (*Haliotis spp.*) produced from abalone fisheries across Australia; owing to the economic significance and unique set of sustainability issues which belong to this portion of the overall industry.

Located in New South Wales, South Australia, Tasmania, Victoria, and Western Australia, abalone fisheries are each managed at a state-level and constitute the start of the supply chains under consideration. A map of the five state fisheries is provided in Figure 2. Continued downward trends in wild-harvest economic value and production volumes suggest the five abalone fisheries across Australia are under threat (Tuynman and Dylewski 2022). Threats to the abalone fisheries include: increasingly constrained Total Allowable Commercial Catch (TACC) quotas, mounting competition from aquaculture (locally and abroad), diminishing beach price, depleting stock health, deteriorating water quality, abalone parasites and diseases, and persistent illegal fishing. In addition to high labour costs that threaten the competitiveness of wild abalone products compared to cheaper aquaculture product, these issues are viewed as major concerns (The Ecology Lab Pty Ltd 2007; Strain, Fabris and Jones 2021). Furthermore, anecdotal reports suggest that there may be a prevalent food waste problem affecting the industry. Anecdotally, it is suggested that approximately two-thirds of the abalone consisting of the shucked viscera (e.g. gut, gonad, heart etc.) and shell is not marketed and sold (Suleria et al. 2017a; Suleria et al. 2017c).

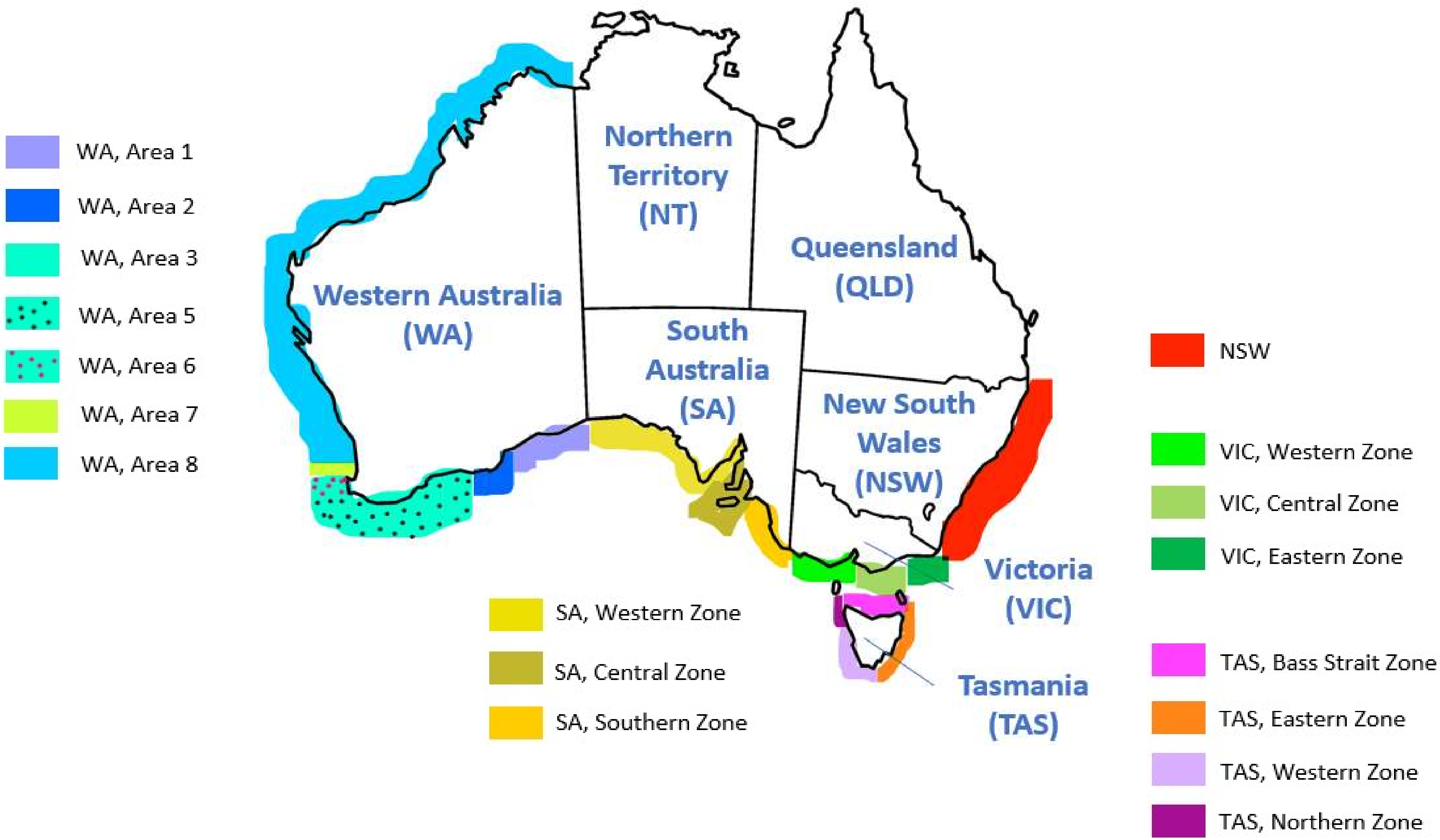


Figure 2. Map of Australia's five abalone state fisheries and management zones. Adapted from: DEDJTR (2015), DPIRD (2021); Parfitt, Croker, and Brockhaus (2021), Mundy and McAllister (2021); Caldeira et al. (2019); Gorzeń-Mitka et al. (2020), Stobart and Mayfield (2021), and The Ecology Lab Pty Ltd (2007); Geissdoerfer et al. (2017).

‘Shucking’ is a term used ubiquitously in the seafood industry to refer to the process of removing shells and viscera of molluscs (e.g. abalone, oysters, clams, mussels) from the meat. In the case of abalone, the shucked meat is sold as a highly-prized delicacy, mostly to Asian markets. Several industry stakeholders have identified an opportunity to maximise their harvest and economic return by seeking potential new revenue streams by better managing their shucking waste (i.e. viscera and shell). Diagrams illustrating the anatomy of an abalone are presented in Figure 3. The left-hand diagram presented in Figure 3 shows the abalone with its shell in-tact, as it would be seen by a diver during harvest; whereas the right-hand diagram is an illustration of the abalone with its shell removed.

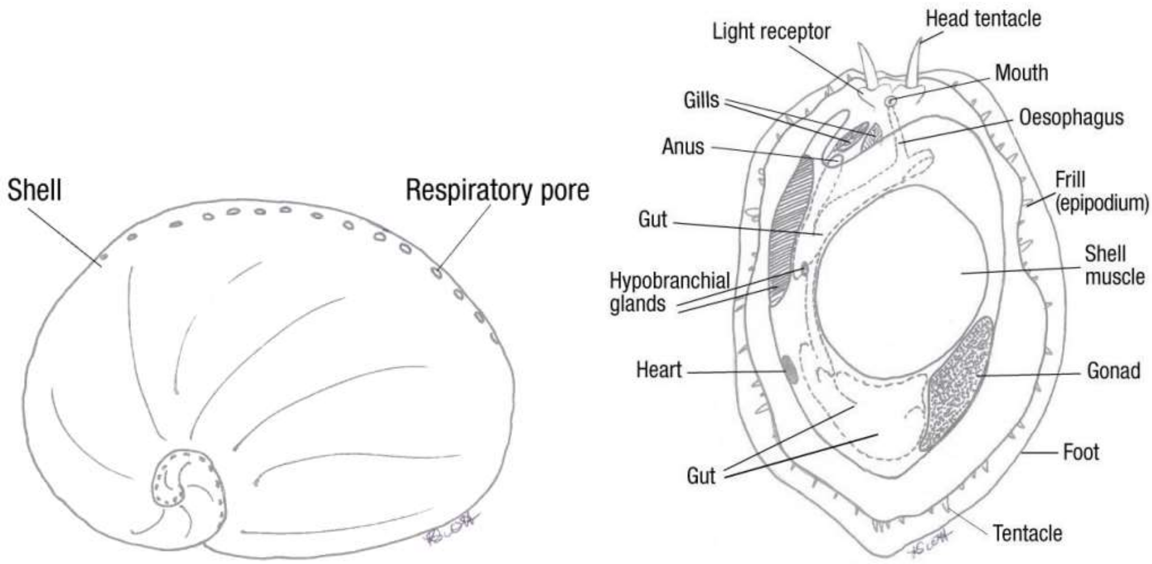


Figure 3. Anatomy of an abalone. Adapted from: Department of Agriculture, Water and the Environment (2020, 10)

Since all businesses involved in upstream (i.e. harvest, processing) and downstream activities (i.e. distribution, transport, food services, and retail) stand to be affected by the economic viability of the abalone fisheries there is an imperative to address these waste management issues from a supply chain and food waste-focused perspective (The Ecology Lab Pty Ltd 2007; PIRSA 2012).

1.1.1 Targeted Species

Four species of abalone are primarily targeted for commercial harvest in Australia: Blacklip abalone (*Haliotis rubra*), Greenlip abalone (*H. laevigata*), Brownlip abalone (*H. conicopra*), and Roe’s abalone (*H. roei*). Populations are targeted based on location, density, and stock health, as determined by the relevant state fishery management body (Mayfield et al. 2021; Mundy et al. 2021; Strain and Heldt 2021a, 2021b). The species of abalone targeted in each state fishery varies and is summarised in Table 1. Being a nationally-focused project, this research will focus on each of the supply chains through which these four species flow.

Table 1. Commercially-targeted Australian abalone species by state fishery.

State	Blacklip	Brownlip	Greenlip	Roe's	Source
New South Wales	✓				NSW Total Allowable Fishing Committee (2021)
South Australia	✓		✓	✓	Stobart and Mayfield (2021)
Tasmania	✓		✓		DPIPWE (n.d.)
Victoria	✓		✓		Mundy et al. (2021); Mayfield et al. (2021)
Western Australia		✓	✓	✓	Strain, Brown, and Jones (2021); Strain, Fabris, and Jones (2021)

1.1.2 Harvest and Processing Methods

Abalone supply chains begin with harvesting; the methods for which are consistent across all five fisheries (Bradshaw 2018; PIRSA 2012; DEDJTR 2015; DPIRD 2016b; The Ecology Lab Pty Ltd 2007). As gastropod molluscs, abalone cling to rock surfaces using their muscular foot (Mayfield et al. 2012). Divers must prise the molluscs from rocks using hand-held flat-bladed knives referred to as 'abalone irons'. The process requires skill and care so that the foot – constituting the highly-valuable meat – is not damaged (Bradshaw 2018). Harvesting operations are efficient, comprising of a small team of one diver and one or two deckhands on a small vessel (Mundy and McAllister 2021; PIRSA 2021). The cold chain begins at this point, when abalone are chilled in 'eskies' (portable ice box coolers) onboard the fishing vessel until they are landed and transported to processors.

The 'processing' phase of the supply chain includes the cleaning, shucking, freezing, cooking, and/or packaging abalone post-harvest. Conversely, live abalone, which are a valuable product format, are not considered 'processed' though the animals are held and purged post-harvest in live holding tanks before being distributed (Pacific Bao Yu n.d.(b)). In addition to the live product format, abalone are processed into a number of formats for human consumption which include, *inter alia*: frozen, canned, dried, and retort-packaged products. Details regarding processing methods are scant in the literature and equally so on company websites; highlighting a gap in publicly available knowledge. Anecdotally, in some states, a high proportion of the shucking waste is produced during the processing phase rather than at harvest; while there are indications that abalone in Western Australia and South Australia are shucked onboard fishing vessels at the point of harvest before being transported to processing facilities. However the extent and frequency of the practice is unclear from the literature (Hart et al. 2017; PIRSA 2021). Information concerning processing practices and volumes shucked at sea and on land are not publicly available, making it difficult to determine the resultant volume of by-product. This is a further knowledge gap to be addressed in this research.

1.1.3 Export Markets and Domestic Sales

Similar to post-harvest processing data, information on the distribution of abalone is scarce. High-level export data are readily available as are anecdotal reports in the fishery management reports (Stevens, Mobsby and Curtotti 2020; Bradshaw 2018; DPIRD 2016b; PIRSA 2012). Conversely, domestic sales data are virtually non-existent, possibly due to the absence of a standardised data collection system for domestic seafood sales in general; inability to obtain confidential sales data from companies; and significant costs associated with collecting the data (McManus and Howieson 2017).

From the limited information that is publicly available, abalone are mostly exported to Asian markets where it is culturally revered as a luxury food item (Bradshaw 2018; Curtotti et al. 2023; Stevens, Mobsby and Curtotti 2020). Deeper and more granular knowledge of the distribution of abalone by species, state, and end-destination (i.e. domestic or export) currently unavailable in the literature will be sought in this research since it has implications on the measurement of industry-wide food waste volumes.

1.1.4 Existing Uses of Abalone Shell and Viscera

Existing uses and preliminary research into the biological attributes of abalone by-products (i.e. abalone shell, viscera, and blood) are one of the motivators for this research. Preliminary research has shown that these by-products can be processed for use in agricultural applications and as bioactive materials (Du et al. 2021; Howieson et al. 2019; Talaei Zanjani et al. 2016; Yamanushi et al. 2022). An active patent reveals that there is some existing commercial interest in extracting bioactive elements from abalone viscera, possibly for therapeutic use (Xu et al. 2022). There is also some – albeit limited – evidence pointing to the edibility of abalone viscera including consumption of the livers as a delicacy in Japanese and Korean cuisine (Chung et al. 2018; Liaw n.d.). Anecdotal information from commercial websites indicate that the shells are sold, primarily to Asian countries, for medicinal and decorative purposes (Blue Sky Fisheries 2010; Hot Dog Fisheries n.d.(b); True South 2021).

Further investigation will be undertaken in this research to determine the market value of the products since this will aid in the analysis of potential food waste management interventions for the Australian abalone fisheries. Now that various aspects of the Australian abalone fisheries have been introduced, the discussion will turn more broadly to food waste.

1.2 Defining Food Waste

'Food waste' is defined in numerous ways in the literature and in practice (Corrado et al. 2019; Gustavsson et al. 2011; Kafa and Jaegler 2021; Papargyropoulou et al. 2016; Parfitt, Croker and Brockhaus 2021; Spang et al. 2019). Thus, it is important to discuss and adopt a reliable definition in this research. The Food and Agriculture Organization of the United Nations (FAO) uses the terms 'food loss' and 'food waste' (Gustavsson et al. 2011), which are commonly-adopted ways of describing and understanding food waste (Parfitt, Croker and Brockhaus 2021). The distinctions between the two terms have been influential in research and practice (Hanson et al. 2016; Kafa and Jaegler 2021; Papargyropoulou et al. 2014; Spang et al. 2019).

However, there are some problematic elements that render the use of separate terms unsuitable for this research. Firstly, making a distinction between 'food loss' (losses that take place at harvest, post-harvest, and processing stages) and 'food waste' (losses that occur at retail and consumer stages as a result of retailer/consumer behaviours) is a cumbersome and distracting approach to understanding and quantifying food waste in this research, which uses a whole chain approach. As Parfitt, Croker, and Brockhaus (2021, 3) explain: a pre-determined distinction between food loss and food waste “distorts the wider understanding of how food waste drivers are linked across supply-chain stages”. For instance, is a product that passes from a processor to a retailer considered ‘food loss’ or ‘food waste’ if the product spoils in store but as a result of packaging, inadequate refrigerated transport, or processor handling? Employing one, all-encompassing term would address any such confusion.

Secondly, the FAO’s definition employs the concept of ‘edibility’ without clearly defining what is meant. “‘Food’ waste or loss is measured only for products that are directed to human consumption, excluding feed and parts of products which are not edible. Per definition, food losses or waste are the masses of food lost or wasted in the part of food chains leading to “edible products going to human consumption”” (Gustavsson et al. 2011, 2). The FAO’s definition fails to account for cultural implications where certain foods may be appreciated as a delicacy by one ethnicity and considered ‘inedible’ (i.e. ‘unpalatable’) by another. An example was already provided in Sections 1.1.4 and 1.3.3 in relation to abalone viscera and liver. The issue of ‘edibility’ will prove problematic in this research when assessing product flows of processing waste and proposing interventions for what is disposed. Owing to these two concerns, the FAO’s definition will not be adopted in this research.

Another framework for categorising food waste that is commonly used in the literature is climate action organisation, WRAP’s framework for categorising food waste as ‘avoidable’, ‘possibly avoidable’, or ‘unavoidable’ (WRAP 2009). However, the framework builds on the FAO’s terms and definitions; and is used to understand the drivers of food waste solely within the context of consumer behaviour (Beretta et al. 2013; Betz et al. 2015; Papargyropoulou et al. 2016; Quested et al. 2011). As this research is focused on food waste at the upstream stages (e.g. harvest, processing) of the abalone supply chain, WRAP’s (2009) definition is also unsuitable in this context.

Conversely, Australia’s National Food Waste Strategy (NFWS) (Commonwealth of Australia 2017) usage and definition of ‘food waste’ has been adopted in this research because it addresses the problematic elements of the FAO's definition (Gustavsson et al. 2011) and WRAP's (2009) framework. The limitation of the NFWS (Commonwealth of Australia 2017) definition is that it is specific to Australia. However, it can be easily adapted and applied to other national contexts. The NFWS defines food waste as:

- Solid or liquid food that is intended for human consumption and is generated across the entire supply and consumption chain;
- Food that does not reach the consumer or reaches the consumer but is thrown away. This includes edible food, the parts of food that can be consumed but are disposed of, and inedible food, the parts of food that are not consumed because they are either unable to be consumed or are considered undesirable (such as seeds, bones, coffee grounds, skins, or peels);
- Food that is imported into, and disposed of, in Australia; and
- Food that is produced or manufactured for export but does not leave Australia. (Commonwealth of Australia 2017, 8)

In addition to addressing the issue of consumer perceptions of edible/inedible food, the definition sets system boundaries for subsequent phases of this research such as supply chain mapping. Throughout the remainder of this research, supply chain mapping will be shown to be a useful tool for addressing food waste. Furthermore, the NFWS' (Commonwealth of Australia 2017) definition encompasses the supply chain in its entirety and addresses the concerns highlighted by Parfitt, Croker, and Brockhaus (2021) which were discussed earlier, regarding the significance of linking drivers of food waste across supply chain stages. In sum, the NFWS' (Commonwealth of Australia 2017) definition of 'food waste' will be adopted in this research since it is an un-skewed and holistic definition that encompasses the whole supply chain and is unbiased in its approach to what is 'edible' or fit for human consumption.

1.3 Overview of Food Waste

Waste from food supply chains is a persisting global problem (Gustavsson et al. 2011; Parfitt, Croker and Brockhaus 2021). Arguably, food waste is an objectionable phenomenon since it affects the availability of affordable, nutritious food, public health, and climate change (FAO et al. 2023). Current measurements of food waste (i.e. within the last five years) at a global scale are, according to the FAO (2019, v), "very rough". The frequently-cited global food waste figures – "1.3 billion tons per year" – approximated by Gustavsson et al. (2011) remain largely unchallenged and widely quoted in the literature (Garrone et al. 2016; Göbel et al. 2015; Ng et al. 2017; Parfitt, Croker and Brockhaus 2021; Spang et al. 2019; Tamasiga et al. 2022; Wu and Teng 2023). What is much less frequently quoted from their seminal report is Gustavsson et al.'s (2011, 15) cautionary statement that "the results in this study must be interpreted with great caution" since numerous measurements of regional food waste are based on assumptions in place of missing data at the national level. This highlights the importance of knowledge generated at a national level rather than globally. Thus, food waste will continue to be explored purely in relation to an Australian context in this section.

Food waste experts in academia and practice agree that the first steps to effectively addressing food waste begin with quantifying volumes of food waste and understanding its causes (Gustavsson et al. 2011; Hanson et al. 2016; Parfitt, Croker and Brockhaus 2021; Xue et al. 2017). In the following sections food waste will be explored specifically in relation to Australia, structured using a 'funnel approach'. Such an approach is intended to reflect the hierarchical levels and systems-thinking approach through which food waste can be examined (Amicarelli, Roe and Bux 2022; Diaz-Ruiz et al. 2018; Hedlund et al. 2020; HLPE 2014). Food waste will be discussed first at a 'macro' national level; then a 'meso' sectorial level within Australian seafood; and finally, a 'micro' supply chain level, focusing on Australian abalone supply chains. In this way, the 'funnel approach' is intended to convey the concept that food waste is a general, global problem that consists of an array of individual agrifood supply chain issues, unique to every country; and requiring tailored attention or interventions (Arcadis 2019; Parfitt, Croker and Brockhaus 2021). Aptly put by the FAO (2019, v-vi): "We cannot generalize about the occurrence of food loss and waste across food supply chains but must, on the contrary, identify critical loss points in specific supply chains as a crucial step in taking appropriate countermeasures."

1.3.1 Food Waste in the Australian Context

In its 2021 baseline, Food Innovation Australia Limited (FIAL 2021) estimated that 7.6 million tonnes of food waste were generated along all parts of the food supply chain in Australia. The food waste data provided by FIAL (2021) and Arcadis (2019) in their reports and online database are the most comprehensive to date at both a national- and state-level, but reveal that gaps remain at a more granular level.

These reports are guided by Australia's NFWS, which was in turn borne out of Australia's commitment to the United Nations' Sustainable Development Goals (SDG) Target 12.3 to, "by 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses" (Commonwealth of Australia 2017; UN 2015, 27). There is an imperative, from an environmental and governmental perspective, to hold true to such a commitment. However, the literature reveals that the knowledge required to guide targeted action at food waste 'hotspots' (areas in the supply chain where high volumes of food waste are generated) needs bolstering (Ambiel et al. 2019; FIAL 2021). Specifically, more data are required in relation to food waste generated across supply chains and at primary production and post-harvest stages – such as the study conducted by Ambiel et al. (2019).

A substantial portion of Australian food waste literature is focused on downstream food waste. Consumer or household food waste patterns, drivers, and interventions have received much attention (Ames and Cook 2020; Ananda et al. 2021; Benyam, Kinnear and Rolfe 2018; Kansal et al. 2022; Karunasena, Ananda and Pearson 2021; Nabi, Karunasena and Pearson 2021; Reynolds et al. 2014; Turner 2019; Wang, McCarthy and Kapetanaki 2021). Retail food waste has been investigated in terms of the effects of food packaging (Dilkes-Hoffman et al. 2018; Verghese et al. 2015; Wikström et al. 2014); and food waste outcomes of high-specification requirements of retailers (Devin and Richards 2018).

However, as a net food-exporter (ABARES 2023), it is likely that a relatively high concentration of food waste (per capita) in Australia is produced at the primary production and post-harvest stages of the supply chain compared to other industrialised countries, rather than purely at the downstream stages (FIAL 2021; Parfitt, Croker and Brockhaus 2021). There have been few attempts in Australia to quantify agrifood waste, meaning food waste generated at the primary production and post-harvest processing stages of the supply chain (Ambiel et al. 2019; FIAL 2021; McKenzie, Singh-Peterson and Underhill 2017; Ridoutt et al. 2014). As such, it is vital the knowledge gap of the quantity and drivers of food waste at the upstream stages of Australian agrifood supply chains is addressed. Arguably, food waste interventions cannot be proposed nor effective without empirical knowledge of food waste hotspots and drivers (FAO 2019; Parfitt, Croker and Brockhaus 2021).

1.3.2 Australian Seafood Waste

Research concerning Australian seafood waste are focused primarily on value-adding to waste products ('valorisation') rather than quantification. This mirrors a trend in the broader literature on food waste (Chiaraluce, Bentivoglio and Finco 2021; de Oliveira, Lago and Dal' Magro 2021).

Australian seafood waste has been investigated as a rich source for nutrient extrusion from the perspectives of food science (Ahmad et al. 2019; Nguyen et al. 2017; Siddik et al. 2021; Suleria et al. 2017a; Suleria et al. 2017b; Suleria et al. 2017c; Xiong et al. 2021); marine science (Branigan, Fitzsimons and Gillies 2020; Diggles 2021); and as a basis for protein production (Hopkins et al. 2021; Shabani et al. 2019). Indeed, valorising food waste or by-products from a scientific perspective is a common theme in the broader academic literature on food waste (Redlingshöfer, Barles and Weisz 2020; Somlai 2022; Xiong et al. 2019).

By contrast, there is a general lack of *current* data and reliable estimates of the extent of seafood wasted in Australia at primary production and post-harvest processing stages. Quantification of seafood is often overlooked and only considered by a handful of studies (Gavine et al. 2001; Howieson et al. 2017; Knuckey 2004;

Raston and Makha n.d.; Tsvetnenko et al. 1994). Moreover, there are few studies that have estimated or measured the extent of seafood waste in Australia at any level (i.e. nationally, industry-wide, or state fishery) within the last five years (Howieson et al. 2017; Koopman et al. 2017). In one extreme case Siddik et al. (2021) cite a misleading ‘2011’ estimate of fish processing discards that, in actuality, originate from a 1982 study that is global in focus (Chalamaiah et al. 2012; Dekkers et al. 2011; Raa, Gildberg and Olley 1982).

As stated in Section 1.3.1 the practical effectiveness of valorisation efforts is questionable without empirical knowledge of the quantities of food waste that will be reduced. Furthermore, estimates based on current data are vital to the assessment of waste hotspots primarily because magnitudes of seafood processing waste change over time – for example, due to changing TACC quotas (Tuynman and Dylewski 2022), or successful commercial development of new markets for by-products (Stephens 2019).

1.3.3 Australian Abalone Waste

The limited understanding of seafood waste volumes is echoed in the literature concerning both aquaculture and wild Australian abalone. Three Australian-based abalone waste studies provide varying, anecdotal volume estimates (Suleria et al. 2017a; Suleria et al. 2017b; Suleria et al. 2017c). Particularly where the viscera component is concerned, anecdotal estimates of waste provided in these studies range from “15-25%” (Suleria et al. 2017c) to 30% (Suleria et al. 2017a). These valorisation studies have also characterised the viscera as “inedible” and “not marketable” (Suleria et al. 2017c, 4195; Suleria et al. 2017a, 712). The assertions that abalone viscera are inedible and unmarketable are questionable based on the knowledge that the liver is used in Japanese and Korean cuisine (Section 1.1.4).

In addition to a lack of knowledge of volumes, focus on the species, sources, and types of abalone processing waste is varied and not easily comparable. Howieson et al. (2017) have studied the valorisation of aquaculture Greenlip abalone waste (shell and viscera); and Tsvetnenko et al. (1994) wild-caught Roe’s, Greenlip, and Brownlip abalone from Western Australia. Where Blacklip abalone viscera is concerned, Suleria et al. (2017a), Suleria et al. (2017b), and Suleria et al. (2017c) utilise wild-caught Blacklip abalone viscera from Victoria and Tasmania, while Yamanushi et al. (2022) source aquaculture Blacklip viscera. A consolidated understanding of the flows and quantities of all species nation-wide would be useful for targeting specific species and fisheries that generate higher volumes of waste.

1.4 Conclusion, Research Questions, and Objectives

In this chapter the motivation and context for this research were described. In Section 1.1 current environmental and economic threats to Australian abalone fisheries were explicated, as were the opportunity to introduce new revenue streams by addressing processing food waste. Food waste was defined in Section 1.2 before an overview of knowledge about food waste at various levels (global, national, industry, supply chain) was provided in Section 1.3.

Furthermore, a number of knowledge gaps were identified. Where Australian abalone fisheries and food waste were concerned, these included a lack of publicly available knowledge concerning: processing activities and product volumes across Australia; discarded volumes of shucking waste at sea and on land; domestic distribution of abalone products; and knowledge of the volumes and drivers of food waste in Australian abalone supply chains. As explained in Section 1.3, addressing these knowledge gaps would enable research and action to be appropriately targeted at food waste hotspots.

Overall the chapter provided the background knowledge required to shape the research problem, questions, and objectives presented in Table 2.

Table 2 The research problem, questions, and objectives. Source: Format adapted from Zikmund (2003).

Problem	Research Questions	Research Objectives
Substantial quantities of potentially useful by-products (abalone shell, viscera, and blood) are disposed of as waste in Australia's wild-harvest abalone industry, resulting in food waste.	**RQ1.** What are the opportunities for reducing food waste in Australia's wild-harvest abalone supply chains that can be identified by mapping current supply chain practices?	a. To map and analyse Australia's wild-harvest abalone supply chains, with a particular focus on food waste in the upstream stages of the supply chain.
	RQ2. How can current supply chain practices be improved to reduce waste along Australia's wild-harvest abalone supply chains?	b. To identify specific management interventions guided by the food waste hierarchy to address food waste along the supply chains.

The research questions and objectives will provide the basis of the research as it unfolds and inform the topics explored in the formal literature review (Chapter 2). The following chapters explicate the pragmatic approach and research design employed to address the research problem, questions, and objectives (Chapter 3), and present and discuss the results in a staged approach (Chapters 4, 5, 6 and 7), before the research questions are directly addressed and conclusions are made in Chapter 8.

2 LITERATURE REVIEW AND THEORETICAL FRAMEWORK

Following the overview of Australia's abalone industry and a brief discussion on the issue of food waste, this chapter is dedicated to further exploring the various dimensions of food waste from a supply chain perspective. Compared to other fields of research (i.e. environmental sciences, engineering), addressing food waste from a supply chain perspective remains a relatively underexplored yet equally crucial research area in the literature given food waste is often caused by suboptimal supply chain practices (Chiaraluce, Bentivoglio and Finco 2021; Gorzeń-Mitka et al. 2020). Thus, the literature reviewed in the following sections will explore food waste through a supply chain lens; and underscore the core constructs of the proposed theoretical framework (proposed at the end of this chapter in Section 2.3) used to guide this research.

A 'supply chain' is typically defined as a network of 'actors' (i.e. firms, suppliers, customers) that transform raw materials into distributed goods by adding value to the materials that flow through the chain from upstream stages (e.g. primary production, processing, manufacturing) to downstream stages (e.g. retail, consumers) (Lambert 2008; Mangan, Lalwani and Calatayud 2021; Mentzer et al. 2001). The definition of 'supply chain' that has been adopted in this research encompasses the concepts of logistics management, interfirm relationship management, value-adding, and competitive advantage of whole supply chains as opposed to individual firms. This definition aligns with the contemporary understanding of supply chain management (Christopher 2011; Lambert 2008; Mangan, Lalwani and Calatayud 2021). Although 'supply chain' has, over time, come to be used synonymously with 'value chain', this research will only use the term 'supply chain' to remain consistent (Fleming et al. 2021; Hara 2014; Hermiatin et al. 2022; Howieson, Lawley and Hastings 2016; MacCarthy, Ahmed and Demirel 2022). Employing the term 'supply chain' will also avoid confusion with Michael Porter's theories concerning individual firm competitiveness and firm-focused analysis, from which the term 'value chain' originated (Christopher 2011; Porter 1998, 1985).

2.1 Addressing Food Waste Along Supply Chains

It could be argued that the food waste problem is, in large part, a supply chain problem since it is often supply chain-related practices that drive the generation of food waste (Aschemann-Witzel et al. 2017; Parmar, Sturm and Hensel 2017; Steynberg, Goedhals-Gerber and Esbeth van 2022). The following sections will explore the extant knowledge and theory regarding food waste along supply chains, with a particular focus on upstream supply chain studies to focus the discussion and relevance to the research context. This approach addresses the research gap identified in Section 1.3.1 that concerned an over-representation of downstream food waste studies in the literature.

2.1.1 Reducing Food Waste Through Supply Chain Improvements

Food waste affects all supply chain stages from harvest (Parfitt, Croker and Brockhaus 2021; Thorsen, Mirosa and Skeaff 2022); post-harvest handling and processing (Garrone et al. 2016; McKenzie, Singh-Peterson and Underhill 2017; Parmar, Sturm and Hensel 2017; Thongsavath et al. 2012); distribution and wholesale (Fernando et al. 2019); retail (de Moraes et al. 2020; Huang et al. 2021; Nikolicic et al. 2021); and consumption (Eriksson et al. 2017; Karunasena, Ananda and Pearson 2021; Papargyropoulou et al. 2016). The literature suggests that by virtue of improving supply chain practices and operations, food waste tends to be eliminated or reduced (Spang et al. 2019). For instance, the improvement of cold chain logistics and co-ordination amongst supply chain members mitigates losses of fresh produce as it travels from upstream to downstream locations (Awad, Ndiaye and Osman 2021; Negi and Trivedi 2021; Steynberg, Goedhals-Gerber and Esbeth van 2022; Waisnawa et al. 2018). In other cases, improved communication between supermarkets and suppliers results in improved supply-demand alignments, and in turn, a reduction in wasted stockpiled or oversupplied food (Stank, Crum and Arango 1999; Towill and McCullen 1999). The cause-effect between improved supply chain practices and reduction in food waste has been well documented.

The literature suggests that food waste drivers are often linked through the supply chain; though some drivers are unique to upstream versus downstream stages of the supply chain (Bhattacharya, Nand and Prajogo 2021; Spang et al. 2019). Drivers have also been assessed in isolation within a particular firm (Papargyropoulou et al. 2016; Secondi et al. 2019). However, numerous studies suggest that food waste occurring at one stage of the supply chain can often be addressed by improving practices at a preceding or subsequent stage (De Steur et al. 2016; Steynberg, Goedhals-Gerber and Esbeth van 2022; Thongsavath et al. 2012). This knowledge further justifies a supply chain approach to addressing food waste.

Drivers of food waste depend greatly on the type of products moving through the supply chain (Fernando et al. 2019; Göbel et al. 2015; Kazancoglu et al. 2021). Food supply chains tend to be conceptualised in terms of the products that flow through each stage – e.g. 'sweet potato value chain' (Parmar, Sturm and Hensel 2017), 'banana supply chain' (Fernando et al. 2019; White, Gallegos and Hundloe 2011), and so on. The particular attributes of each food product determine the drivers of food waste and, in turn, the supply chain practices that are required to mitigate food waste (Madigan 2008; Manoj et al. 2020; Steynberg, Goedhals-Gerber and Esbeth van 2022). Concomitantly, Ambiel et al. (2019) and Ludwig-Ohm, Dirksmeyer, and Klockgether (2019) suggest that on-farm losses are also associated closely with environmental factors such as seasonal conditions (e.g. temperature, weather) and geography. Findings in the literature support the strategies conceived by governments (Commonwealth of Australia 2017), intergovernmental organisations (FAO 2019), and non-governmental organisations and projects (FIAL 2021; van Gogh et al. 2017; Vittuari et al. 2016) that drivers of food waste must be addressed using strategies tailored to specific supply chains and regions (Spang et al. 2019). While individual drivers of food waste should be assessed at a supply chain-specific level, there are some general, unique attributes of food supply chains that are consistently investigated in the literature.

There exists a crucial link between food waste and four unique sensitivities of food supply chains: time, temperature, packaging, and handling (Beretta et al. 2013; Madigan 2008; Manoj et al. 2020; Luo, Olsen and Liu 2021; Steynberg, Goedhals-Gerber and Esbeth van 2022; Verghese et al. 2015). The literature suggests that when one or more of these four elements are not properly managed food waste often occurs along the supply chain. Conversely, when timeliness, temperature control, appropriate packaging, and safe handling of food are addressed by supply chain actors, the supply chain is considered ‘optimised’, ‘efficient’, and ‘sustainable’ (Göbel et al. 2015; Wesana et al. 2019).

Notably, time, temperature, and handling are focused on more frequently where food waste is studied from a supply chain perspective since these three elements are directly aligned with activities, logistics, and practices that are linked through different stages of the supply chain (Awad, Ndiaye and Osman 2021; De Steur et al. 2016; Manoj et al. 2020; Steynberg, Goedhals-Gerber and Esbeth van 2022). However, packaging’s role in mitigating food waste from production/processing to retail and consumption has certainly been commented on from a supply chain perspective (Goossens et al. 2019; Verghese et al. 2015; Wohner et al. 2019).

Despite knowledge of the important role supply chain management plays in reducing food waste, the topic remains relatively underexplored in comparison to other areas of food waste research such as environmental impact and food waste valorisation (Göbel et al. 2015; Viscardi, Colicchia and Creazza 2023). The unique attributes of food supply chains and their relationship to supply chain management were considered and informed the tools used to address food waste in this research.

2.1.2 Economic Impacts of Addressing Supply Chain Food Waste

Waste from food supply chains also concerns the economic impact of implementing food waste management interventions, particularly in the upstream stages of the supply chain. ‘Management interventions’ are the suggested or implemented improvements to supply chain practices, which in this research relate specifically to improving food waste management to reduce or prevent food waste (Hawkes 2009). Generally, comments on the economic impacts of implementing food waste management interventions are scarce; likely due to the nascence of cost-benefit methodologies that sufficiently address food waste reduction and economic impacts simultaneously (De Menna et al. 2018). This is in contrast to the attention that the environmental impacts (e.g. reduced carbon emissions) of reducing food waste (Chiaraluce, Bentivoglio and Finco 2021; Gorzeń-Mitka et al. 2020).

Arguably, the economic impact of implementing management interventions is an important aspect of reducing food waste, particularly for upstream supply chain actors who have commercial interests at stake. Just as drivers of food waste can be linked through the supply chain, Cox and Chicksand (2005) and Korhonen, Honkasalo, and Seppälä (2018) suggest that, generally, unintended effects of implementing management interventions can also flow through the supply chain. For instance, Cox and Chicksand (2005) contend that implementation of lean management principles across the UK beef supply chain created unintended wastage and economic losses at the primary production stage but delivered economic benefits to retailers. Although not specifically concerned with food waste but sustainability generally, Cox and Chicksand (2005) and Korhonen, Honkasalo, and Seppälä (2018) suggest a connection between three concepts: (1) uneven distribution of economic losses/benefits through the supply chain; (2) implementation of management interventions; and (3) waste creation/reduction. Where food waste is concerned, Willersinn et al. (2017) found that changes to operational practices (e.g. sorting and grading) at the primary production stage had material economic and food waste implications on subsequent stages of the supply chain (i.e. distribution, wholesale, and retail). Although it can be difficult for actors to manage interventions and their effects outside the firm (Lambert, Knemeyer and Gardner 2008), adopting a supply chain perspective – which considers several, if not all stages of the whole chain – allows for economic risks to be mitigated or at least understood.

As negative economic impacts can act as potentially significant barriers to implementing food waste interventions in the upstream stages of the supply chain, this aspect of addressing food waste deserves further investigation by food waste researchers such that any practical or commercial disincentives (e.g. uneven distribution of benefits amongst supply chain actors) to preventing or reducing food waste can be overcome.

2.2 Core Constructs of the Theoretical Framework

The literature review will now continue with a more in-depth discussion of concepts central to the theoretical framework. The core constructs build on the understanding put forth in Section 2.1 of food waste as a supply chain issue, requiring management interventions that enable improvements to practices.

2.2.1 Understanding Food Waste from a Supply Chain Perspective

The literature suggests there are five aspects of food waste that can be understood and addressed comprehensively from a supply chain perspective. Certainly, there are a number of valid perspectives such as environmental science (Caldeira et al. 2020) or behaviour change (Ananda et al. 2021; Karunasena, Ananda and Pearson 2021) *inter alia*, that are prominent in the literature. However, the literature suggests that a supply chain perspective – specifically, supply chain analysis and mapping – can be an effective approach to understanding five fundamental aspects of food waste in a single framework (Batista et al. 2021; Hedlund et al. 2020). These include:

- '**What'** – the types of waste created along agrifood supply chains (Garcia-Garcia et al. 2017).
- **'Where'** – the locations and stages where food waste is created and flows to, including hotspots (defined in Section 1.3.1).
- **'How much'** – volumes of food waste or other associated impacts of food waste (Amicarelli, Roe and Bux 2022; Betz et al. 2015; Redlingshöfer, Coudurier and Georget 2017; Xue et al. 2017).
- **'Who'** – those responsible for food waste (Anastasiadis, Apostolidou and Michailidis 2020).
- **'Why'** – reasons or drivers of food waste (Ananda et al. 2021; de Moraes et al. 2020; McKenzie, Singh-Peterson and Underhill 2017).

Examples of the ways in which the five fundamental aspects of food waste can be understood and addressed are outlined in Table 3.

Table 3. Five fundamental aspects of understanding and addressing food waste through different perspectives.

Aspects of Food Waste	General Examples	Supply Chain Perspective
'What' is created	Food waste, CO_2 emissions	Specific food waste categories
'Where' it is created and flows to	Supply chain stages, supply chain actors, industries, geographic locations, social groups	Supply chain stages/actors, geographic locations
'How much' is created and the magnitude of impact	Volumes or magnitude	Volumes of food waste; volumes relative to total food production
	Food insecurity, climate change, economic opportunity cost	Opportunity cost, inefficient operations
'Who' creates food waste	Primary producers, processors, consumers	Supply chain actors, interfirm relationships
'Why' it is created	Consumer behaviours, high-specification demand by retailers, lack of cold chain	Cold chain, poor communication, slow lead times

Overall, a supply chain perspective is a broad lens which suitably addresses all five aspects of food waste and justifies the need to fill the gap in food waste literature mentioned in Section 2.1.1, concerning the limited research of managing supply chains to reduce food waste. The following sections will explore supply chain analysis and mapping as specific management tools for understanding and addressing food waste.

2.2.2 Supply Chain Analysis

In practice, supply chain analysis has been recommended as a necessary first step to addressing food waste (Bellu 2013; FIAL 2021; van Gogh et al. 2017; Vittuari et al. 2016). However, the use of supply chain analysis in food waste research is in nascent development and relatively underutilised (Anastasiadis, Apostolidou and Michailidis 2020; Batista et al. 2021; Beretta et al. 2013; Secondi et al. 2019; Wakiyama et al. 2019). Somlai (2022) and Jones et al. (2023) have identified that, generally, the use of business management and decision-making tools in food waste research is an underexplored topic. Thus, the theoretical framework focuses on supply chain analysis as a beneficial tool for addressing food waste generated at the supply chain-level.

By contrast, there are numerous examples in the literature that demonstrate the benefits of supply chain analysis in improving the performance and sustainability of agrifood supply chains more generally (Alarcon et al. 2017; Anastasiadis, Apostolidou and Michailidis 2020; Carvalho, Cruz-Machado and Tavares 2012;

Faße, Grote and Winter 2009; Hara 2014; Jacobi et al. 2019; Kabu and Tira 2015; Kiambi et al. 2018; Masamha, Thebe and Uzokwe 2018; Nguyen, Bui and Jolly 2017). The prevalence of these studies in the broader literature on sustainable agrifood supply chain management highlights an opportunity to improve theory, empirical knowledge, and credibility of supply chain analysis tools in food waste research. Although supply chain analysis is part of the broader field of supply chain management and operations research, the focus in this theoretical framework will be on this specific tool and its intersection with improving the management of food waste.

'Supply chain analysis' is a broad, common practice in supply chain management that begins the process of improvement to operations and performance (Surie and Wagner 2008). There are many ways to conduct supply chain analysis since there are numerous frameworks that are commonly used (e.g. SCOR, Lean thinking, Agile management, Lean and Agile, Global Supply Chain Forum or GSCF, life cycle assessment); and each can be applied to myriad types of supply chains that have different attributes, processes, structures, and so on (Christopher 2011; De Menna et al. 2020; Denham et al. 2015; Goldsby and García-Dastugue 2008; Lambert, Garcia-Dastugue and Croxton 2005). At its core, however, the practice of supply chain analysis consists of two elements: modelling and performance (Surie and Wagner 2008).

Modelling, which is referred to commonly in the literature as 'supply chain mapping', involves visually representing the structures, processes, relationships between actors, material flows, and governance that connect each stage of the supply chain; providing a 'blueprint' of sorts (Farris 2010; Gardner and Cooper 2003; Goldsby and García-Dastugue 2008). Supply chain mapping can also encompass visual modelling of interfirm strategies as they relate to processes and flows across each supply chain stage (Gardner and Cooper 2003; Lambert, Garcia-Dastugue and Croxton 2005). Where agrifood supply chains are concerned, supply chain mapping has been conducted not only to assess performance but also as a revelatory process. For instance, an understanding of food waste drivers and flows can be developed by mapping the supply chain (Batista et al. 2021). Moreover, through supply chain mapping previously unknown, little understood or informal supply chains are made ‘visible’ and comprehended (Alarcon et al. 2017; Kabu and Tira 2015; Kiambi et al. 2018; Ilbery et al. 2006). Mapping agrifood supply chains is also beneficial where intricate stakeholder relationships or structures are involved (Anastasiadis, Apostolidou and Michailidis 2020; Colloredo-Mansfeld et al. 2014). This research will adopt the term ‘supply chain mapping’ to describe this modelling practice.

Performance, the second mandatory element of supply chain mapping, is defined by whichever managerial or strategic objectives are set by supply chain actors. For example, in agrifood supply chain literature performance can be measured in terms of supply chain resilience (Carvalho, Cruz-Machado and Tavares 2012; Davis, Downs and Gephart 2021; Mubarik et al. 2021; Schrobback, Rolfe and Star 2020); operational efficiencies such as improved lead times (Das 2019; De Steur et al. 2016; Manoj et al. 2014); or reduced food waste (Batista et al. 2021). In scenarios where performance is measured by supply chain competitiveness, supply chain analysis can be viewed as an extension of Porter’s (1985) value chain analysis which is concerned only with individual firm competitiveness (Christopher 2011; Sundarakani, Razzak and Manikandan 2018). Regardless of the chosen indicator (i.e. competitiveness, operational efficiency, sustainability), performance is difficult to measure without first mapping the supply chain, since the metrics for processes, structures, flows, and/or relationships can be visually represented all at once on the map itself (Surie and Wagner 2008).

2.2.3 Supply Chain Mapping

As it has been established that it is the necessary initial step to supply chain analysis itself, supply chain mapping constitutes one of the core elements to the proposed theoretical framework developed in this research. Although supply chain mapping is itself a process – the details of how it was operationalised in this research is discussed in the Research Design (Section 3.6) – it was necessary to explore its relationship to understanding food waste, thereby deserving attention in the proposed theoretical framework. As suggested by Whetten (1989), theory development concerns the relationships between concepts, which will be the primary focus of this and the following sections concerning supply chain mapping and its application to food waste.

Supply chain mapping is wholly distinct from other kinds of mapping often performed in food waste and agrifood supply chain literature that do not visually represent the supply chain. For instance, it should not be confused with choropleth and geographic mapping of supply chains (Ambiel et al. 2019; Shahid and Hittinger 2021; Thongsavath et al. 2012; Underhill, Leeroy and Zhou 2019; Wakiyama et al. 2019); mapping of concepts and themes as in literature reviews (Gorzeń-Mitka et al. 2020; Żmieńka and Staniszewski 2020); or material flow diagrams such as Sankey diagrams (Amicarelli, Roe and Bux 2022; Garcia-Garcia, Stone and Rahimifard 2019). The agrifood supply chain literature suggests that a 'blueprint' or supply chain map facilitates supply chain improvement since it captures the essence of current operations and strategy, which in turn provides a basis for designing and implementing an improved future system (Alarcon et al. 2017; Carvalho, Cruz-Machado and Tavares 2012; Kurdve et al. 2015).

In food waste research, mapping has often been conducted using Value Stream Mapping (De Steur et al. 2016; Manoj et al. 2020; Wesana et al. 2019). This is problematic for two reasons. Firstly, Value Stream Mapping in its purest iteration focuses only on single-firm modelling rather than on structures, flows, relationships, and governance across the whole chain (De Steur et al. 2016; Rother and Shook 2003; Wesana et al. 2019). The importance of addressing food waste across the supply chain was explained earlier (Section 2.1).

Secondly, Value Stream Mapping originates from the Lean thinking framework of supply chain analysis (Section 2.2.1). Where Lean thinking principles have been adapted to supply chain analysis (as opposed to single firms alone), Value Stream Mapping has also been adapted in an iteration known as 'Extended Value Stream Mapping' (Goldsby and García-Dastugue 2008). Nonetheless, authors such as Cox and Chicksand (2005) and Hedlund et al. (2020) have theorised that the Lean framework's concept of 'value' does not necessarily align with managing food or production sustainably across whole supply chains. Thus, there is an opportunity to improve upon the supply chain mapping and analysis frameworks employed in food waste research. Incidentally, Value Stream Mapping should not be confused with Porter's (1985) 'value chain analysis' which is focused on single-firm competitive advantage and differentiation strategy rather than operational efficiency (Section 2.2.1).

Where specific mapping techniques are concerned, there is also an opportunity to improve on the approach and conventions employed for mapping food waste. Food waste flows are often mapped using Sankey diagrams (Amicarelli, Roe and Bux 2022; Garcia-Garcia, Stone and Rahimifard 2019; Wakiyama et al. 2019). Thus, other crucial elements of the supply chain such as structure, interfirm relationships, or governance that would help in the analysis of drivers are decoupled from the quantified product flows (i.e. food inputs and food waste). By contrast, Batista et al. (2021) devise a comprehensive qualitative food waste mapping and analysis framework that does not include food waste volumes. Beretta et al. (2013) provide a rare example of a supply chain map that equally illustrates material flows (in this case, energy) and drivers. As explicated in Section 1.3 both drivers and volumes of food waste are important elements to understanding and addressing waste generating practices.

All in all, these gaps constitute barriers to mapping and analysing food waste in a comprehensive manner which both volumes and drivers. Without a comprehensive framework for supply chain mapping and analysis, the ability to effectively improve food waste management practices may be hindered. The following sections expand on the various considerations for constructing effective supply chain maps.

2.2.4 Establishing Mapping Purpose

An effective map must have a clear purpose, which flows on from the concept of 'signposting' described in Section 2.2.5. Since mapping is linked to performance (Section 2.2.1), it follows that the mapping purpose must be driven by the performance indicators that are measured in the overall supply chain analysis (Gardner and Cooper 2003; Surie and Wagner 2008). In this way, the results of performance measurement can be viewed as an outcome of mapping.

Where food waste is concerned, supply chain performance can be measured in terms of reducing food waste volumes (Amicarelli, Roe and Bux 2022; Betz et al. 2015; Bedoya-Perales and Dal' Magro 2021; Beretta et al. 2013) or improved outcomes for food waste, such as avoiding disposal or preventing food waste altogether (Aschemann-Witzel et al. 2017; Garcia-Garcia et al. 2017; Papargyropoulou et al. 2016). The literature review revealed a lack of frameworks and food waste mapping examples that link mapping and performance measurement such that a comprehensive of analysis of the supply chain, food waste volumes, and drivers can be conducted. Thus, the primary purpose of mapping in this research is conceptualised as mapping to both: understand (e.g. volumes, drivers) and address (e.g. prevent, reduce, recycle) food waste along the agrifood supply chain.

2.2.5 Attributes of an 'Effective' Map

Supply chain mapping involves collecting, collating, and visualising data in such a way that information is contextualised and cogent (De Steur et al. 2016; Donaldson, Brice and Midgley 2020; Fabbe-Costes, Lechaptois and Spring 2020; Kiambi et al. 2018). This section is concerned with a key question in supply chain mapping literature of what makes a supply chain map effective (Donaldson, Brice and Midgley 2020; Farris 2010; Gardner and Cooper 2003).

Carvalho, Cruz-Machado, and Tavares (2012), Donaldson, Brice, and Midgley (2020), Farris (2010), Gardner and Cooper (2003), Lambert, García-Dastugue, and Knemeyer (2008), and Rother and Shook (2003) agree that an effective map possesses certain attributes, including:

- Meaning that is conveyed with immediacy – e.g. information about the direction in which products flow, who actors are, what relationship dynamics are at play, and so on.
- 'Signposting' or drawing map readers' attention to the most salient parts of the map that convey the map's purpose and areas for improvement along the supply chain.

To achieve these attributes, mappers must:

- Not overcrowd the supply chain map with information (Farris 2010; Gardner and Cooper 2003). A low- to medium-density of clearly-displayed information is more likely to enable the map reader to extract meaning with immediacy (Carvalho, Cruz-Machado and Tavares 2012; Farris 2010). Examples of low-, medium-, and high-density supply chain maps are provided in Figures 4, 5 and 6 respectively.

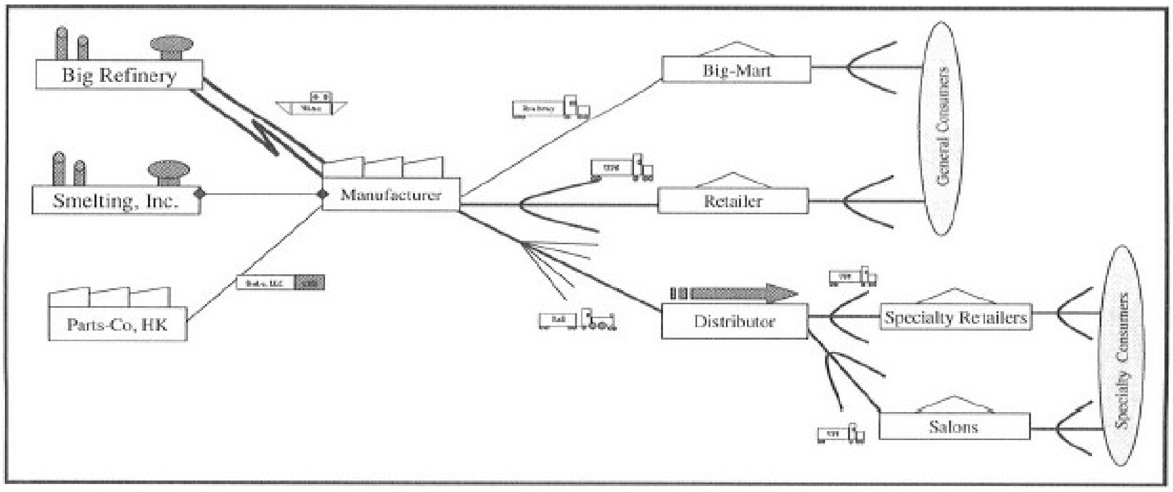


Figure 4. Example of a low-density supply chain map. Source: Gardner and Cooper (2003, 57).

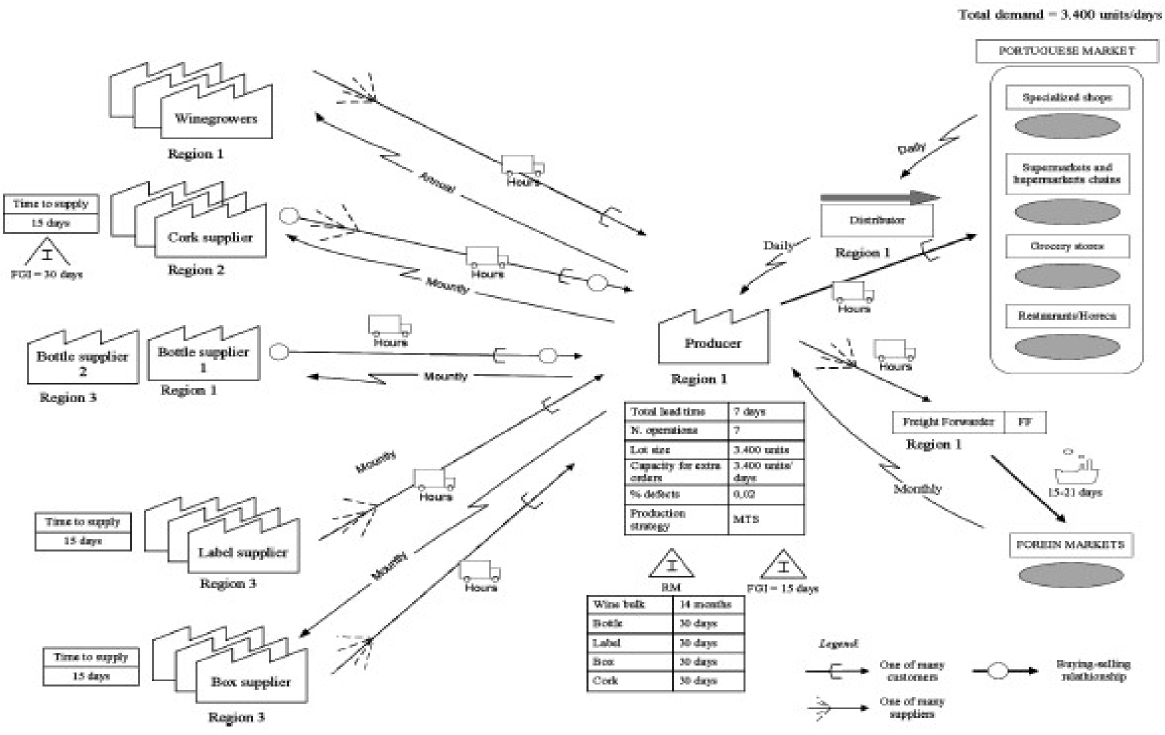


Figure 5. Example of a medium-density supply chain map. Source: Carvalho, Cruz-Machado, and Tavares (2012, 367).

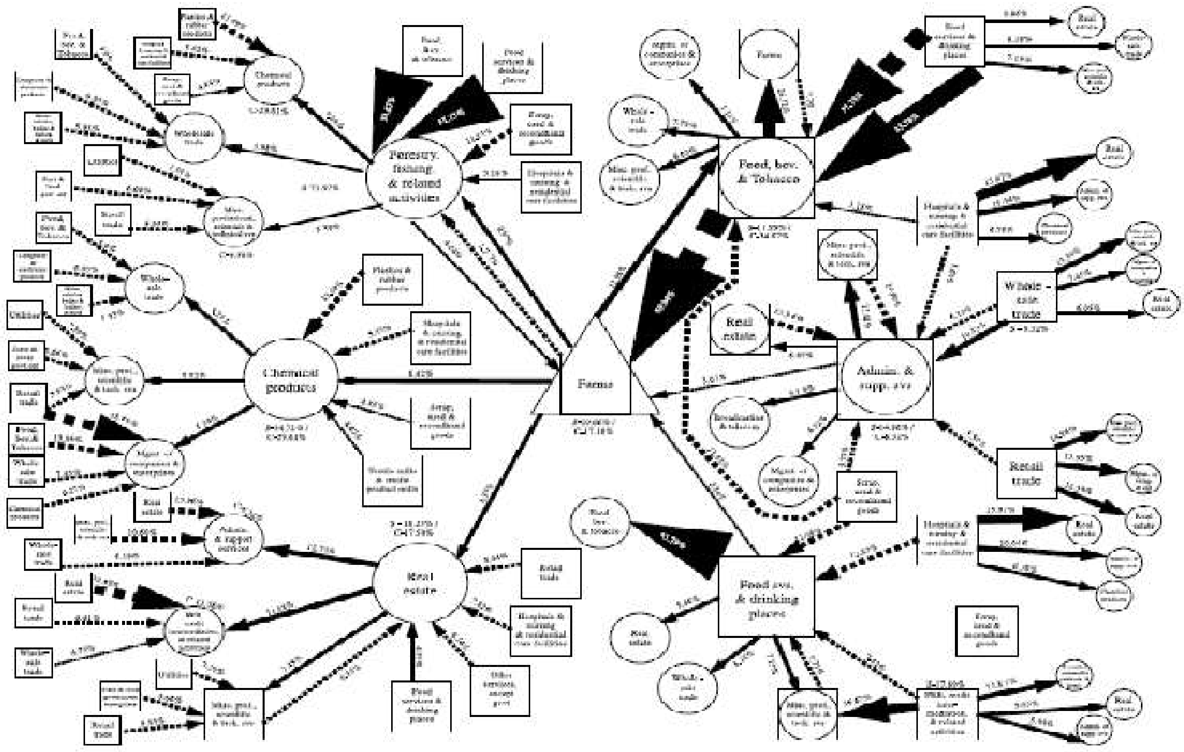


Figure 6. Example of a high-density supply chain map. Source: Farris (2010, 172).

- Show clearly-delineated supply chain stages or tiers, as in Figures 4 and 5. A ‘network’ view, exemplified in Figure 6 does not adequately contextualise supplier-customer flows and relationships, which are particularly evident in Figures 4 and 5.
- Use easily- or commonly-understood symbols (e.g. arrows, boxes, icons), or existing, well-established conventions from existing frameworks (e.g. Value Stream Mapping) shown in Figures 4 and 5.

In the food waste literature, supply chain mapping techniques tend to be driven by researchers’ inclinations or novel techniques rather than extant theory (Anastasiadis, Apostolidou and Michailidis 2020; Batista et al. 2021; de Moraes et al. 2020; Parmar, Sturm and Hensel 2017). In this way, food waste mapping does not appear to be based on reliable methods adapted from general supply chain mapping theory and operations research. Employing or adapting existing supply chain mapping conventions to a food waste context and in a standardised manner would assist the credibility of supply chain mapping of food waste in research (Batista et al. 2021). Furthermore, standardised conventions would help to overcome potential barriers to conveying meaning about food waste volumes and drivers with immediacy (Gardner and Cooper 2003). Conveying meaning with immediacy is a naturally assumed objective and the primary utility of supply chain mapping, akin to visualising data (Gardner and Cooper 2003; Kennedy et al. 2016).

2.2.6 Determining Mapping Parameters and Elements

In supply chain mapping theory a map's parameters are determined by the purpose of the exercise. Parameters can be categorised as 'primary' or 'secondary'. Primary parameters set the broad scope or 'skeleton' of the mapping; and secondary parameters that illustrate the particular workings, or 'internal organs', of the supply chain. Primary parameters include:

- **'Length'** – which refers to the number of supply chain stages included in the map; this is typically known as the number of 'tiers' supply chain mapping terminology (Gardner and Cooper 2003; Lambert, García-Dastugue and Knemeyer 2008; Lambert et al. 2008).
- **'Perspective'** – which refers to whether mapping is conducted from a firm-focal point of view (Carvalho, Cruz-Machado and Tavares 2012; Powell et al. 2017; Suarez-Barraza, Miguel-Davila and Vasquez-Garcia 2016) or a wider perspective that treats the flows between actors/stages with equal detail (Murungi et al. 2021; Schrobback, Rolfe and Star 2020).
- **'Breadth'** - which refers to the number of food products that are covered in the supply chain map (Gardner and Cooper 2003; Rother and Shook 2003).
- **'Time period'** – which refers to the 'snapshot' in time of which the product, information, and financial flows and activities are representative (Donaldson, Brice and Midgley 2020). For example, whether the flows and activities are representative of what occurs on a daily, fortnightly, monthly, or annual basis.

Where agrifood supply chains are concerned, secondary parameters most often include:

- Flows of material (i.e. raw material, products), information, and finances between primary supply chain actors, including quantitative measurements like volume, frequency, or economic value (Alarcon et al. 2017; Carvalho, Cruz-Machado and Tavares 2012; De Steur et al. 2016);
- Activities such as operational processes and logistics, whether intrafirm or interfirm, including production/delivery lead times, and storage or inventory (Carvalho, Cruz-Machado and Tavares 2012; de Moraes et al. 2020; De Steur et al. 2016; Parmar, Sturm and Hensel 2017);
- Supply-demand relationships between supply chain actors, and firm structure (Carvalho, Cruz-Machado and Tavares 2012; Knoll et al. 2017; Schrobback, Rolfe and Star 2020);
- Governance, such as policies or regulations (Kiambi et al. 2018);
- Other structural and actor attributes relevant to the particular mapping purpose such as power, critical flows, or gender (Masamha, Thebe and Uzokwe 2018; Murungi et al. 2021; Parmar, Sturm and Hensel 2017; Schrobback, Rolfe and Star 2020).

The literature suggests all supply chain maps must include the primary parameters since these set the broad scope for the map (Gardner and Cooper 2003; Lambert, García-Dastugue and Knemeyer 2008). However, the secondary parameters are selected based on the purpose and objectives of the supply chain analysis and mapping. As such, not all of the aforementioned secondary parameters would be included on a single map lest it be overcrowded with information.

The circular economy approach to analysing systems at a micro-, meso-, or macro-level (Section 1.3) is apt for setting length and perspective boundaries in agrifood supply chain mapping. By synthesising supply chain mapping theory (Gardner and Cooper 2003; Lambert, García-Dastugue and Knemeyer 2008) and food waste analysis studies (Amicarelli, Roe and Bux 2022; Diaz-Ruiz et al. 2018; Messner, Johnson and Richards 2021), a three-category system for determining mapping length and perspective was devised. This is presented in Figure 7.

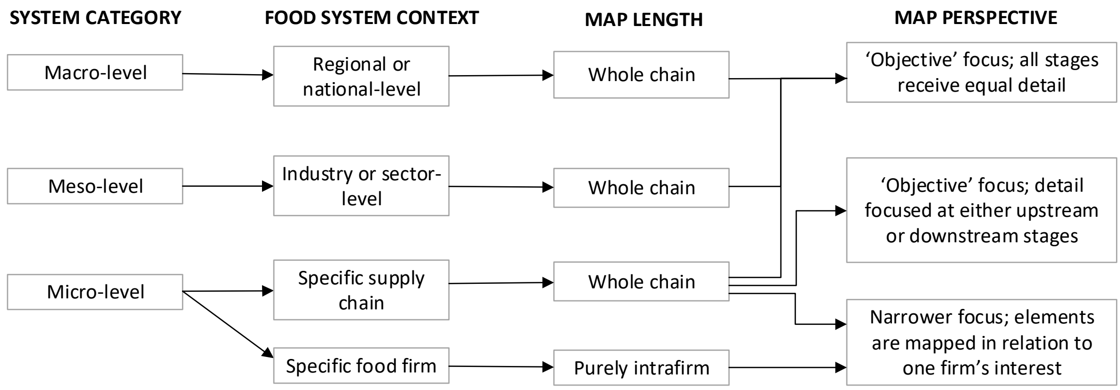


Figure 7. Relationship between a circular economy systems-view and supply chain mapping parameters.

Finally, the concept of 'elements' will be discussed. Within each parameter, there are several relevant elements that convey information to map readers about the supply chain. This is best explained by way of an example from the food waste literature. Beretta et al.'s (2013) map of energy flows (terajoules) and food waste in the Swiss food industry uses three parameters (product flow, actors, activities) and a number of related elements (energy volumes, types of food waste, various agrifood industries, related processes). Figure 8 shows the relationship between the map's purpose, parameters, and elements where the mapping parameters flow from the mapping purpose, and can be explained using various elements.

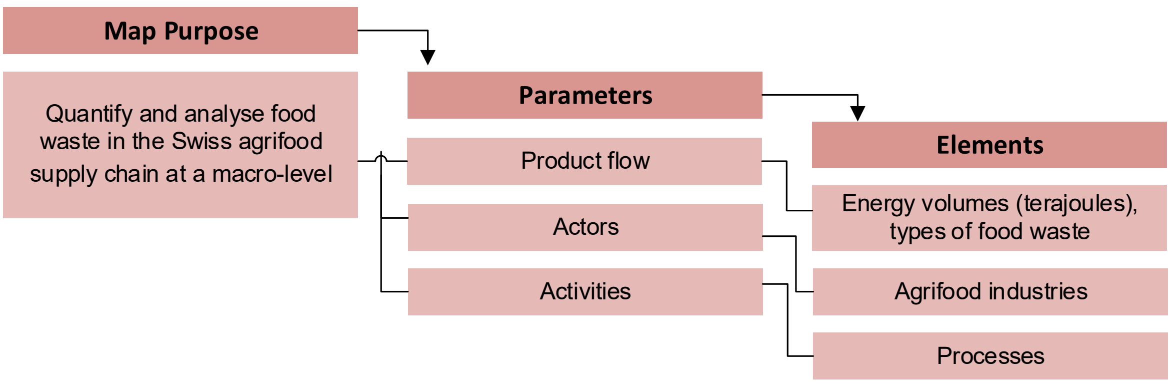


Figure 8. Analysis of Beretta et al.'s (2013) supply chain map according to the theoretical framework.

As explained in Sections 2.2.4 and 2.2.5, food waste mapping examples in the literature have tended to be conducted using unconventional approaches or frameworks that have not been adequately adapted to the needs of food waste research. The approach proposed in the theoretical framework addresses this gap by synthesising circular economy concepts (e.g. macro, meso, and micro levels of analysis), and key supply chain mapping conventions from operations research that are adaptable to a food waste context (i.e. primary and secondary parameters, and elements).

2.2.7 Current- and Future-State Mapping

Addressing food waste by proposing interventions for the future cannot occur without first analysing the 'current state' supply chain that is mapped (Batista et al. 2021; Manoj et al. 2014). A current-state map models the supply chain at a particular point in time as it is in reality – imperfections, inefficiencies and all – rather than how operations *should* work in an ideal situation (Batista et al. 2021; Donaldson, Brice and Midgley 2020; Rother and Shook 2003). To enable an effective analysis of current operations a specific time period, as defined in Section 2.2.6, should be associated with activities (Carvalho, Cruz-Machado and Tavares 2012; Donaldson, Brice and Midgley 2020; Parmar, Sturm and Hensel 2017). A future-state map addresses the inefficiencies identified in the current-state map by illustrating suggested changes to supply chain practices; and can also forecast future activities and demand (Knemeyer, Lambert and García-Dastugue 2008; Rother and Shook 2003).

The concept of mapping a 'current state' in order to design an improved 'future state' of the supply chain is borrowed from Value Stream Mapping (Rother and Shook 2003; Womack 2006). Despite Value Stream Mapping/Lean thinking's questionable suitability to mapping food waste and agrifood supply chains in general (discussed in Section 2.2.3), the current- and future-state mapping aspect of the framework is adaptable and beneficial to the process of improving waste management practices which has been demonstrated by Goldsby and García-Dastugue (2008), Hedlund et al. (2020), and others (De Steur et al. 2016) in Extended Value Stream Mapping. Food waste studies tend to focus only on current-state mapping (Anastasiadis, Apostolidou and Michailidis 2020; de Moraes et al. 2020; De Steur et al. 2016; Parmar, Sturm and Hensel 2017). This is a considerable gap in the literature considering the generally-understood importance of addressing food waste (i.e. imagining a future-state).

Batista et al. (2021) demonstrate that contrasting current- and future-states can be beneficial for illustrating changes to food waste flows (Figure 9).

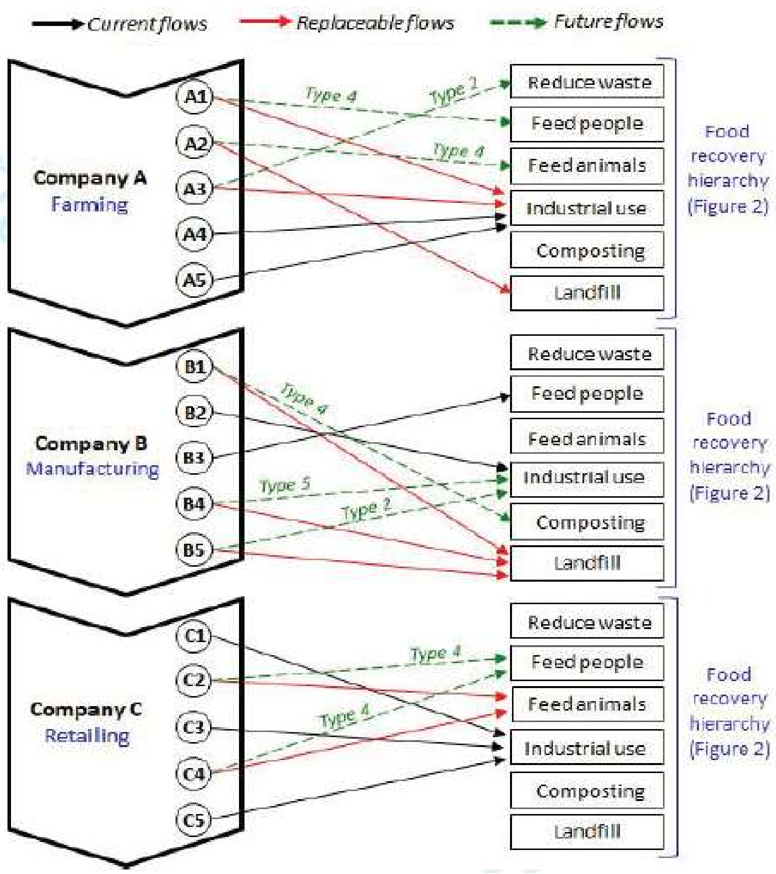


Figure 9. Current and future flows of food waste along an agrifood supply chain. Source:Batista et al. (2021, 13).

By applying future-state mapping Batista et al. (2021) manage to connect food waste flows and improvement to management practices to circular economy principles. This is a key strength of Batista et al.'s (2021) mapping framework since the literature suggests that food waste is most effectively addressed using circular economy principles.

The following two sections will delve further into other aspects of the future-state mapping, including: the application of circular economy principles to managing food waste sustainably (Section 2.2.8); and the use of feasibility analysis to address the economic impacts of implementing management interventions (Section 2.2.9).

2.2.8 Circular Economy Principles and Food Waste

In the literature, food waste is addressed by two different and prominent approaches: (1) a circular economy approach (Batista et al. 2021; Garcia-Garcia et al. 2017; Goodman-Smith, Mirosa and Skeaff 2020; Papargyropoulou et al. 2016; Parmar, Sturm and Hensel 2017; Redlingshöfer, Barles and Weisz 2020); and (2) Lean thinking principles (De Steur et al. 2016; Manoj et al. 2020; Wesana et al. 2019). As the limitations to managing food waste using Lean thinking was already discussed in Section 2.2.3 the focus of this section will remain on circular economy principles.

The concept of the circular economy is underpinned by principles from industrial ecology and process manufacturing where industrial systems and products are designed or re-imagined with regenerative or restorative attributes in mind (Caldeira et al. 2020; Chiaraluce, Bentivoglio and Finco 2021; Geissdoerfer et al. 2017; Hedlund et al. 2020). The idea of 'circularity' is intended to evoke a contrast to traditional, linear systems where products are manufactured, used, and disposed (Geissdoerfer et al. 2017; Kirchherr, Reike and Hekkert 2017). In principle, products in the circular economy are optimally designed for disassembly and/or re-use; which gives rise to the 'R' framework for directing product flows (i.e. reduce, re-use, recycle) (Garcia-Garcia et al. 2017; Hedlund et al. 2020). A general 'R' framework, which is based on circular economy principles, is presented in Figure 10. In theory, extraction and throughput of natural resources and negative ecological impacts of disposal are reduced by keeping materials circulating through industrial systems; thereby leading to more sustainable operations (Geissdoerfer et al. 2017; Hedlund et al. 2020; Pagotto and Halog 2016).

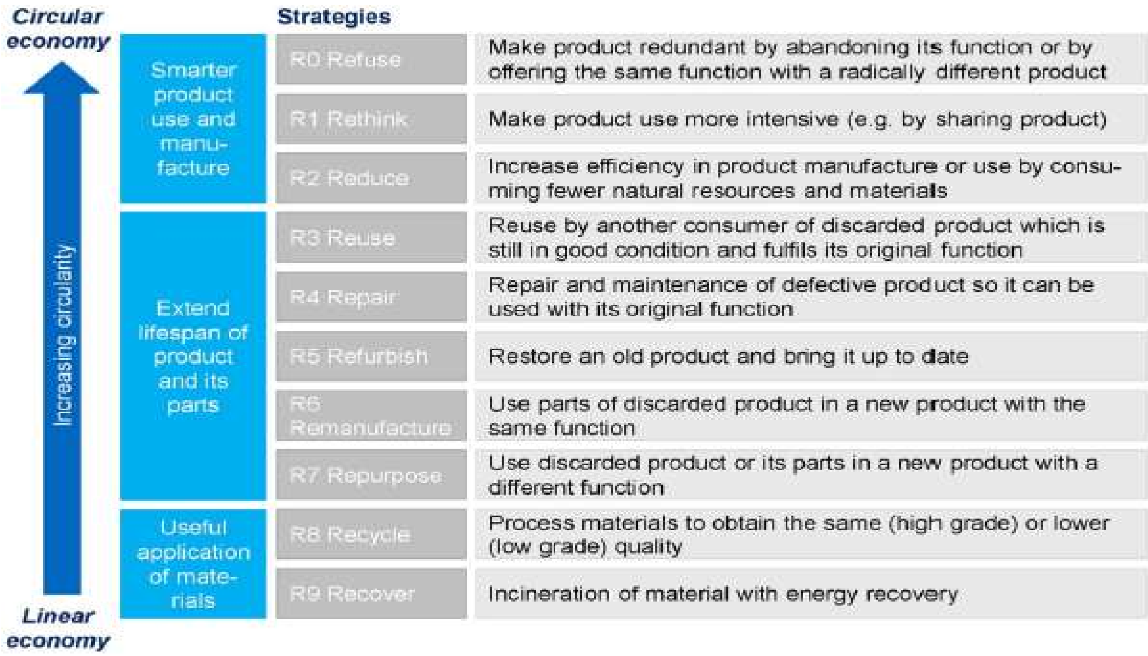


Figure 10. Example of a circular economy 'R' framework. Source:Kirchherr, Reike, and Hekkert (2017, 224).

Owing to the unique characteristics of agrifood supply chains, circular economy principles have been adapted to food waste research and practice in the form of the 'food waste hierarchy' (Batista et al. 2021; Garcia-Garcia et al. 2017; Papargyropoulou et al. 2014; Tamasiga et al. 2022). The food waste hierarchy is a tailored framework for countering food waste according to the 'R' framework (Batista et al. 2021; Garcia-Garcia et al. 2017; Papargyropoulou et al. 2014). Key elements of the food waste hierarchy include: management options that are organised by tiers from 'most preferable' to 'least preferable'; and five core management options or strategies that include prevention, re-use (sometimes termed 'redistribution'), recycling, recovery, and disposal. Three examples of food waste hierarchies are provided in Figures 11, 12, and 13 that, when compared, demonstrate the variance and similarities found in the literature.

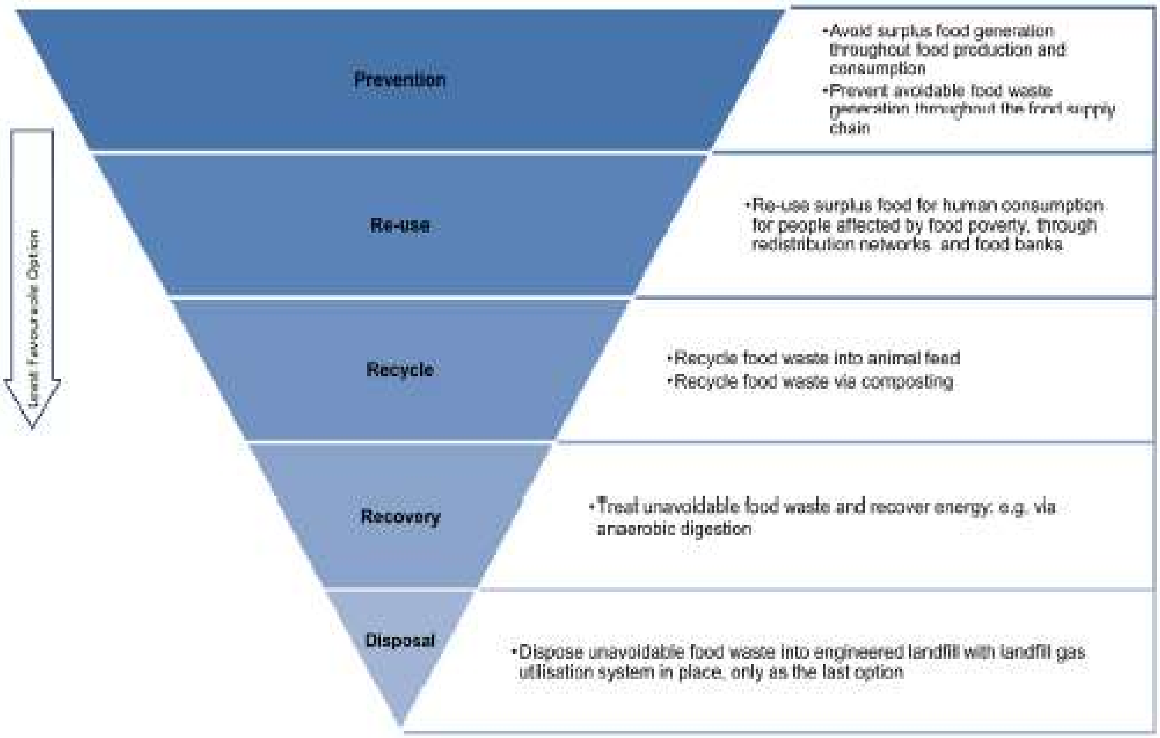


Figure 11. Example of a five-tier food waste hierarchy. Source: Papargyropoulou et al. (2014, 113).

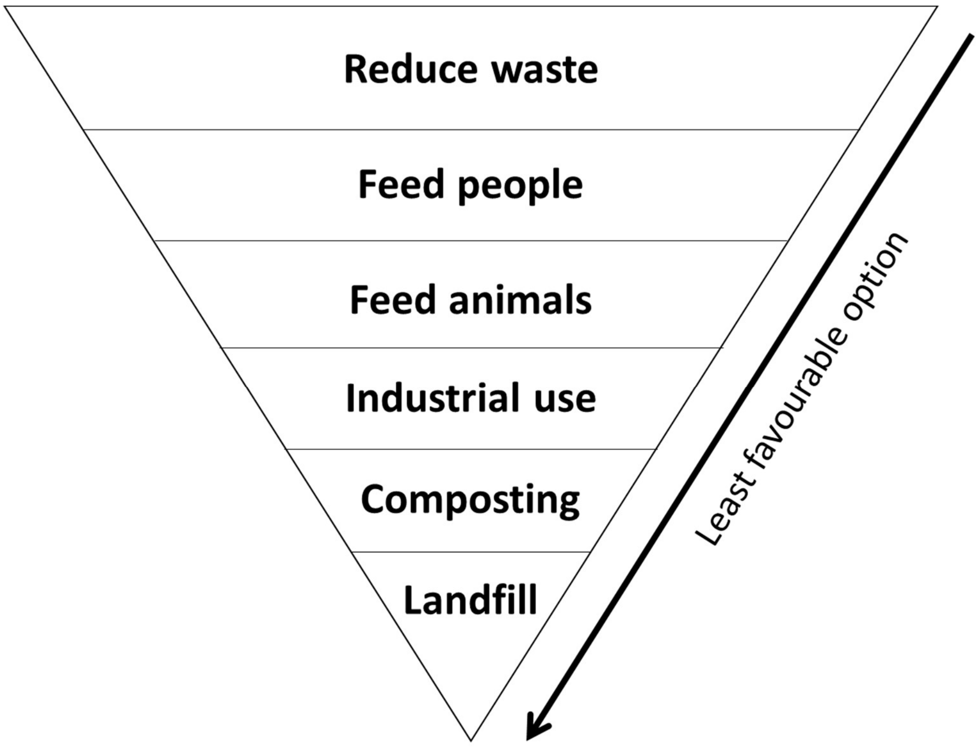


Figure 12. Example of a six-tier food waste hierarchy. Adapted from: Batista et al. (2021, 6).

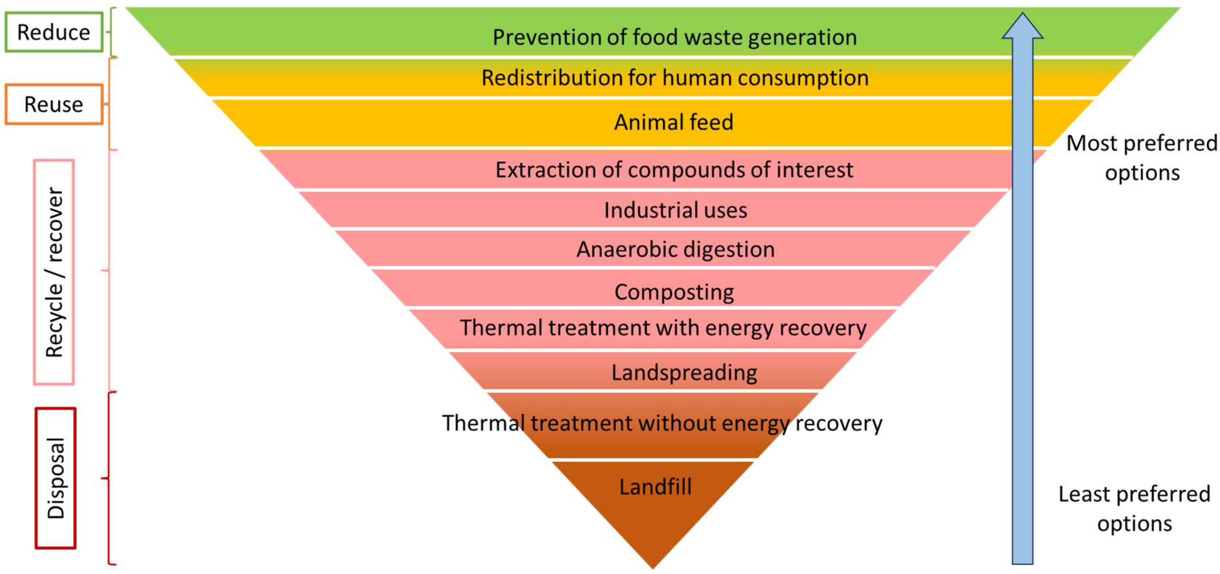


Figure 13. Food waste hierarchy model adopted in this research. Adapted from: Garcia-Garcia et al. (2017, 2235).

Figure 11 exemplifies the most common iteration of the food waste hierarchy where five waste management interventions (defined in Section 2.1.2) are based on the 'R' framework. Figure 12 and Figure 13, on the other hand, demonstrate the propensity for authors to expand the five core management options into subcategories. For instance 're-use' is separated into 'feed people', 'feed animals'; and 'recycle' into 'industrial use' and 'composting', *inter alia*.

The theoretical framework proposed in this research will adopt the food waste hierarchy put forth by Garcia-Garcia et al. (2017) (Figure 13) for two reasons. Firstly, in this iteration of the food waste hierarchy, the relationship between waste management interventions (reduce, re-use, recycle etc.) and subcategories (prevention, redistribution, animal feed etc.) is clear; whereas other versions do not necessarily clarify these connections as in Figure 12. Secondly, the preferability of each subcategory is clearly ordered in tiers rather than provided as general examples as in Figure 11. Furthermore, Garcia-Garcia et al. (2017) use several reliable sources in extant literature to compile the waste management options. Hierarchies with fewer options were found to be too brief to adequately address the research problem and objectives.

A final gap in current knowledge will be discussed before moving on to the final core construct of ‘feasibility’. Where food waste mapping studies were concerned, there are limited examples and frameworks that incorporate the food waste hierarchy or circular economy principles. Batista et al. (2021) appeared unique in their effort to include the food waste hierarchy within the mapping framework. However, Batista et al.’s (2021) framework is purely qualitative in its approach. Beretta et al. (2013) allude to food waste hierarchy (e.g. food donations, animal feed) but the model itself is an incidental element to the mapping rather than a means of guiding management strategies. Thus, the extant literature lacks a framework that maps food waste volumes *and* drivers, and also encompasses the food waste hierarchy as a food waste management tool. This gap is addressed in the proposed theoretical framework developed in this research.

2.2.9 Feasibility Analysis

Another element of future-state mapping concerns economic impacts since this element of mapping concerns *proposed* rather than *implemented* management interventions. Analysis of the potential economic costs and returns of undertaking proposed management interventions is therefore a key step in initiating change, especially in business and government policy settings (De Menna et al. 2018). Furthermore, food waste studies often concern the development of previously untested products and management interventions (McCarthy, Kapetanaki and Wang 2019; Moraes, Lermen and Echeveste 2021; Papargyropoulou et al. 2016). Thus, techno-economic feasibility is key to determining if food waste management interventions should be pursued (De Menna et al. 2018; Jones et al. 2023; Mahmudul et al. 2022; Pai, Ai and Zheng 2019; Yetilmezsoy et al. 2022).

In more exploratory studies, such as this research, where there is the potential to explore several management interventions and/or technical feasibility is yet to be tested, pre-feasibility studies are an appropriate way to identify potential technical, economic, or regulatory barriers to proceeding with more in-depth efficacy studies (Generosi et al. 2012; Jones et al. 2023; Karagiannidis et al. 2009; Ortiz-Sanchez, Solarte-Toro and Cardona Alzate 2023). Altogether, the literature indicates that feasibility analysis is necessary to anticipate the environmental, economic, and regulatory impacts of food waste management interventions, whereas pre-feasibility is necessary as an initial step to determining the interventions that present the most potential. Despite its importance in the implementation of food waste management interventions, the literature review revealed a limited number of studies and frameworks that included feasibility analysis in their scope (Jones et al. 2023; Ortiz-Sanchez, Solarte-Toro and Cardona Alzate 2023).

Both types of feasibility analysis are similar in that they are multidisciplinary; requiring technical (e.g. scientific), economic, and governance expertise (Mahmudul et al. 2022; Ortiz-Sanchez, Solarte-Toro and Cardona Alzate 2023). However, the aim of a pre-feasibility study is not to conduct a fully-fledged technical, environmental, economic, nor risk assessment (Generosi et al. 2012; Karagiannidis et al. 2009; Stander, Harrison and Broadhurst 2022). Rather, pre-feasibility analysis is smaller in scale and scope; focusing on particular barriers that may altogether hinder the ability to pursue a particular management intervention (Stander, Harrison and Broadhurst 2022). It is for this reason that feasibility/pre-feasibility analysis rather than cost-benefit analysis proved more relevant to the theoretical framework of this research. Cost-benefit analysis, which involves weighing potential revenues against capital outlay and ongoing operating costs over the life of a project to assess profitability, is more appropriately conducted at a firm-level and once technical feasibility has been demonstrated (Boardman et al. 2018; Mishan and Quah 2020; Ortiz-Sanchez et al. 2020; Stone, Garcia-Garcia and Rahimifard 2019).

Both feasibility analyses are adaptable and scalable to different contexts. Analysis can be conducted at micro-, meso-, and macro-levels and therefore complements a circular economy approach to managing food waste (Generosi et al. 2012; Pai, Ai and Zheng 2019; Stander, Harrison and Broadhurst 2022). Given the overarching objective, perspective, and time constraints of this research, the focus of the theoretical framework will be limited to economic pre-feasibility, which is concerned with the theoretical economic competitiveness of possible waste management solutions (Jones et al. 2023; Pai, Ai and Zheng 2019; Stander, Harrison and Broadhurst 2022).

2.3 Adopted Food Waste Mapping Framework

In this section the theoretical framework devised in this research is presented (Figure 14). The theoretical framework brings together the themes and core constructs presented in this chapter; and is underpinned by a pragmatist worldview which will be discussed in Section 3.1.1.

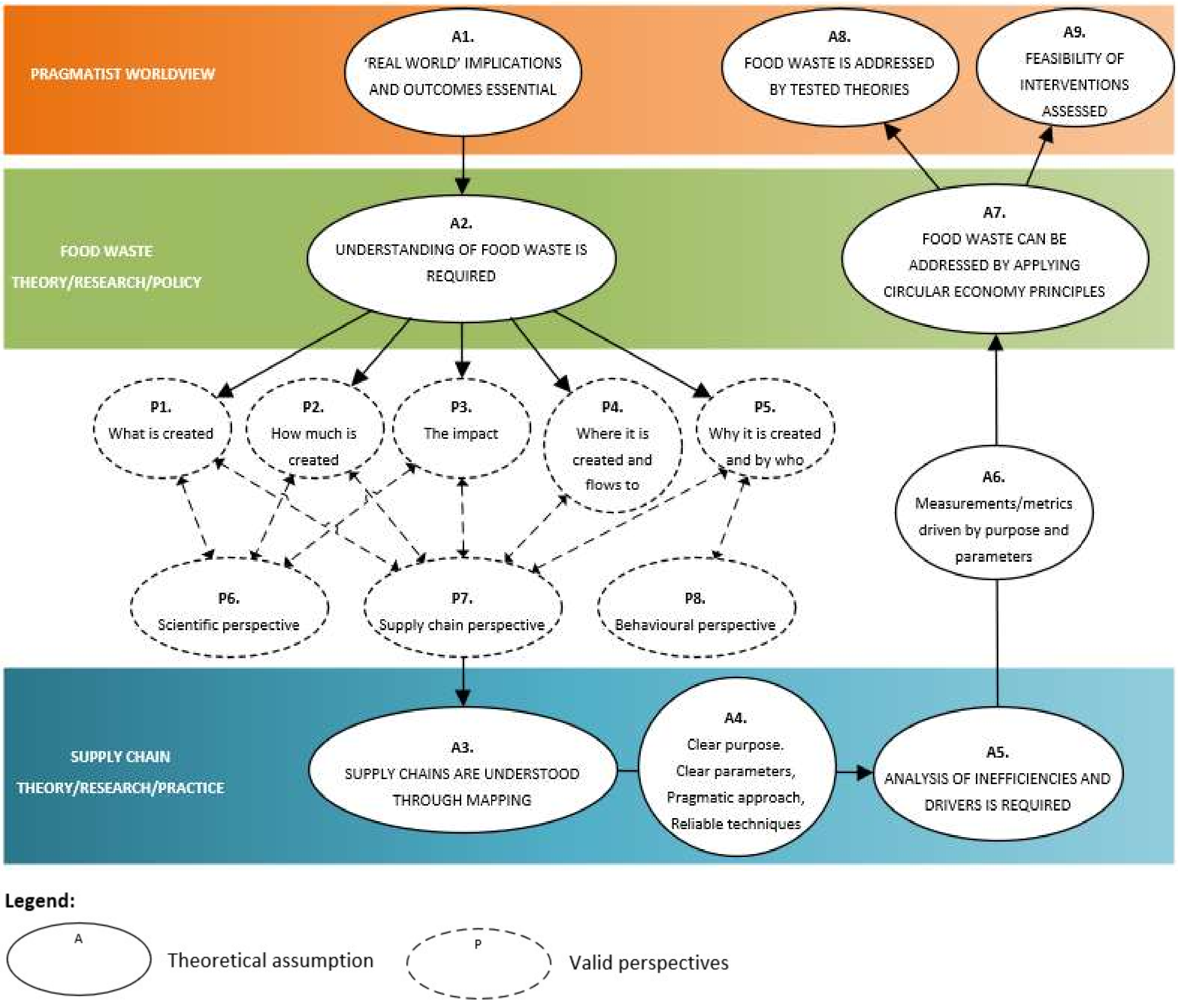


Figure 14. Theoretical framework devised in this research.

The diagram presented in Figure 14 illustrates how the two overarching concerns of this research – food waste and supply chain management – are connected. The theoretical assumptions (labelled 'A1', 'A2' etc.) and examples of valid perspectives (labelled 'P1', 'P2' etc.) are drawn from the literature discussed in the preceding sections of this chapter. The flow of the diagram illustrates how an understanding of food waste (A2) – which is required as a precursor to addressing food waste (A7) – can be examined from the five fundamental aspects (P1 to P5) that were discussed in Section 2.2.1, as well as through several valid perspectives (P6 to P8). A supply chain perspective is selected (P7) for the reasons discussed in Sections 2.1, 2.1.1, and 2.2.1. Based on the themes from the literature, supply chain mapping is identified as an underutilised, yet useful, tool for understanding the volumes and drivers of food waste created along supply chains (A3). Knowledge about supply chain mapping were synthesised to form the basis of A4, A5, and A6. Given the industry-driven objectives of the research, these assumptions flow from a pragmatist worldview (A1) and seek to achieve outcomes that are not purely theoretical, but practical as well (A8 and A9).

This chapter will now be summarised before the pragmatist worldview and its relevance to this research is explained in Sections 3.1.1 and 3.1.2.

2.4 Conclusion and Significance

In this chapter, the literature concerning food waste, sustainable agrifood supply chain management, and supply chain mapping were explored. Overall, it was discovered that each of these fields have intersecting interests, and indeed, when considered altogether the major themes and theories can be synthesised in an effort to counter food waste. Specifically, it emerged that supply chain analysis and mapping are useful in managing and creating sustainable agrifood supply chains, including the understanding and management of food waste. Additionally, supply chain mapping is an effective heuristic for better understanding informal or little understood agrifood supply chains. Based on this understanding, as well as the research motivations and problems that were introduced in Chapter 1, supply chain mapping is of particular importance to this research.

The literature revealed that supply chain mapping remains underutilised in food waste research despite its usefulness. Moreover, where supply chain mapping has been used in food waste research, there remains an opportunity to improve current mapping techniques and approaches. Food waste experts and supply chain management theory suggests that supply chain mapping is a crucial first step in understanding supply chain inefficiencies (e.g. food waste); which should precede actions to optimise the supply chain (e.g. improve practices to prevent or reduce waste). The theoretical framework proposed in Section 2.3 was developed with addressing these gaps in mind. The proposed theoretical framework of this research builds on existing agrifood and food waste mapping frameworks by proposing supply chain mapping (which encompasses performance measurement) as a beneficial tool for understanding food waste volumes and drivers.

Generally, a supply chain perspective to addressing food waste emerged as a growing, but still minor, area of interest in academic research. This is in contrast to the overwhelming portion of literature that is focused on technical, scientific means to valorising food waste. Nevertheless, the literature revealed that food waste can not only be *addressed* from a supply chain perspective but *understood* as well. It is generally accepted that a whole chain approach is key to achieving these objectives since this approach supports collective action and holistic interventions (e.g. circular economy practices) that lead to optimised agrifood supply chains.

3 RESEARCH DESIGN

With the research problem clearly identified and the research questions and objectives proposed, the purpose of this chapter is to detail how a pragmatist philosophical approach was operationalised in the research by employing a mixed methods research design. Firstly, however, to justify its use in addressing the research questions the mixed methods research approach and its implementation in food waste studies will be introduced.

Creswell (2009) and Morse and Niehaus (2009) caution against the random or whimsical concurrent use of qualitative and quantitative methods lest the theoretical requirements of either or both components be compromised; rendering the findings of the study invalid. Hence, it is crucial that the research design used in this research was guided by extant typologies. The research design was guided primarily by the typologies proposed by Morse and Niehaus (2009) and Teddlie and Tashakkori (2009) owing to their robustness and broad application to numerous social science fields compared with other sources (Creswell 2009; Creswell and Plano-Clark 2018; Leech and Onwuegbuzie 2009). This chapter is dedicated to explaining the core concepts and principles on which the research design is based.

The term ‘mixed methods’ is defined in this research as a study which consists of qualitative and quantitative components (Burke Johnson, Onwuegbuzie and Turner 2007; Teddlie and Tashakkori 2009). The typologies proposed by Morse and Niehaus (2009) and Teddlie and Tashakkori (2009) are centred around the pacing and dominance of each component, which are common approaches to designing mixed methods research (Leech and Onwuegbuzie 2009; Onwuegbuzie and Collins 2007). In this research the components’ dominance is referred to by the widely-accepted shorthand developed by Janice Morse: the core, dominant component is indicated by capital letters (e.g. ‘QUAL’); and the supplementary component by lower-case letters (e.g. ‘quan’) (Creswell and Plano-Clark 2018; Leech and Onwuegbuzie 2009; Morse and Niehaus 2009; Onwuegbuzie and Collins 2007; Teddlie and Tashakkori 2009). This notation and common mixed methods typologies are explained in Figure 15.

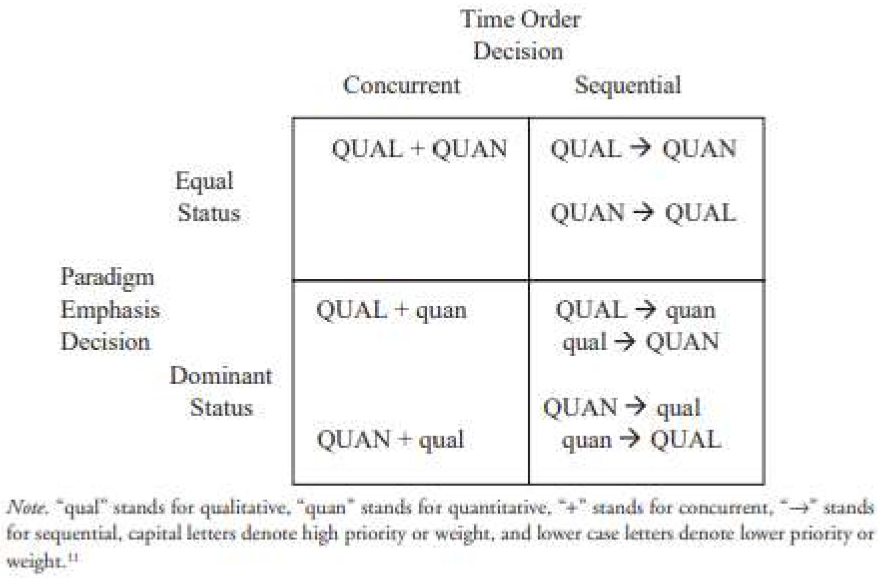


Figure 15. Types of mixed methods research designs and typology notation devised by Janice Morse. Source: Burke Johnson and Onwuegbuzie (2004, 22).

In conceptualising the research design, other mixed methods food waste studies were reviewed for their strengths, weaknesses, pros, and cons. Very few food waste studies with similar desired outcomes to this research were found to use mixed methods designs, as most employ purely quantitative methods (Goodman-Smith, Mirosa and Skeaff 2020; Papargyropoulou et al. 2016). Table 4 lists the mixed methods food waste studies that were used as reference points for the research design. The studies were deemed to be similar to this research in purpose, either by quantifying food waste (Beretta et al. 2013); or understanding the drivers of food waste (Goodman-Smith, Mirosa and Skeaff 2020; Goonan, Mirosa and Spence 2014; Papargyropoulou et al. 2016). The research designs of each study listed in Table 4 were compared with mixed method research design theory (Creswell and Plano-Clark 2018; Morse and Niehaus 2009; Onwuegbuzie and Collins 2007; Onwuegbuzie, Johnson and Collins 2009; Onwuegbuzie and Leech 2007; Teddlie and Tashakkori 2009). This proved useful for reflecting on and avoiding concerns with validity and reliability in this research.

Table 4. Food waste studies used as reference points for the research design, and categorised according to Teddlie and Tashakkori's (2009) Methods-Strand Matrix.

Study	Aim of study	Sampling Methods	Data Collection Methods	Data Analysis Methods	Classification according to Methods-Strands Matrix
Beretta et al. (2013)	To quantify food losses at each stage of the value chain and in a range of product categories in Switzerland, to determine potential reduction in losses and waste	Not described in detail. Sample size (QUAN+qual): *n* = 31	QUAN: literature, secondary databases, primary data sources (not described in detail) QUAL: not described	QUAN: volume measurements and estimates of food waste based on literature and primary data	QUAN+qual Quantitatively-driven
Goodman-Smith, Mirosa, and Skeaff (2020)	To identify the key drivers for food waste reduction in the New Zealand retail food sector	Convenience sampling (purposive) Sample size (QUAN+QUAL): *n* = 16	QUAN: site waste audits; secondary food waste data QUAL: semi-structured interviews	QUAN: descriptive and inferential statistics using Excel QUAL: thematic analysis using NVivo 11	QUAN+qual Quantitatively-driven, fully integrated mixed
Goonan, Mirosa, and Spence (2014)	To understand the drivers of food waste before the consumption stage in food service using case studies of three New Zealand hospitals	Mixed ethnographic methodology Sample sizes: (observations) *n* = 3; (focus groups) *n* = 66; (semi-structured interviews) *n* = 7	QUAN: document analysis QUAL: observations, focus group sessions, semi-structured interviews	QUAL: thematic analysis using Excel and Word 2007	QUAL+quan Qualitatively-driven, sequential
Papargyropoulou et al. (2016)	To test the conceptual framework for studying patterns and drivers of food waste generation in the hospitality sector using the case study of a hotel in Malaysia	Unique case study purposively-selected (*n* = 1)	QUAN: site waste audits QUAL: ethnographic methods – observations, focus group (*n*=1), interviews (*n*=19)	QUAN: material flow analysis, economic flows, Sankey diagrams, eco-efficiency analysis QUAL: grounded theory and constant comparative analysis	QUAL+quan Qualitatively-driven, fully integrated mixed

Overall, the mixed methods research design literature, rather than the mixed methods food waste studies provided a more solid foundation on which to justify and structure the strategies adopted in this research. Owing to the national scope of this research and resource limitations (i.e. project timeline and finances) the research designs implemented by Goodman-Smith, Mirosa, and Skeaff (2020), Goonan, Mirosa, and Spence (2014), and Papargyropoulou et al. (2016) could not be followed in this research since they involved prolonged site visits. However, some of the constituent techniques employed by these researchers (e.g. secondary data collection, semi-structured interviews, grounded theory methods) informed aspects of the data collection, analysis, and sampling decisions discussed in this chapter.

3.1 Philosophical Approach

The following sections (Sections 3.1.1 and 3.1.2) describe what it means to adopt a pragmatist worldview for this research and how it underpins mixed methods research.

3.1.1 The Pragmatist Worldview

Pragmatists are concerned with the consequences of ideas, concepts, and objects *in practice*. This research adopts the classical pragmatist concept that pragmatism is a “laboratory habit of mind” (Dewey 1907, 378). In other words, it is as much a philosophy as it is a heuristic; clarifying thought and resolving epistemological and metaphysical debates (Cherryholmes 1992; Creswell 2009; James 2014a)**.** The following question posited by William James – one of the pioneering proponents of pragmatism – encapsulates the two essential ideas of practicality and truth of this worldview also adopted in this research: “Pragmatism… asks its usual question. ‘Grant an idea or belief to be true,’ it says, ‘what concrete difference will its being true make in anyone’s actual life? … What, in short, is the truth’s cash-value in experiential terms?’” (James 2014b, 200). This research is concerned with ‘real world’ of Australia’s abalone industry and the consequences or outcomes in the practice of managing food waste. This is what James meant by ‘truth’s cash value in experiential terms’ (Putnam 2004).

Indeed, certain pragmatist ideas are echoed in other major philosophical worldviews such as constructivism and post-positivism (Phillips and Burbules 2000; von Glasersfeld 1996). These similarities and differences are presented in Figure 16.

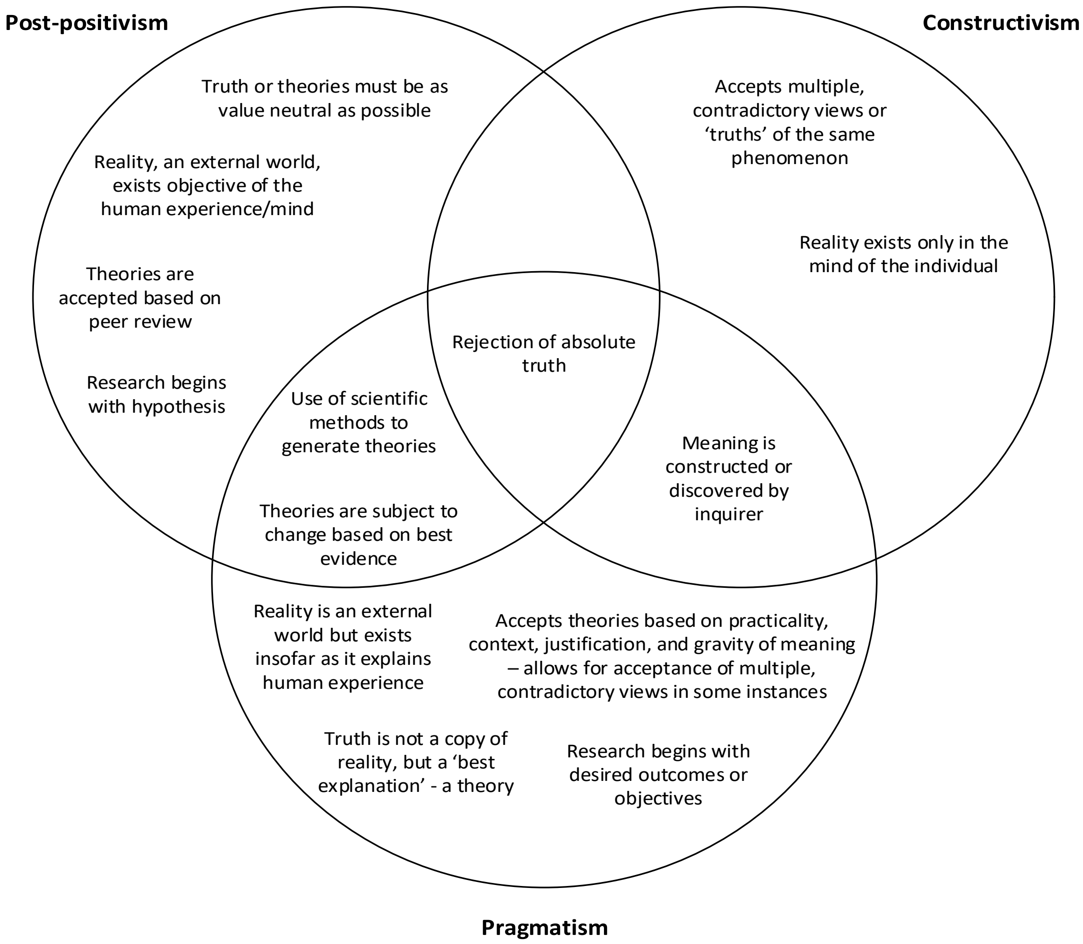


Figure 16. Shared and distinct principles of pragmatism, post-positivism, and constructivism. Adapted from: Cherryholmes (1992), Creswell (2009), Glasersfeld (1996), Phillips and Burbules (2000), and Putnam (2004).

However, neither constructivism nor post-positivism have been adopted as worldviews in this research because neither wholly aligns with the motivations and context of this research. This research, being driven by the desired outcomes or objectives of abalone industry stakeholders to resolve food waste and economic concerns, is by nature not value-neutral as a post-positivist worldview requires (Creswell 2009; Teddlie and Tashakkori 2009). It has been argued that research cannot be value neutral – i.e. separated from a researcher's politics, social context, *inter alia* – and pragmatism addresses this possible 'blind spot' of post-positivism (Cherryholmes 1992).

The exploratory parts of this research may be supported by a constructivist worldview (typically associated with qualitative research) since industry stakeholder insights will be essential to understanding the supply chains, and the researcher's *a priori* knowledge peripheral (Cherryholmes 1992; Dewey 1911; James 2014a). However, it is essential that the worldview that is adopted supports the idea that 'truth' and 'reality' can be corroborated and verified by multiple sources or best reliable evidence to lead to some quantitative results (typically associated with post-positivist and pragmatist worldviews) that are necessary for an assessment of food waste volumes generated along the Australian wild-harvest abalone supply chains. In many ways pragmatism addresses the shortcomings of constructivism and post-positivism.

A key criticism of pragmatism is that it stands for little since pragmatists are willing to embrace multiple contradictory views (Rorty 1995). On the contrary, pragmatists will accept an idea as 'true' as long as it is practical. Although some pragmatists diverge on whether 'truth' is a necessary goal of inquiry, the commonly accepted understanding is that an idea or theory is considered 'true' insofar as there is sufficient evidence, verified by triangulation, and with nothing being omitted to support it (Dewey 1911; James 2014b; Burke Johnson and Onwuegbuzie 2004; Putnam 2004; Rorty 1995; Rorty et al. 2004). 'Practicality' in this worldview consists of three elements, presented in Figure 17 (Dewey 1907; Putnam 2004).

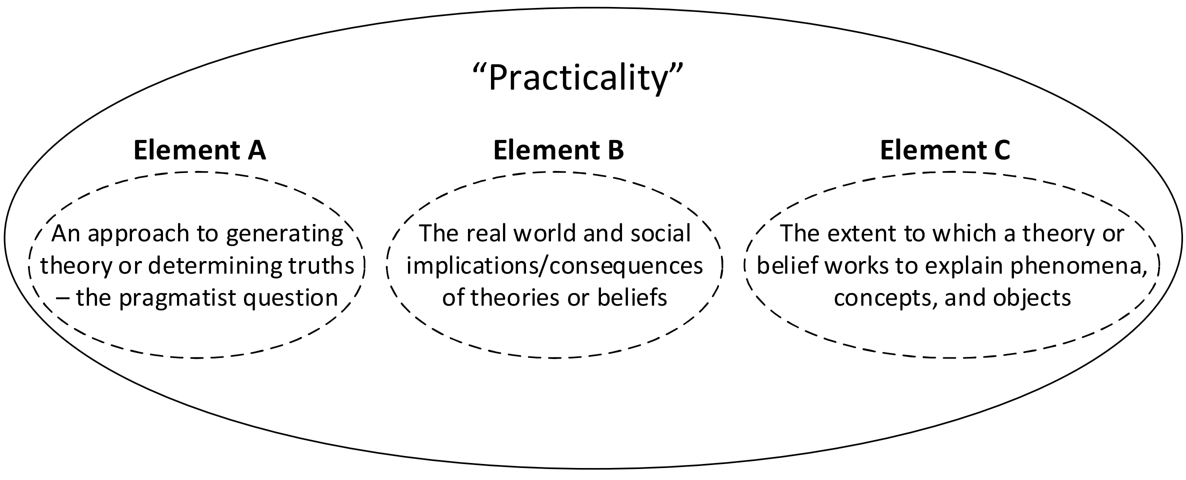


Figure 17. What pragmatists mean by 'practicality'. Adapted from: Dewey (1907).

Pragmatists agree that ‘truth’ and ‘theory’ about phenomena, ideas, and objects, is dynamic and must have social relevance (Creswell 2009; Dewey 1911). Theories are a best explanation or representation of the external world as experienced by individuals and the collective; since the ‘real world’, as it truly is, independent of one’s mind, cannot be known (Cherryholmes 1992). By adopting a pragmatist worldview this research will produce practical outcomes; generating conclusions that do not seek to be absolute, but instead, best explanations with social (i.e. industry, community, research, governance) implications in mind.

3.1.2 Pragmatist Mixed Methods Research Approach

In sharing some key assumptions with constructivism and post-positivism, pragmatism lends itself to the use of both qualitative and quantitative methods. And, as a result, generating conclusions that are both narrative and numeric in nature (Burke Johnson and Onwuegbuzie 2004; Onwuegbuzie, Johnson and Collins 2009). This was alluded to in Section 3.1.1. Furthermore, some contend that the pragmatist’s approach to finding meaning is neither primarily deductive nor inductive, but abductive (Creswell 2009; Morgan 2007; Teddlie and Tashakkori 2009). The pragmatist researcher “rejects the either/or choices associated with the paradigm wars” and instead selects whatever methods necessary (qualitative/quantitative) to address the research problem in a meaningful way Teddlie and Tashakkori (2009, 7). Thus, a pragmatist worldview underpins mixed methods research (Burke Johnson and Onwuegbuzie 2004).

The simultaneous or sequential use of both qualitative and quantitative methods, underpinned by a pragmatist worldview, has gradually become an accepted practice in social science research (Creswell and Plano-Clark 2018; Morse and Niehaus 2009; Burke Johnson, Onwuegbuzie and Turner 2007). This research will adopt a pragmatist mixed methods approach. Although it is a relatively new research paradigm in the grand scheme of research philosophy, there is a substantial amount of theory to support the research design and principles. Books and peer reviewed articles by pre-eminent authors including Creswell (2009), Creswell and Plano-Clark (2018), Burke Johnson and Onwuegbuzie (2004), Leech and Onwuegbuzie (2009), Morse and Niehaus (2009), Onwuegbuzie and Collins (2007), and Teddlie and

Tashakkori (2009) have been used to inform the validity and reliability of the research design which is elaborated upon in the remainder of this chapter.

3.2 Qualitatively-Dominant Sequential Design Adopted in the Research

As a precursor to the following sections, Figure 18 is presented as a visual representation of the research process.

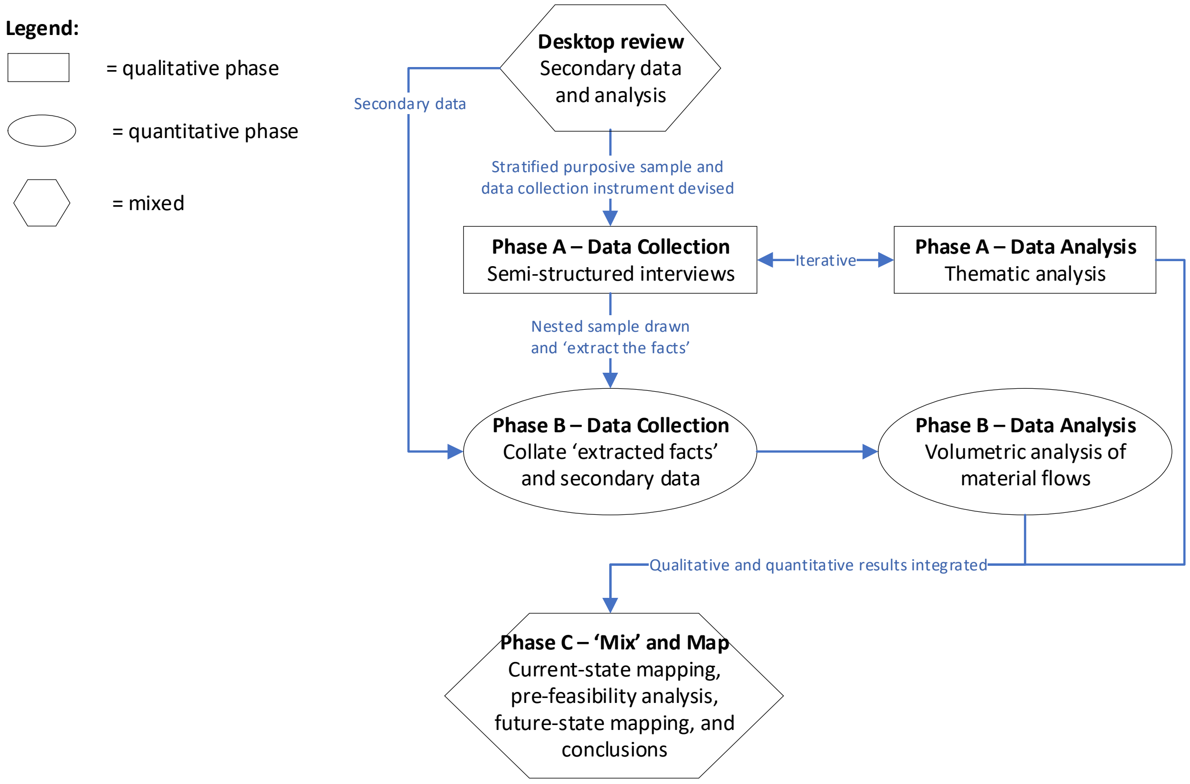


Figure 18. Visual representation of the research design.

The research design can be considered a qualitatively-dominant sequential mixed methods design according to the typologies proposed by Morse and Niehaus (2009) and Teddlie and Tashakkori (2009). It was determined that neither a purely quantitative nor purely qualitative design could satisfactorily address the research questions and objectives which were stated in Section 2.4. Both qualitative and quantitative data were required to understand supply chains in the Australian abalone fisheries, drivers of food waste, and volumes of waste.

According to Morse and Niehaus (2009) mixed methods can consist of only one dominant, or core, component of research (‘QUAL’ or ‘QUAN’) and a less dominant, or supplemental, component (‘quan’ or ‘quan’) given that the *overall* theoretical drive of the research can only be either inductive (qualitative) or deductive (quantitative). Thus, a qualitatively-dominant approach was judged to be appropriate for this research owing to the unique characteristics of the sample population and research questions which were primarily focused on understanding food waste management practices, and secondarily on understanding quantities of food waste. These elements will be fully parsed and further justified in the remainder of this chapter, as will issues of maintaining validity and reliability in adoption of both qualitative and quantitative methods.

3.3 Exploratory Phase Design: Desktop Review

It was determined that a desktop review, constituting an ‘exploratory phase’ should be conducted before embarking on the core (QUAL) and supplemental (quan) phases of the research. Desktop reviews, or exploratory research, are common in business research and in practice (Tsvetnenko et al. 1994; Zikmund 2003) and the social sciences (Stebbins 2001). Zikmund (2003, 111) writes, “exploratory research is a useful preliminary step that helps ensure that a more rigorous, more conclusive future study will not begin with an inadequate understanding of the nature of the management problem.”

In this phase of the research, secondary data sources were scanned for the best available evidence relevant to: supply chain practices, supply chain actors, size of industry and market share, industry regulations, supply chain structures, product types, waste flows and volumes, catch volumes, TACC quotas (Section 1.1), distribution volumes, beach pricing, revenue or production value of catch, pricing of abalone by-products. A mix of sources were drawn on to elicit this information including existing datasets obtained from the Australian Bureau of Agricultural Economics and Sciences (ABARES) and the Australian Bureau of Statistics (ABS), grey literature, academic literature, government regulations and industry association and company websites.

‘Best available evidence’ was defined in this research according to three principles suggested by Slocum, Spencer, and Detrich (2012):

- Evidence should be directly relevant, in a pragmatic sense, to the research question.
- Evidence should be strong, in terms of volume and methodological rigor.
- Where strong, directly relevant evidence is unavailable; the use of available, indirectly relevant and/or weaker evidence is preferable over no evidence at all.

Similar principles were adopted to build data reliability in a food waste study conducted by Beretta et al. (2013) where secondary data were used to estimate waste volumes. The systematic strategy for seeking best available evidence in this phase of the research is illustrated in Figure 19.

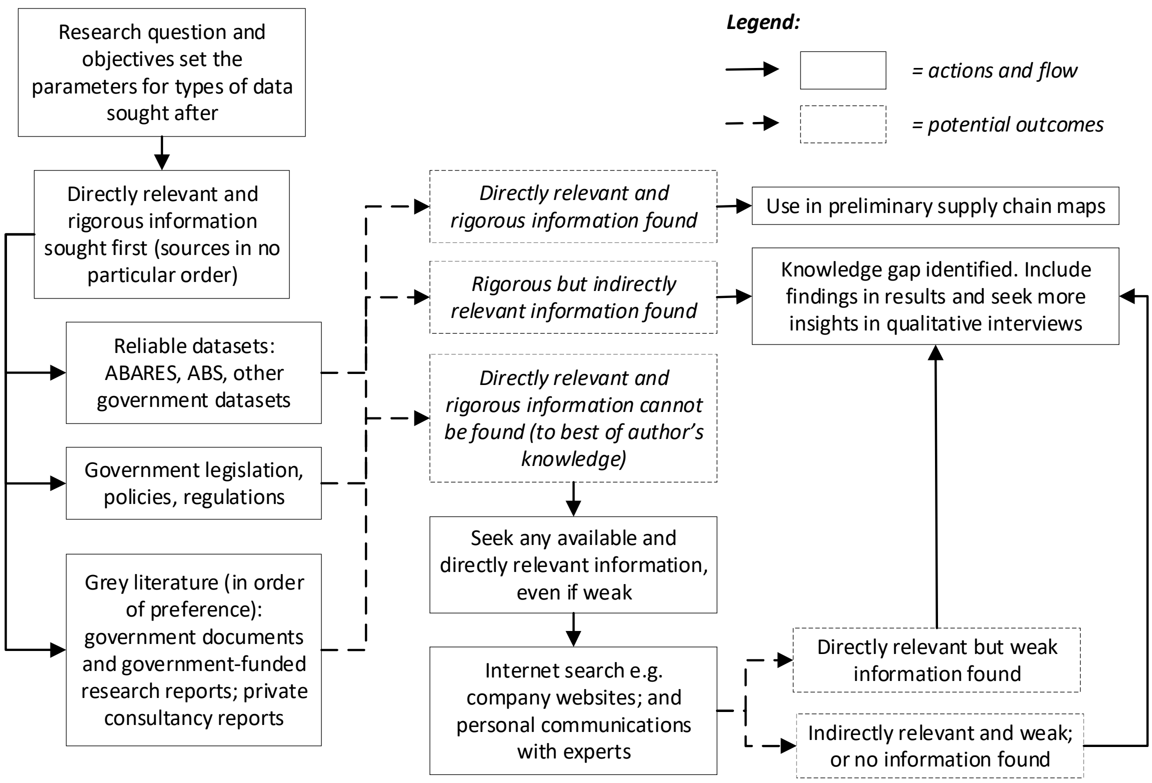


Figure 19. Strategy for seeking best available evidence adopted in this research. Adapted from: Slocum, Spencer, and Detrich (2012).

As suggested by Zikmund (2003), the objective of the desktop review was to develop a better understanding of the management issues under study. To consolidate this understanding and to highlight any identified gaps in publicly available knowledge, preliminary supply chain maps were created as a means of collating the best available evidence gathered over the course of the desktop review. Evidence-based supply chain maps are generally constructed by following such a process (Beretta et al. 2013; Carvalho, Cruz-Machado and Tavares 2012; Farris 2010). The information that was gathered and gaps that were identified in this exploratory phase also informed the design of the data collection instrument in Phase A (QUAL) and sampling frame.

3.4 Phase A Design: 'QUAL'

The purpose of this phase of the research is to gain a holistic view of Australian abalone supply chains which addresses RQ1 and Research Objective A (Section 2.4, Table 2), in particular. A qualitative approach is appropriate for understanding practices, systems, and rules of specific contexts (Lewis et al. 2014; Miles, Huberman and Saldana 2020). In this section, the use of semi-structured interviews and thematic analysis will be justified based on their reliability in qualitative research and mixed methods food waste studies (Goodman-Smith, Mirosa and Skeaff 2020; Goonan, Mirosa and Spence 2014; Papargyropoulou et al. 2016).

3.4.1 Qualitative Sample Selection

Interview participants in this phase of the study were selected using stratified purposive sampling, expert recommendation, and snowball sampling (Miles and Huberman 1994; Onwuegbuzie and Collins 2007). The initial sampling frame was devised by employing stratified purposive sampling and is presented in Table 5. According to Onwuegbuzie and Collins (2007) stratified purposive sampling is appropriate where the sample population can be divided into subgroups. In the case of this research, the sample population was divided into subgroups based on supply chain stages (e.g. primary production, processing, distribution, consumption). As the focus of the research was on food waste created at the upstream stages of Australian wild-harvest abalone supply chains, the subgroups that were selected for the sampling frame (Table 5) were primary producers – referred to as 'quota owners' – and processors.

Table 5. Sampling frame based on a stratified purposive sampling technique.

		Number of licenses according to state and subgroup				
		NSW	SA	TAS	VIC	WA
Subgroups	Quota owners	35-48	23-34	119-121	50	52
	Processors	Unknown	Unknown	20	13	14
Sources		*NSW Total Allowable Fishing Committee (2021); The Ecology Lab Pty Ltd (2007)*	*PIRSA (n.d.(a), n.d.(b), n.d.(c))*	*DPIWE (2003); Tasmanian Government*	*DEDJTR (2015)*	*Government of Western Australia (2020b, 2020a); Hart et al. (2017)*

Quota owners and processors were selected as the primary sample, rather than lease divers, because of their knowledge and position as key industry stakeholders. Using Mendelow's (1981) power dynamism matrix (Figure 20) – also commonly referred to as the 'stakeholder analysis grid' – quota owners and processors were determined to be key stakeholders because of their high-power, high-interest position in the upstream segment (i.e. primary production, post-harvest processing) of the supply chain. These two subgroups consist of core project funding partners, senior managers, and business owners; whereas lease divers inhabit roles closer to contractors or employees (low interest, low power).

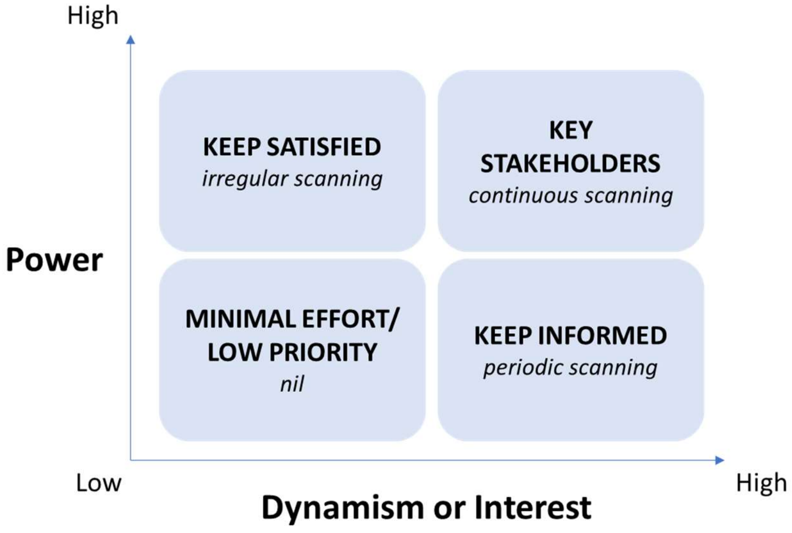


Figure 20. Power dynamism matrix or stakeholder analysis grid. Adapted from: Mendelow (1981).

The sample population size could only be approximated based the number of licenses elicited from government documents and grey literature reviewed in the exploratory desktop review phase. In two cases (New South Wales and South Australia) the number of processing licenses could not be determined from the available information. Moreover, the number of quota owners or businesses was, in reality, likely to be fewer than the number of licenses since a single quota owner can own multiple fishing and processing licenses (PIRSA 2018; Strain, Fabris and Jones 2021; Tasmanian Government). Information regarding the number of actual businesses or quota owners was not publicly available either.

Nonetheless, an exact population size was not crucial to the selection of participants given that the sample did not have to be statistically representative (Curtis et al. 2000). Furthermore, by following a qualitative theoretical drive, the final size of the sample was determined based on theoretical saturation (Guest, Bunce and Johnson 2006; Morse 1995). The total number of interviews were also determined based on theoretical saturation, where marginal interviews no longer yielded substantively new information (Guest, Bunce and Johnson 2006). From the sampling frame presented in Table 5, an initial group of interview participants for Phase A (QUAL) was selected based on expert recommendation by the research industry partner, Abalone Council of Australia Ltd. This initial group of interview participants was used to generate suggestions for additional participants using snowball sampling (Guest, Bunce and Johnson 2006; Onwuegbuzie and Collins 2007).

3.4.2 Semi-Structured Interviews

Interviews are a commonly-employed data collection technique in qualitative social science research (Brinkmann and Kvale 2018; Doody and Noonan 2013; Patton 2002). Interviews take form in numerous variations including focus groups (Kitzinger 1995; Onwuegbuzie et al. 2009), structured interviews, unstructured interviews, and semi-structured interviews (Doody and Noonan 2013). A well-executed interview can generate high-quality, detailed, and mostly narrative data about the participants' experiences, opinions, attitudes, values, behaviours, quotidian activities, and processes (Doody and Noonan 2013; Rowley 2012).

Interviews, rather than focus groups, were the preferred method for this research owing to the confidential nature of some of the topics discussed with participants, including business practices and market share. As Rowley (2012) suggests, interviews are a more appropriate approach in scenarios where participants need to feel free to speak candidly without breaching confidence or trust. Moreover, a number of food waste studies conducted semi-structured interviews with industry experts to elicit insights into supply chain or business practices (Batista 2021; Goodman-Smith, Mirosa, and Skeaff 2020; Papargyropoulou et al. 2016).

Doody and Noonan (2013) assert that both qualitative and quantitative data can be obtained from interviews, where qualitative data are obtained through open-ended questions and quantitative data through closed. For the purposes of this research, the semi-structured interview presents a balance between:

- A central set of pre-determined questions to compare participant responses, including closed-ended questions to elicit quantitative information; and
- Deeper, spontaneous probing to better understand phenomena as the occasion arises; and elicit rich and meaningful data about each supply chain (Brinkmann and Kvale 2018; Rowley 2012).

The interview guide for the semi-structured interviews consisted of a few, well-phrased and open-ended questions (Doody and Noonan 2013). Rowley (2012) suggests approximately six to 12 pre-written questions that should be asked in mostly the same order. The pre-set questions were accompanied by follow-up prompts or probes (Doody and Noonan 2013; Rowley 2012) which were approved by Curtin University's human ethics approval process (Approval Number: HRE2021-0714).

In keeping with Brinkmann and Kvale's (2018) recommendations, the interview guide was piloted in a practice interview setting with a colleague who had experience working with the abalone industry before minor refinements were made. The pilot interview responses were not included in the data analysis. A sample of the refined interview guide is provided in Appendix A.

The interview guide was devised with minimising bias in mind to improve interview quality. Primarily this was done by constructing non-leading questions and probes (Brinkmann and Kvale 2018). Furthermore, the desire to improve the outcomes of shell and shucking waste is acknowledged as an intrinsic bias of this research, though the questions were constructed to be as neutral as possible (Brinkmann and Kvale 2018; Rowley 2012).

To further enhance interview quality, interviews were conducted face-to-face where possible with Western Australian participants, at a time and location that was convenient for the participants. The intention was to set the participant at ease, thereby improving the quality of responses (Doody and Noonan 2013). Interstate participants (i.e. those in New South Wales, South Australia, Tasmania, and Victoria) were interviewed by Curtin-supported video conference (Webex) where in-person meetings were not possible due to the COVID-19 travel restrictions which were in place over the course of the data collection period and resource constraints. As most participants were located in regional areas, it was anticipated that interviews by video conference may not be practical nor possible (e.g. due to poor Internet connection) so provisions for recorded telephone interviews were also made.

All interviews were recorded and immediately transcribed verbatim. Due to time and financial constraints a transcription software (Otter.ai) was used to transform audio to text, and the resultant transcripts ‘cleaned up’. ‘Cleaning’ the transcripts involved listening to the audio recordings to verify the transcribed text, and adding supplemental information such as background noise, notes about body language, or tone of voice that were anticipated to be relevant to analysis later on (Fontana and Frey 2000).

Finally, some post-interview protocols were followed. These included capturing thoughts, impressions, and other important participant attributes on a ‘contact summary sheet’ immediately following the interview. Brinkmann and Kvale (2018), Miles and Huberman (1994), and Patton (2002) recommend this practice take place before further analysis distorts or buries initial, salient thoughts relevant for inferences made later on. The template of the contact summary sheet that was devised and used for post-interview reflections in this research is provided in Appendix B.

3.4.3 Data Preparation and Preliminary Analysis

The consensus in the literature is that data must be prepared prior to formal analysis (Miles and Huberman 1994; Saldana 2013; Sandelowski 1995; Silverman 2000). Halcomb and Davidson (2006) and McLellan, MacQueen, and Neidig (2003) recommend that, regardless of the size of the qualitative study, a transcription protocol be produced and followed. The transcription protocol used to prepare the data is supplied in Appendix C.

At this point in the qualitative data analysis, participants were also assigned a participant code according to their role (e.g. quota owner, processor, fisheries scientist), state (e.g. Western Australia, New South Wales), and chronological interview number (e.g. 1, 2, 3 etc.) to preserve anonymity. For example, if a quota owner from South Australia participated in the second interview the participant code, QO-SA-2, would be assigned. The participant codes were only finalised during data preparation and preliminary analysis and are therefore presented in Section 5.1.

Miles and Huberman (1994), Saldana (2014), and Sandelowski (1995) are consistent in the view that analysis effectively starts in the data preparation phase. As the researcher becomes more familiar with the material through continuous listening to the recorded interviews, transcribing, ‘cleaning’, and (re)reading of the transcripts, it is inevitable that some initial pattern recognition occurs or certain participant responses stand out as particularly salient – even if it is not yet clear to the researcher why that may be. To preserve these lines of thought the process of ‘jotting’ was employed by using the ‘Comments’ function in Microsoft Word (Miles, Huberman and Saldana 2020; Saldana 2013; Sandelowski 1995). These comments served as an audit trail to assist with validity (Creswell 2009). The data preparation and preliminary analysis subsequently led to the formal thematic analysis which used Saldana’s (2013) First and Second Cycle Coding framework.

3.4.4 First Cycle Coding

The coding strategy employed to facilitate the thematic analysis in this phase of the research followed Saldana's (2013) First and Second Cycle Coding framework; which in turn is based on grounded theory methods. Saldana's (2013) First and Second Cycle Coding framework encourages what Brinkmann and Kvale (2018, 132) refer to as "bricolage", or an "eclectic form of generating meaning – through a multiplicity of *ad hoc* methods and conceptual approaches [which] is a common mode of interview analysis." Several authors agree that the interplay of *ad hoc* techniques can act as stimulus for the researcher when attempting to integrate, construct, or conceptualise insights from participant responses (Brinkmann and Kvale 2018; Creswell and Plano-Clark 2018; Ryan and Bernard 2000; Saldana 2013).

Coding techniques used in the First Cycle of coding included initial coding (similar to open coding in grounded theory) and *in vivo* coding, where codes were derived directly from participants' words (Charmaz 2000; Saldana 2013). Additionally, Brinkmann and Kvale (2018) and Miles, Huberman, and Saldana (2020) recommend theoretical reflexivity when reading interview transcripts. Thus, an initial set of codes was devised, based on some themes that emerged as prominent in the literature review. Such an approach allows for an initial conceptual framework or stimulus for coding (Dey 2007; Miles, Huberman and Saldana 2020). This is a pragmatic means of focusing the coding process, though not a purist approach to grounded theory (Charmaz 2000; Glaser 2005). Miles and Huberman's (1994, 65) suggestion that, "the analyst should be ready to redefine or discard codes when they look inapplicable, overbuilt, empirically ill-fitting, or overly abstract" was followed.

The process of coding was iterative. Data were coded and re-coded until intercoder agreement and saturation were reached. 'Saturation' is a concept adapted from constant comparative analysis where the analyst judges no significantly new properties, codes, or dimensions can be gleaned from the data (Glaser 1965; Morse 1995). 'Intercoder agreement', which was sought in this phase between the researcher and two supervisors, is concerned with validity in that it mitigates against bias (Brinkmann and Kvale 2018). It is a process whereby team members independently code data yet agree on what should be coded and the meaning of codes (Creswell 2009; Patton 2002; Saldana 2013). Miles and Huberman (1994) suggest that as coding progresses, a sufficient level of intercoder agreement is demonstrated if approximately 90% of codes match.

To further ensure validity and rigour, analytic memos and a codebook were maintained throughout the coding process. Analytic memos were written to document the thought processes behind any coding decisions (Charmaz 2000; Glaser 1965; Glaser and Strauss 1967; Ryan and Bernard 2000; Saldana 2013). The memos were crucial for the final write-up of results and served as points for reflection and verification of thematic development as coding progressed (Creswell 2009). The codebook served the purposes of: (1) organising codes and subcodes, aiding the formation of categories and themes later on; (2) keeping track of the properties or meanings of codes so that concepts did not shift as coding and comparison progressed; (3) ensuring all team members involved in analysis understood the parameters of each code; and (4) facilitating intercoder agreement (Creswell 2009; Patton 2002; Saldana 2013).

Data analysis occurred in parallel with the interviews since the parallel analysis and collection of data permits a “reshaping” of knowledge and perceptions about the phenomena under study in qualitative research (Miles and Huberman 1994, 65). ‘Reshaping’ not only leads to validity in the interview process, but richer theoretical insights as well (Brinkmann and Kvale 2018; Saldana 2013). Validity is built because participants responses can be continually checked and questioned as the interviews progress (Brinkmann and Kvale 2018). Richer theoretical insights are reached since responses are interpreted almost in ‘real time’ before being further explored in subsequent interviews (Morse 1995; Saldana 2013). Operationally, this involved refining the interview guide as the interviews progressed; which is a common practice in qualitative research (Doody and Noonan 2013; Rowley 2012; Saldana 2013).

3.4.5 Second Cycle Coding

Second Cycle coding begins once the interviews have been completed – i.e. theoretical saturation is reached (Saldana 2013). The purpose of Second Cycle coding is to delimit codes and develop broader themes from the data (Miles and Huberman 1994; Saldana 2013).

Moving from codes to themes is facilitated by a ‘transitional’ phase. Visual displays were used to synthesise and refine first cycle codes; and develop new insights and connections between participants, codes, and concepts emergent from the literature and the data *corpus* (Miles and Huberman 1994; Ryan and Bernard 2000; Saldana 2013). Miles and Huberman (1994, 11) draw attention to the fact that humans are not equipped to process or deal with large amounts of data (e.g. multiple interview transcripts and codes) and contend that “displays are a major avenue to valid qualitative analysis… matrices, graphs, charts, and networks. All are designed to assemble organized information into an immediately accessible, compact form… it is part of analysis.” To perform this transitional phase, operational model diagramming was employed to develop new insights and connections (Miles, Huberman and Saldana 2020; Saldana 2013). Diagramming was carried out by using pen and large pieces of paper before recreating the diagram on Microsoft Visio for clarity and neat presentation.

Focused and pattern coding were used as the primary techniques for Second Cycle coding. Focused coding builds naturally on the First Cycle coding processes employed because codes are grouped together in broader categories based on common concepts or meanings (Holton 2007; Saldana 2013). Where a code in First Cycle coding constituted either a one- or two-word label, or a short phrase used to refer to a deeper meaning or concept; a category in Second Cycle coding comprised of multiple codes and was better represented using a phrase containing nuance, subtleties, or abstractions drawn from the singular codes (Saldana 2013).

Pattern coding was employed because it can subsequently lead to themes when categories are connected in a consequential, cause/effect manner which are reflected in the label (Guest, MacQueen and Namey 2012; Saldana 2013).

Importantly, deviant or discrepant cases that ran counter to any theme were included in the pattern coding as a means of enhancing validity. This is based on the concept that 'real life' can be complex and contradictory. Thus, presenting contradictions that emerge during analysis serve to make the qualitative conclusions more pragmatic and credible (Creswell 2009; Miles, Huberman and Saldana 2020). Finally, Saldana (2013) suggests pattern coding to be a suitable technique in research such as this where multiple cases are under study. The use of pattern coding can lead to the discovery of common themes amongst cases.

Once Second Cycle coding was complete, the themes were set aside while quantitative analysis was conducted. The qualitative results were subsequently 'mixed' with the quantitative results at the 'point of interface' in Phase C (Morse and Niehaus 2009).

3.5 Phase B Design: 'quan'

Now that the process of collecting and analysing data in the qualitative phase of the research has been detailed, this section will focus on the research design for the supplemental quantitative component.

3.5.1 Quantitative Sample Selection

A nested sampling approach was selected for this research, after careful consideration of the potential methodological pitfalls of collecting quantitative and qualitative data from one sample (Morse and Niehaus 2009; Onwuegbuzie and Collins 2007; Teddlie and Tashakkori 2009). Nested sampling, described in detail by Onwuegbuzie and Collins (2007), is where one sample is used to collect data for one component of the research (Sample A); and a smaller sample (Sample B) is subsequently derived from the original sample to collect data for the second component of the research. Sample B is drawn from Sample A based on attributes driven by the objectives of the research (Onwuegbuzie and Collins 2007). The mixed methods food waste study by Goodman-Smith, Mirosa, and Skeaff (2020) (outlined in Table 4) employed nested sampling and provides precedence for this strategy. Similar to this research, Goodman-Smith, Mirosa, and Skeaff (2020) focused on a sample population that had limited entrants, each possessing a large market share.

It should be noted, however, that the authors themselves described it as a convenience sample.

Nested sampling was selected as the most appropriate strategy for this phase of the research due to the nature of the Australian abalone fisheries. As restricted-entry fisheries, each state consists of few supply chain stakeholders that possess a large market share (i.e. portion of the TACC quota). Thus, the industry insights and knowledge of participants were determined to account for a significant portion of the catch in each state as shown in Table 6. The industry information concerning market share that was needed to justify the sample for Phase B was not sufficiently available from public sources and could only be gathered during Phase A. Nested sampling provided a reliable strategy for extrapolating this information from participants' responses in Phase A (Onwuegbuzie and Collins 2007).

Table 6. Market share of processors that constitute the nested sample (Sample B) selected in Phase B (quan).

	Active Processors in Fishery		Total Interviewed	Participants' Market Share of Fishery in 2019
	2018/19	**2022/23**		
NSW	3	3	1	35-40%
SA	5	5	2	69%
TAS	≤ 5	≤ 5	2	≥ 75%
VIC	7	7	2	61%
WA	4	2	3 *	52%
* N.B.: WA participants included 1 active processor and 2 previously active processors				

Table 6 shows the population of active processors in each state, the total number of participants interviewed (constituting Sample B), and the collective market share of the participants by state. In the case of the New South Wales abalone fishery efforts were made to interview more participants, but recruitment proved unsuccessful (evidenced in Appendix D).

The estimated market share of specific operators interviewed has not been shown individually, but collectively, to ensure the confidentiality and anonymity of participants is maintained where possible. Market share was estimated as the volume of unprocessed catch (i.e. whole weight tonnage) that flowed through each processing facility for the 2019 fishing season divided by the total volume processed in the state. Estimates are based on self-reported data as well as information about competitors; with both types of responses corroborated, or triangulated, between several participants during the qualitative interviews (Creswell 2009). The level of corroboration amongst different participants depended on the number of times a 'fact' was repeated (Batista et al. 2021; Miles, Huberman and Saldana 2020; Sandelowski 1995).

Given the supplemental function of Phase B and the qualitatively-dominant nature of the study overall (Section 3.2), analytic results rather than statistical generalisability were sought from the nested sample (Curtis et al. 2000; Onwuegbuzie and Collins 2007). Although the outcomes of sampling are typically driven by the traditionally dichotomous underpinning worldviews of the research being conducted, Onwuegbuzie and Collins (2007, 283) argue that the "choice of sampling class (i.e. random vs. non-random) should be based on the type of generalization of interest (i.e. statistical vs. analytic)" (Morse and Niehaus 2009; Teddlie and Tashakkori 2009).

The research questions and objectives of the overall study (Section 2.4) dictated the interest in analytic generalisability in this research. By seeking out processors that were able to account for the flows and outcomes of a significant portion of production and processing volumes on a state-by-state basis, the results of Phase B would be able to show how waste flows "fit with" total production volumes and more general estimates of food waste in Australia (Curtis et al. 2000, 1002).

3.5.2 Data Collection

Data for this phase of the research were collected in the Exploratory Phase and in Phase A. Secondary datasets obtained in the Exploratory Phase provided production volumes, TACC quotas, and some indication of abalone export volumes. Further detail and confirmation was elicited from Sample B (*n*=10) concerning:

- Processing volumes
- Market share (catch landed or processed by supply chain actors)
- Domestic and export distribution percentages
- Percentages of processing by-product (viscera, blood, shell) that are generated, used, and discarded

Data were elicited from Sample B during a segment of the semi-structured interviews dedicated to verifying the validity of the preliminary supply chain maps and addressing information gaps. This segment of the interview was akin to a verbal questionnaire (Doody and Noonan 2013; Rowley 2012).

Data elicited from Sample B were coded using NVivo according to species and state (e.g. NSW Blacklip, SA Greenlip, and so on) using a technique referred to by Sandelowski (1995, 374) as “extracting the facts”. Sandelowski (1995, 374) defines ‘facts’ as “those elements of data that are the least subject to errors of inference and to lack of consensus about what they are; anyone looking at one of these facts would agree on what it is.” In this way, facts are coded under labels for the sole purpose of collating and organising rather than to seek deeper themes later on as was the case with the coding process in Phase A. Finally, this practice is recommended by the Food Loss and Waste (FLW) Standard’s Quantification Method Ranking Tool as a means of verifying and clarifying existing secondary data (Hanson et al. 2016).

3.5.3 Mass Flow Analysis of Abalone Products and By-products

The quantitative data analysis in this research arose from Research Objective A (Table 7). This section focuses on the quantitative methods that were used to estimate product flows along each supply chain.

Table 7. Stages of quantitative analysis in Phase B and relationship to Research Objective A.

Research Objective		‘Phase B’ (quan) Analysis
A.	To map and analyse Australia’s wild-harvest abalone supply chains, with a particular focus on food waste in the upstream stages of the supply chain.	Estimate of actual product flow to be included in supply chain maps, including volumes of: harvested abalone; product formats; shucked shells, viscera, and blood

A standardised accounting method for quantifying food waste is urgently called for in the literature (Bux and Amicarelli 2022; Corrado et al. 2019; Parfitt, Croker and Brockhaus 2021; Spang et al. 2019). The FLW Standard’s Quantification Method Ranking Tool is regarded as the foremost guide to quantifying food waste in academia and practice (Hanson et al. 2016; Parfitt, Croker and Brockhaus 2021; Spang et al. 2019; Xue et al. 2017). Based on the research objectives and available data, the FLW Standard’s Quantification Method Ranking Tool recommended ‘records’ and ‘mass balance’ approaches to quantifying food waste in this research (Appendix E). ‘Records’ refers to the use of existing, high-quality data (e.g. warehouse record books, secondary datasets) that have been recorded and saved for purposes other than quantifying food waste; while the ‘mass balance’ approach, also commonly referred to as ‘mass flow analysis’ is a systematic accounting approach to quantifying food waste (Hanson et al. 2016). In this accounting approach, it is assumed that: inputs equal outputs; and all flows are represented according to their real weight at each stage of the supply chain (i.e. tonnes harvested, tonnes processed) (Caldeira et al. 2019; Dong et al. 2022; Hanson et al. 2016). The mass balance estimates in this research are based on high-quality secondary data collated from government datasets for stock management and traceability purposes (described in Section 3.3) which constitute the ‘records’ and primary data collected in Phase A on the breakdown of abalone products into its constituent parts and product formats (‘extracted facts’ discussed in Section 3.5.2).

Two slightly different approaches were taken as the method for estimating the mass balance of product flows (abalone products and processing by-products) depending on whether shucking at sea was practised within a fishing zone. The method for estimating product flows in shuck-at-sea areas (South Australia’s central and Western Zones, and Areas 2 and 3 in Western Australia) is illustrated in Figure 21; while the method for estimating product flows in fishing zones where abalone must legally be landed whole (New South Wales, all zones in Victoria, all zones in Tasmania, South Australia’s Southern Zone, and Western Australia’s Roe’s abalone fishery) is presented in Figure 22. In this phase of the research, it was vital that the most current catch data from the same one-year fishing season was used across all states. Comparing catch data within the same time period allowed for fair comparison of annual waste volumes relative to total catch. Once the processes presented in Figures 21 and 22 were completed, the total volumes for each by-product were summed in various ways to form an overall understanding of hotspots across each fishery and nation-wide. This process, shown in Figure 23, was repeated for each constituent by-product of the abalone (viscera, shell, blood) and subsequently all three by-products collectively.

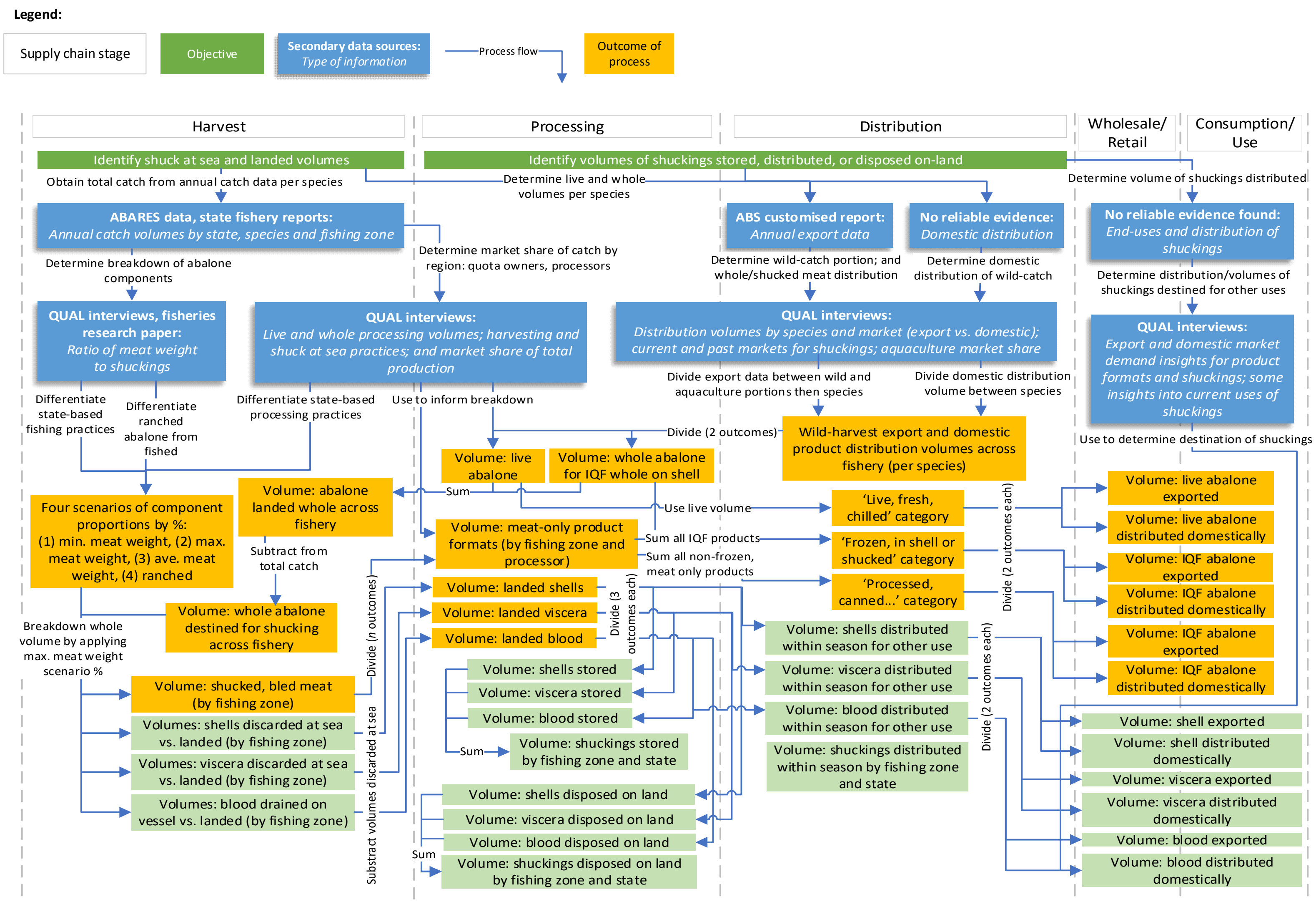


Figure 21. Process flow diagram for conducting mass flow analysis in fishing zones where shucking at sea is permitted.

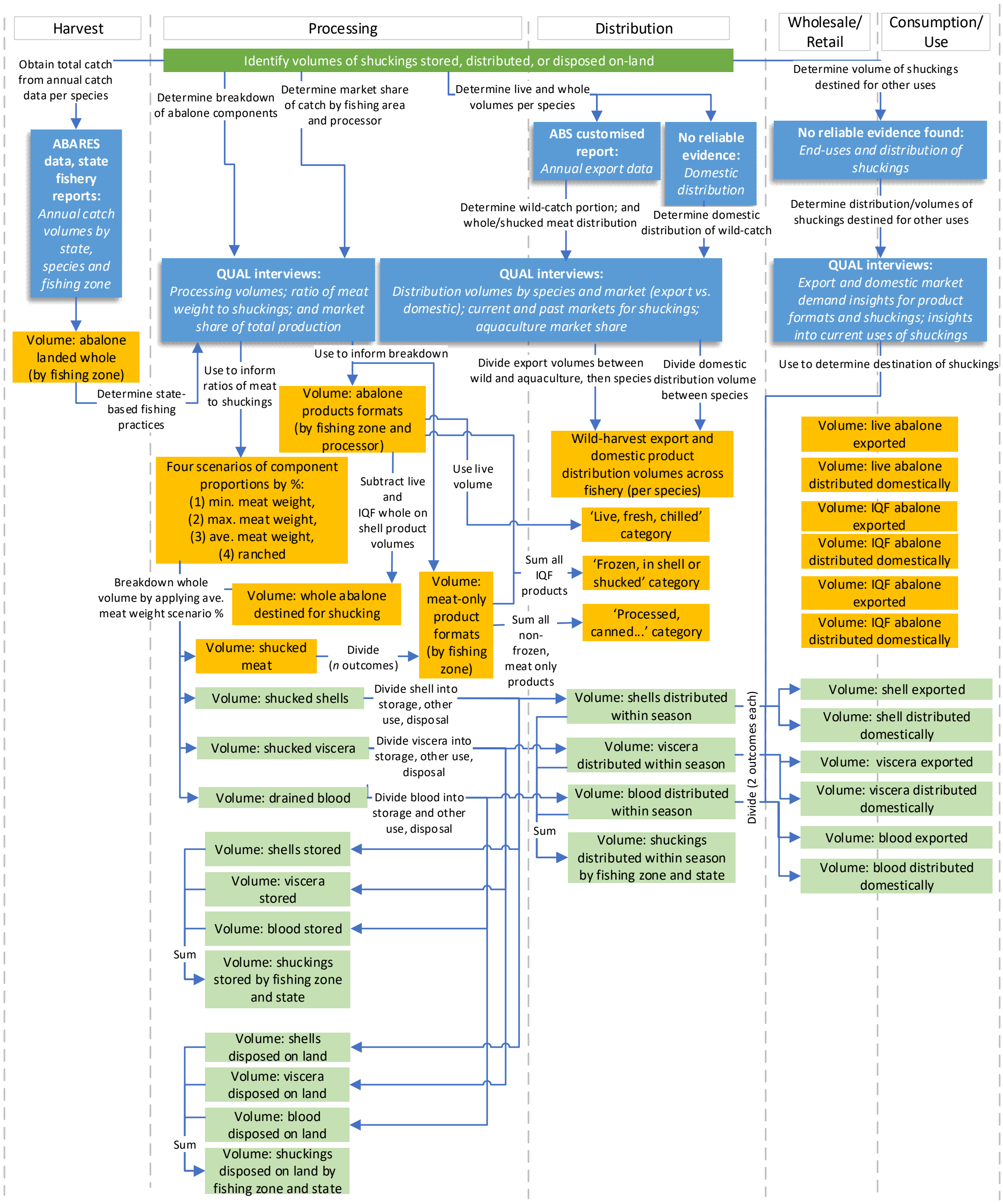


Figure 22. Process flow diagram for conducting mass flow analysis in fishing zones where shucking at sea is not permitted..

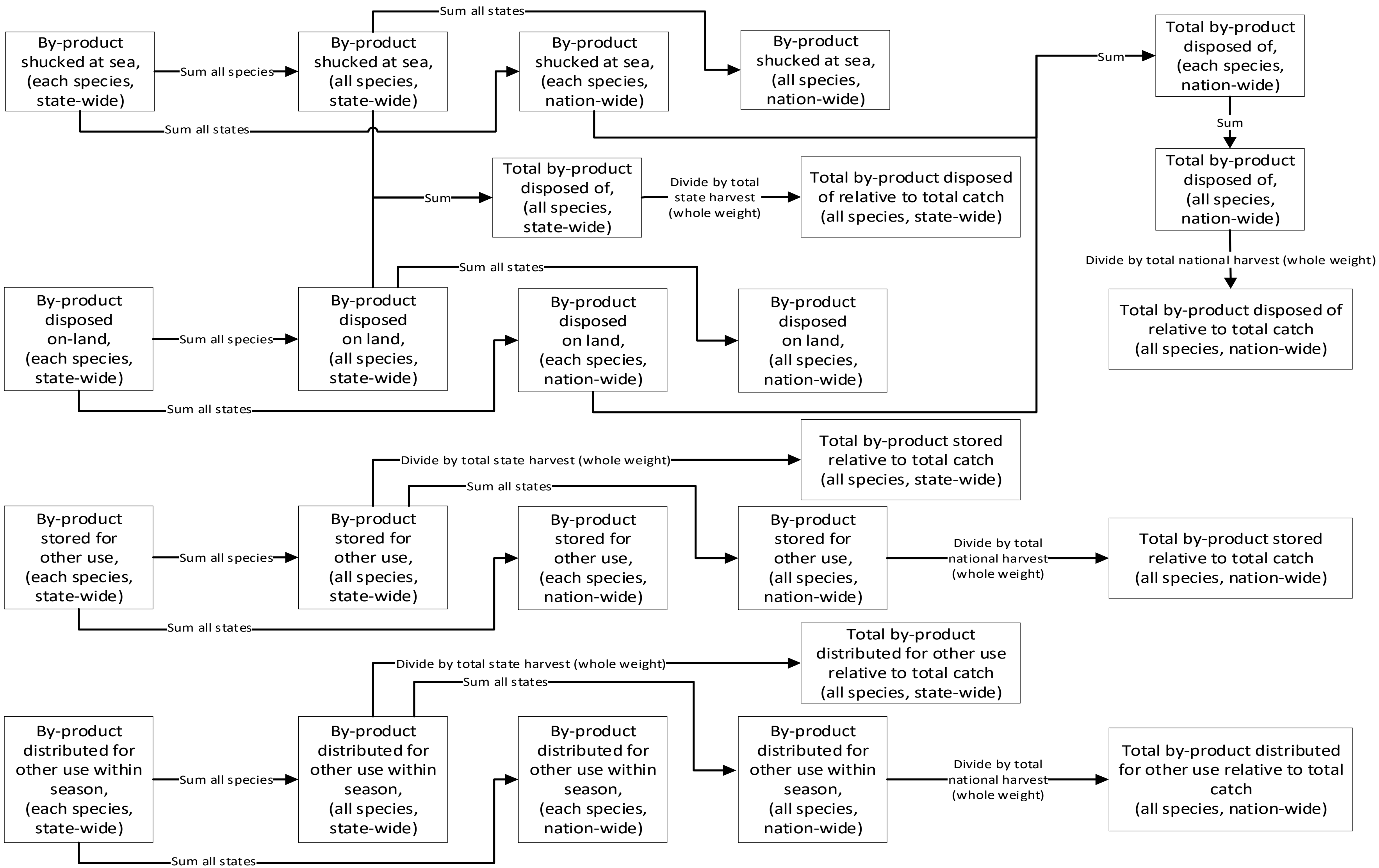


Figure 23. Process flow diagram to consolidate the mass flow analyses conducted in each fishing zone to obtain an industry-wide total.

Overall, Figures 21 to 23 set out the methods, or process flow, of estimating abalone product flows and volumes. The results of this approach are presented later in the thesis.

3.6 Phase C Design: Mixing 'QUAL' and 'quan' by Supply Chain Mapping

Phase C was the 'point of interface' of the qualitative and quantitative results (Morse and Niehaus 2009; Teddlie and Tashakkori 2009) where knowledge of food waste management practices and the mass flow analysis, generated in Phases A and B respectively, were integrated. The results are integrated by supply chain mapping which will be discussed in the following sections before explaining the process of future-state mapping. The concept of current- and future-state mapping was discussed in Section 2.2.7. The mosaic of data collected in each phase and the process of integration of the data towards Phase C is outlined in Figure 24.

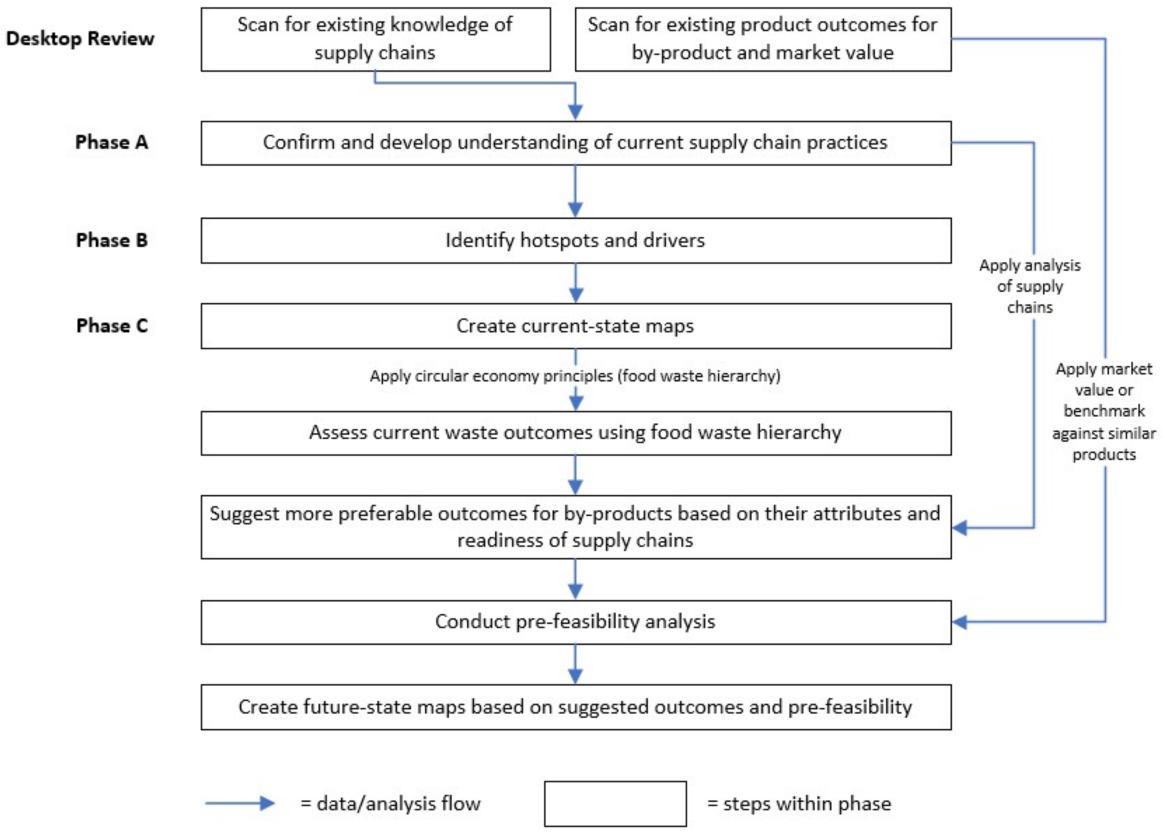


Figure 24. Diagram illustrating how data collected during each phase of the research are integrated in Phase C.

3.6.1 Current-state Mapping: Purpose, Parameters and Approach

In this section the primary and secondary mapping parameters and elements will be established. As explained in the theoretical framework (Sections 2.2.4 to 2.2.7) the mapping parameters and elements must flow from the mapping purpose (Research Objective A). Table 8 has been constructed to demonstrate the flow of mapping elements from the parameters, that in turn flow from the mapping purpose. Primary mapping parameters are indicated by blue text, while secondary mapping parameters are indicated in green text.

Table 8. Flow of mapping parameters and elements from the mapping purpose.

Mapping Purpose	Mapping Parameters		Mapping Elements (qualitative)	Mapping Elements (quantitative)
Research Objective A: To map and analyse Australia's wild-harvest abalone supply chains, with a particular focus on food waste in the upstream stages of the supply chain.	Length	All supply chain stages		
	Perspective	'Objective', wide; particular attention paid to flows in the upstream stages: primary production and processing		
	Breadth	One species per map, state-by-state basis		
	Time period	One fishing season (one year)		
	Material flow	Products and by-products	Product types, product outcomes (distributed, stored, discarded)	Catch volumes, product volumes
	Firm/supply chain structure	Across upstream stages	Integration of fishing, processing, and/or distribution	Number of operators
	Governance	Across upstream stages	Shucking at sea rules	
	Other structural/actor attributes	Fishing and processing stages	Geography: fishing locations, processing facilities Drivers of food waste or by-product utilisation	

Each of the secondary parameters and elements were selected based on their pertinence to the understanding of waste volumes and drivers. Their importance was either confirmed by or emergent from participant responses in the semi-structured interviews.

‘Approach’ refers to whether the research design will consist of purely qualitative, purely quantitative, or a mix of both to collect and analyse data (Batista et al. 2021). There is no singular approach to mapping food waste along supply chains. There are a number of examples of purely qualitative (Anastasiadis, Apostolidou and Michailidis 2020; Batista et al. 2021; Luo, Olsen and Liu 2021); purely quantitative (De Steur et al. 2016); and mixed methods approaches (Beretta et al. 2013; de Moraes et al. 2020; Folinas et al. 2014; Parmar, Sturm and Hensel 2017). In each case the approach is driven by the purpose of mapping and chosen framework. For example, studies that employ Value Stream Mapping tend to address food waste from a purely quantitative approach.

3.6.2 Mapping Conventions

For the purposes of understanding food waste, both qualitative and quantitative approaches are required (Batista et al. 2021). To understand the volumes of food waste along an agrifood supply chain, quantitative information is primarily required (Beretta et al. 2013); and to understand drivers both qualitative and quantitative information are useful (Batista et al. 2021; De Steur et al. 2016; Parmar, Sturm and Hensel 2017). Thus, to understand volumes as well as drivers, a mixed methods approach is necessary.

The mapping conventions devised in this research were based on theory discussed in Section 2.2.5 regarding existing agrifood supply chain mapping techniques and visual effectiveness. These techniques included signposting, appropriate density of information, clearly delineated tiers, and commonly- or easily-understood symbols and icons, *inter alia*. The selected conventions have been adapted from agrifood supply chain mapping studies more generally, rather than purely food waste mapping studies owing to the scarcity of the latter in the literature (explicated in Section 2.2.1).

The supply chain maps created by Beretta et al. (2013) (Figure 25) and Carvalho, Cruz-Machado, and Tavares (2012) (Section 2.2.5) were particularly influential in the selection of mapping conventions in this research (Table 9). The mapping conventions presented in Table 9 are a synthesis of simple box-and-arrow, process flow diagrams (Beretta et al. 2013; Schrobback, Rolfe and Star 2020), Extended Value Stream Mapping conventions (Carvalho, Cruz-Machado and Tavares 2012; Farris 2010; Gardner and Cooper 2003; Lambert, García-Dastugue and Knemeyer 2008), and other simple yet novel techniques that assist in conveying meaning about the supply chain (Beretta et al. 2013; Fabbe-Costes, Lechaptois and Spring 2020; Kiambi et al. 2018; Schrobback, Rolfe and Star 2020). As the purpose of Table 9 is to demonstrate the connection between the conventions and mapping parameters (introduced in Section 3.6.1, Table 8), the variations on each type of mapping convention (i.e. variations in colours) has not been shown. Rather, the full extent of variations will be provided later on in the thesis as a map legend (Section 7.1).

The mapping conventions were chosen for their flexibility of use in both current- and future-state mapping contexts. To ensure continuity and comparability between current- and future-state scenarios, the same set of conventions were used across both map types. A consistent thread of meaning ensured that any proposed management interventions in the future-state map could be easily ‘signposted’ to the user (Donaldson, Brice and Midgley 2020; Rother and Shook 2003).

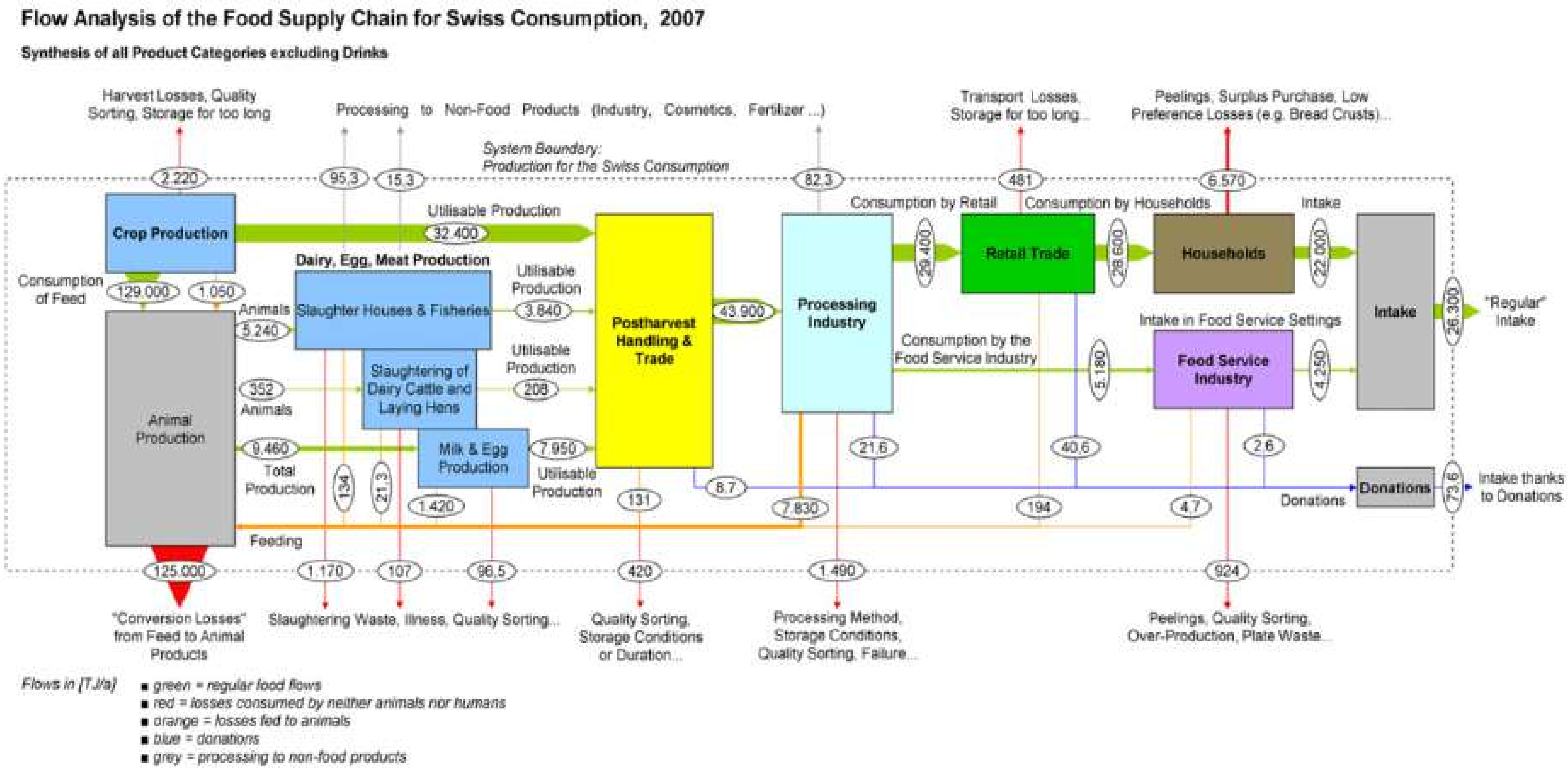


Figure 25. Supply chain map of material flow and drivers of food waste at a macro-level. Source:{Beretta, 2013 #392

Table 9. Mapping conventions used to create the supply chain maps in this research.

Primary Parameters and Mapping Elements	Mapping Convention	Sources Adapted From
PRIMARY PARAMETERS		
All supply chain stages, yet an objective 'wide' perspective. Particular attention to flows in the upstream stages: primary production and processing	Clearly delineated supply chain stages More granular operational information at primary production and processing stages	Beretta et al. (2013); Carvalho, Cruz-Machado, and Tavares (2012); Gardner and Cooper (2003)
One species, state-by-state basis One fishing season	Map title and information	
MATERIAL FLOW:		
Product types Catch, product volumes (tonnes), type of transport or movement	Whole and meat-only products moving within firm or transported by road; By-products moving within firm or transported by road etc.	Beretta et al. (2013); Carvalho, Cruz-Machado, and Tavares (2012); Fabbe-Costes, Lechaptois, and Spring (2020); Rother and Shook (2003)
Product stages / outcomes and number of operators **Other attributes:** fishing and processing locations, travel time	Single supply chain actor, facility or location; Multiple supply chain actors, facilities or locations; Product storage categories for distribution	
Other attributes: By-product outcomes, categorised according to waste hierarchy	**Preventi on** Prevention of excess production or by-products; **Re-use #1** Redistribution of food/by-products for human consumption etc.	Garcia-Garcia et al. (2017)
FIRM/SUPPLY CHAIN STRUCTURE:		
Firm vertical integration	Vertical integration (box surrounds actors/ facilities/locations)	Schrobback, Rolfe, and Star (2020)
GOVERNANCE:		
Shucking at sea rules	Shucking at sea permitted in fishing area; Shucking not permitted in fishing area or facility	None
Blue text = primary parameters	Green text = secondary parameters and elements	

Lambert, García-Dastugue, and Knemeyer (2008) suggest that, in supply chain mapping, relationships must be mapped separately from activities. However, some agrifood supply chain mapping studies successfully combine both elements into single maps (Carvalho, Cruz-Machado and Tavares 2012; Kiambi et al. 2018); while Gardner and Cooper (2003) suggest that it is the overall strategic desires of the mappers that dictate the parameters. With these opposing suggestions in mind, the conventions that were devised in this research were simple yet clear in meaning, and directly related to conveying an understanding of food waste volumes and drivers. In this way an overload of information was mitigated, and the overall map could be effectively read and understood to the ends of the overall strategic purpose.

3.6.3 Future-state Mapping and Pre-feasibility Analysis

The future-state mapping component of this research involved the application of circular economy principles and economic pre-feasibility analysis. The significance of these concepts to the theoretical framework was discussed in Sections 2.2.8 and 2.2.8, respectively. Table 10 demonstrates the relationship between Objective B and this component of the research.

Table 10. The relationship between Objective B and Phase C to the future-state mapping and pre-feasbility analysis.

Research Objectives			'Phase C' Mapping and Analysis
B	To identify specific management interventions guided by the food waste hierarchy to address food waste along the supply chains.	→	Present future-state maps that show management interventions to reduce food waste, accompanied by economic pre-feasibility.

The circular economy principles and specific version of the food waste hierarchy proposed by Garcia-Garcia et al. (2017) (discussed in Section 2.2.8) guided the selection of management interventions that were proposed in the future-state maps. Finally, only the most promising outcomes for reducing waste that emerged from the supply chain analysis and current-state maps would be selected for future-state mapping.

A number of pre-feasibility food waste studies focused on prevention or valorisation were found in the literature. However, some were not adaptable to this research owing to their specific application to assessing the pre-feasibility of infrastructure projects (Ortiz-Sanchez et al. 2020; Ortiz-Sanchez, Solarte-Toro and Cardona Alzate 2023), or purely technical analysis (Generosi et al. 2012; Karagiannidis et al. 2009) and were thus excluded. Instead, the economic analysis components of studies by Jones et al. (2023) and Stander, Harrison, and Broadhurst (2022) were synthesised and adapted to this research, resulting in a process illustrated in Figure 26. It should be noted that the study by Stander, Harrison, and Broadhurst (2022) concerns waste management outside of an agrifood context, but the methods applied in their economic pre-feasibility analysis were relevant to the geographic and transport considerations in this research.

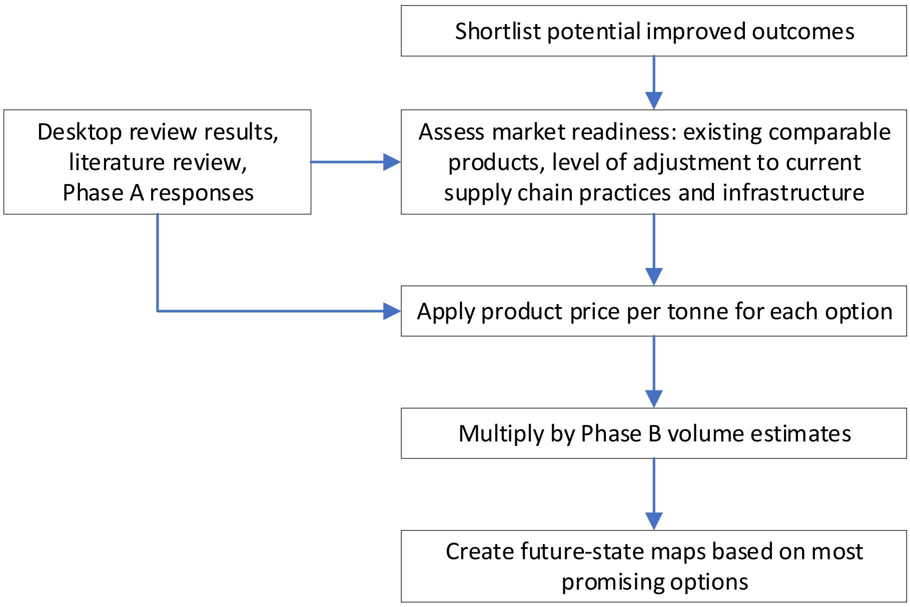


Figure 26. Economic pre-feasibility analysis process flow diagram.

To reflect the dynamism of market forces and supply chain practices, the future-state maps considered TACC quotas and supply chain practices relevant to the year 2022 onwards. Evidence-based supply chain maps should represent as current a scenario as possible to ensure any proposed management interventions remain relevant (Carvalho, Cruz-Machado and Tavares 2012; Donaldson, Brice and Midgley 2020; Fabbe-Costes, Lechaptois and Spring 2020; Rother and Shook 2003).

3.7 Ethics Approval

Human ethics approval for all phases of the research involving human participation was granted on 12 November 2022, for a duration of 12 months (Approval Number: HRE2021-0714); and renewed for a further 12 months thereafter to allow for more time to collect qualitative data. A copy of the consent form, participant information sheet, interview guide, participant recruitment email text and data management plan which were submitted for approval has been included in Appendix F.

3.8 Conclusion

In this chapter the philosophical underpinnings of the research and research design were described. The relevance of each component or phase of the research was shown to flow directly from the research objectives. In this way, the adoption of a mixed methods research design was justified; which was recommended by Morse and Niehaus (2009) and Teddlie and Tashakkori (2009). Moreover, the integration of qualitative and quantitative results through supply chain mapping, circular economy principles, and leading food waste theory directly demonstrated how the core constructs of the theoretical framework (Sections 2.2 and 2.3) were operationalised.

Typologies of mixed methods research designs and sampling strategies were discussed as were a number of extant food waste studies similar to this research. The consideration of theory and similar food waste studies ensured the reliability and validity of the research design. The four phases of this research were subsequently described: the initial exploratory desktop review; the dominant qualitative component (Phase A ‘QUAL’); the supplementary quantitative component (Phase B ‘quan’); and the final point of interface (Phase C) where both qualitative and quantitative results were integrated. The resulting design matched qualitatively-dominant sequential typologies described by Morse and Niehaus (2009) and Teddlie and Tashakkori (2009). The results and discussion of each phase will now be presented, beginning with the desktop review.

4 DISCUSSION OF RESULTS: DESKTOP REVIEW

The purpose of the desktop review, as an exploratory phase, was to gather existing best available evidence through secondary data sources concerning: supply chain practices, supply chain actors, size of industry and market share, industry regulations, supply chain structures, product types, waste flows and volumes, catch volumes, TACC quotas, distribution volumes, beach pricing, revenue or production value of catch, pricing of abalone by-products (detailed in Section 3.3). This chapter has been structured according to the aspects of the supply chain that appear to influence the magnitude of waste generated along the supply chains and how waste is managed, followed by the preliminary supply chain maps that were created at the end of the desktop review.

The five aspects, or themes, that are presented in Sections 4.1 to 4.5 include: fishery management and governance, harvesting and shucking at sea, abalone processing, outcomes of by-products from processing, and the distribution of abalone products. The themes emerged from a review of fishery management reports, fishery rules and regulations, company websites, and government datasets. As the desktop review was an exploratory precursor to the main piece of research, it contributed a significant amount of background information that was essential to the design of Phases A ('QUAL') and B ('quan'). The preliminary supply chain maps that are presented in Sections 4.6.1 to 4.6.5 were created as a means of collating the gathered information and any identified gaps that needed to be addressed in Phases A and B to, in turn, address the research questions (explained in Section 3.3).

4.1 Fishery Management and Governance

The desktop review revealed that abalone fisheries are heavily regulated across Australia and managed in largely the same way. These findings are consistent with literature that is focused on the success of sustainable management of Australian abalone fisheries; though principally from a regulatory and stock management perspective (Bose and Crees-Morris 2008; Gilmour, Dwyer and Day 2013; Mayfield et al. 2012; Prince et al. 1998). However, it is noteworthy that the collation of fishing zone and licensed operator data has not previously been undertaken for the purposes of supply chain mapping or analysis. From a supply chain perspective, this of concern because it exposes the lack of knowledge on key supply bases in an economically-significant, Australian primary production industry that has been subject to a number of environmental and economic threats for over a decade (Mayfield et al. 2012).

As state-managed fisheries, licensed fishing operators (businesses or divers) are limited to harvesting abalone within state waters and specific fishing zones. All five states are managed as restricted-entry fisheries, meaning there are a limited number of licenses and quota units permitted and administered by the state. This is significant to note from a waste perspective because, theoretically-speaking, the limited quota imposes a limit on the amount of waste that can be generated. The desktop review also indicated that the delineation of fishing zones and number of licensed operators is relatively stable and not subject to frequent changes over time. This is significant to note for future-mapping purposes, and any proposals for supply chain improvements. The evidence that was used to create the preliminary supply chain maps will now be presented.

Fishing Zones

In all but the New South Wales fishery, state waters are divided into distinct zones for TACC quota setting, catch reporting, and licensing purposes. All fishing zones and relevant species that are permitted for harvest are listed in Table 11. Not all species of abalone can be fished within each fishing zone and this has been clearly shown in Table 11. Because the quota of abalone that can be harvested within each zone is strict and pre-determined by the state-sanctioned TACC quotas on an annual basis, a conscious effort was made to spatially distinguish the fishing zones and landed catch in the preliminary supply chain maps.

Table 11. Fishing zones and species of abalone that are permitted for harvest in each zone.

State Fishery	Fishing Zones	Species Fished	Sources
New South Wales	Nil – waters not divided	Blacklip (*H. rubra*)	NSW Total Allowable Fishing Committee (2021); Government of New South Wales (2020)
South Australia	Western Zone Central Zone Southern Zone	Blacklip (*H. rubra*) Greenlip (*H. laevigata*)	Mayfield et al. (2021);Mundy et al. (2021)
Tasmania	Eastern Zone Western Zone	Blacklip (*H. rubra*)	Mundy and McAllister (2020)
	Northern Zone Bass Strait Zone	Blacklip (*H. rubra*) Greenlip (*H. laevigata*)	
Victoria	Central Zone Eastern Zone	Blacklip (*H. rubra*) Greenlip (*H. laevigata*)	Victorian Government (2019b);Victorian Government (2019a)
	Western Zone	Blacklip (*H. rubra*)	
Western Australia	Fishing Areas: 1 and 2	Blacklip (*H. rubra*) Greenlip (*H. laevigata*) Roe's (*H. roei*)	Gaughan and Santoro (2021);Strain, Fabris, and Jones (2021)
	Fishing Area: 3 and 4	Blacklip (*H. rubra*) Greenlip (*H. laevigata*)	
	Fishing Areas: 5, 6, 7, 8	Roe's (*H. roei*)	

Licensed Fishing Operators

Information regarding the number of fishing operators in each state was varied in terms of detail and reporting; likely because each fishery has slightly different management and licensing arrangements. Generally, operators can be licensed to own quota and to harvest or dive for abalone. These operators, termed 'quota owners' or 'licensed operators' in the industry and in this research, are typically proprietors of fishing businesses. Individuals can also be licensed to dive for abalone but do not own the quota rights. These individuals (termed 'lease divers') are either paid by quota owners to dive for abalone on their behalf or enter into an agreement with quota owners where the rights to quota are 'leased'. Crucially, neither of these figures provides a true indication of the number of businesses operating since one business can own multiple licenses and quota units; and divers can harvest on behalf of several businesses or quota owners. As a result, the number of businesses and market share within each fishery could not be determined; having implications on determining the sampling frame for the qualitative interviews (alluded to in Section 3.4.1).

One of the aims of creating the supply chain maps was to accurately capture the volumetric flow of catch from point of harvest to landing. Knowledge of the number of active, operating fishing businesses and market share would have assisted in the estimates of product and by-product flow and outcomes. This presented as a significant gap in the current knowledge towards mapping food waste and its drivers in the Australian abalone fisheries. Nevertheless, the best available evidence on the number of licenses and operators was obtained from various fishery reports and government gazettes. The information is presented in the supply chain maps as well as in Table 12.

Table 12. Abalone licensing and business nformation collated from existing literature and datasets.

State fishery	Fishing zone	No. of licenses	Estimated no. operating businesses	Sources
New South Wales	Whole fishery	48 available, only 35 endorsed to fish	Unknown	NSW Total Allowable Fishing Committee (2021);The Ecology Lab Pty Ltd (2007)
South Australia	Central Zone	6	3	PIRSA (n.d.(a));
	Southern Zone	6	6	PIRSA (n.d.(b));
	Western Zone	22	17	PIRSA (n.d.(c));Stobart, Mayfield, and Heldt (2020)
Tasmania	All zones	121	Unknown	Mundy and McAllister (2021)
Victoria	Central Zone	34	Unknown	Victorian Fisheries Authority (2019)
	Eastern Zone	23	Unknown	
	Western Zone	14	Unknown	
Western Australia	Roe's (all areas)	28	21 vessels, total businesses unknown	Hart et al. (2017);Strain, Brown, and Jones (2021)
	Greenlip/Brownlip (Areas 2 and 3)	23-24	20 vessels, total businesses unknown	Hart et al. (2017); Strain, Fabris, and Jones (2021)

Western Australia's and South Australia's fishery management reports and databases provided some additional information where other states did not; and this too is shown in Table 12. South Australia lists all quota owners on its fisheries public register by zone; which allowed for a better approximation of individual businesses. Licenses owned by corresponding director or licence holder surnames and/or corresponding holding private company names and directors were assumed to be related (therefore 'individual' businesses). However, this information will need to be verified in the interviews.

All other states considered ownership information confidential (L. Strain, personal communication, January 14, 2022). Western Australia had some published labour and economic information concerning the number of operating vessels, divers, and deckhands which is shown in Table 12. However, the number of individual businesses could not be extrapolated from this information. Existing literature seeking to understand Australian abalone fishing practices has not, so far, focused on quantifying the number of active businesses nor market share (Bose and Crees-Morris 2008; Gilmour, Dwyer and Day 2013).

Overall, the lack of information regarding active businesses and market share of active primary producers in the supply chains constituted a knowledge gap that would need to be addressed in Phase A, in order for an accurate map of the supply chains to be constructed.

4.2 Harvesting Data and Shucking at Sea

As catch data are reported on an annual basis for all states, obtaining data on production volumes was relatively straightforward. However, because each state fishery – and, indeed, even individual fishing zones within the same state – have different reporting periods it was not possible to collect complete data for the most recent fishing season (2020/21).

The most recent data for each state varied, as shown in Table 13. The misalignment of reporting periods highlighted data gaps in terms of current catch data in Victorian and Western Australian fisheries. The most current fishing year's catch data (2021) could only be obtained on an *ad hoc* basis from the New South Wales Department of Primary Industries. This was not possible where the other state fisheries were concerned. TACC quotas could have been used to estimate waste volumes, however actual catch data were judged to be a truer indication of current operations. A comparison of TACC and actual catch volumes revealed that the latter tends to be lower than TACC quotas. The difference was marginal (≤ 6%) but unpredictable in most states, except Western Australia's fisheries where actual catch was consistently and materially lower than the TACC quotas by 28%, taken as a 3-year average (2017 to 2019) across all fishing zones. The consistently lower catch rates in Western Australia are a result of the underperforming Roe's fishery. According to Strain, Brown, and Jones (2020) the Roe's fishery has been affected by low market value of catch since the year 2000 resulting from competition with aquaculture abalone products.

Table 13. Most recently-published catch data for all Australian abalone fisheries, by zone.

Fishing Zone	Catch Data	Blacklip (tonnes)	Greenlip (tonnes)	Brownlip (tonnes)	Roe's (tonnes)	Sources
New South Wales	2021	91.7	-	-	-	D. Makin (personal communication, January 7, 2022)
South Australia						
Central Zone *	2020	1.21 mw	28.1 mw	-	-	Burnell, Mayfield, and Bailleul (2021)
Southern Zone		109.1	1.9	-	-	Burnell, Mayfield, and Hogg (2021)
Western Zone *		40.7 mw	49.4 mw	-	-	Stobart and Mayfield (2021)
Tasmania						
Bass Strait Zone	2020	93.0	85.0	-	-	Mundy and McAllister (2021)
Northern Zone		70.0		-	-	
Eastern Zone		220.0	-	-	-	
Western Zone		542.0	-	-	-	
Victoria						
Central Zone	2019	271.0	3.0	-	-	Mayfield et al. (2021); Mundy et al. (2021)
Eastern Zone		350.0	-	-	-	
Western Zone		68.0	3.0	-	-	
Western Australia						
Area 1	2019	-	-	-	0.0	Gaughan and Santoro (2021)
Area 2 *		-	22.9	9.4	13.0	
Area 3 *		-	19.3	12.1	-	
Area 5		-	-	-	6.0	
Area 6		-	-	-	4.0	
Area 7		-	-	-	24.0	
Area 8		-	-	-	0.0	
mw = meat weight * = shucking at sea permitted Figures are rounded to the nearest tenth of a tonne (±0.1)						

The most reliable and current sources of actual catch data were fisheries reports (i.e. stock assessments, sustainability assessments, strategic plans, annual reports), listed accordingly in Table 13. These reports feed into higher-level government datasets, such as those published by ABARES and the ABS (Stevens, Mobsby and Curtotti 2021). Catch data, also presented in Table 13 were used to inform product flow volumes on the preliminary supply chain maps.

Shucking at Sea

Shucking at sea is a practice restricted to only a few abalone fishing zones, including South Australia's Western and Central Zones, and Western Australia's Area 2 and Area 3. Fishing areas where shucking at sea is permitted are indicated by an asterisk (*) in Table 13. In areas where shucking at sea is permitted, the volume of shucked meat ('meat weight') rather than volumes of whole abalone ('whole weight') are reported in fishery management reports. As such, a distinction is made in Table 13 where meat weights rather than whole weights (meat + shell + viscera + blood) are presented. Knowledge of the volumes of abalone shucked at sea were important to the mapping of product flows since some amount of shell, viscera, and blood appear to be disposed at the point of harvest. This, in turn, has implications on the quantification of waste hotspots (explained in Section 3.5.3). However, the desktop review revealed two information gaps relating to shucking at sea practices which made it difficult to estimate the mass flows of abalone product and shucking waste. These will be discussed before moving on to the next section which will focus on information gathered on abalone processing activities and products.

Firstly, no data could be found regarding the volumes of shells and shucking waste disposed of at sea in either Western Australia or South Australia. Western Australian Greenlip and Brownlip divers are required to land the shells along with the shucked meat for research and reporting purposes (Hart et al. 2017). Presumably this means viscera are thrown overboard, but the extent of the practice is not documented. In South Australia there is no legislation stating whether shells must be landed, so it assumed that both shells and viscera are thrown overboard. Again, the extent of the practice is not documented. Additionally, the impacts – food waste or otherwise – of shucking at sea practices in Australian abalone fisheries are not discussed in the literature and suggests an area for further research (Mayfield et al. 2012). The assumptions concerning viscera and shells shucked at sea have been signposted on the preliminary supply chains maps for both states.

Secondly, where only meat weights were reported in the catch data, it was not possible to determine whether any portion of catch is landed whole for live or whole-on-shell products. It was assumed that at least the available export data could shed some light in this respect. However, the provenance (i.e. aquaculture or wild stocks), species of the products, and whether they were distributed whole-on-shell or as meat-only product formats were unclear from the export data. Clarification on these datasets could not be found in the data explanatory notes and literature; and therefore constituted a gap in knowledge to be addressed in the qualitative interviews.

The lack of clear reporting on whole versus shucked abalone product is a major information gap where the quantification, mapping, and recovery of food waste is concerned (the process for which was explained in Section 3.5.3). However, from a supply chain perspective – and given the economic threats faced by the wild-harvest industry – clearly segmented data between wild-harvest and aquaculture product, and whole-on-shell and meat-only product formats could assist wild-harvest primary producers and processors in improving collective strategy and their responsiveness and alignment to market demands, thereby improving financial performance. The literature suggests that strategically-shared knowledge supports decision making, innovation, and in turn, financial return (Hult et al. 2006; Wowak et al. 2013). The discussion of abalone processing and products will continue in the following section.

4.3 Land-based Abalone Processing and Products

Abalone processing, the subsequent stage in the supply chain after harvesting, was defined in this research as the cleaning, shucking, freezing, cooking, and/or packaging of abalone post-harvest (Section 1.1.2). Information on the processing of abalone into various products was relatively accessible on company webpages. However, reliable data on the number of active processors within each state was difficult to obtain. The lack of data is reflected in the literature where there has been little comment on abalone processing practices or products specific to the Australian context.

Processing

In all states, abalone processors are required to hold a specific license administered by the relevant state-managed fishery authority. Thus, this stage of the supply chain is also restricted by entry as the primary production stage is. Table 14 presents any reported information (i.e. number of permitted licenses in the state) that could be found and an estimate of processors on a state-by-state basis, according to a scan of Internet listings (i.e. estimated number of active processors). As shown in Table 14 it was not possible to find any current indications of the number of licenses permitted in each state except for Victoria and Western Australia. The number of active, operating processors could only be estimated by Internet listings; however, their respective market share was not possible to deduce. Overall, the lack of information regarding the number of active, licensed processors and market share constituted a gap that needed to be addressed in Phase A and is highlighted accordingly in each of the preliminary supply chain maps.

Table 14. Number of licensed and active abalone processors by state.

State	No. of Permitted Licenses and Sources		Estimated No. of Active Processors and Sources	
New South Wales	Unknown	Nil	1	Pacific Bao Yu (n.d.(b))
South Australia	Unknown	Nil	4	Dover EX27 Pty Ltd. (n.d.); Hot Dog Fisheries (n.d.(a)); Streaky Bay Marine Seafoods (n.d.); Western Abalone (n.d.)
Tasmania	33	DPIWE (2003)	3	Candy Abalone (2022); Tasmanian Seafoods (2022); True South (2021)
Victoria	11	Victorian Fisheries Authority (2020)	5	Austanz Abalone (2022); Kansom Australia (2020a); Southern Canning Pty. Ltd. (n.d.); Southern United Seafood Australia Pty. Ltd. (2004a); Mallacoota Abalone Limited (2015)
Western Australia	14	Government of Western Australia (2020b, 2020a)	4	Esperance Abalone Enterprises (n.d.); KB Seafood Co. (2022); Magic Abalone (n.d.); Southern Trading Australia Pty. Ltd. (2009)

Processors in all states except New South Wales appear to be vertically integrated across processing, wholesale, and export activities. The scan of New South Wales-based operators yielded only one result for a processor (Pacific Bao Yu n.d.(a)), while other operators in the state were solely engaged in distribution (retail, wholesale, export). Also of note was the Rare Foods Australia company in Western Australia which marketed their abalone products as ‘wild’, though the abalone appear to be cultivated on submerged, artificial reefs. The classification of this processor and its product as ‘wild’ or ‘aquaculture’ required further confirmation in the following phase and were not included in the preliminary supply chain maps. The inclusion or exclusion of processing volumes based on provenance and production method will have a bearing on the estimates of shell and shucking waste produced.

Where licensing and processing activities are concerned, each state enforces similar regulations. These pertain to the administration of licenses and to the receiving of abalone from the divers/operators. Receiving abalone involves adhering to rules concerning catch verification (e.g. species, volumes, divers), and transport lead times from the landing locations, and sale of abalone; but not to the actual processing or handling of abalone. This was the case in all states according to the regulations listed in Table 15. However, in Western Australia more insights regarding processing and landing could be gleaned from a report by Hart et al. (2017) rather than in the regulations; and thus have not been included in Table 15. The listed regulations (Table 15) were in force at the time the desktop review was conducted and are reflected in the preliminary supply chain maps.

Table 15. List of relevant regulations concerning abalone processing in Australian abalone fisheries.

State	Legislation or Regulation	Paragraph No.
New South Wales	*Fisheries Management (Abalone Share Management Plan) Regulation 2000*	37 – Shucking of abalone
	Fisheries Management (General) Regulation 2019	194 - Fish consignments by registered fish receivers to be labelled 195 - Fish receivers to supply information
South Australia	*Fisheries Management (Fish Processors) Regulations 2017*	8 – Requirements relating to processing of abalone
Tasmania	*Fisheries (Processing and Handling) Rules 2021*	6 – Possession of abalone, rock lobster, and giant crab at certain places 10 – Transporting after taking possession
Victoria	*Fisheries Regulations 2019*	322 – Abalone must be delivered to holder of Fish Receiver (Abalone) Licence within 24 hours 323 – Activities authorised by Fish Receiver (Abalone) Licences
Western Australia	Nil	Nil

The listed regulations are noteworthy from a supply chain perspective because they restrict product flow (e.g. volume, types of products, where products can flow from and to); supply chain activities (e.g. harvesting, handling, distribution, reporting); and actors (e.g. number of actors). Restrictions on product flow induces product scarcity which can, in turn, increase product value if demand for the product is high (Barton, Zlatevska and Oppewal 2022; Ladeira et al. 2023; Worchel, Lee and Adewole 1975), as is the case with wild Australian abalone products. Where food waste is concerned, these restrictions could affect the value of the shucking waste given these components of the abalone would also be restricted in volume; which, in turn, could have implications on any proposed management interventions and economic feasibility.

The regulations listed in Table 15 also restrict product flow and facilitate some level of supply chain co-ordination in that divers must bring in ('land') their catch at designated landing areas which are pre-arranged with their chosen processor and the fishing authority. Abalone are landed in sealed and labelled boxes that detail the catch area, volume, catch hours, and species contained before being transported by trucks to the processing facility. These activities are detailed in the preliminary supply chain maps. In Western Australia where shucking at sea is practiced, abalone shells can be disposed of once the catch is verified at the landing area or at the processors by the fishing authority. Once abalone are transported to the processors the regulations stipulate that catch records and volumes of received abalone must be verified by the processors. Presumably, the legislation covers these aspects of receiving and reporting rather than the processing itself for traceability and to mitigate against black market products.

Products for Wholesale and Retail Sale

Information about abalone products was gathered from fishery reports, ABS export data, and company webpages following the strategy illustrated in Section 3.3, Figure 19. Three major gaps were apparent from the sources reviewed. Firstly, information regarding the breakdown of abalone products relative to total catch was not publicly available. As shown in process flow diagrams in Section 3.5.3 (Figures 21 and 22) this data would have informed the amount of shucked meat, and in turn, the volumes of shucking by-products; leading to a better understanding of the volume of waste produced along the supply chain. Secondly, it is also unclear whether any meat is wasted in addition to the viscera and shells. These factors will require confirmation in the qualitative interviews. Thirdly, while processors often specified the species of abalone sold or marketed, the geographical provenance and production method (wild-harvest versus aquaculture) was often unclear. Thus, these three gaps considered, the quantified flows of abalone products originating from wild-stocks, and subsequently, any associated by-products presented in the preliminary supply chain maps are speculative at best.

The speculative figures are based on assumptions about the relative prevalence of certain downstream abalone products processed in each state. These assumptions were made by scanning processors' product or online shop webpages and comparing the products found with ABS export data (ABS 2021). The figures were highlighted in the preliminary supply chain maps as information requiring clarification, comment, and amendment by industry experts in Phase A.

Nevertheless, the desktop review of abalone products helped to provide some knowledge of the possible flow of abalone from the processing stage to downstream ends of the supply chain. The results of the scan for abalone products are presented in Tables 16 to 20 including provenance and species. In each of the tables, the products listed are sourced from wild stocks unless otherwise indicated. There are several ubiquitous abalone products that were found across all states. Whole on-shell abalone products include live and individually quick frozen (IQF) whole abalone. Meat-only products include IQF, retort, canned, and dried formats. Other products such as abalone salts, flakes, sashimi, cooked pre-sliced meat appear to be company-specific offerings rather than conventional, industry-wide product ranges.

In sum, only a *sense* of the types of product formats in the market could be gleaned in this desktop review. Knowledge gaps included the volumes of product (quantified by species and state), as well as unclear provenance in some cases. These gaps were noted for further investigation in the subsequent phases of this research.

Table 16. Abalone products marketed by New South Wales processors and retailers.

Company (source), Location	Live	IQF, whole	IQF, meat only	Retort	Canned	Dried	Other
Claudio's Seafood (n.d.)	BL	AQ-GL					
Peter's Fish Market (2022)	BL		GL				Sashimi (GL)
Sydney Fish Market (n.d.)	BL, GL	BL, GL		BL, GL		BL, GL	
Abalone Narooma (2022)	BL						
Fortune Abalone (2022)	GL (SA)		GL	GL	BL, GL (TAS)		
Pacific Bao Yu (n.d.(a)) (also operates in Victoria)	BL	BL, AQ-GL	BL, AQ-GL	BL, AQ-GL			
BL = Blacklip GL = Greenlip Red text = provenance unclear Yellow highlight = sourced from another state AQ- = aquaculture SA = South Australia TAS = Tasmania							

Table 17. Abalone products marketed by South Australian processors.

Company (source), Location	Live	IQF, whole	IQF, meat only	Retort	Canned	Dried	Other
Eyrewoolf Abalone (n.d.)		BL, GL, R	R	BL	BL		
Streaky Bay Marine Seafoods (Blue Sky Fisheries 2010; Streaky Bay Marine Seafoods n.d.)			BL, GL	BL	BL		
Hot Dog Fisheries (n.d.(a))		BL, GL	BL, GL	BL, GL	BL, GL		
Dover EX27 Pty Ltd. (n.d.)					R		
Western Abalone (n.d.)	BL, GL, R	BL, GL, R	BL, GL, R	BL, GL, R	BL, GL, R		
Ausgold (n.d.) – distribution only			GL				
BL = Blacklip GL = Greenlip R = Roe's							

Table 18. Abalone products marketed by Tasmanian processors.

Company (source), Location	Live	IQF, whole	IQF, meat only	Retort	Canned	Dried	Other
Candy Abalone (2022)			GL	GL	BL	BL, BrL, GL	
True South (2021)	Products unspecified, but BL and GL marketed						
Tasmanian Seafoods (2022) (also operates in Victoria)	BL, GL		BL, GL	BL, GL	BL, GL		
Tas Live Abalone (2019) (also operates in Queensland)			BL, GL	BL, GL	BL, GL	BL, GL	
Great Barrier Seafoods (Great Barrier Seafoods 2014a, 2014(b)) – distribution only	BL, GL	BL, GL	BL, GL	BL, GL	BL, GL		
BL = Blacklip BrL = Brownlip GL = Greenlip R = Roe's							

Table 19. Abalone products marketed by Victorian processors.

Company (source), Location	Live	IQF, whole	IQF, meat only	Retort	Canned	Dried	Other
Austanz Abalone (2022)					BL		
Kansom Australia (2020a)				BL, GL	BL, GL		
Southern Canning Pty. Ltd. (n.d.)				X	X		
Southern United Seafood Australia Pty. Ltd. (2004a, 2004b)		BL, GL	BL, GL	BL, GL	BL, GL		
Mallacoota Abalone Limited (2015)		BL	BL		BL		
BL = Blacklip GL = Greenlip X = Species unspecified							

Table 20. Abalone products marketed by Western Australian processors.

Company (source), Location	Live	IQF, whole	IQF, meat only	Retort	Canned	Dried	Other
Magic Abalone (n.d.)		BrL, GL	BrL, GL, R	BrL, GL, R	R	BrL, GL, R	Abalone flakes and salt (X)
Southern Trading Australia Pty. Ltd. (2009)	AQ-GL		BrL, GL, R	BrL, GL, R	BrL, GL, R, AQ-GL		
Rare Foods Australia (2022)		GL		GL	GL		
KB Seafood Co. (2022)		GL (SA)					
Esperance Abalone Enterprises (n.d.)	Products not specified, but BrL, GL, and R marketed						
BL = Blacklip BrL= Brownlip GL = Greenlip R = Roe's X = species unspecified Red text = provenance unclear Yellow highlight = sourced from another state							

4.4 Outcomes of Viscera, Shell, and Unmarketable Meat By-products from Processing

Although consideration of Australian wild-harvest abalone supply chains is important to this research, it is equally important to explore any information concerning the outcomes of by-products (e.g. viscera, shell) from abalone processing given the research questions and objectives are focused on food waste management. Publicly available information concerning the outcomes of shucked viscera, shells, and unmarketable meat could not be found. The lack of information regarding volumes of shell and viscera disposed of in areas where shucking at sea is permitted was already mentioned in Section 4.2. Information regarding the volumes and outcomes of by-products shucked on land was similarly lacking. Thus, several assumptions had to be made in creating the preliminary supply chain maps.

Where food waste in Australian abalone industries (wild and aquaculture) is concerned, the literature has focused primarily on the technical aspects of improving waste outcomes for abalone viscera rather than estimating waste volumes (Howieson et al. 2017; Suleria et al. 2017a; Suleria et al. 2017b; Suleria et al. 2017c). Moreover, quantification of processing waste in the Australian abalone industries has not occurred since 2017 (Howieson et al. 2017). All in all, the findings of this desktop review were consistent with the lack of knowledge surrounding volumes and outcomes of abalone processing waste in the literature.

Variables for estimating shell and shucking volumes were found by following the search desktop search strategy (Section 3.3, Figure 19). South Australia's *Fisheries Management (Abalone Fisheries) Regulations 2017* (in force since January 3, 2018) declares that in South Australia reported abalone meat weight is estimated "by multiplying the number of kilograms in weight of the whole abalone by the conversion value of 0.3333". Alongside Suleria *et al.*'s (2017a; 2017c) estimates that the viscera and shell comprise two-thirds of the abalone, the conversion value of 0.3333 was also used to estimate the constituent components volume of shells and viscera relative to whole weight for all states. The conversion values informed the breakdown of whole abalone into constituent parts at the processing and shucking at sea stages.

In addition to volumes, the outcomes (e.g. disposal, consumption etc.) of viscera, shell, and unmarketable meat were also assumed. Assumptions were based on various products that were found during the search for abalone products in general, reported in Section 4.3. Australian products derived from shells and viscera are listed in Tables 21 to 24 according to specific uses or product categories. The retail prices (RP) of each product have been listed where possible; as have the dollar (AU$) per unit to enable a price comparison between products. As shown in Section 3.6, Figure 23 the inclusion of this information in the desktop review will assist in conducting the economic pre-feasibility analysis planned for Phase C of the research.

Table 21. List of products marketed for human consumption believed to be derived from Australian abalone by-products.

HUMAN CONSUMPTION				
State	**Company (Source)**	**Product**	**By-product Used**	**RP and AU$/unit**
Victoria	Kansom Australia (2020b)	Abalone sea sauces – dipping sauce, human consumption	Not specified, assumed viscera or liver only	$12.95 = $71.94/L
	Kansom Australia (Dan Murphy's 2023; Kansom Australia n.d.)	Abalone beer – human consumption	Not specified, assumed viscera or liver only	$150 (24-pack x330ml) = $454.40/L

Table 22. List of products marketed for decorative use derived from Australian abalone by-products.

DECORATIVE USES				
State	**Company (Source)**	**Product**	**By-product Used**	**RP and AU$/unit**
South Australia	Blue Sky Fisheries (2010)	Shells – use unspecified	Greenlip shells (wild and aquaculture)	Not specified
	Western Abalone (n.d.)	Shells – use unspecified	Shells (species unspecified)	Not specified
Tasmania	Candy Abalone (2022)	Shells – decorative use in gift box	Greenlip and Brownlip shells	≥ $3,000/box
	True South (2021)	Shells – decorative use	Abalone (species unspecified) and paua shells	Not specified
Western Australia	Rare Foods Australia (2022)	Shells – decorative use in gift box	Greenlip shells	$70/box
	Esperance Abalone Enterprises (n.d.)	Shells – decorative use	Greenlip and Brownlip shells	Not specified

Table 23. List of products marketed for animal feed believed to be derived from Australian abalone by-products.

ANIMAL FEED / PET FOOD				
State	**Company (Source)**	**Product**	**By-product Used**	**RP and AU$/unit**
Queensland	All Fish For Dogs (2019)	Abalone powder pet food supplement	Not specified, assumed viscera	Not specified, wholesale only
n/a – Australian, online retail	Benefit (Menudogg 2022)	Abalone powder pet food supplement	Tasmanian abalone, assumed viscera	$29.99 (150g) = $199.93/kg
Queensland, online retail, and wholesale	Fishtastic (2023); (Petstock 2023)	Abalone powder pet food supplement*	Wild and aquaculture Australian abalone, assumed viscera	$34.95 (125g) = $279.60/kg
Western Australia and online retail	Petfresh (2023)	Abalone powder pet food supplement	Tasmanian abalone, assumed viscera	$18.95 (100g) = $189.50/kg
Queensland, online retail, wholesale	Clear Dog Treats (2023); (Vet-n-pet Direct 2023)	Abalone powder pet food supplement	Tasmanian wild abalone, assumed viscera	$18.95 (100g) = $189.50/kg
* Note: restricted distribution; prohibited from shipping to Tasmania for biosecurity reasons				

Table 24. List of products marketed for therapeutic use (humans) derived from abalone by-products.

THERAPEUTIC USE				
State	**Company (Source)**	**Product**	**By-product Used**	**RP and AU$/unit**
Tasmania	True South (2021)	Traditional Eastern medicine	Abalone (species unspecified) and paua shells	Not specified
n/a	Alibaba.com (Alibaba.com 2023c, 2023a)	Abalone shell powder, health supplement	Abalone shells – provenance unknown	$7.00-$20.00/kg
n/a	Alibaba.com (2023b)	Abalone peptide powder	By-product not specified, provenance unknown	$400.00/kg

While abalone shells are marketed ‘as is’, products derived from viscera are not explicitly advertised as such. Some examples include pet food supplements listed in Table 23, abalone ‘sea sauces’ (Kansom Australia 2020b), and abalone beers (Kansom Australia n.d.). Rather, knowledge about the use of viscera to manufacture these products was obtained by personal communication with industry experts in the course of the desktop review (J. Howieson, personal communication, April 21, 2021; S. Murray, personal communication, January 25, 2022). Notably, one of the pet food products listed in Table 23 manufactured by Fishtastic (2023) cannot be shipped to Tasmania for biosecurity reasons, suggesting the imperative to also understand the biosecurity aspects of utilising abalone shucking waste.

Of all the shucked parts of the abalone, decorative use of Greenlip shells is prevalent – for example, use in furniture inlays, clothing buttons, jewellery, and as display items. There was also some mention of the use of Brownlip shells for these purposes. Overall, however, the extent of the usage (e.g. in volumes or percentages) of shell and shucking waste was not available, and therefore assumptions concerning the amount of waste disposed versus what is utilised have been made in the preliminary supply chain maps.

Owing to the speculative nature of the estimates and assumed outcomes of viscera, shell, and unmarketable meat, the information was highlighted on the preliminary supply chain maps as requiring confirmation and clarification by industry experts in Phase A. The findings will now turn to the distribution of abalone products before the preliminary supply chain maps are presented.

4.5 Downstream Distribution of Abalone Products

The desktop review confirmed that data and information regarding the distribution of abalone are limited (Bradshaw 2018; DPIRD 2016b; PIRSA 2012). Because publicly available export information was generally lacking or too high-level to extrapolate specific industry information, a customised report had to be obtained from the ABS (2021). Domestic sales data could not be found.

In the course of this desktop review, it emerged that knowledge of aquaculture production volumes could go some way to assist the estimates of wild-harvest exports and, in turn, processing volumes. This emerged because the ABS (2021) export data does not differentiate between wild-harvest and aquaculture provenance (L. Mendelovits, personal communication, November 30, 2021). As a growing sector within the Australian abalone industry, cultured abalone products represent a substantial portion of exports from certain states like South Australia, Tasmania, and Victoria (Mobsby et al. 2021; Stevens, Mobsby and Curtotti 2021). The growing significance of Australian cultured abalone reflects trends discussed in the literature (Cook 2014).

However, a search for aquaculture production volumes for comparable years with wild-harvest volumes (Section 4.2, Table 13) yielded limited results, as indicated in Table 25. Production volumes were either preliminary (Stevens, Mobsby and Curtotti 2021) or notional indications of operating capacity, rather than actual production figures, on aquaculture firm websites (see Table 25). Thus, distribution figures could not be accurately deduced in the desktop review based on extant data and this is highlighted in the preliminary supply chain maps as requiring further confirmation in Phase A. The lack of distribution data that was yielded in this desktop review reflects a lack of knowledge in the literature of recent trends (i.e. 2018-2022) in Australian abalone export and domestic markets (Gordon and Cook 2004; Mayfield et al. 2012).

Table 25. Australian abalone aquaculture production volumes (2019-20).

Active Farms by State		**Estimated Aquaculture Production Volumes (tonnes)**
New South Wales	0	Nil
South Australia	1	285 *p*
Tasmania	3	264 *p*
Victoria	2	≤ 250 *
Western Australia	1	≤ 100 *

p = preliminary figures from Stevens, Mobsby, and Curtotti (2021)
* = estimates based on company websites (888 Abalone n.d.; Yumbah Aquaculture 2021)

Overall, the desktop review confirmed three major gaps in publicly available knowledge on the distribution of Australian abalone for the purposes of supply chain mapping and quantifying food waste at a micro-level that was discussed in Sections

1.1.2 and 1.1.4. Firstly, the provenance of abalone is not reported in export data, including the proportions of species exported (ABS 2021). Secondly, the ABS (2021) export data do not distinguish between whole and shucked, meat-only abalone products; making it difficult to extrapolate shell and shucking volumes from existing datasets (see Table 26). Thirdly, no domestic sales data have been published and cannot be accurately deduced from existing secondary data.

Table 26. The relationship between the ABS export data product classifications, product formats found in this desktop review, and the icons used in the preliminary supply chain maps. Adapted from: ABS (2021, 2006).

ABS Classification	Product Formats Included	Icon in Preliminary Supply Chain Maps
Live, fresh or chilled abalone (*Haliotis spp.*), whether in shell or not	• Live, whole abalone • Shucked, chilled abalone meat	Live, fresh or chilled *Storage = holding tanks; ice slurry*
Frozen abalone (*Haliotis spp.*), whether in shell or not	• IQF, whole abalone • IQF, meat only	Frozen *Storage = freezer*
Abalone (*Haliotis spp*.), whether in shell or not, frozen, dried, salted, in brine or smoked, whether or not cooked before or during the smoking process	• Canned meat • Retort meat • Dried meat • Other cooked/dried products – e.g. salt flakes	Prepared, preserved, dried *Cool, dry storage*

From a supply chain perspective, these data gaps are of concern given the high-value and heavily-regulated nature of an industry that is experiencing economic decline and mounting competition from aquaculture products. Arguably, improved reporting and knowledge can form the basis for improvements or ongoing management of government policies that affect the wild-harvest industry's product flows and volumes, activities, and in turn, financial performance. For instance, a study by Hoshino et al. (2015) suggested that wild Australian abalone are relatively substitutable with aquaculture product in Japan – one of the major export markets of Australian abalone. Hoshino et al. (2015) conjectured that the restrictions on wild-harvest production may have negative economic consequences for the fishery in the long-term; but these assertions would be difficult to assess at a national-level without clear delineation between wild-harvest and aquaculture products in government export data.

The ABS classifications of abalone products will be discussed briefly before closing this section of the findings. In each of the preliminary supply chain maps, abalone products (listed in Section 4.3) are illustrated as flowing through three categories in a storage and distribution phase. Pictured in Table 26, the storage and distribution categories are represented by a labelled triangle symbol that has been adapted from Value Stream Mapping (Rother and Shook 2003). The three categories are based on ABS product export classifications (ABS 2021, 2006). Although the ABS (2021) export data was not sufficient to deduce wild-harvest distribution volumes, it was still important to ground the supply chain maps in existing frameworks and data, as part of a practical, evidence-based approach.

In sum, it was not possible to determine the domestic and export distribution volumes for Australian abalone products owing to the lack of secondary data. In turn, it was neither possible to extrapolate the types of products produced at the processing stage, nor to determine how much shell and shucking waste is generated along the supply chain. Furthermore, knowledge of domestic sales data, had it been available, would have indicated the amount of shell and shucking waste generated at downstream supply chain stages within Australia from the consumption of live abalone and whole-in-shell products (e.g. from catering, hospitality, tourism, households). The latter is pertinent given the definition of food waste adopted in this research (Section 1.2), which includes food waste produced at all stages of the supply chain within Australia and excludes any food that is exported. Altogether, the findings of this desktop review confirmed the need for further research into supply chain practices and product flow in Australian abalone fisheries.

4.6 Preliminary Supply Chain Maps

In the initial research design (Section 3.3), it was anticipated that there would be sufficient publicly-available secondary data to create preliminary, evidence-based supply chain maps at the end of the desktop review that would more clearly define the food waste management problem at hand. However, as explained in the preceding sections of this chapter, several secondary data gaps and a lack of clear reporting were principal barriers to defining the food waste management problem and accurately mapping the supply chains in the first place. Thus, the preliminary supply chain maps that were created and presented in Sections 4.6.1 to 4.6.5 ultimately served the dual purposes of: (1) highlighting the numerous gaps in publicly available knowledge about food waste in each supply chain; and (2) acting as a stimulus for participants to discuss product flows, and food waste management practices in the following phase of the research (Phase A 'QUAL') to elicit the data required to address the research questions.

Individual preliminary supply chain maps were created for each species and on a state-by-state basis, resulting in a total of 10 maps. The preliminary supply chain maps presented in this section were created based on the best available evidence discussed in this chapter, and notably, signpost the gaps in knowledge that were identified throughout the desktop review. For instance, unknown information requiring confirmation by participants are signposted in red text and the many assumptions that were made (also requiring confirmation or clarification by participants) are signposted in green text (see Figure 27). In this way, the preliminary nature of the supply chain maps are highlighted clearly, as are the requirements for more sufficient data.

LEGEND

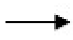
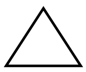
Red text	= more information required		= supply chain activity, actor, or location
Blue text	= general information and notes to clarify map		= flow of product and volume
Green text	= assumptions made where data was missing		= product or by-product from processing stage

Figure 27. Legend for the preliminary supply chain maps presented in Sections 4.6.1 to 4.6.5.

Despite the data gaps, current data and knowledge concerning Australian abalone fishery practices and product flows has not been done previously in the literature. The full suite of conventions (Section 3.6.2) was not used in this phase of the research because some of the conventions illustrated in Section 3.6.2 were not devised until after important themes emerged in Phase A. The remainder of this section is dedicated to presenting the preliminary supply chain maps.

4.6.1 New South Wales

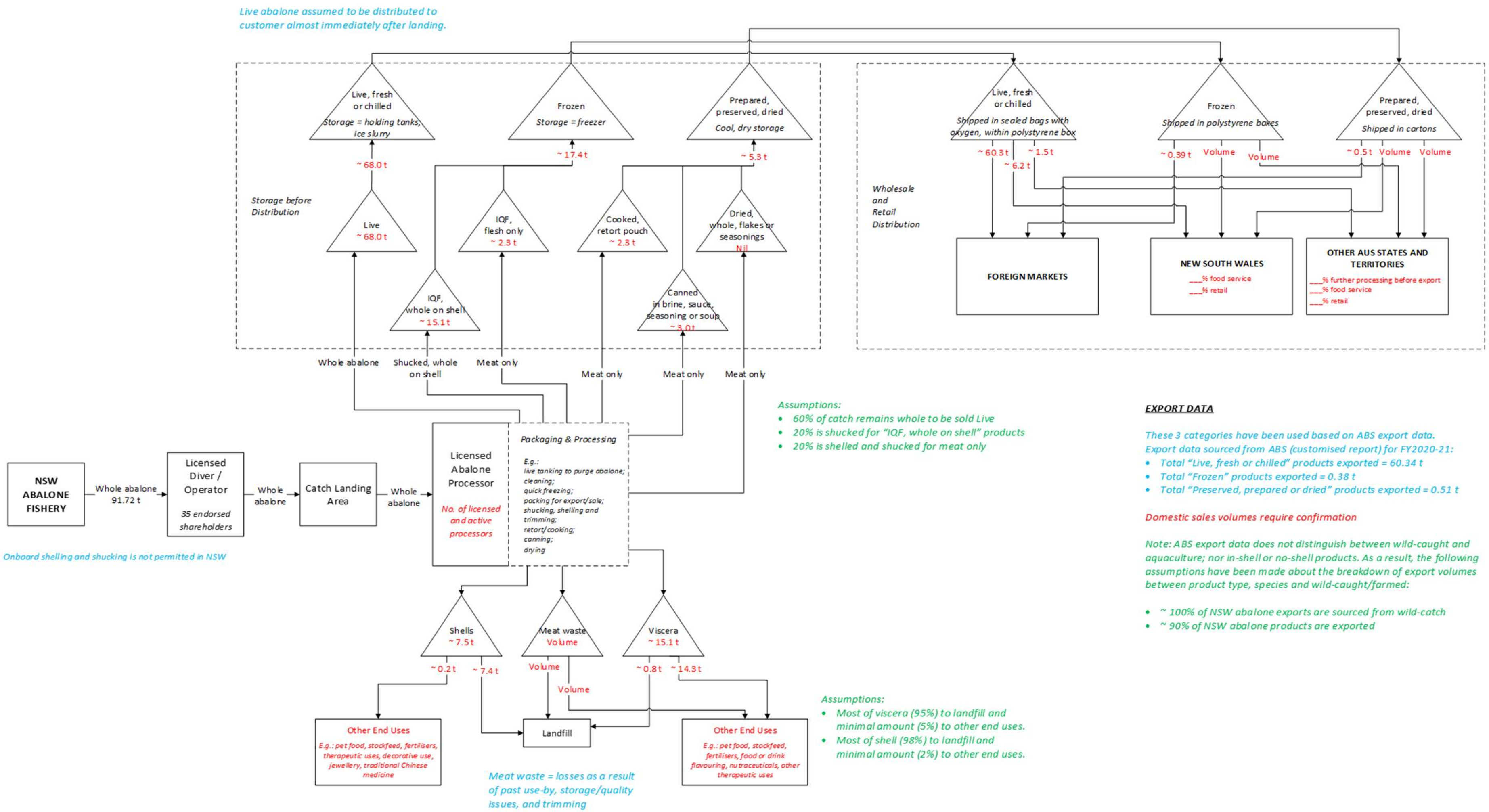


Figure 28. Preliminary supply chain map of the New South Wales Blacklip fishery, 2021 fishing season.

4.6.2 South Australia

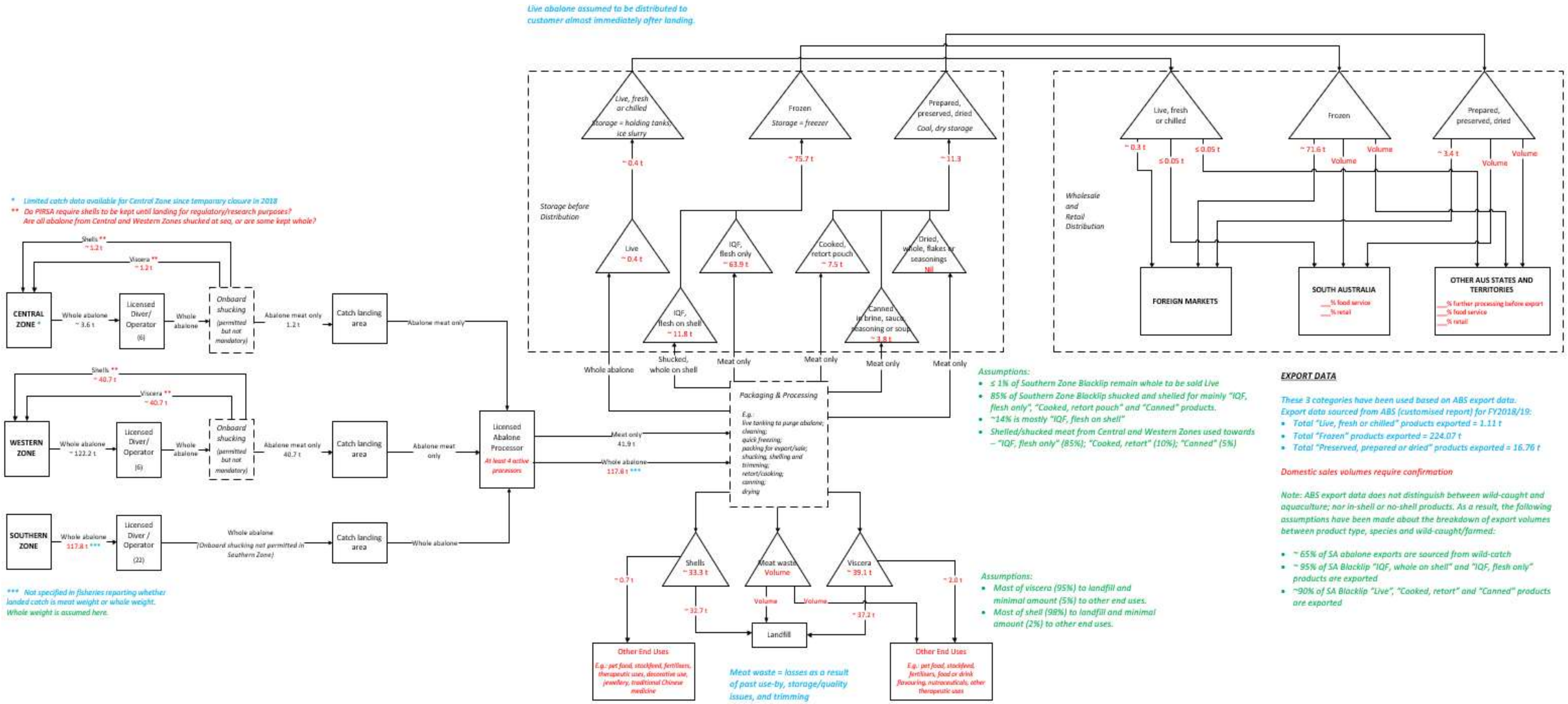


Figure 29. Preliminary map of South Australia's Blacklip abalone supply chain, 2020 fishing season.

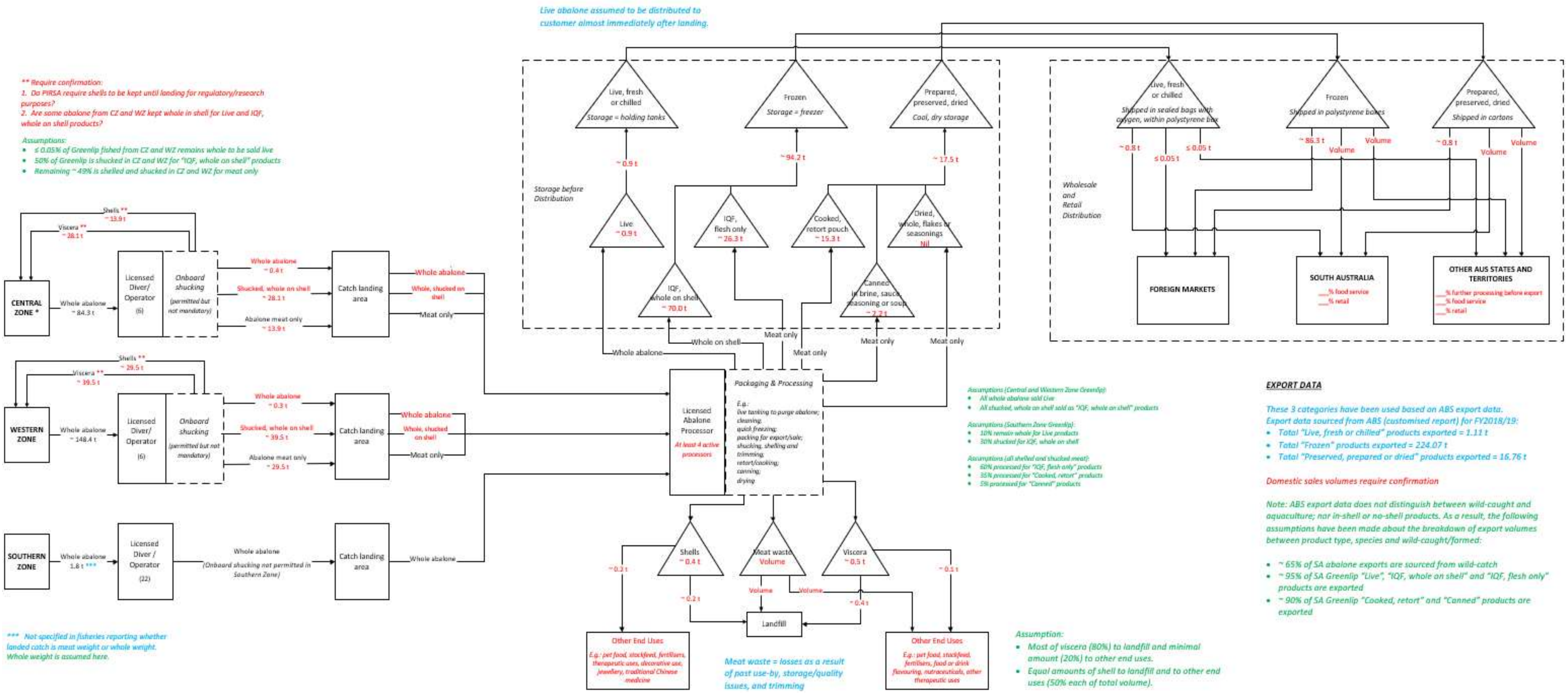


Figure 30. Preliminary map of South Australia's Greenlip supply chain, 2020 fishing season.

4.6.3 Tasmania

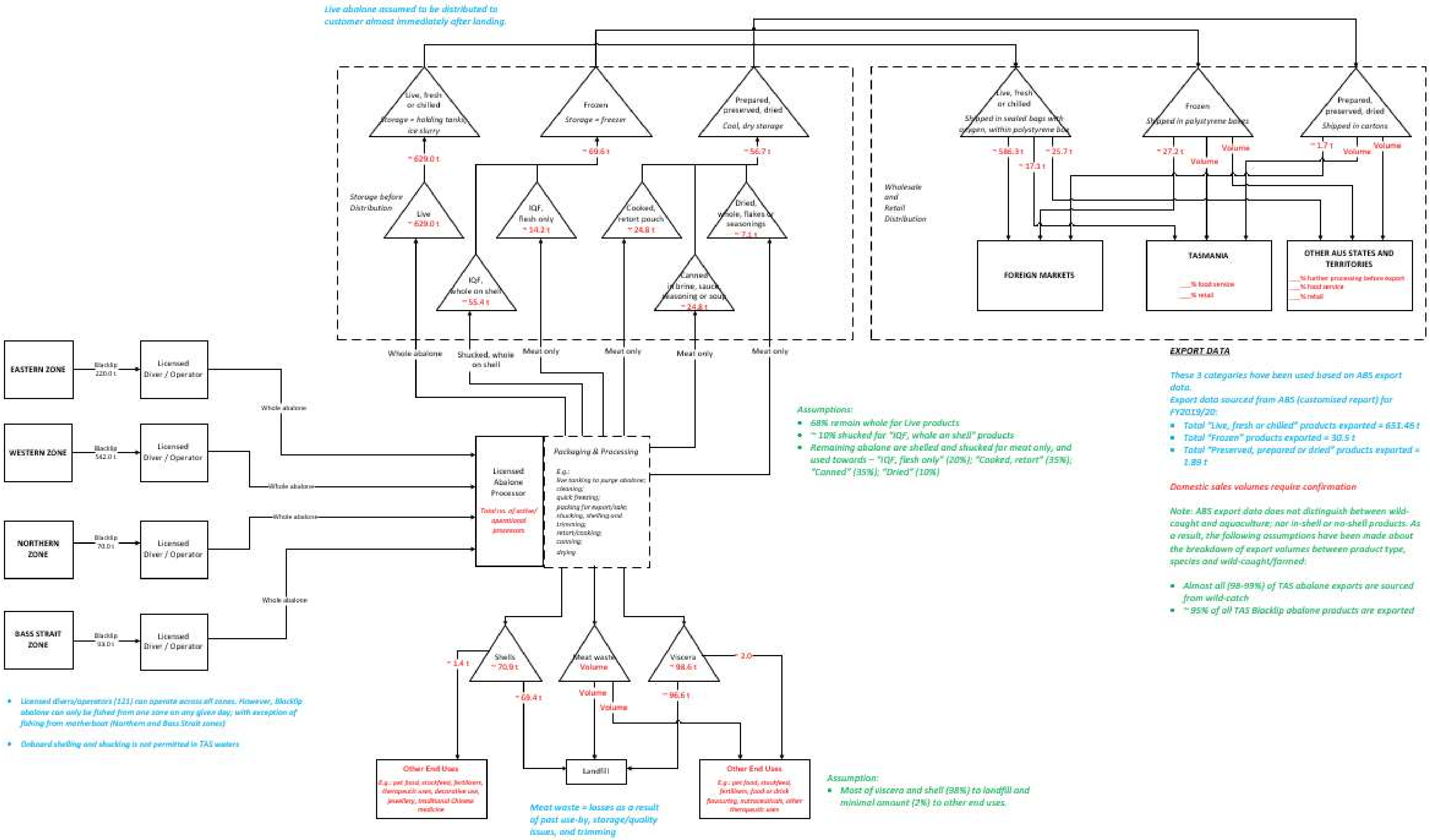


Figure 31. Preliminary map of Tasmania's Blacklip supply chain, 2020 fishing season.

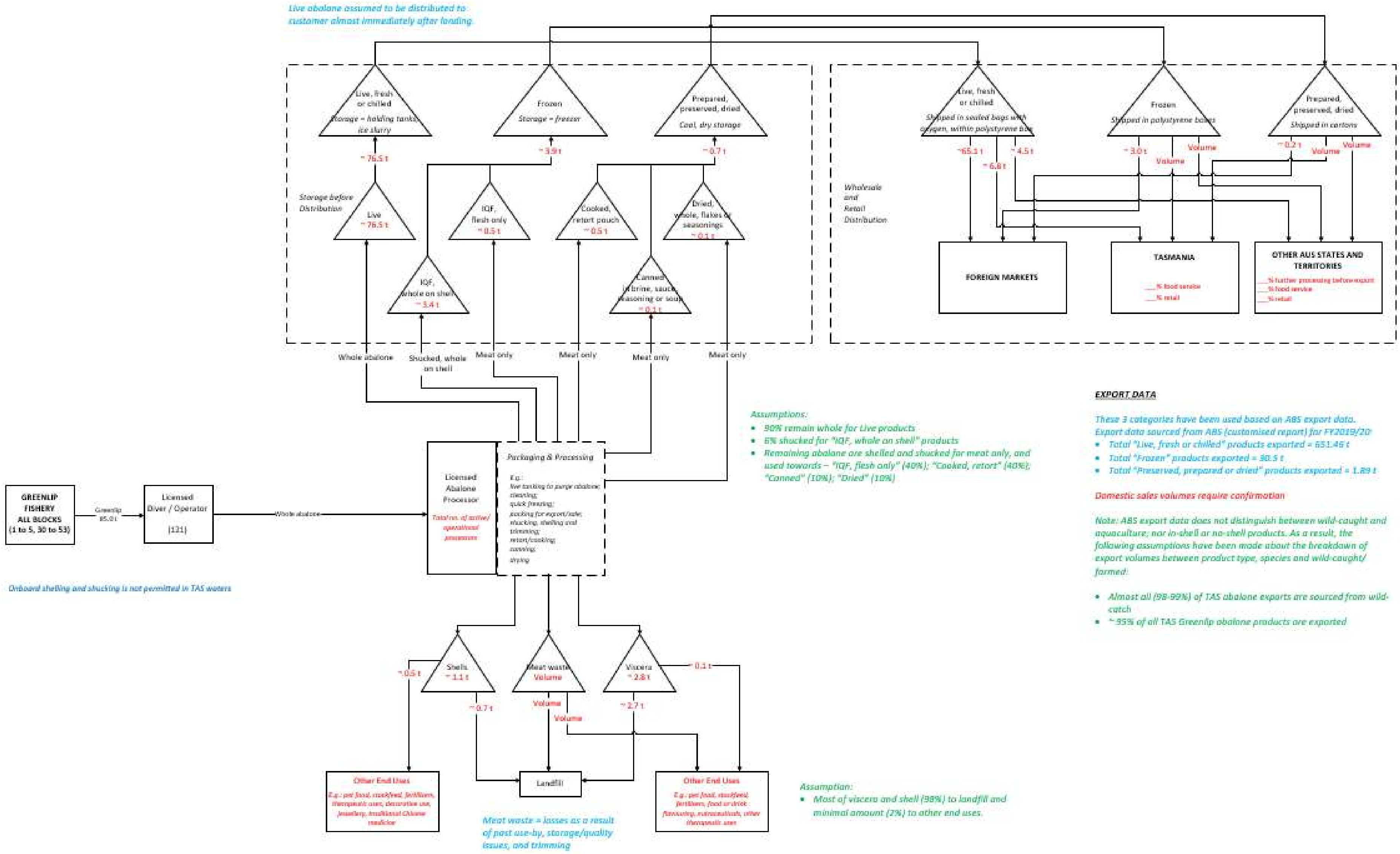


Figure 32. Preliminary map of Tasmania's Greenlip supply chain, 2020 fishing season.

4.6.4 Victoria

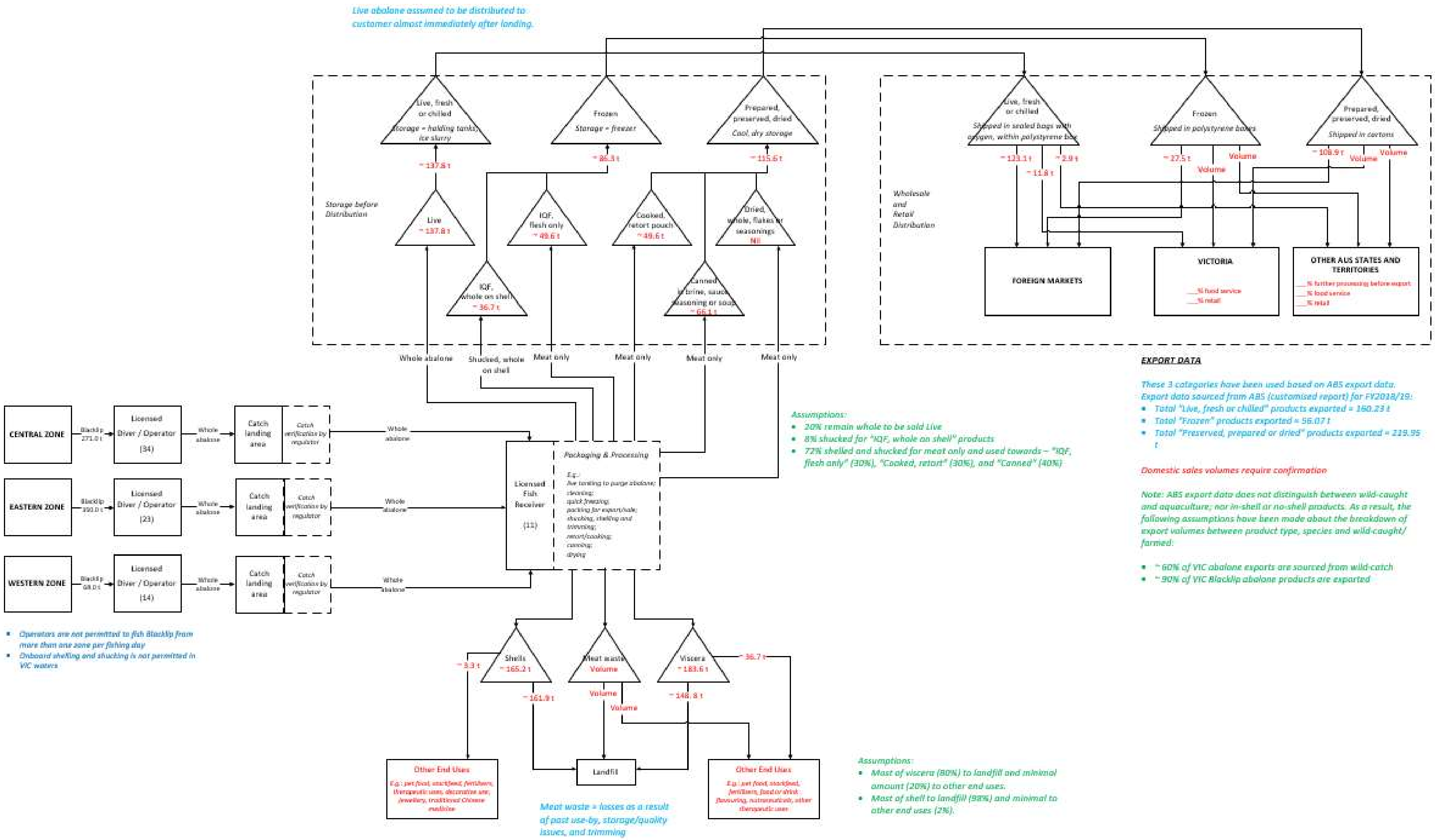


Figure 33. Preliminary map of Victoria's Blacklip supply chain, 2019 fishing season.

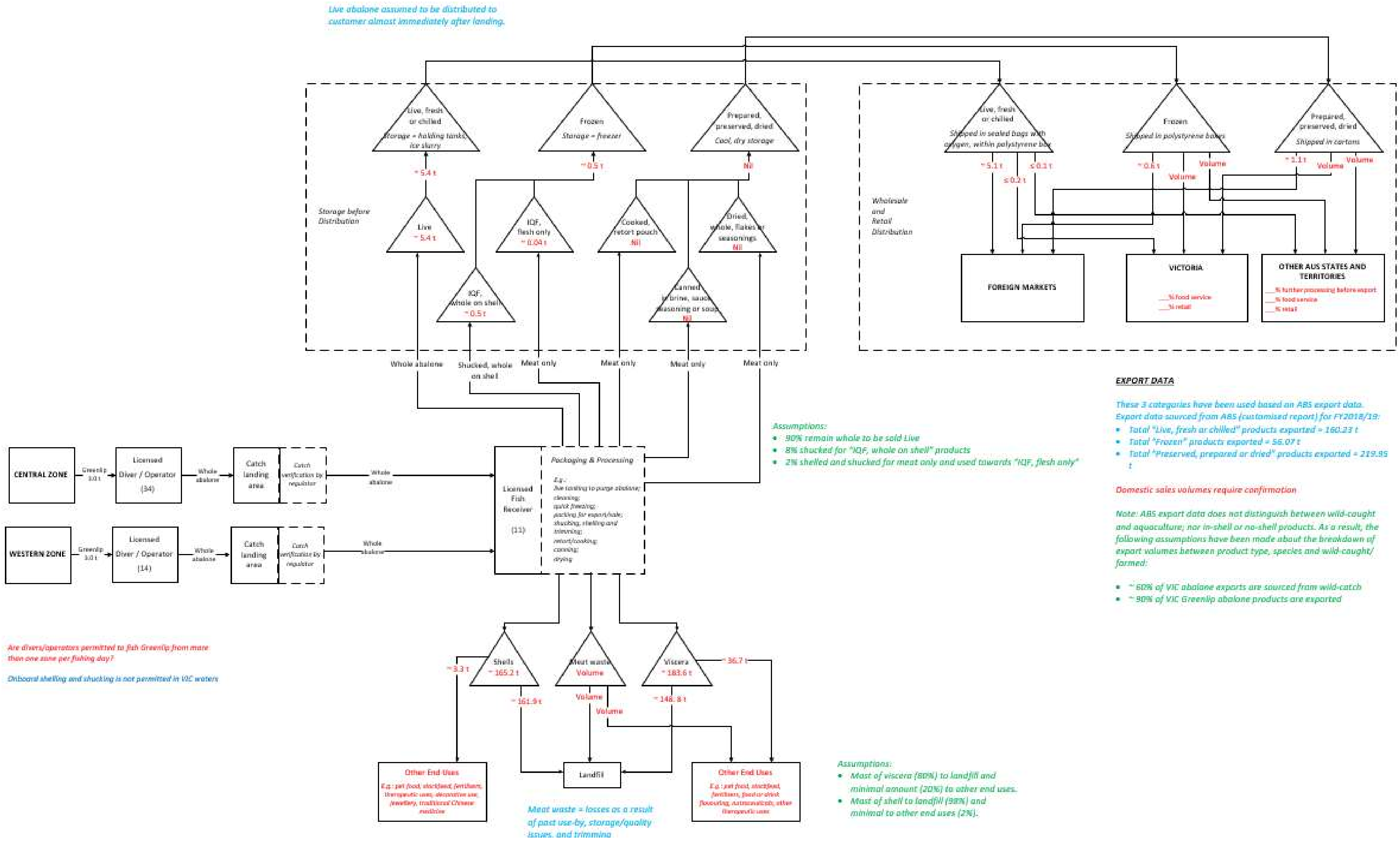


Figure 34. Preliminary map of Victoria's Greenlip supply chain, 2019 fishing season.

4.6.5 Western Australia

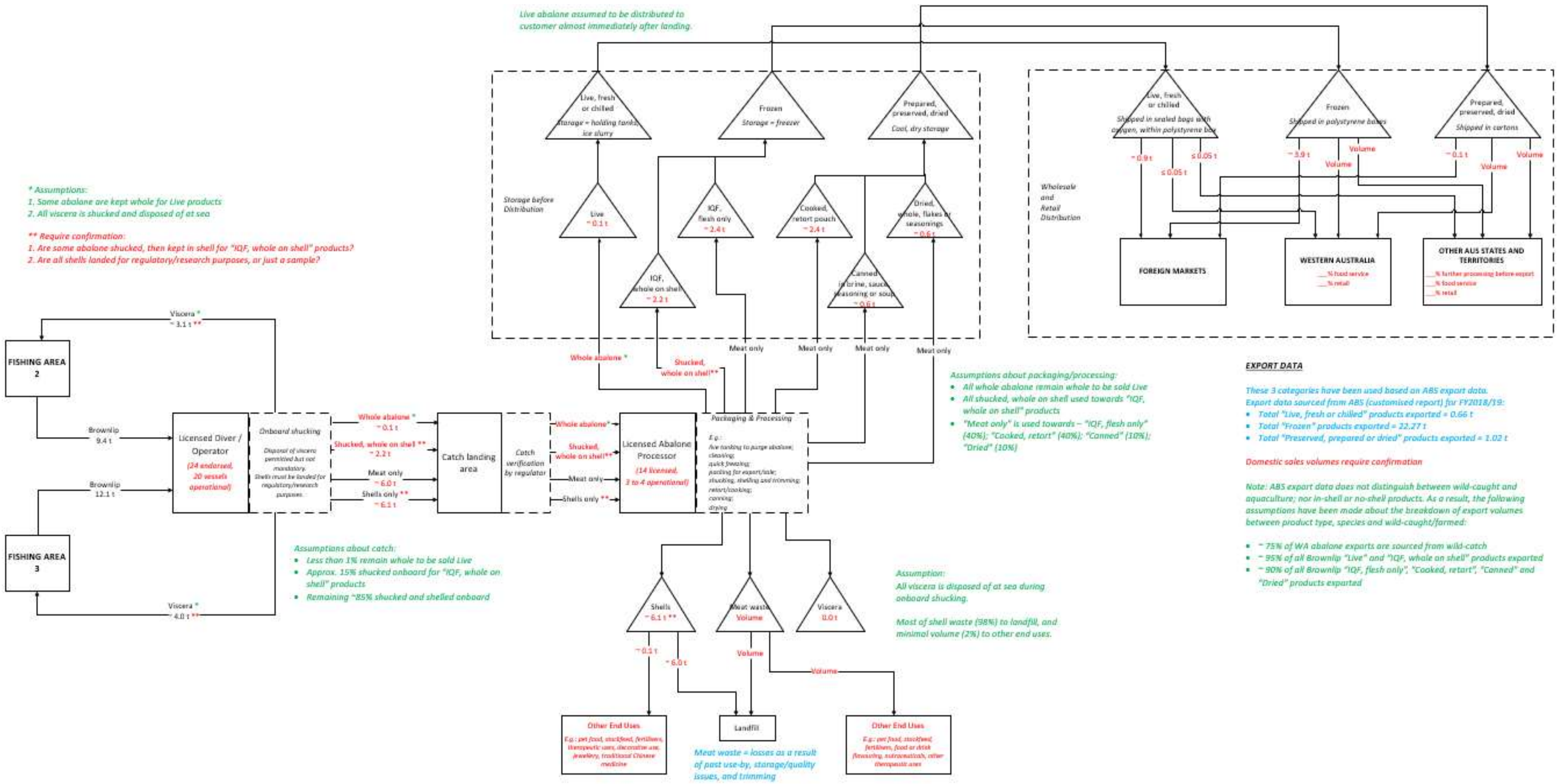


Figure 35. Preliminary map of Western Australia's Brownlip supply chain, 2019 fishing season.

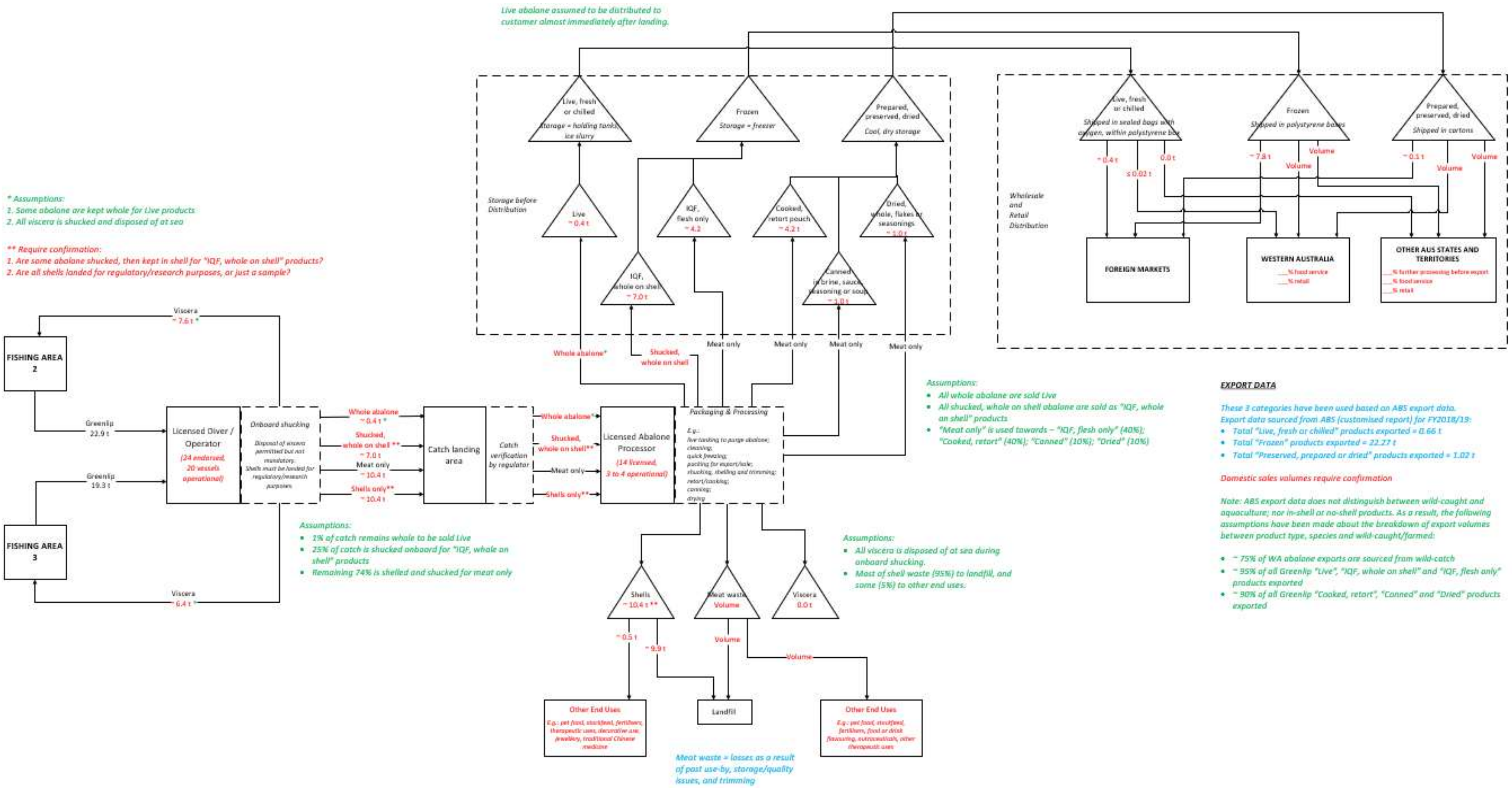


Figure 36. Preliminary map of Western Australia's Greenlip supply chain, 2019 fishing season.

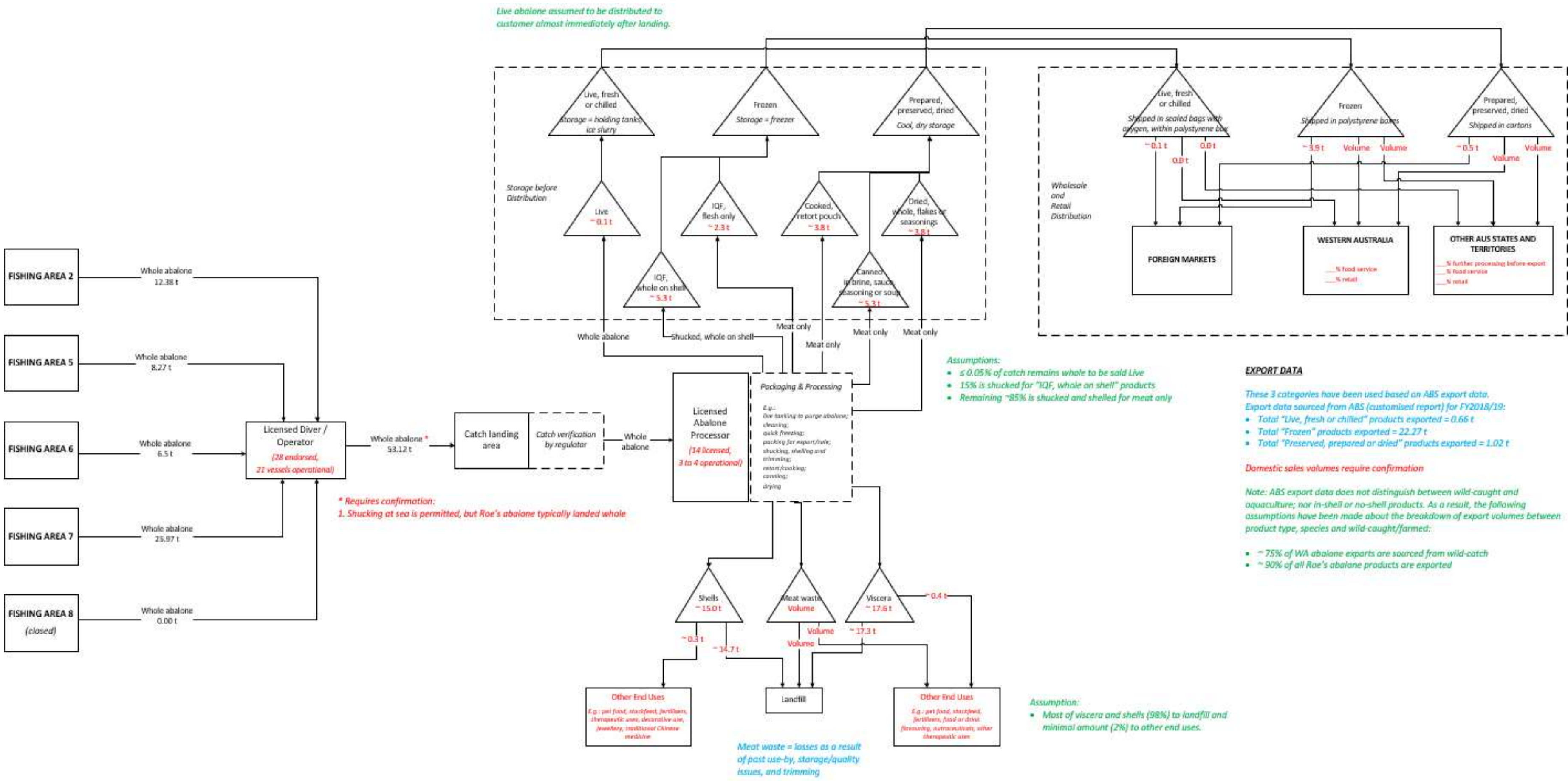


Figure 37. Preliminary map of Western Australia's Roe's abalone supply chain, 2019 fishing season.

5 DISCUSSION OF RESULTS: PHASE A (QUAL)

The results presented in this chapter begin to fill several of the data gaps that were identified in the desktop review (Chapter 4). In this chapter, the codes and four major themes that emerged from the 16 semi-structured interviews conducted in the dominant qualitative (QUAL) component of this research are presented. The thematic analysis, which was guided by Saldana's (2013) First and Second Cycle Coding framework, revealed the Opportunities and Motivations to Improve Food Waste Management (Theme 1) and Barriers to Improvement (Theme 2) in each supply chain which addresses RQ1 (Section 2.4) and details food waste management practices. The thematic analysis also yielded Strengths to be Leveraged Along the Supply Chain (Theme 3), and Systemic Forces (Theme 4) which addressed how supply chain practices might be improved (RQ2). Each theme comprised several aspects that added nuance and depth to the theme titles. These will be explored in Sections 5.3.1 to 5.3.4.

5.1 Qualitative Sample

In this section participant attributes are described to demonstrate the quality and internal validity of the sample. The final sample consisted of 16 highly-experienced industry stakeholders. The number of interviews conducted was comparable with other mixed methods and qualitative food waste studies that conducted 16 to 19 semi-structured interviews concerning food waste management practices before theoretical saturation was reached (Goodman-Smith, Mirosa and Skeaff 2020; Papargyropoulou et al. 2016). Each of the interviewees (*n*=16) possessed a minimum of 10 years' experience in the seafood industry, and an average of 23 years' experience. A profile of each participant is provided in Table 27 according to the chronological order in which the interviews occurred. As explained in Section 3.4.3 participants were each assigned a code during analysis (see Table 27). Because the participant codes are re-identifiable, and the sample population relatively small, the state fisheries to which the participants belong have not been specified in the code legend.

Table 27. Participant profiles and codes, listed in chronological order of interviews.

Interview Order	Code	Supply Chain Stage	Years in Industry	Participant Expertise
#1	FS-B1	Governance (fisheries)	≥ 12	Fisheries research, governance
#2	OP-E1	Harvest, processing, distribution, wholesale, domestic retail	≥ 40	Fishing, quota ownership, processing, market development
#3	OP-B2	Harvest, processing, distribution, wholesale	20	Abalone diving, executive management, industry representation
#4	OP-B3	Harvest, processing, distribution, domestic retail	≥ 25	Abalone diving, quota ownership, executive management, industry representation
#5	FS-E2	Governance (fisheries)	≥ 20	Fisheries and aquaculture research, governance
#6	O-A1	Harvest	47	Abalone diving, quota ownership, executive management, industry representation
#7	OP-E3	Harvest, processing, domestic retail	≥ 20	Abalone diving, quota ownership, executive management, industry representation
#8	OP-C1	Harvest, processing, distribution, wholesale	40	Abalone processing, consulting, executive management
#9	OP-E4	Harvest	≥ 35	Abalone diving, quota ownership, processing, industry representation
#10	IR-D1	Harvest, processing	2	30+ years in seafood biosecurity risk management, 2 as abalone executive/industry representative
#11	O-D2	Harvest, wholesale, domestic retail	20	Abalone diving, quota ownership, market development, stock management, industry representation
#12	OP-B4	Harvest, processing, distribution, wholesale, domestic retail	≥ 30	Abalone diving, quota ownership, processing, wholesale/retail, executive management
#13	P-D3	Processing, distribution, wholesale	≥ 30	Abalone processing, executive management
#14	OP-C2	Harvest, processing, distribution, wholesale	2	15 years as executive in seafood industry, 2 as CEO in abalone industry
#15	ME-1	Downstream	≥ 10	Premium food marketing including abalone, market development
#16	OP-A2	Harvest, processing, distribution, wholesale	≥ 20	Abalone diving, quota ownership, processing, wholesale, market development, executive management
FS = fisheries scientist IR = industry representative ME = marketing expert O = quota owner/operator P = processor OP = vertically integrated quota owner/processor				

Of the total sample, 87% (*n*=14) held a range of 10 to 47 years' experience specific to the abalone industry. Participants IR-D1 and OP-C2 were experienced in other seafood industries but had worked for only two years each in the abalone industry at the time they were interviewed. Nonetheless, these two participants were able to provide valuable insights specific to business practices and other themes relevant to the research.

In terms of gender, the sample was heavily skewed towards male participants (*n*=14, 88%). This is reflective of the wider population, as confirmed by interviewees in the snowball sampling process. IR-D1 said, *"There's not a lot of females in the abalone* *industry because not many of them go diving."* Attempts were made to recruit additional female participants, but with little success (Appendix D). Additionally, it was determined that representation of market share, experience diving and processing, and years spent working in the industry were more appropriate attributes to seek in participants rather than gender.

The final sample can be characterised by two categories or 'sampling schemes', as shown in Figure 38: typical cases and critical cases (Onwuegbuzie and Collins 2007; Teddlie and Tashakkori 2009). Papargyropoulou et al. (2016) employed a similar sampling scheme in the qualitative component of their mixed methods food waste study; albeit interviewing 16 typical cases and 3 critical cases. 'Typical cases' are selected for their ability to provide insights and knowledge on norms or the average experience; whereas 'critical cases' are selected because they fall outside the norm, but possess specific characteristics that allow them to provide compelling insights on a phenomenon of interest to the researcher (Creswell 2009; Onwuegbuzie and Collins 2007). In the case of this research, typical cases were selected for their knowledge of abalone supply chains, fishing, and processing practices. Critical cases were included in the sample because of their knowledge of biosecurity risks of shucking at sea practices (fisheries scientists, *n*=2), and to provide market development insights (premium food marketing expert, *n*=1).

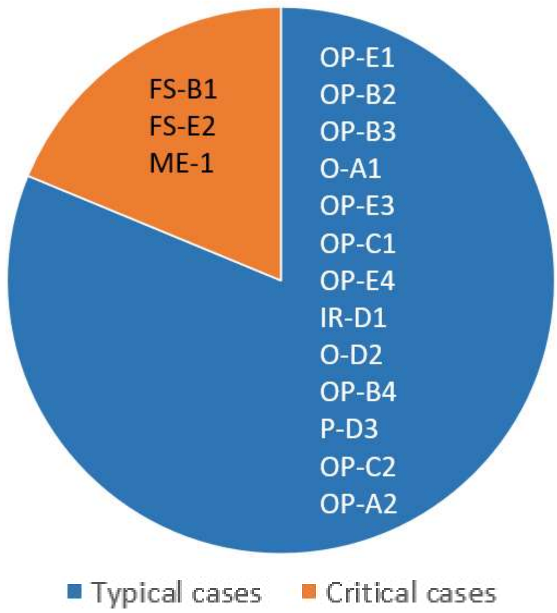


Figure 38. Grouping of participants according to the 'typical case' and 'critical case' sampling schemes.

Notably, operator-processors ('OP') emerged as a significant group amongst typical cases (*n*=8) compared to other groups such as operators (*n*=2), processors (*n*=1), and industry representatives (*n*=1). The breakdown of typical cases according to supply chain role or stage is presented in Figure 39. Operator-processors were supply chain actors whose businesses or employers were vertically-integrated across quota ownership, fishing, and processing activities. Thus, these individuals could provide in-depth insights into both primary production and processing stages. Given the market share of the participants, the relatively high representation of operator-processors in the sample is indicative of the population overall.

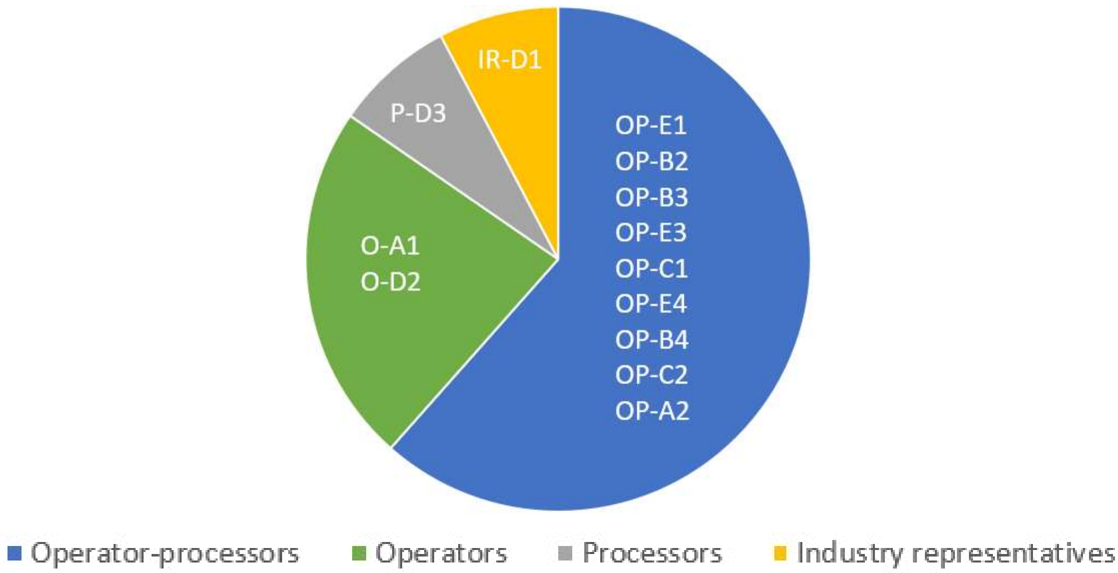


Figure 39. Grouping of typical cases according to their specific supply chain roles or stages.

Overall, the typical cases consisted of:

- Small and medium-size enterprise (SME) owner-operators who had an average of 30 years' experience in abalone quota ownership, fishing, and processing (62%, *n*=8); and,
- Executive managers employed by major abalone fishing and processing firms with an average of 19 years' experience in the abalone industry (38%, *n*=5). Typically these individuals had worked for several years as divers or processors across various firms before holding an executive position. Thus, they possessed strong working knowledge of supply chain practices and business operations.

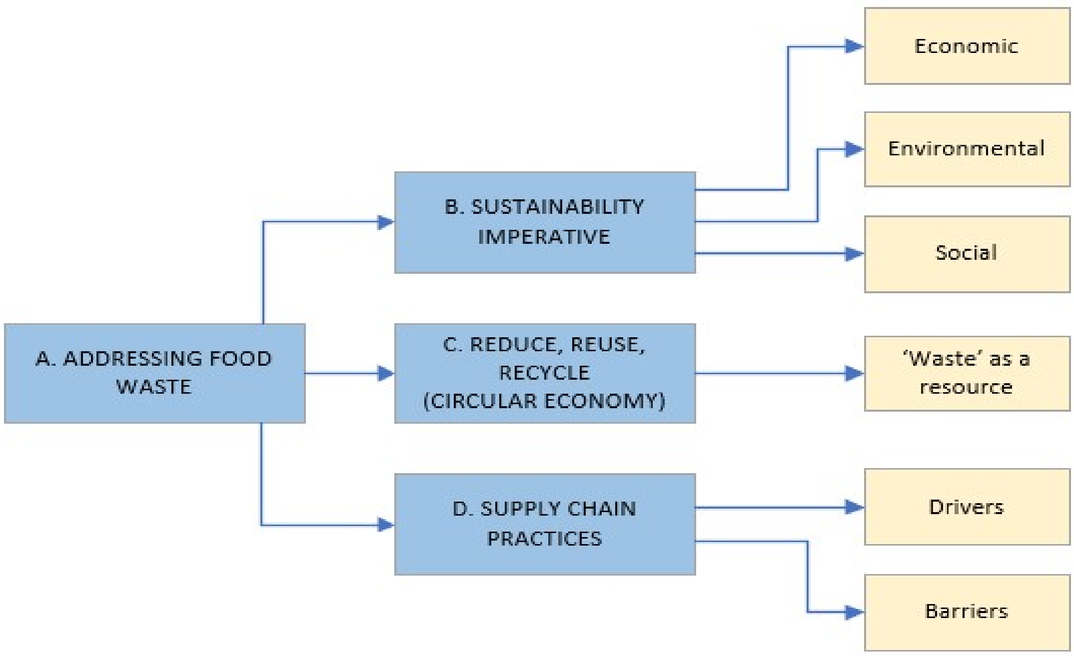
5.2 Codes from First Cycle Coding

This section focuses on the coding outcomes of the First Cycle coding of the interview data, which led to the point of theoretical saturation. As explained in Section 3.4.4, the objective of First Cycle Coding was to label (‘code’) passages of data until no significantly new codes could be elicited from participants’ responses and theoretical saturation, defined by Morse (1995), was reached. In the coding process several techniques (e.g. *in vivo* coding, initial coding) adapted from grounded theory were used to generate meaning and group codes from the interview data (i.e. into parent codes and subcodes) that, in turn, addressed the research questions.

The semi-structured interviews (*n*=16) took place over six months (May 30, 2022 and November 18, 2022) and data analysis occurred in tandem with the interviews. Following the qualitative sampling frame that was developed prior to data collection (Section 3.4.1), an initial set of typical cases were interviewed from each state fishery based on expert recommendation by the Abalone Council of Australia Ltd. (*n*=5); and critical cases were recommended by the Western Australian and South Australian fisheries departments (*n*=2). Subsequent typical and critical cases were identified and interviewed based on snowball sampling until themes began to recur with no significant new information emerging from participants. This was the point theoretical saturation was reached, as defined by Morse (1995).

Critical case ME-1 posed an exception to the theoretical saturation that was determined amongst the other participant responses. Theoretical saturation was not reached where market development insights were concerned. Attempts were made to recruit more participants who could speak to this emergent theme (Appendix D). However, owing to concerns about commercially-sensitive information amongst potential participants, recruitment was unsuccessful within the designated data collection timeline.

As explained in Section 3.4.4 an initial set of codes (presented in Figure 40) based on themes and theory from the literature review was devised. This was disseminated to the research team to encourage theoretical reflexivity while coding. This initial set of codes (Figure 40) evolved rapidly by the time the first few transcripts were analysed. Unexpected topics raised by participants, and not previously identified in the literature review, informed several of the codes that led to the themes developed later on. The literature was revisited and compared to the qualitative results; and will be discussed in the following section in relation to the themes. In this way, the coding process was faithful to a grounded theory approach (Bryant and Charmaz 2007).



A. Batista et al. (2021); Gustavsson et al. (2011)
B. Amicarelli, Roe, and Bux (2022)
C. Chiaraluce, Bentivoglio, and Finco (2021); de Oliveira, Lago, and Dal' Magro (2021)
D. Ada et al. (2021); Anastasiadis, Apostolidou, and Michailidis (2020); Aschemann-Witzel et al. (2017); Batista et al. (2021); Göbel et al. (2015)

= Themes and theory from literature   = Codes

Figure 40. Initial set of codes devised based on themes and theory from the literature review, displayed as a conceptual framework.

To build internal validity in the data analysis, two intercoder meetings were held with the research team over the course of the six-month data collection/analysis phase. Intercoder agreement (explained in Section 3.4.4) was reached on 26 of 29 codes (90%) at the first meeting (August 8, 2022). By the end of the second meeting (November 3, 2022) 34 of 37 codes (90%) were agreed upon.

At the point of theoretical saturation, 37 codes had been developed (10 categories or 'parent codes', 27 subcodes). A full list of these codes is presented in Appendix G with representative data indicating the meaning of the codes. No new codes were developed following the eleventh interview with a typical case (Interview #13, P-D3). However, two further interviews with typical cases were conducted to ensure that theoretical saturation had been reached. Once theoretical saturation was reached, Second Cycle coding began and themes were developed from the First Cycle codes.

5.3 Themes from Second Cycle Coding

In the Second Cycle of coding the First Cycle codes were refined and broader themes were developed. As recommended by Miles and Huberman (1994) and Saldana (2013), the Second Cycle coding process involved: (1) the use of visual displays to delimit codes by identifying patterns in the data; and (2) the subsequent construction of themes resulting from the identified patterns and delimited codes. To delimit the codes the research questions and objectives were considered. In this way, the most salient data were elicited from the abundance of insights that were collected from the 16 interviews.

Additionally, Saldana's (2013) methods for eliciting a narrative from the data using a 'top 10 list' was employed to aid a narrative approach to devising the themes. In this method, 10 of the most salient passages of data are selected by the researcher. In this case, the 10 passages were selected and placed in a separate Word document. Saldana (2013) suggests the passages are re-arranged, one after another, thereby enabling the researcher to make sense of how the data points connect to one another in a narrative manner. Some methods have been discussed here since it was not possible to determine prior to the data collection, the specific thematic analysis techniques that would be required to construct themes from the data (Saldana 2013). Further adding to the bricolage of techniques (Section 3.4.4), a visual display was used to distil the codes into salient themes that would address the research questions. Figure 41 was devised based on the central tenets of this research: the research questions and supply chain mapping.

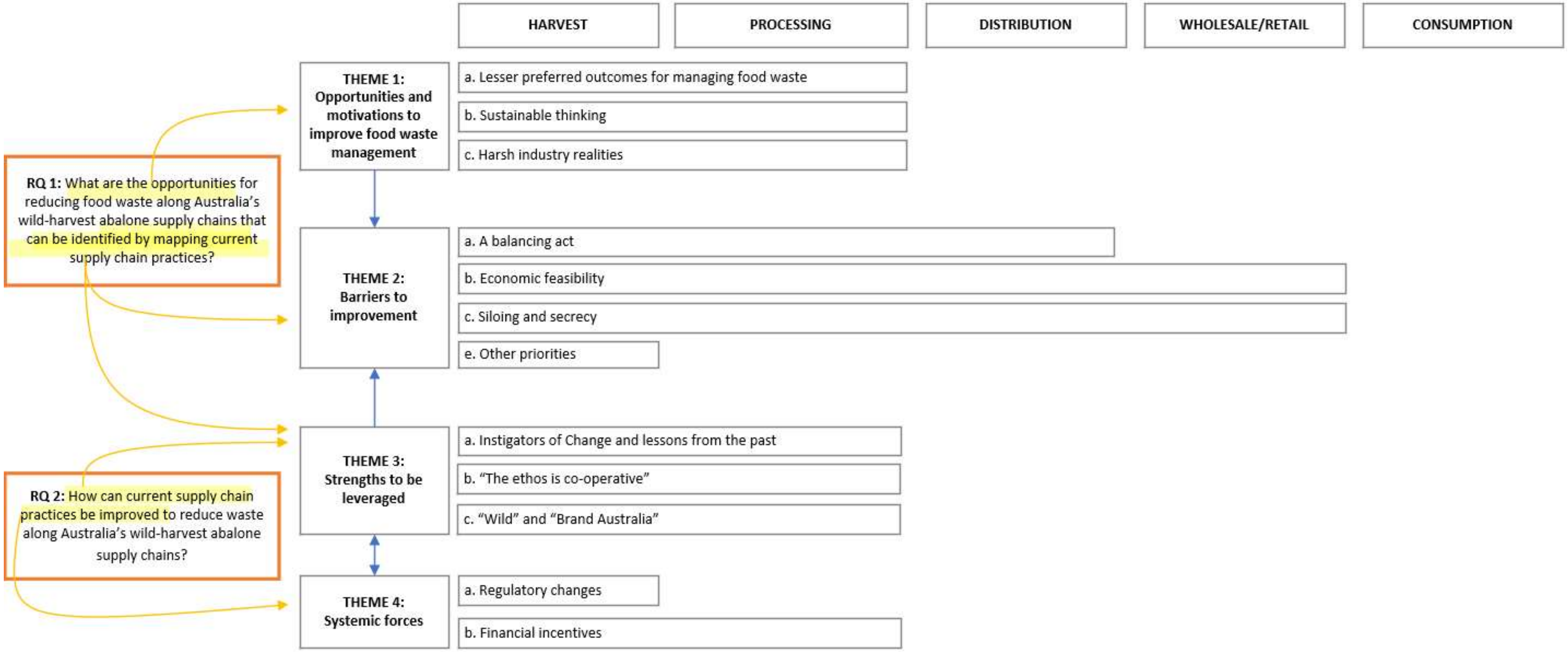


Figure 41. Visual display summarising the themes which relate directly to the research questions.

Figure 41 shows how the themes directly address the research questions; and, in turn, how various aspects of each theme relate to stages of the supply chain. Being interconnected in several ways, the themes are not necessarily linear; and it is possible to explain and present them in many ways. Nevertheless, the themes have been visualised in Figure 41 in the most linear fashion possible to ensure that the written explanation of the themes in Sections 5.3.1 to 5.3.4 will unfold with clarity. The blue arrows connecting the themes show Opportunities and Motivations to Improve Food Waste Management (Theme 1) are met with several Barriers to Improvement (Theme 2). However, there are several existing Strengths to be Leveraged Along the Supply Chain (Theme 3) as well as Systemic Forces (Theme 4) that could potentially be employed to foster changes to supply chain practices and, theoretically, reduce food waste.

A summary of the number of participants that contributed to each theme is presented in Figure 42.

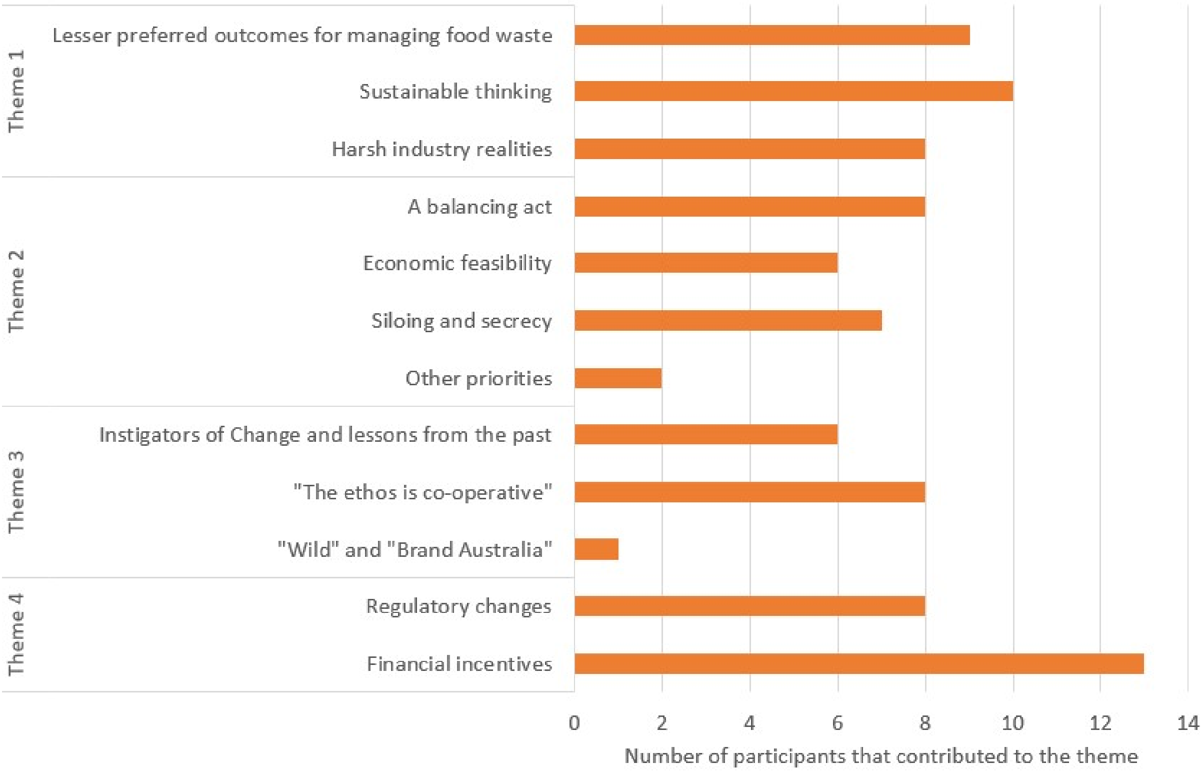


Figure 42. Summary of themes and participant mentions.

Similar themes about motivations and barriers to reducing food waste have been found in other qualitative and mixed methods food waste studies (Beausang, Hall and Toma 2017; Goodman-Smith, Mirosa and Skeaff 2020; Graham-Rowe, Jessop and Sparks 2014; Papargyropoulou et al. 2016). However, the focus in these studies has been on downstream, consumer, retail, and household food waste behaviours or practices; as opposed to upstream segments of the supply chain that were focused on in this research.

Qualitative studies conducted on the drivers of food waste in primary production or post-harvest processing segments of the supply chain are few but increasing in number (Batista et al. 2021; Beausang, Hall and Toma 2017; Herzberg, Trebbin and Schneider 2023). Batista et al. (2021), Beausang, Hall and Toma (2017), and Herzberg, Trebbin and Schneider (2023) explore food waste a supply chain perspective and using a qualitative approach; but focus on fruit and vegetable supply chains. From this perspective the research has addressed a major gap in the literature by reporting insights of primary producers and processors belonging to economically-significant seafood supply chains in Australia, which arguably, have different logistic and waste management concerns to contend with compared to fruit and vegetable producers. Furthermore, despite the value of their proposed framework, Batista et al. (2021) did not attempt to connect an in-depth qualitative analysis of the supply chain (e.g. governance, firm structure) with stakeholders' motivations and barriers to prevent or reduce food waste as the themes in this research have achieved. By suggesting a link between supply chain governance and structures, and supply chain actors' motivations and challenges to improve their waste management practices, the conclusions of this research have extended the framework proposed by Batista et al.'s (2021).

The focus on the perspectives of upstream agrifood supply chain stakeholders in a high-income country also addresses a prominent gap in the literature (Kafa and Jaegler 2021; Parfitt, Croker and Brockhaus 2021). While the motivations and barriers of reducing food waste amongst consumers (Karunasena, Ananda and Pearson 2021; Nabi, Karunasena and Pearson 2021; Papargyropoulou et al. 2016) and retailers (Goodman-Smith, Mirosa and Skeaff 2020; Huang et al. 2021) are well-documented, the primary producers and processors in this research expressed different concerns within the four themes compared to participants in downstream food waste studies.

The remainder of this chapter is dedicated to discussing the four themes and the various aspects of each that were presented in Figure 41 and how they compare with current knowledge.

5.3.1 Theme 1: Opportunities and Motivations to Improve

Although RQ1 is limited to *opportunities* to reduce waste, it emerged from the data that *motivations* were equally important and intertwined with opportunities. Thus, the first theme explored herein is the ‘opportunities and motivations to improve’ supply chain practices to reduce waste. The connection between opportunities and motivations to reduce food waste have rarely been commented upon in the literature, particularly from a primary production perspective (Beausang, Hall and Toma 2017; Goodman-Smith, Mirosa and Skeaff 2020; Thorsen, Mirosa and Skeaff 2022).

Lesser Preferred Outcomes for Managing Food Waste

This aspect of Theme 1 directly addresses RQ1, by identifying the opportunities to reduce waste in Australian abalone fisheries. The food waste management practices discussed in this aspect of Theme 1 are presented according to the ranking of ‘preferred outcomes’ modelled on the food waste hierarchy proposed by Garcia-Garcia et al. (2017) (see Figure 13, Section 2.2.8), beginning with the lesser preferred outcomes since these are the primary focus of improvements to waste management in this research.

In particular, participants from South Australia, Victoria, and Western Australia described practices that would be classified as lesser preferred outcomes for managing food waste according to the food waste hierarchy (Section 2.2.8). For instance, FS-E2 confirmed of the majority of shells harvested Western Australia: “*I’ve seen plenty of piles [of shells] at tips or in paddocks, or people’s driveways*”. While OP-B2 said of their business: “*We also have 88 tonnes of viscera that doesn’t even make it to shore, and [of] 88 tonnes of shell probably 50, 60-plus tonnes stays in the water, too.”* Finally, P-D3, a stalwart of the abalone industry, confirmed other major processors in the state also send their viscera to landfill: "*I do know that [Processor P] up until just lately, they haven't been saving their gut. [Processor S] don't [save theirs either]"*. (Incidentally, processors' company names have been redacted and replaced with codes – for example, Processor P, Processor S and so on – to protect the anonymity of participants and commercial information. A list of processor codes is provided in Appendix H). Overall, lesser preferred outcomes for managing food waste described by several operators and processors belonging to these states (*n*=9) included landspreading, landfilling, and disposal at sea.

Participants largely commented on the outcomes of abalone shell and viscera by-products but also mentioned the blood component. The mention of blood by participants was not anticipated given the information yielded from the desktop review, which did not indicate that blood was a noteworthy by-product of abalone processing. On the whole, participant responses indicated that in areas where shucking at sea is permitted (South Australia's Western and Central Zones, Western Australia's Area 2 and 3), abalone meat is typically drained of blood to produce 'fully bled' meat products which are considered more desirable by knowledgeable customers and consumers.

> *"We refer to our product from a shucked-at-sea fishery as a fully bled product, because it's shucked live more blood comes out. Whereas most fisheries in Australia when the animal is delivered whole and it's shucked the next day or that night, more of the blood stays within the animal - within the muscle. … That's something that sophisticated consumers are aware of, particularly chefs." (OP-B2)*

In other fishing zones where shucking at sea is not permitted, the blood remains within the meat or is unintentionally bled during processing. P-D3 commented that in the canning process, blood is incidentally drained as a result of rumbling (i.e. where abalone are placed in a machine that simultaneously cooks and trims the meat): *"[The blood] really does drain out as they're being shucked. And a lot of it's squeezed out in the rumbler as well. So there's a lot of blood in the tissues and that all comes out as you're preparing it for canning."* These two examples provide insight into shucking at sea and shucking on land practices, respectively. In both scenarios the blood is neither captured nor used, but rather, drained and typically discarded at sea or in sewerage.

There are few examples of blood being used towards more preferred management outcomes such as human consumption. Negligible amounts of blood are captured in South Australia and Western Australia by a handful of operators, as a preserving agent for abalone meat destined for dried product formats. OP-B3 explained:

> *"For one of the dryers, we keep the blood and basically just bag it up the same as the meat. It doesn't turn out to be a great amount … we have to mix the abalone meat once it's weighed off [for fisheries compliance] with blood and salt and that starts the drying process." (OP-B3)*

Participants also suggested abalone blood has potential commercial and therapeutic value, although details on this topic were limited. OP-B2 commented that *"A few years ago, someone in Tassie was playing around with blood, but they're quite secretive about it"*; whereas OP-B3 revealed that *"the abalone blood – the blue blood … has hemocyanin in it and that is something that potentially could be explored."*

These claims were corroborated by preliminary research conducted by Talaei Zanjani et al. (2016) and highlights the opportunity to extract nutrients from the blood. In terms of management interventions on the food waste hierarchy, this type of use would constitute one of the more preferred options for abalone blood. However, these options appear to remain in the preliminary stages of technical development.

From a circular economy perspective, there is indeed a clear opportunity to improve the outcomes for abalone shells, viscera, and blood in South Australia, Victoria, and Western Australia. The outcomes of waste reported by participants in these states was similar to primary producers in other food waste studies by Batista et al. (2021), Beausang, Hall, and Toma (2017), and Erasmus et al. (2021).

Conversely, the Tasmanian and New South Wales fisheries presented different issues where circular economy *cum* supply chain improvements were concerned. In

New South Wales, abalone harvested within the state have, until recently, been sold exclusively as live product owing to a number of factors.

Firstly, trust has developed between downstream customers – primarily located in Japan – and New South Wales exporters over a number of years. OP-A2 explained that the Japanese market has come to trust the quality and consistency of live Blacklip abalone from the New South Wales supply chain:

> *"The main reason that is the fact that our abalone in New South Wales is probably one of the hardiest abalone because it's grown up in reasonably warm water over its lifespan. … It's got a good name in the live market because it actually survives really, really well at the other end when they put it back into [live] tanks." (OP-A2)*

New South Wales supply chain actors (divers, quota owners, and processors) are also able to supply a consistent size and quality of abalone which are specifically sought by the Japanese market. Over time this has built trust in the supply chain between overseas buyers and New South Wales exporters; and aids in the efficiency of production (i.e. harvesting), sales, and distribution. OP-A2 explains: *"70% of our product in New South Wales would be 300-400 grams. So that size abalone is perfect for the Japanese [live] market and that's the market that most of our live abalone goes into."*

Participants also confirmed that the focus on live export by New South Wales supply chain actors is as a result of there being no licensed processors in the state (i.e. permitted to shuck abalone) up until 2020 (*n*=1), with a further processing license (*n*=2) granted in 2022. A more appropriate term for processors in New South Wales prior to 2020 would be 'abalone receivers'. Prior to 2020, abalone receivers in New South Wales were permitted only to receive and purchase abalone from divers and hold the abalone in tanks before distributing the products live to domestic and export customers. This information has neither been previously reported in the literature, nor in publicly available industry documents (Gilmour, Dwyer and Day 2013; Mayfield et al. 2012). OP-A2 explains when asked about how many processors there are in New South Wales:

“There’s three. There's a processor in Eden, [Processor B], but they are also in Melbourne. So they’re allowed to process product in Melbourne, but their facility in Eden is only a live holding facility. They can’t process there. And then you've got [Processor C] - is the only one in New South Wales that actually processes abalone. That's only a recently new thing in the last couple of years because of COVID.” (OP-A2)

With an additional processing license granted to OP-A2 in 2022, opportunities to improve waste outcomes may arise in New South Wales in future. However, the state is well-established as a specialist live abalone supplier; and current shucking volumes were reported as sporadic and negligible.

In Tasmania, the participants interviewed process a significant collective market share of catch on an annual basis (≥75%). Each confirmed that they had found alternative outcomes to disposal for the majority of their viscera and shells, with the remainder in storage for varying periods of time awaiting future sale. OP-C2 explained that shells are dried *“for a few months, and then we put it into the container and move it off”* while viscera *“gets put into the freezer and then sent off for processing into the sauces or into the nutraceutical segment”*. According to the food waste hierarchy, the aforementioned outcomes for viscera constitute some of the most preferred outcomes for by-products: prevention and extraction of compounds of interest, respectively (Garcia-Garcia et al. 2017).

To date, the use of abalone viscera in sauces has not been explicitly recorded in the literature, though there have been allusions to its edibility (Olley and Thrower 1977). Additionally, reports by participants of viscera being used in nutraceuticals refer to the research trials conducted by Suleria et al. (2017a; 2017b; 2017c). OP-C2 indicated that viscera directed towards nutrient extrusion are *“not in a commercial position right now, but [expected to] come to life in the next couple of years”*. The use of viscera reported by participants with such large market share challenge the characterisation of viscera in the literature as ‘unmarketable’ or ‘inedible’ (Section 1.1.4).

OP-C1 also mentioned that *"a little bit of gut we get [from one of our factories] we accumulate over a long period of time and that usually ends up in a compost pit of an Amish community that use that and add sawdust, etcetera, to it for promoting the growth of new vegetable"*. This outcome would constitute one of the lesser preferred outcomes on the food waste hierarchy adopted in this research; and indicates that, theoretically, there is room for improvement. However, from a pragmatic perspective, these supply chain members are seeking waste management options that are cost-effective and act in symbiosis with their communities and existing business practices.

This idea of satisfying operational efficiencies (e.g. cost, less wasted catch) and sustainability emerged as dual motivations to reduce waste amongst Tasmanian operators. The concept was reinforced by OP-C2's comment that: *"it's about generating revenue or margin from all parts of the abalone. Certainly from a commercial perspective, but then also the sustainability side … We're always working towards zero waste."* Thus, the opportunities to improve waste outcomes, both theoretically and practically, exist within other states such as Victoria, South Australia, and Western Australia; and less so in New South Wales or Tasmania.

Furthermore, it emerged from the interviews that, across the board, shells are largely exported to foreign markets. OP-C1 confirmed a practice pervasive in most fisheries, that *"we sell the shells. They're well sought after because of the size. Big abalone shells are sought after. The smaller they are the harder they are to sell".* Based on the definition of 'food waste' adopted in this research (Section 1.2), shells that are exported fall outside the scope of this project. The opportunities to improve outcomes for shells that are exported will, therefore, not be discussed in this chapter. Where shells are disposed of within Australia, the opportunities to improve outcomes will be discussed. Ultimately, however, the focus of participants' responses fell primarily on the viscera for several reasons that will become clearer as this chapter unfolds.

Sustainable Thinking

This aspect of Theme 1 concerns participants' motivations to act sustainably while also recognising the long-term economic opportunity to maximise returns on their catch.

Several of the typical cases (*n*=8) in Victoria, Western Australia, and South Australia expressed strong environmental and economic sustainability values. These values were evidenced by their conviction to sustainable fishing practices and recognition that the long-term economic viability of their businesses is tied to the health of abalone stocks. OP-B2 says of their firm:

> *"All my directors are license holders … They're long-term in the business and in terms of their outlook. So we're here to try and ensure that the boats and licenses are as profitable as possible and that the fishery is being looked after." (OP-B2)*

By extension, participants who were driven by a commitment to the long-term economic and environmental viability of their fisheries wished to find a use for their by-products. OP-B2 continues, "*The opportunity's there – there's more of our resource that we don't use so I see it as a waste … Rather than just throwing [viscera] over the side, if we can find a better way of using it, I think we should."*

The economic imperative to maximise catch has been highlighted several times in the literature, particularly in industry-driven research (Howieson et al. 2013; Howieson et al. 2017; Jecks et al. 2018; Knuckey 2004; McDonald et al. 1999; Nichols et al. 1997; Raston and Makha n.d.; Tsvetnenko et al. 1994). However, the attitudes of Australian abalone fishers and processors towards sustainability and stewardship of their fisheries which was revealed in this research has not previously been recorded in the literature. The few studies that have explored abalone diver and quota owner views on fishing matters have been concerned with stock management and compliance, rather than food waste or sustainability as a broader topic (Bose and Crees-Morris 2008; Gilmour, Dwyer and Day 2013). Furthermore, the data analysis conducted in these studies have been quantitative and statistical rather than thematic; and as such, the 'voices' of the stakeholders have thus far not been published.

Part of the sustainable way of thinking demonstrated by participants was the characterisation of the viscera and shells as a resource, rather than 'waste'. OP-B4 said, *"the good quality Greenlip shell is retained - is cleaned … That's not a waste product, it's a valuable product*." OP-C1 also emphasised their perception of the viscera and shells as a resource, saying *"I don't call it waste because in a lot of cases we don't waste it."* The distinction participants made between an economic 'resource' and 'waste' was a key motivation to use their processing by-products, and evidence of a sustainable mode of thinking. In this way, the impetus to seize the opportunity of improving their economic returns is equally valued to environmental concerns.

OP-B4 stood out in their discussion of different sustainability concerns not mentioned by other typical cases, which acted as a motivating factor to seeking a use for their abalone viscera. OP-B4 remarked in their closing comments, regarding shuck-at-sea practices:

> *"I've been getting more and more concerned with boats seeming to move around a lot more at sea with their fishing practices. So they might dive in an area in the morning, and then the conditions might change so then they might move potentially 20 miles into another area and fish in the afternoon. They may have some biosecurity issues there if they're shucking out abalone from where they dived in the morning, and then shuck that out in the area that they dive in the afternoon. And I'm not sure if you're aware of the Perkinsus virus that does impact our fishery here … We have lost some areas of fishing due to the spread of this disease or virus … Divers aren't fishing in those areas so that's affecting our fishery in other ways [as well]. So I'm trying to look at ways of making that easier for fisher to access [those Perkinsus-affected areas] and cover off on the biosecurity as well." (OP-B4)*

OP-B4's concerns about the biosecurity and sustainability threats to their fishery posed by the *Perkinsus* parasite and fishing practices (i.e. divers fishing in one area and shucking the harvested abalone in another area) have not previously been captured in the literature. OP-B4's concerns were corroborated in an interview with FS-B1. FS-B1 explained:

> *"It's still unpublished information but essentially [the viscera] go straight through the fish and they come out as viable parasite … So the fish eating them is not taking [parasites from abalone] out of the system and it's actually probably making it worse." (FS-B1)*

Additionally, FS-B1 suggested that finding a commercially-valuable use for the viscera could incentivise divers and quota owners to change their shucking at sea practices.

> *"Actually bringing the viscera in [to shore] and making a commercial use of them … would have removed the whole [biosecurity] problem." (FS-B1)*

OP-B4 and FS-B1's primary sustainability concerns are not about the food waste created by disposing of viscera, but rather, the sustainability of a fishery experiencing significant biosecurity threats. Nevertheless, this is both a motivator and opportunity to change supply chain practices; which might incidentally address the food waste problem presented by disposing viscera and shells at sea.

Such views, linking disposal of primary production waste to biosecurity risks, have been previously discussed in relation to landspreading (Rao et al. 2007) and anaerobic digestion (Abuhena et al. 2022) but not in relation to fisheries or disposal at sea. For instance, Erasmus et al. (2021) discuss the risk of utilising seafood processing waste owing to poor storage and handling practices; and briefly mention shucking at sea practices. However, the biosecurity risks of disposing fish waste in open water were not addressed.

Overall, where attitudes about fishing practices and waste disposal were concerned, participants demonstrated economic and environmental sustainability values without necessarily mentioning the three pillars framework; or using the term 'sustainability'. Rather, these topics were earnestly discussed within their particular fishing or processing contexts indicating a genuine belief in these sustainability imperatives. The 'sustainable thinking' expressed by participants is relevant to this research because it was mentioned as a major driver of improving waste management practices. The motivation to operate more sustainably by utilising their viscera, shell, and blood by-products provides a favourable foundation for implementing 'circular' management interventions modelled by the food waste hierarchy.

Harsh Industry Realities

The harsh realities of the industry that face the Australian abalone supply chain at large – but particularly quota owners and processors – also emerged from the data as a motivator to seek out uses for processing waste alongside participants' genuine desire to adopt circular economy waste management practices. Harsh industry realities included: steadily declining TACC quotas, threatened sustainability of abalone stocks, competition with aquaculture product, and high operating costs. This is the final aspect that shaped Theme 1 and provides an additional driver for operators to maximise their catch by implementing management interventions. OP-C2 describes a narrative common to each of the five fisheries:

> *"The viablity of the entire abalone industry has decreased dramatically in the last five years, due to increased costs, but also logistical barriers and also the biomass decrease due to historical overfishing, but also the warming of the waters. We're not seeing the same growth and recruitment [of abalone]. So what that means is that utilising waste for revenue is really important, and it's going to continue to be important." (OP-C2)*

The pressures described by OP-C2 align with what has been reported in the literature previously, but not from the perspective of primary producers and post-harvest processors concerned with economic or operational viability (Mayfield et al.

2012). Furthermore, participants inadvertently confirmed a central tenet of sustainability theory through their first-hand experiences. The central tenet concerns the limitations of natural capital (i.e. abalone stocks) and the resultant limitations of economic growth – the economy being a subsystem of the natural environment. Continued economic growth without sustained throughput of natural capital is therefore unrealistic (Farley and Smith 2020; Goodman-Smith, Mirosa and Skeaff 2020; Pezzey 1992).

In states such as Western Australia, South Australia, and New South Wales where remote fishing is prevalent, unavoidable, and costly from an operating perspective, the motivation to maximise returns on catch is tangible. FS-E2 explains that when divers *"go out fishing for a couple of days… It's harder to keep your product in as good a quality. So as soon as your product quality starts declining, your [beach] price starts declining, your economic viability starts declining."* Quota owner, diver, and processor, OP-A2 explained the motivation to seek improved revenue streams as a result of remote fishing practices and the high associated operating costs: *"To travel 500 km, spend the time down here, pay for accommodation, fuel, and so forth. It wasn't financially viable so that's why I started up my own factory."* To date, the impact of remote fishing on abalone divers and quota owners has not been published in the literature.

In addition to the economic pressures posed by remote fishing, FS-E2 and OP-E3 described the tangible economic pressures placed on their fishery by competing aquaculture products in the export marketplace. As a result, quota owners have sought to develop new domestic markets.

> *"For the last three years we left the Roei – except for last season, a portion of it we caught – but the rest of it we left in the water because it just wasn't viable … It competes directly with the aquaculture-sized product." (OP-E3)*

> *"The price [of Roe's] was struggling … So these guys diversified which is great – they've been able to build a local live market." (FS-E2)*

Furthermore, FS-E2 commented on the direct effect low quotas have had on the need for divers and quota owners to utilise all parts of the abalone:

> *“There’s no real regulation, compliance-wise, around guts and viscera having to be landed … So that’s the way the fishery’s worked for a long, long time. That’s starting to change now because of the low quotas and therefore they [divers and quota owners] require a greater income out of the product, from my understanding.” (FS-E2)*

The threatened economic viability of the Roe’s abalone fishery has been alluded to briefly in management reporting (Strain, Brown and Jones 2021). However, the impacts have not been detailed to this extent in the literature.

Altogether, the high operating costs, competition with aquaculture, consistently reduced quotas, and threatened sustainability of abalone stocks constitute the ‘harsh realities’ that have pushed abalone divers, quota owners, and processors to seek improved revenue streams by changing supply chain practices.

5.3.2 Theme 2: Barriers to Improvement

The second major theme to emerge from the qualitative data concerned several barriers to improving outcomes for processing waste. Overall, it emerged that the barriers concern the viscera and blood components rather than the shell. A significant portion of shells are already sold for various purposes; and much of the discussion that took place in the interviews gravitated towards the problems posed by handling and processing of the viscera and blood.

Given that the participants interviewed represent significant portions of catch in their respective fisheries (see Section 3.5.1, Table 6), key supply chain issues such as the barriers to storing, handling, and processing waste described in this section are of importance. Additionally, while some barriers were common across the country, several were particular to one or two fisheries. This confirmed the case for assessing food waste at a supply chain-level discussed in the literature (Sections 1.3.1 to 1.3.3).

A Balancing Act

The phrase ‘balancing act’ refers to the number of logistic and operational considerations that need to be weighed against the operators’ desires to run a sustainable business. The data revealed several barriers common to all five fisheries, including: potential economies of scale, existing infrastructure, maintaining quality of product, sporadic supply, and operating capacity. Spatial proximity (i.e. large distances) between operators and processors was an additional barrier, though specific only to Western Australia and South Australia where remote fishing and shucking at sea are commonly practised.

The barriers mentioned by operators and processors were often interlinked. OP-C1, employed by a company that already sells its viscera for varied purposes, draws the connection between economies of scale, existing infrastructure, and operating capacity:

> *“When we shift gut around for further processing, it’s 10, 11 pallets at a time and there’s a tonne a pallet, which is what you need to make it efficient … Having volumes that are efficient is definitely a pinch point. … [Our company] is lucky. All of our plants have huge freezers … We’re talking how many* ***containers*** *of product waiting to be processed.” (OP-C1)*

Other processors noted the importance of storage infrastructure in accumulating processing waste to achieve sufficient volumes for a commercially efficient outcome. P-D3 explained that *“we’re inner city [Melbourne], so we’ve got nowhere to store the shell.”* As a result of its warehousing limitations, the company generally requires a rapid turnover of product. Thus, storing by-products over a prolonged period of time to accumulate tens-of-tonnes of viscera or shell as OP-C1 described is not possible. Instead, the company sends its shells to landfill rather than accumulating it for export as done by other processors across the country.

OP-C1 provided insights on maintaining product quality, based on their experiences of selling viscera. OP-C1 discusses the various levels of product quality of viscera that are required depending on the end-usage:

> *"Depends on what it [the viscera] is used for. … Pet food manufacture is another one that we do a bit in. Shelf-life is not overly important – it's still treated and cooked regardless – a little bit of freezer burn on the outside of the product is neither here nor there. I had stock that we're selling that would be seven-plus years old. That's quite sellable in the right market." (OP-C1)*

Conversely, where nutraceutical use is concerned, OP-C1 remarked that: *"A lot of the time they need very fresh product … It has to be the latest production. It's got to be under three-months old."* Overall, OP-C1 indicates that there are a range of existing markets that will accept varying qualities of viscera. These are valuable insights that could be used to guide quality assessment, decision-making and market development for viscera products.

Meeting downstream market requirements has been well-documented in the literature as a driver of food waste. This appears as a prominent theme in the literature where packaging, high-specification food grading, food expiration, and consumer perceptions are concerned (Garrone, Melacini and Perego 2014; Goodman-Smith, Mirosa and Skeaff 2020; Priefer, Jörissen and Bräutigam 2016). However, the market requirements for food waste products towards improved outcomes such as value-adding or composting is less explored (Li, Jin, et al. 2019). This was a theme that could have been delved into further with the recruitment of additional processors and market development experts. However, this was not possible given the difficulties with recruitment which was explained in Section 5.1.

Cold storage emerged as a potential barrier to ensuring product quality in both shuck-at-sea fisheries (Western Australia and South Australia) because fishing and processing locations are separated by long geographic distances. For example, abalone travel several days by boat followed by hours-long road transit from the point of harvest and shucking to arriving at a processing facility. Therefore, maintaining the quality of viscera on the boats for days at a time requires particular attention. As OP-E3 explained, *“the viscera, it goes sour very quickly. It needs to be chilled and looked after, straightaway if you wanted to value-add to it.”* Consequently, cold storage for the viscera would be required on the fishing vessels which presented an additional obstacle to changing supply practices. OP-B2 explained:

> *“We tow boats long distances between where we live and where we fish. There's always space constraints inside these smaller vessels … So as soon as you’re asking [lease divers] to bring extra weight in, it does have some implications for them.” (OP-B2)*

Dive operations are lean. As explained by OP-B2, and corroborated in fishery management documents, fishing vessels are typically small; measuring less than nine metres in length (DPIRD 2021). Moreover, vessels are only operated by a two-person crew consisting of a diver and a deckhand, responsible for shucking and chilling the abalone. OP-E3 suggested the labour capacity in such a lean operation may already be stretched. OP-E3 expressed concerns to:

> *“Not put extra work on [the divers’] day that’s already out at sea in rough conditions. You know, another layer of things to do at the end of the day and prior to the day. There would be some resistance there for sure.” (OP-E3)*

In an earlier interview, FS-B1 remarked that divers *“really don’t like landing [the abalone] in shell at all - it adds to the weight on the boat, and it's more of a hassle.”* Similarly, on potentially landing viscera that would otherwise be disposed of at sea, OP-B3 stated:

> *“We're landing, say, four or five eskies of meat on a good day and that would translate into, say, three or four eskies of viscera as well. So that would take up all the spare room in a boat that's used.” (OP-B3)*

In this way, it emerged that the current operating capacity of diving vessels in South Australia and Western Australia is limited but theoretically has capacity to allow for viscera to be landed in addition to the shucked meat. Thus, the barrier lies in the perceived burden of stretching the capacity of the small boats and crew.

The barrier presented by limited storage capacity on fishing vessels was also discussed in a seafood waste study by Erasmus et al. (2021), albeit within a developing nation context. A crucial difference from this research, however, was that fishers and fishery managers interviewed by Erasmus et al. (2021) considered processing by-products to be 'waste'. As a result, it was indicated in the study that transporting 'waste' alongside the catch intended for sale would be in violation of their Hazard Analysis Critical Control Point (HACCP) safety plans. This appears to be a contradiction to a study by Hwang et al. (2011) which indicated HACCP-certified fish processing facilities enable, rather than prevent, further use of processing by-products; since the higher standards of storage and handling mitigate the contamination of processing by-products and seafood. Indeed, responses from participants in this research, suggested that food safety would only be an issue if the viscera were not stored appropriately (i.e. chilled on boats or frozen once landed).

Lastly, limited labour was also connected to the issue of sporadic supply. Operators in all states corroborated that harvest periods are sporadic and unpredictable. *"Divers may only fish 50 to 70 days a year because [the sea is] so rough. Swell and wind and all that",* explained OP-E3. While IR-D1 similarly related: *"Some of the divers said to me, "We're lucky to have gone out four days this month to work.""* However, a number of processors had opposing experiences and conclusions concerning the barriers posed by a limited labour force and sporadic fishing patterns. On one level, sporadic supply and a limited number of divers may be prohibitive to accumulating quantities of by-product that are necessary to meet cost- and logistical efficiencies, as well as information of product availability for customers. Says OP-E3:

> *"There's probably only 15 divers in the [fishery]. But they're all [fishing] different species at different times at different locations. So to actually co-ordinate that and then get back to a hub to utilise the waste is not practical." (OP-E3)*

This barrier may be mitigated by storing and accumulating volumes over time, as described earlier by OP-C1. However, P-D3 highlighted that the typically sporadic supply of abalone has an impact on the company's ability to retain processing staff:

> *"We just cannot get staff … They're nearly always casuals – and then we get a run of bad weather like we've had the last month … And if they don't get a full week's work, they're off finding work somewhere else." (P-D3)*

As a result of their company's limited labour supply, P-D3 identified limited processing capacity as a barrier to storing and properly handling processing waste for other use since "*[the abalone meat] takes priority – the quicker you process it, the better your recovery, the yield. So that becomes your priority in the processing."* However, on this front, two other processors' experiences directly opposed P-D3's experience. OP-C2, employed by a company that is processing and selling their viscera, explained:

> *"What we found is by bringing in those other product forms and processing flows, we're able to provide casual work for our casuals all year round." (OP-C2)*

OP-C2's experience was echoed by OP-A2; which suggests that introducing new product lines from the viscera component may go some way to addressing the difficulties with sporadic abalone supply and a stable workforce.

The consistency of supply of food waste in the development of valorised products has received some attention in the literature. This research confirms unpredictable, seasonal volumes of food waste as a potential barrier to utilising food waste in large-scale, commercial processes (Lin et al. 2013; Pfaltzgraff et al. 2013; Stone, Garcia-Garcia and Rahimifard 2019). However, the relationship between consistency of waste volumes and processing capacity was more tenuous given the differing experiences between P-D3, OP-C2, and OP-A2. In supply chain management theory it is generally accepted that stable, or at least planned, supply enables optimal use of labour and processing capacity (Christopher 2011; Stadtler 2008a). OP-C2 and OP-

A2's experiences substantiate this theory; whereas P-D3's experience only suggests at the negative effects of underutilised labour (i.e. inability to retain staff). Seasonality in food production, food waste, and labour issues have been explored as overlapping themes in the literature but not from the perspective of processing capacity. Studies in other industrialised primary production contexts have identified different drivers of on-farm food waste to this research, including increasing cost of labour (Baker et al. 2019) and insecure migrant labour workforces (Soma, Kozhikode and Krishnan 2021).

All in all, the barriers to better managing food waste highlighted by participants across all fisheries provided pertinent examples of the need for supply chain co-ordination and planning. The barriers discussed in this aspect of Theme 2 related primarily to economies of scale, sporadic supply, storage and handling of waste, and operating capacity. These barriers were themes echoed in other food waste studies in the literature, though across a range of different primary production contexts and with subtle differences in detail.

Economic Feasibility and Risk

Participants (*n*=5) in some states were able to confirm that the market value of viscera is currently very low. The low per-kilogram price of viscera was enough to incentivise processors to improve waste outcomes in scenarios where abalone must be landed whole (i.e. South Australia's Southern Zone, Western Australia's Roe's abalone fishery, Victoria, Tasmania, New South Wales), but not where shucking at sea is an option. Among the Western Australian and South Australian participants (*n*=8), the negligible market value of abalone viscera was viewed as a barrier to storing, handling, and processing this component of waste compared to the ease of shucking at sea.

> *"… There's no costs incurred on us as a facility with this [viscera] waste. So for one, we're not really fixing a problem. … It's easier for [the divers and deckhands] to throw it over the side." (OP-B2)*

Based on offers received from buyers in the past, participants were unwilling to initiate broadscale changes to supply chain practices to store, handle or process viscera. OP-B4 summed up an experience common to several other participants:

> *"The buyers that are looking to do something with it are only prepared to pay a very low per kilo price." (OP-B4)*

These particular buyers, based interstate, were unwilling to pay a price that would have at least covered the cost of packaging and handling the whole viscera because they *"were looking to use it for an abalone sauce for human consumption and using parts of the viscera, not all of the viscera"*; rendering a value-adding component an extra and unviable cost prior to sale. OP-B4 explained that this added to the already high expense of shipping the viscera interstate as a whole and frozen product from their remote processing facility to the buyer – only for a small part to be used in sauces later on. The business case did not make sense for the buyer and the opportunity to valorise this portion of by-product passed.

Incidentally, this example also highlights some of the logistic and economic barriers to utilising the waste accumulated in regional or rural areas, where most primary production activities are generally located. In this particular instance, cold chain over large distances is cost-prohibitive to transporting raw material that is high in liquid content. OP-E4 provided the following insight about the content of viscera:

> *"Most of it is fluid anyway. If you shuck it into a container, at the end of the day you've got 80% fluid and a bit of gut material left." (OP-E4)*

OP-B4's experience confirms what has been discussed in the literature regarding high transportation costs as a barrier to recovering and utilising food waste (Bottani et al. 2019; Cristóbal et al. 2018). In particular, where moisture content is high and nutritional value minimal transportation has been identified as a disincentive to improve food waste outcomes (O'Connor et al. 2021).

Returning now to the market value of viscera, the experiences of the participants in several states suggest that the market value of viscera is approximately AU$1-2 per kilogram. The current market value of viscera is comparable to the cost of sending what is accumulated to landfill. OP-B2 shared:

> *"We sell some [viscera] just as a bulk frozen product, but it's like $2-something a kilogram. It's really just covering the costs that we would incur in disposing of it and maybe making a few cents." (OP-B2)*

The low value of frozen viscera threatens the long-term economic viability and incentive of simply handling and packaging viscera as a raw material. OP-B2 asserted that: *"We would need to dry it here or, sort of, on-process it to some extent, rather than just trying to freeze it and put it in a shipping container or something and send it to somebody. That's only ever going to be a very low value option."*

In terms of market value for frozen viscera, OP-B4 independently corroborated OP-B2's responses: *"For a waste product, you're probably only looking at getting maybe $1.50 or $2 for it."* Participants were careful not to specify which markets (e.g. pet food, sauce manufacturing) had offered the low per-kilogram price for viscera to preserve commercial confidentiality. Nevertheless, the market value of viscera has not been previously reported in the literature. Generally, the market value of food waste and/or extracted compounds of interest is alluded to but not widely reported in the literature (Kim et al. 2016; Teigiserova, Hamelin and Thomsen 2019). What has received more attention in the literature is the opportunity cost of wasting food (Nahman and de Lange 2013; Wen, Wang and De Clercq 2016).

The low market value of viscera perpetuates the perception of viscera as a waste product, rather than a resource for some participants. Owing to these perceptions. OP-E4 said that, historically:

> *"[Selling the viscera] was really just a thing that you gave to your deckhand to do as a bit of a sidebar if they wanted to try and make a couple of dollars or something, but it wasn't something that the diver or the owners would get involved with, really." (OP-E4)*

Consistent amongst participants interviewed from shuck-at-sea fisheries was the idea that without a sufficient financial incentive, lease divers and deckhands would not be willing to land the viscera. This highlights the difference in motivation between lease divers and quota owners who were interviewed. Persuading the divers and deckhands of this change to their practices constituted one of the greatest hurdles mentioned by this group of participants. OP-E3 was particularly frank on this point:

> *"It's all about money … The product that you develop from the waste has to be worth a certain amount for the divers to keep it and then someone to collect it off the divers." (OP-E3)*

This barrier confirmed the importance of feasibility analyses identified in the literature review (Section 2.2.8); and the likelihood that viscera is wasted in Australia's wild-harvest abalone supply chains because current uses are not economically viable, especially compared to the option of disposing at sea.

Siloing and Secrecy

It emerged in the interviews that organisational silos are prevalent in several fisheries across Australia. Silos can be viewed in two ways across the abalone fisheries: siloing of fishing and processing activities; and siloing amongst competitors. This is problematic since organisational silos limit important communication and information sharing between supply chain stakeholders, which are cornerstones of trusting, transparent, and competitively advantageous business relationships (Christopher 2011; Kilger, Reuter and Stadtler 2008; Koçoğlu et al. 2011).

Organisational siloing can be a barrier to improving waste outcomes where quota owners are removed from post-harvest processing, such as in Western Australia and South Australia. In these scenarios, lease divers with no current vested interest in improving waste outcomes or maximising their catch must be convinced by quota owners and processors to land the viscera alongside the shucked meat – this was discussed earlier in terms of economic feasibility. Siloing between fishing and processing activities occurs when lease divers fish on behalf of quota owners, and/or when quota owners do not have a vested interest in the processing. In other words, when vertical integration is minimal. As FS-B2 describes it:

> *"That's the disconnect for the fishers between a fisher or a licence holder, then handing it over to processor, which is often potentially a different company. It goes off [to the processor] and the actual fisher loses, somewhat, control of the product - they're effectively just filling an order to a processor." (FS-B2)*

Based on participants responses, siloing occurs for the most part in Victoria and New South Wales; to some extent in Tasmania and Western Australia; and to a minimal extent in South Australia. This reinforces the concept, commented on in the literature, that food waste requires tailored interventions owing to the particular challenges experienced by individual supply chains (Section 1.3).

Siloing amongst competitors concerns secrecy and lack of supply chain collaboration where waste management practices, use of by-products, and current markets for by-products were concerned. For example:

> *"There was a few years ago, someone in Tassie was playing around with blood, but they're quite secretive about it" (OP-B2).*

Secretiveness, or a lack of information sharing, is a barrier to utilising more volumes of viscera than is currently generated; since infrastructure, processing knowledge, and marketing efforts are not shared strategically between processors. Conversely, secretiveness does not affect the ability for processors to sell their shells because shells are largely exported as raw material to long-standing markets in Vietnam, Korea, and China. It was apparent from participant responses, however, that little is really known about what becomes of the shells once they are exported; suggesting a further layer of secretiveness between overseas buyers and Australian processors (suppliers of abalone shell). When asked what buyers of their shells use the product for, OP-E1 remarked: *"They won't tell us."*

Speaking from experience working with the industry, critical case, ME-1 said of some of the Australian wild-harvest abalone supply chain members:

> *"[They've] got an interest in holding on to [their] patch. And sometimes [their] patch involves knowing something that somebody else doesn't. So seeing each other as competitors competing against each other, rather than "There are areas that we could work on together competitively"." (ME-1)*

Here, ME-1 connects the tendency to remain secretive which feeds competitiveness between firms rather than supply chains. OP-E4, a stalwart of the industry, independently corroborated ME-1's comments by saying, *"I'm not sure whether [Processor P in Victoria] would like to do the interview [for this research], but they certainly have the knowledge about [utilising abalone processing waste] … Because everyone thinks they've got any sort of competitive advantage they want to keep it. Rather than talk about things, they'd often shut up about it."*

Victoria was particularly affected by this barrier of secrecy amongst fishers and processors, and amongst competitors. The high number of processors competing for market share of limited catch compared to other states appeared to be a major contributor to this barrier. P-D3 confirmed: *"The industry's really fragmented over the last few years"* and *"Everyone's very protective of their market share".* Processors in Victoria were particularly conscious of protecting market share and waste valorisation practices from competitors as well as fishing operators:

> *"There's one processor in Melbourne [who's] got a use for his product and - I can understand this - he's very protective of that. And I know when this project come up through ACA, he was a little bit concerned … He was thinking that everyone might start doing it and flood the market and piggybacking on what he's done." (O-D2)*

Processors who had first-hand experience of utilising abalone viscera in commercial products were recommended in the snowball sampling process. However, the tendency to remain secretive was confirmed in the recruitment process and affected the recruitment of additional processor participants in Victoria as well as New South Wales (Appendix D).

It is well-documented in supply chain management literature that information sharing leads to improved business performance (e.g. level of agility, export performance, market positioning, building skills or knowledge of the workforce, long-term contractual stability) for firms engaged in trusting B2B, supplier-customer relationships (Ayman Bahjat et al. 2021; Christopher 2011; Jraisat, Gotsi and Bourlakis 2013; Koçoğlu et al. 2011; Muafi and Sulistio 2022). Conversely, information asymmetry can lead to supply chains that are less efficient and resilient (Vosooghidizaji, Taghipour and Canel-Depitre 2020). The benefits of primary producers' and post-harvest processors' participation in collective structures (i.e. producer organisations or co-operatives) has also been highlighted, particularly where market positioning or differentiation (Hooks et al. 2018); and lowering financial costs to manage natural resources more sustainably are concerned (Ghauri et al. 2022). Whether collaboration occurs between suppliers and customers or between competitors, it is beneficial for stakeholders to share information in a manner that is controlled, pre-planned, formal, and strategic; typically facilitated through use of legal structures (e.g. contracts, legal entities) (Feng, Patton and Burgess 2019; Hooks et al. 2018; Jraisat, Gotsi and Bourlakis 2013; Myšková and Kuběnka 2019).

Conclusions about the potential barrier presented by organisational siloing and secrecy was reached by extrapolating themes from the literature that suggest the benefits of collaboration between competitors and actors to reduce food waste (Akbar et al. 2020; Aschemann-Witzel et al. 2017; Dania, Xing and Amer 2018; Thorsen, Mirosa and Skeaff 2022). Thus, taken as the antithesis of collaboration and information sharing, organisational siloing, secretiveness, and information asymmetry are potential barriers to improving waste. However, the cause-effect relationship between organisational siloing/secretiveness and reduced food waste utilisation in Australian wild-harvest abalone supply chains cannot be fully substantiated based on the qualitative data gathered in this research. It is for this reason that this aspect of Theme 2 could only be viewed as a *potential* barrier to improving waste outcomes. It is also important to note that not all fisheries or zones were affected by organisational siloing and secrecy. In particular, the South

Australian fishery was highly collaborative. This will be discussed later on in Section 5.3.3.

Other Priorities

Other pressing industry concerns and priorities presented a final barrier to upstream supply chain actors improving outcomes for shucked viscera, blood, and shell.

In Victoria, where stocks were lost to a large degree in recent history to the abalone viral ganglioneuritis (AVG) outbreak, IR-D1 was of the opinion that the divers, quota owners, and processors are *“more interested in rapid diagnostics and understanding the vectors [of AVG] rather than looking at the innovative side of where we can better utilise shell or viscera”*. IR-D1’s response highlights that biosecurity risks are more of a concern to Victorian quota owners and processors than addressing food waste. This diminishes the opportunity to improve waste outcomes in the Victorian fishery. Concurrently, OP-E4 highlighted that in his zone, where license holders are predominantly an ageing group, innovation and change in the use of by-products is not a priority:

> *“Certainly the licence holders are old – all of us. I’m probably the average age [70 years-old] for a licence holder in the zone … I think it makes [change and innovation] difficult because there's other people around that are closer to 80 than 70. And so they're in the point of their life where they're very comfortable. They own everything they want to own … so there's not much need to change.” (OP-E4)*

Furthermore, as licence holders age, the propensity to use lease divers increases and siloing occurs:

> *“People [license holders], once they got into the industry have stayed for a very, very long time and nobody gets out. So even the ones that are older than me - they're not talking about selling out, they've just got contract divers in.” (OP-E4)*

Beausang, Hall, and Toma (2017) came to similar conclusions about primary producers' focus on more immediate priorities compared to food waste concerns, including pests and disease. 'Other priorities' such as fulfilling consumer satisfaction, and food safety have also been discussed as barriers to improving food waste outcomes in other studies; though not as a standalone theme (Goodman-Smith, Mirosa and Skeaff 2020; Papargyropoulou et al. 2016).

This constitutes the fourth and final barrier of Theme 2. The following sections propose how these barriers might be overcome.

5.3.3 Theme 3: Strengths to be Leveraged Along the Supply Chain

Despite the barriers described in Theme 2, each fishery possessed several strengths that can be leveraged to overcome existing and potential hurdles.

Instigators of Change and Lessons from the Past

It was evident from the interviews that past improvements to supply chain practices in the Australian wild-harvest abalone industry have been initiated and developed over the past five to 10 years by a group of actors referred to in this research as 'Instigators of Change' or 'Instigators'. Past improvements have included: changes from non-selective to more sustainable, selective fishing practices in one particular fishing zone where abalone are now only harvested during select months of the year; and changes to state-wide regulations in another fishery where divers and quota owners were previously prohibited from selling abalone directly to consumers but are now permitted to. Both of these examples were described by participants as significant changes to their respective supply chains. Principally, the changes were significant because the implemented improvements generally enabled divers and quota owners in those specific regions to return a higher margin on their catch. Both improvements will be discussed in more detail in this aspect of Theme 3.

The actors who were identified as Instigators tended to be leaders in the industry – not necessarily in terms of market share, but in terms of leadership attributes and/or industry roles (e.g. industry representatives, industry advocates, company directors). It should be noted that, through use of the purposive sampling techniques described in Section 3.4.1, individuals in organisational and industry leadership roles (i.e. ‘key stakeholders’ with high power and high interest) were targeted for the qualitative interviews owing to their expertise and years in industry. Thus, the relative prevalence of Instigators (*n*=6 or 37%) amongst a sample (*n*=16) of industry leaders is probably unsurprising.

However, interview participants were neither targeted for specific leadership attributes nor a track record of initiating change in the industry. The researcher also possessed no prior knowledge of changes to supply chain practices in the Australian abalone industry when selecting participants and, as such, the emergence of this theme can be attributed to a grounded theory approach to analysis rather than selection bias. Moreover, this aspect of Theme 3 warranted some attention as a key strength of the supply chains under study that could be used to overcome the several barriers identified in Theme 2.

In this research, individuals were considered ‘instigators of change’ if they recounted professional experience of initiating changes to supply chain practices with the intention of benefiting the industry as a whole, as opposed to their own firm or interests alone. This reflects the literature on supply chain leadership where effective leadership can drive continuous improvements to supply chain operations and foster supply chain integration, in particular, information sharing (Berbiche, Hlyal and Alami 2020; Brun, Karaosman and Barresi 2020; Stadtler 2008b).

Supply chain leaders have also been referred to as ‘champions’ in the literature and display specific leadership attributes (Kilgour et al. 2008; Phillips-White et al. 2019). These attributes include: a collaborative mentality, drive for continuous learning and improvement, persistence, strategic thinking, pro-activeness, interest in improving economic and environmental sustainability performance for a whole industry or supply chain as opposed to their firm alone, and reputation as an industry champion (Berbiche, Hlyal and Alami 2020; Kilgour et al. 2008; Phillips-White et al. 2019; Zhang et al. 2018). In this research reputation was inferred based on recommendations in the snowball sampling process. For example O-D2 was independently recommended as an interview recruit by other participants (*n*=2) and the industry project partner, Abalone Council of Australia Ltd. Overall, Instigators are a 'strength to be leveraged' in the supply chain because they are individuals with a set of specific, demonstrated leadership attributes and not merely, or necessarily, as a result of their job title or dominant market share. This phenomenon is supported by the literature on supply chain leadership.

Amongst the participants, FS-B1, OP-B3, OP-B4, O-D2, OP-E1 and OP-A2 emerged as Instigators. These participants were spread across multiple fishing zones in Western Australia, South Australia, Victoria, and New South Wales. As an example of initiating change to benefit the industry and not only their own business interests, O-D2 was pro-active in changing state fishing regulations. The regulatory changes enabled quota owners to sell abalone directly to the public at a local level; thereby undertaking substantial work to open new revenue streams and improving profit margins for all fishers within the zone:

> *"Yeah it took a lot of work. I did do most of that with the previous Minister [for Fishing and Boating] … Took her diving to show them what we do and then explain the benefits to the small coastal towns and the economy to be able to do that. So they changed the legislation … I did a trial for a while to make sure it was working and compliance was happy. And now there's a few permits across the state which is good." (O-D2)*

Instigators, FS-B1 and OP-B3, had success in collaborating on a project that resulted in an improvement on fishing practices within their fishing zone. OP-B3 explained:

> *"[The project] was driven through a group of us that were fishing in what we believed was the correct way. And frustration from us of others that didn't seem to see it that way. It was like, "Okay, we'll get the science to prove it."" (OP-B3)*

Speaking on the outcomes of the project, OP-B3 remarked that when:

> *"Everybody could see it and realise that fishing during the wrong months was not only doing detriment to the resource, but also their back pocket,*

there was wholesale change through the industry to fish at the right times of year." (OP-B3)

Incidentally, the conviction to underpin action by research, demonstrated by OP-B3 in these passages, was also a common trait amongst Instigators identified in this research. Similar to OP-B3, OP-B4 has collaborated on a project with FS-B1 to find a solution to the biosecurity concerns that were discussed in the 'Sustainable Thinking' aspect of Theme 1 (Section 5.3.1). Meanwhile, on finding innovative solutions to using viscera, OP-E1 said:

"We're at our infancy stage when it comes to that side of it. All we've been doing now is just throwing the ideas on paper and then together with the technicians – the food scientists – and a bit of market ingenuity to find out what the market will take." (OP-E1)

Crucially, each of the Instigators indicated a strong support for improving outcomes for by-products and underpinning the process with research; and presented four out of the five state fisheries. Passages evidencing support for improving waste outcomes were presented in the 'Sustainable Thinking' aspect of Theme 1 (Section 5.3.1). The attributes and experiences possessed by the six Instigators are, arguably, a strength that can be leveraged to initiate supply chain improvements to by-product outcomes; based on their previous successes at effecting systemic changes within their fishing zones.

The theme of supply chain leadership in reducing food waste emerged as an underexplored area of addressing food waste. Mithun Ali et al. (2019) theorise that poor supply chain or organisational leadership has been linked to higher instances of food waste; albeit in downstream segments of the supply chain. Other studies by Palmer et al. (2023) and Mourad (2016) suggest that community leaders are important in influencing changes to business practices, thereby reducing food waste. However, the aforementioned studies did not draw any causal links between leadership and changes to food waste practices. The findings presented in this particular theme contribute to this underexplored, and potentially important, area of food waste research by suggesting that the demonstrated leadership of the six ‘instigators of change’ may be a critical influence in reducing food waste in Australian wild-harvest abalone supply chains

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The experiences recounted by the six Instigators not only provide evidence that improvements to abalone fishery practices are possible. Their experiences also provide valuable lessons for how future supply chain improvements might be implemented. For example, FS-B1 provides the following insight based on previous successful experiences with changing industry practices through research. FS-B1 highlights the importance of demonstrating economic feasibility:

> *“You have to have some real numbers of: if you bring the viscera in, and dry it’s worth this much money. And if you did it across the fleet that would make you X million dollars. That would be a real incentive … [the divers and quota owners] are reasonably open to that sort of thing.” (FS-B1)*

However, previous *unsuccessful* attempts at changing industry-wide practices also provide valuable lessons for future pursuits. OP-B3 and ME-1 independently discussed what they learned from a past collaboration that did not come to fruition. Their collaborative attempt failed to engage quota owners nationally, despite the project’s clear benefits to the industry as a whole, had it been successful. Unprompted, both OP-B3 and ME-1 commented on the lesson of understanding stakeholders’ traits, priorities, and approaches to business when making a case for change. OP-B3 said the project:

> *“… got convincingly defeated by the quota owner voters, who happened to be a lot of the investors. They were just looking from year to year for immediate returns, rather than having to pay a couple of percent for a long-term gain.” (OP-B3)*

OP-B3 went on to characterise the lost vote as *“disappointing but identifies the short-sightedness of the industry that we have at the moment”.* Adding another dimension to OP-B3’s comments, ME-1 said:

> *"it was a watertight business case. It was facts and figures … But unfortunately, what we didn't account for was the person stuff, the mindset stuff. And so we were trying to combat emotional responses with facts and figures. And that never works." (ME-1)*

When prompted further, ME-1 described 'mindset stuff' as individuals' *"biases, attitudes, beliefs"*. Alongside economic feasibility, OP-B3 and ME-1's comments reinforced the significance that ethos and culture play in either driving or inhibiting changes to supply chain practices in the abalone industry.

Notably, Instigators' past experiences altogether highlighted the differences in successful outcomes which were achieved at a *zonal* level versus the unsuccessful attempt at industry-wide change at a *national* level. Certainly, the one instance of a failed national-level project discussed in the interviews was not sufficient to show a pattern, as in the several cases of successful zonal changes. However, it does provide some indication of the relative pitfalls of a nation-wide approach. As shown in Section 5.3.2 the barriers that effect each fishery are slightly different, in part driven by the structures (i.e. vertical integration) in place. However, as O-D2 put it, *"Every zone has different challenges or different personalities".*

"The ethos is co-operative"

The *"different personalities"* described by O-D2 refer to the varying cultures and ethos present in each zone. Several participants (*n*=9) commented on culture and ethos as being zone-specific, and largely influenced by the quota owners. For example, OP-B4 said of their fishing zone:

> *"We have a strong Association in [this] zone… A lot of us have been in the game – we're second generation … still family businesses and hold the industry very close to our hearts, really because we've been in it so long, and we want to see it flourish for the future and on to other generations." (OP-B4)*

Similar to OP-B4, several participants (*n*=8) tended to draw a connection between the following three concepts: (1) a custodian approach to fishing and business; (2) a willingness to collaborate with competitors; and (3) quota ownership by local, intergenerational owners. Moreover, participants implied that the long-term and local nature of quota ownership fostered long-term relationships between supply chain actors within the zone, including amongst competitors; and this was overall characterised as a positive phenomenon that was beneficial to supply chain. This is the antithesis of the organisational siloing and secrecy discussed in Section 5.3.2; and strongly aligns with the advanced supply chain management strategies amongst heterogenous, upstream supply chain groups (i.e. groups of primary producers, groups of processors) discussed by Akbar et al. (2020), Dania, Xing, and Amer (2018), and Zhuo and Ji (2019). In one example, OP-E4 explained:

> *"There's a fair bit of camaraderie in the [zone] – most divers are competitors but they're not enemies. There's generally a fair bit of talk about what happens and what's going on and what's good for the [local] industry and what's not." (OP-E4)*

OP-E4's response highlights the connection between several topics discussed in Section 5.3.2 and 5.3.3 ('Instigators of Change and Lessons from the Past') concerning trust and collaboration (*"fair bit of camaraderie"*), information sharing (*"fair bit of talk"*), and their relationship to the long-term interests of the fishing zone (*"what's good for the industry and what's not"*).

Moreover, local ownership by second- or third-generation residents within the zone, rather than "investors", was identified as a key attribute to maintaining sustainability within the zone and fostering supply chain collaboration. 'Investors' was a catch-all term used by participants to refer to superannuation funds and private equity firms, typically owned by foreign investors. Like several other participants, OP-B2 implied a negative association with investors and a positive one with "long-term, multigenerational family-held" quota.

> *"Tasmania, for example, has a lot of investors. Here, because we're fortunate that we're a long way away from most places and most people,*

it is still mainly family business here. … the vast majority is still long-term, multi-generational family-held stuff." (OP-B2)

Negative associations with investor take-overs of quota that has occurred in Tasmania and Victoria were based on concerns about aggressive, short-term gain approaches to operating. OP-B3's comments on the short-sightedness of investors which were provided in the previous aspect of Theme 3, 'Instigators of Change and Lessons From the Past' (Section 5.3.3) was one example of these concerns.

The link between local quota ownership and a collaborative mentality was particularly evident amongst operators in remote fishing areas where sharing knowledge, skills, infrastructure, operating costs, and labour have been particularly important to remaining operational. The historied nature of such relationships in remote fishing areas was described by IR-D1:

"More particular to [this] zone, especially. When it was set up in the 60s, it's so remote that they decided, "Well, let's set up a factory". Electricity eventually came." (IR-D1)

The co-operative structure alluded to by IR-D1 remains in place to the present day. OP-E4, OP-B2 and OP-B3 highlighted that a co-operative mentality can exist even if the organisation is legally structured as a limited company rather than a co-operative. OP-B2 said, *"We're not structured as a co-op. We're structured as a private entity. But the ethos is co-operative."* Similarly, OP-E4 said of their zone's privately-owned company, putting collaboration ahead of profitability:

"The processing factory that we have was owned by six licence holders so those six people have collaborated for 35 years … It's always just been a service company, if you like. It was never designed to be a profitable business. It was designed to process product, sell product, and then act as a cost-only operation." (OP-E4)

Collaborative efforts, made easier by a shared cooperative ethos and long-term relationships, are notable as solutions to some of the barriers described in 'A

Balancing Act' in Theme 2 (Section 5.3.2). Furthermore, a feature of these three instances of co-operative models or ethos is that the quota owners tended to have an equal or similar share of quota. The sustainability implications of long-term family ownership of abalone quota have not been discussed in the literature previously; though the self-management of abalone stocks has been investigated (Gilmour, Dwyer and Day 2013), as has the sustainable management of Australian fisheries (Mayfield et al. 2012).

However, the phenomenon of family quota ownership was not without its exceptions. Insights provided by OP-E4 in the 'Other Priorities' aspect of Theme 2 (Section 5.3.2.) regarding the first-generation quota owners who have held on to their quota were notable for their unwillingness to change practices. OP-E4's comments and evidence from other participants suggest that progressiveness – in particular, a willingness to change operating practices in the interest of personal sustainability values – is cultivated by the second- and third-generation owners who have been passed on quota such as OP-B2, OP-B3, OP-B4, and others. In this way, the *intergenerational* aspect of ownership is key. The findings presented here concerning intergenerational quota ownership and its intersection with economic and environmental sustainability align with what has been previously studied by Dangelico, Natasi, and Pisa (2019). Specifically, the authors found that second generation family members were particularly driven by their personal environmental and economic sustainability values to operate innovative, 'green' businesses.

However, this research is more relevant to the small body of literature concerning the change in quota ownership from local families to geographically-removed corporate entities; and the increase of lease fishing arrangements which are two phenomena occurring in several other fisheries outside of abalone, and outside of Australia (Edwards and Pinkerton 2020; Knott and Neis 2017). Knott and Neis (2017) contend that the shift in quota ownership from intergenerational family groups to non-local investment firms or corporations can have negative outcomes on the sustainability of wild, restricted-entry fisheries and their supply chains. This is because of the propensity for such entities to monopolise whole fisheries and prioritise short-term financial gains. In the context of this research and seafood supply chains more generally, this phenomenon is of concern and worth further study because monopolisation or asymmetric market power along food supply chains can threaten: the quality or, at worst, safety of consumer products (Qi, Cai and Cui 2023); the natural capital and livelihoods of local communities (i.e. workers, associated businesses) upon which the supply chain depends (Edwards and Pinkerton 2020; Knott and Neis 2017).

Overall, community (or localness) and intergenerational quota ownership was strongest in South Australia, Victoria's eastern and Western Zones, and Western Australia. These attributes appeared to drive sustainability (e.g. sustainable fishing practices, motivation to utilise by-products) and supply chain collaboration in most cases. In turn, sustainable business practices encompassed the desire to use of all parts of the abalone; and supply chain collaboration has the potential to enable competitiveness when developing markets. Both are pre-conditions for the development of products and markets for valorised viscera, blood, and shell.
On the topic of supply chain collaboration, ME-1 confirms, *"You can still grow the whole category and still differentiate yourself or make yourself distinctive within a category. And it's when people get to that level of thinking that change can happen",* and *"it is about competitiveness of the [supply] chain, not about individual company competitiveness."* Thus, drivers of supply chain collaboration such as the culture and ethos of each zone should be harnessed as a strength to overcome some of the barriers discussed in Section 5.3.2.

"Wild" and "Brand Australia"

Expanding on the importance of supply chain competitiveness, ME-1 discussed the inherent strengths possessed by the wild-harvest industry that could be used to stakeholders' advantage in market development. ME-1 highlighted the provenance of Australian wild abalone as an inherent strength. This consisted of two elements. Firstly:

> *"I think the biggest competitive advantage that Australian wild-caught abalone has is that it's wild … and farmed [abalone] will never be able to copy that" (ME-1)*

Additionally, ME-1 suggests that *"The fact that it's from Australia, you know, capitalising on 'brand Australia'"*. Speaking from experience, ME-1 made clear that this was *"something that's just not done"* and *"an opportunity going begging"*. Although ME-1's insights were based on past experiences of market development for existing abalone products, the suggestion was made that wild, Australian provenance attributes could also be used to market future viscera products. The literature on the marketability of wild food products is largely focused on consumer preferences and perceptions (e.g. willingness to pay) for wild versus farmed seafood (Allegro et al. 2021; Hilger et al. 2019; Polymeros et al. 2015); and potential to differentiate wild seafood from aquaculture products in the marketplace (Hoshino et al. 2015; Kecinski et al. 2017; Williams 1992). Hunting of game meat (e.g. wild boar, kangaroo, antelope) as a potential means of sustainable food production has also received much attention in the literature (Branciari and Ranucci 2022; Chaves et al. 2018; Czarniecka-Skubina et al. 2022; Hercock 2004; McCrindle et al. 2013). However, owing to the relevance of seafood marketing to this particular aspect of Theme 3, the discussion will focus on the marketability of wild seafood compared to aquaculture products.

ME-1's claims are substantiated by the literature, but the emergent themes from the literature indicate that more research is required on this aspect of Theme 3. For example, a review by Maesano et al. (2020) revealed that country of origin was the most important attribute in relation to consumer choice of seafood products; and wild seafood, rather than aquaculture products, was generally preferred by consumers owing to perceptions of its superior taste, quality, health, and safety standards. However, the differentiation of products based on provenance (i.e. wild and country of origin) in the marketplace is highly dependent on how the product is packaged (i.e. labelling); and where it is sold and consumed (i.e. in restaurants or at retail outlets, geographical region) (Kecinski et al. 2017; Maesano et al. 2020; Williams 1992; Zheng, Wang and Lu 2018). Other studies have also suggested that willingness to pay for seafood products, wild or aquaculture, is highly dependent on the species of seafood desired by the consumer (Allegro et al. 2021; Kecinski et al. 2017). It is important to note that these themes are specific to common seafood products (i.e. canned tuna, oysters, prawns), rather than by-products of seafood.

The literature concerning credence attributes of food by-products or valorised food waste appears underexplored (Zheng, Wang and Lu 2018); although credence attributes in agrifood product marketing is a well-traversed topic in the literature generally (Latino et al. 2022; Moser, Raffaelli and Thilmany 2011; Schrobback et al. 2023; Young et al. 2022), and especially in relation to 'sustainable seafood' (Castro et al. 2021; Maesano et al. 2020; Roheim and Zhang 2018). Zheng, Wang, and Lu (2018) found that consumers in China who often purchase wild seafood were more likely to purchase by-products (i.e. fish heads and bones) of wild-caught Alaskan salmon; owing to their overall perceptions of the benefits of consuming wild seafood originating from clean, safe, and high-quality origins. The findings of this research support the theme from the broader literature on wild versus aquaculture seafood marketing and product differentiation; and indicate that there is potential to market Australian wild-harvest abalone viscera based on credence attributes. However, further research is required to substantiate these conclusions. As mentioned in Section 5.2, theoretical saturation was not reached for this aspect of Theme 3 and more insights could have added depth to ME-1's suggestions. As such, this research has not contributed new knowledge in this area; but rather, provided a basis for future research.

Overall, three strengths were identified in this theme, which included: (1) Instigators of Change and Lessons from the Past; (2) "*The ethos is co-operative*"; and (3) "*Wild"* and "*Brand Australia*". Each were discussed in relation to the literature on sustainable agrifood practices and supply chains. Thus, this theme is relatable to each of the five fisheries though some fishing zones displayed more strengths than others, furthering the case for a zone-level approach to initiating improvements to waste outcomes.

5.3.4 Theme 4: Systemic Forces

The fourth and final theme to emerge from the interviews relates to: (1) regulatory changes that can be implemented to drive changes to supply chain practices; and (2) financial incentives that could be offered by fishery authorities to quota owners and/or divers to utilise their by-products.

Regulatory Changes

The strong influence of state regulations on the structure and practices of wild-harvest abalone supply chains was mentioned by several participants (*n*=9). For example, vertically-integrated fishing and processing firms are more prevalent in fishing zones where TACC quotas set by the fishing authority are high (i.e. above 100 tonnes per annum). As OP-A2 explains:

> *"A processing facility needs to put through about 100 tonne a year to be financially viable." (OP-A2)*

OP-E4, quota owner and co-owner of the remote processing facility described in Section 5.3.3 ("The ethos is co-operative"), similarly linked the ability to vertically integrate fishing and processing activities with sufficient TACC quotas:

> *"We're not processing at the moment because of we've had a severe cut of our quotas".*

Any regulatory changes to improve waste outcomes would be most impactful in shuck-at-sea fishing areas where the majority of viscera and to some extent, shells, are disposed of at sea. In the absence of an economic case for utilising viscera versus disposing of it at sea (discussed in Subsection 5.3.2, 'Economic Feasibility'), regulatory change may be the systemic push that is required for operators to land this component of their catch.

Regulatory changes appear more likely to occur in South Australia than Western Australia where disposing of viscera at sea poses a more pressing biosecurity risk to abalone stocks (explicated in Section 5.3.1, 'Sustainable Thinking'). Even then, however, the South Australian fishing authorities are conscious of making incremental rather than broad-sweeping changes that consider impact on operators and their harvesting practices. On potential regulatory changes to mitigate the spread of *Perkinsus*, FS-B1 said:

> *"If we ask them to start bringing in [abalone] in-shell all over [this] zone, I think there'll be uproar. They would not be happy at all about it … the next question is, is it necessary to land everywhere in shell? We're going to have part of the [Perkinsus biosecurity] project involve having a workshop [with operators] on that." (FS-B1)*

Several participants in addition to FS-B1 described changes to abalone fishing regulations that were often driven by operators and regulators working together. Significant examples were described in Section 5.3.3 ('Industry Champions') by participants O-D2, OP-B3, and OP-B4. However, it should be noted that changes occurred at a zonal-level and were underpinned by a push from quota owners. This furthers the case for approaching changes to supply chain practices using an incremental strategy that tackles improvement to waste outcomes at a state- or zonal-level first, rather than as a nation-wide effort.

The co-management of abalone fisheries in Australia has been studied previously in the literature (Gilmour, Dwyer and Day 2013). However, the implications on biosecurity and food waste outcomes have not been explored. The effectiveness of governance in reducing food waste along abalone supply chains cannot be extrapolated from the interview data. Moreover, there is some evidence from the literature that suggests regulatory change as a measure to reduce food waste is ineffectual compared to solutions to supply chain inefficiencies directly at the firm-level (Diaz-Ruiz et al. 2019; Thyberg and Tonjes 2016). The influence of regulatory change over downstream food waste has been speculated in the literature in a European context, but not within Australia nor specific to primary production contexts (Giordano et al. 2020; Szulecka and Strøm-Andersen 2022). As such, this suggests a gap in the literature that could be addressed with further research.

Financial Incentives

This aspect of Theme 4 was only raised by one participant, OP-B4, but was a pertinent, additional dimension to addressing economic feasibility concerns of operators in shuck-at-sea fishing areas. OP-B4 said:

"We're a cost-recovered fishery. [Quota owners] paying for management of our fishery so we're not a burden to the taxpayer. Whatever resources are spent on our fishery are costs recovered from us. I think compliance would be, 30 or 40% of our overall licence fees. So if we could reduce that some way, without incurring costs in other areas to encourage divers to land the shell and viscera to then return a reduced fee … that's something they [the divers] would be very interested in." (OP-B4)

That the potential to decrease licensing fees by landing viscera and shells was raised by only one participant does not discount the importance of the idea; since the approach taken to data analysis was pragmatic and thematic rather than a content analysis strategy (Creswell 2009). Furthermore, high licensing costs has been documented in the literature as pervasive across the five fisheries (Mayfield et al. 2012). OP-B4 confirms what has been reported in the literature, in that licensing fees are a means of funding stock assessments and compliance activities carried out by the fishing authorities

OP-B4's comments highlighted an absence of discussion in the qualitative interviews about the financial incentives to reduce waste disposal derived from lowering administrative and taxation costs; as opposed to the financial incentives of potential new revenue streams by valorising waste. This was a limitation of the data collection instrument as topics such as tax offsets were not explored in the initial literature review (Chapter 2).

However, savings on landfill fees by utilising viscera and shells were discussed briefly with some participants (*n*=5). These participants confirmed that, despite the low market value for viscera, operational costs were still reduced by finding a market for their shucking by-products. For example, where exporting shells is concerned, OP-E1 confirmed that:

"It's not a lot [of revenue]. But it pays us to do it. It's saving on landfill." (OP-E1)

Similarly, in relation to the difficulty of finding some value for viscera, OP-C2 confirmed: *“Disposing of the viscera had a cost … [in] eliminating that expense of disposal, from a commercial perspective, we made a saving”.* The views expressed in this aspect of Theme 4 reinforce stakeholder views in other food waste studies concerning financial incentives of recovering or recycling food waste (Mak et al. 2018). Furthermore, the views captured by this theme align with Amicarelli, Roe and Bux’s (2022) proposition that firm-level savings on disposal fees has collective benefits for more sustainable food waste management and economic resources.

5.4 Conclusion

In this phase of the research four major themes, emergent from participants’ responses, were presented. The four themes were: (1) Opportunities and Motivations to Improve Food Waste Outcomes; (2) Barriers to Improvement; (3) Strengths to be Leveraged Along the Supply Chain; and (4) Systemic Forces. Each constituted a number of aspects that gave each theme nuance and breadth, thereby building the internal validity of the findings as defined by Miles, Huberman, and Saldana (2020). Furthermore, the themes interacted with one another (Section 5.3, Figure 41) such that an understanding could be developed of: current waste management practices (Theme 1); supply chain actors’ desires and challenges faced to reduce waste (Themes 1 and 2); and the factors that might assist in overcoming real and potential challenges of improving waste management practices (Themes 3 and 4).

Overall, it emerged that opportunities to improve food waste outcomes were entangled with supply chain actors’ motivations to operate more sustainably. This was particularly evident amongst South Australian and Western Australian participants who described waste management practices that would be considered ‘lesser preferred outcomes’ according to the food waste hierarchy. Practices included landspreading, disposal at sea, and landfilling, which participants from these states generally wished to improve. In Tasmania, where operator-processors already manage their food waste more sustainably by comparison, participants still spoke of their economic motivations to maximise revenue from catch and minimise operating costs by distributing all parts of the abalone rather than disposing of the by-products.

The focus on opportunities as well as motivations to reduce waste supported themes previously explored in the literature on food waste, particularly consumer- and retail-focused studies (Goodman-Smith, Mirosa and Skeaff 2020; Papargyropoulou et al. 2016). However, the commitment to sustainability, understanding of its core tenets, and desire to improve food waste management practices of abalone primary producers and processors across Australia has not previously been captured in the literature. The research contributes a new aspect to the body of extant literature which has focused on the sustainable management of Australian abalone stocks and regulatory compliance by operators from a purely quantitative and technical perspective (Bose and Crees-Morris 2008; Gilmour, Dwyer and Day 2013; Mayfield et al. 2012). Moreover, capturing the views of primary producers and processors in the Australian abalone industry confirms the economic and environmental pressures faced by wild-harvest operators, but contributed new knowledge by documenting the resultant changes to supply chain practices and motivations to maximise catch.

The barriers to improving supply chain practices and waste outcomes were numerous; ranging from logistic and economic to more abstract matters such as a lack of information sharing, and operators having other priorities than addressing waste management practices. Operator-processors in shuck-at-sea fishing zones such as South Australia’s Western and Central Zones, and Western Australia’s Areas 2 and 3 tended to be more concerned with logistic challenges and economic risk; whereas Victorian supply chain stakeholders faced challenges of organisational siloing, lack of information sharing, and other biosecurity priorities. Conclusions about the barriers presented by such challenges were made by comparing the results with the literature on meeting downstream market requirements, consistency of supply, and supply chain collaboration (i.e. information sharing).

Existing strengths to be leveraged along the supply were explored as potential avenues for overcoming the aforementioned barriers. It emerged that in South Australia, Western Australia, New South Wales, and Victoria, there were several ‘Instigators of Change’ – supply chain actors who demonstrated specific leadership traits and who had experience initiating changes to supply chain practices, either in their fishing zone or nationally across the industry. Not only were the leadership traits possessed by these Instigators a strength to be leveraged, but the lessons they shared about initiating change in the past also proved valuable in considering food waste management interventions. A review of the literature revealed that supply chain leadership in food waste appears an underexplored topic, despite its significance in general supply chain management theory. The co-operative ethos present in the South Australian and Western Australian fisheries, in particular, were discussed as a further strength of those particular supply chains; and when compared with the literature on seafood supply chains and quota ownership in restricted-entry fisheries, yielded a potentially important area of future research. Marketing aspects were also discussed, based on ME-1's suggestions that provenance attributes of Australian wild-harvest abalone could be leveraged to successfully commercialise future abalone viscera products. However, as theoretical saturation could not be reached on this aspect of Theme 3, the literature on credence attributes for wild seafood and food by-products was reviewed before making conclusions. It was determined that there was potential for "wild" and "brand Australia" attributes to be leveraged, but further research would be required on suitable markets, and consumer perceptions of Australian abalone viscera.

Finally, systemic forces were discussed as an additional channel through which food waste management interventions could either be implemented or incentivised. These systemic forces included two aspects: (1) changing the regulations to prevent shucking or disposal of viscera and shells at sea, particularly given the biosecurity risks associated with the practice; and (2) incentivising operators in shuck-at-sea zones to land their by-products alongside the shucked meat by offering decreased licensing fees. The financial motivation to reduce on-land disposal costs for the viscera and shell would subsequently apply to operator-processors; as is the case in other state fisheries such as Tasmania and Victoria where abalone must be landed whole. The literature suggests that of the two options discussed, financial incentives may be more effective in changing food waste management practices than regulatory changes.

The themes discussed in this chapter formed the foundations of the overall conclusions presented in Phase C (Chapter 7). The overall conclusions were made by integrating the qualitative results elicited in this phase with the quantitative results of Phase B, which will be discussed in the following chapter.

6 DISCUSSION OF RESULTS: PHASE B (quan)

In this chapter the estimates of food waste that were yielded from the supplemental component of this research, Phase B (quan), are presented and compared with the literature. As explained in Section 3.5, the mass flow estimates of abalone by-products were determined by combining the secondary data initially collected in the desktop review (Sections 4.2 and 4.5) and data elicited from Sample B (n=10).

The mass flow analysis of food waste undertaken in this research supplements the information about waste management practices presented in Chapter 5 in that it constitutes the 'performance' element of supply chain analysis and accompanies the mapping of product flows. By estimating the levels of food waste generated at the upstream stages of Australia's wild-harvest abalone supply chains, waste hotspots (defined in Section 1.3.1) can be identified; and this information subsequently integrated with the knowledge of waste management practices in the following phase of the research (Chapter 7) to make inferences about what drives the creation of waste hotspots and how these high levels of waste might be reduced.

In this chapter waste estimates are presented at an industry-wide level first (Section 6.1) in order to discuss some of the findings that were generally applicable to all fisheries (Sections 6.1.1 to 6.1.4). More granular estimates are then presented on a state-by-state basis and according to species in Sections 6.2.1 to 6.2.5.

6.1 Industry-wide Mass Flow Analysis

The volume of by-products (viscera, blood, shell) generated from the upstream stages Australia's wild-harvest abalone supply chains in 2019 amounted to approximately 42% (1,195.8 tonnes) of the total annual national catch. These results are presented in Table 28, which summarises how by-products were assessed based on provenance (fished, ranched, state fishery), species (Blacklip, Greenlip, Brownlip, Roe's), by-product type (viscera, blood, shell), by-product outcomes (disposal at sea, disposal on land, storage for future use, other use within the same season), and shucking location (at sea, on land).

Table 28. Summary of mass flow analysis of abalone by-products generated for each abalone species and state fishery.

2019	NSW	SA		VIC		TAS		WA				All States
Species	●	●	●	●	●	●	●	●	● (fished)	● (ranch)	●	● ● ● ●
Total catch harvested whole weight (tonnes)	99.8	302.3	356.7	689.0	6.0	1140.0	109.2	21.5	42.3	55.0	47.0	**2868.7**
Total by-products generated (tonnes): *												
Viscera	0.0	46.6	84.2	191.4	0.9	118.0	19.7	5.3	10.0	9.2	10.7	**496.0**
Blood	0.0	13.5	26.5	0.0	0.0	0.0	0.0	1.5	2.8	0.0	0.0	**44.3**
Shell	0.0	61.5	111.1	252.7	1.2	155.8	26.0	6.9	13.2	12.9	14.2	**655.5**
Total generated (tonnes)	**0.0**	**121.6**	**221.7**	**444.1**	**2.2**	**273.8**	**45.7**	**13.7**	**26.0**	**22.1**	**24.9**	**1195.8**
% of total catch across Australia	**0%**	**4%**	**8%**	**15%**	**0%**	**10%**	**2%**	**0%**	**1%**	**1%**	**1%**	**42%**
Location of shucking:												
Shucked at sea	np	106.6	221.7	np	np	np	np	13.7	26.0	np	np	**368.0**
Shucked on land	0.0	15.0	0.0	444.1	2.2	273.8	45.7	0.0	0.0	22.1	24.9	**827.8**
Outcomes of by-products generated (tonnes) *												
Disposed at sea	-	106.6	161.3	-	-	-	-	9.7	16.2	-	-	**293.8**
Disposed on land	0.0	15.0	0.0	268.6	0.7	49.8	3.6	4.0	3.2	0.0	24.9	**369.8**
Stored for future use	0.0	0.0	0.0	37.3	0.1	26.3	6.6	0.0	0.0	8.8	0.0	**79.0**
Other use	0.0	0.0	60.4	138.2	0.5	197.6	35.6	0.0	6.6	13.4	0.0	**452.3**

Legend:

- ● Blacklip abalone
- ● Greenlip abalone
- ● Brownlip abalone
- ● Roe's abalone
- * By-products from processing that occurs within state; figure may include abalone harvested from other fisheries

np Shucking at sea is not permitted

(grey) Blood retained in meat, or unintentionally drained during processing

(orange) Waste hotspots – i.e. highest instances of by-product discards by volume

(green) Highest instances of waste utilisation by volume

Notably, in Table 28, the blood component of abalone was excluded from the estimate of total by-products generated in certain scenarios. This included Greenlip and Blacklip abalone shucked on land in Victoria and Tasmania; and Roe's abalone and ranched Greenlip abalone shucked on land in Western Australia. As explained in Section 5.3.1, on-land processors do not intentionally drain the abalone meat of blood as shuck-at-sea operators do. For this reason, the blood components have not been included in the total estimate of by-products generated in Table 28. Rather, the blood component from abalone shucked on land is presented separately in Table 29 as *potential* volumes that could be recovered should processors wish to.

Table 29. Potential volume of blood generated from fisheries where meat is not intentionally drained of blood.

2019	**VIC**		**TAS**		**WA**		**All States**
Species	●	●	●	●	● (ranch)	●	● ● ●
Blood	69.4	0.3	42.5	7.1	3.7	3.0	**126.0**

The overall outcomes of blood are presented in Figure 43. There are no indications from abalone processors across Australia that blood is harvested or used in a significant way despite suggestions by participants and in the literature of potential therapeutic value (discussed in Section 5.3.1). As shown in Figure 43, the majority of blood from shucked abalone is estimated to remain in the meat (74% or 126.0 tonnes).

N.B.: Asterisk (*) indicates that blood is either retained in the abalone meat or incidentally drained during on-land processing.

Figure 43. Outcomes of blood in each of the five state fisheries across Australia in 2019, all species combined.

More generally, it was estimated that of the 1,195.8 tonnes of by-product generated at the upstream stages of the supply chain (Table 28), 100% is generated at harvest or post-harvest processing and none during distribution. Owing to the drive, scope, and project timeline of this research, a mass flow analysis of abalone by-products generated from downstream segments of the supply chain (i.e. retail, food service, household consumption) was not undertaken.

In this research it was estimated that 55% (666 tonnes) of all by-products generated are disposed of either at land or at sea. This represents 23% of the total annual catch volume. As shown in Table 28, Victoria and South Australia yielded the highest volumes of disposed by-products, whether at sea or on land. These volumes, highlighted in red in Table 28, consisted mostly of Blacklip shells (206.6 tonnes) and viscera from Blacklip and Greenlip abalone (257.1 tonnes). Overall, by-products were classified according to 16 categories by which they were compared and analysed to identify possible drivers or correlated characteristics of food waste across the five fisheries. A summary of the 16 categories used to analysed by-products is presented in Figure 44.

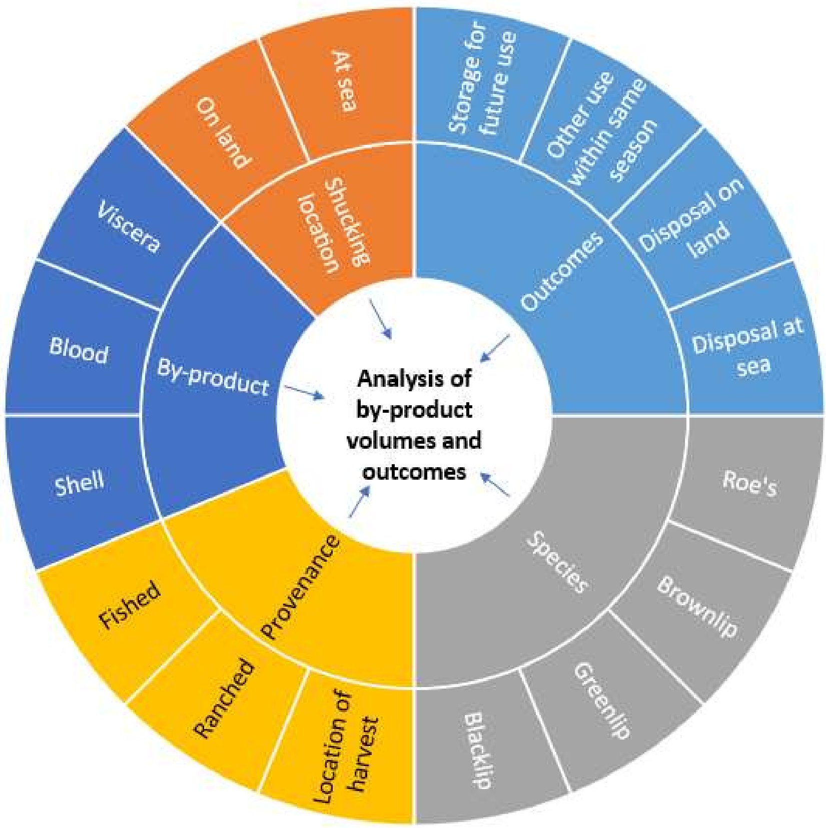

Figure 44. Categories (n=16) used to analyse by-product volumes and outcomes in this research.

By comparing the by-products based on the categories shown in Figure 44, supply chain practices (e.g. shucking at sea, on-land processing) could be linked to volumes of waste; thus highlighting possible drivers of waste hotspots or by-product utilisation. Some industry-wide factors emerged from this approach to analysis and are presented in the following Sections (6.1.1 and 6.1.2). Additionally, use of the aforementioned categories (*n*=16) enabled analysis of the impact of fishing practices on the volume of by-products generated, which is explored in Section 6.1.3.

In the literature, abalone processing waste generated in Australia has been estimated at a national scale based on 2013 data by Howieson et al. (2017). However, the results reported herein contributes to knowledge by extending the categories used by Howieson et al. (2017) which were limited to waste quantified according to shucking on land versus at sea. Furthermore, this research was able to quantify volumes of viscera, shell, and blood shucked at sea which were not presented in the estimates by Howieson et al. (2017).

The volumes of by-product and their respective outcomes that are presented in this chapter are a contribution to knowledge; as this quantity of supply was previously unknown and undocumented at a national-level. This results presented in this chapter provide empirical evidence for supply chain development where recovering and valorising by-products are concerned. The estimate of product and waste flows from harvest to distribution (export and domestic) have not previously been documented in the literature for any other economically-significant Australian seafood industry – e.g. prawns, lobster, and tuna (Stevens, Mobsby and Curtotti 2021) – within the last five years. Quantitative studies assessing the sustainability of Australian prawn (Farmery et al. 2015) and rock lobster (van Putten et al. 2016) industries have been conducted from a general environmental perspective (i.e. life cycle assessment) but not specifically in relation to food waste. The results presented in this chapter provide insight into the sustainability of the Australian abalone industry from a food waste perspective. In doing so, this research also addresses broader gaps discussed in Section 1.3.1 regarding understanding primary production food waste from a supply chain perspective, and in industrialised countries' upstream supply chain stages.

6.1.1 Largest Categories of Waste

From an industry-wide perspective, most of what is disposed of consists of shells (312.6 tonnes) and viscera (306.7 tonnes). Most shells were discarded at sea in South Australia as a result of shucking at sea practices (104.8 tonnes) or at landfill by processors in Victoria as a result of lack of storage (144.2 tonnes). The outcomes of viscera are presented in Figure 45. The same two drivers also resulted in the high volumes of discarded shell (Figure 46). Specified volumes of viscera and shell outcomes categorised by state and/or species are provided in Appendix I. As shown in each of the following figures, the prevalence of certain outcomes (e.g. disposal at sea versus disposal on land) vary greatly between each fishery depending on fishing practices. These differences will be explored in the following sections on a state-by-state basis.

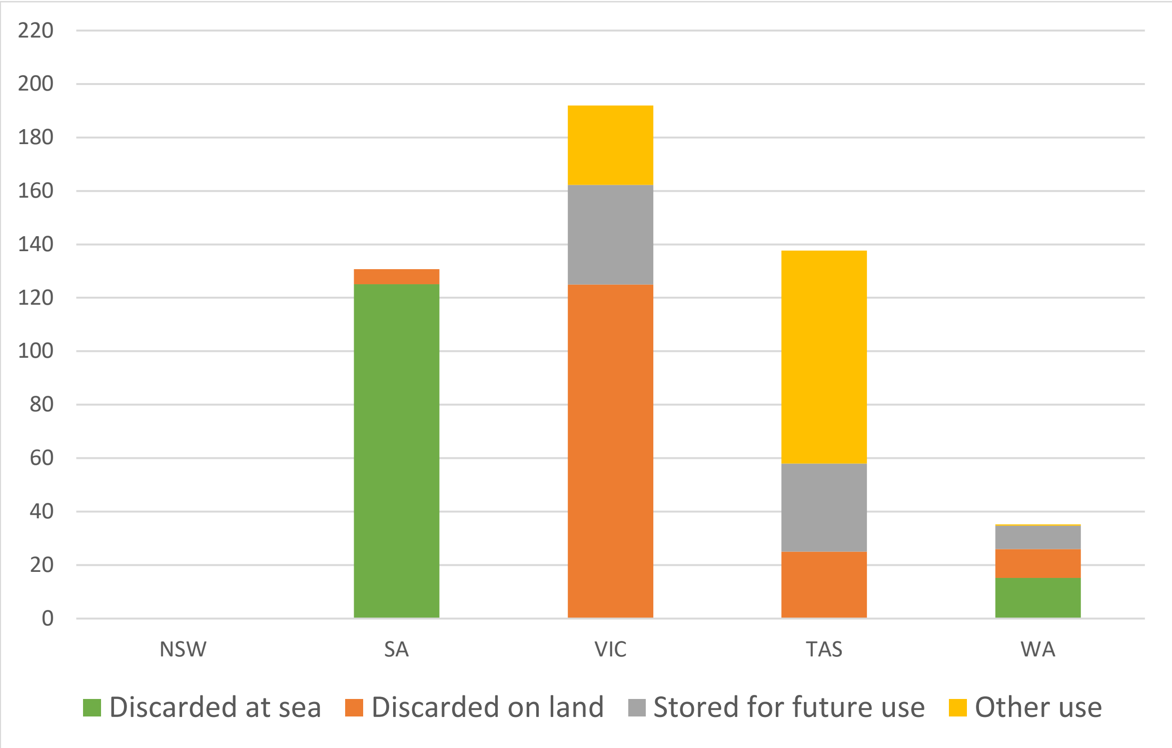

Figure 45. Outcomes of visecera (tonnes) generated at primary production and post-harvest stages in each state fishery for all species combined.

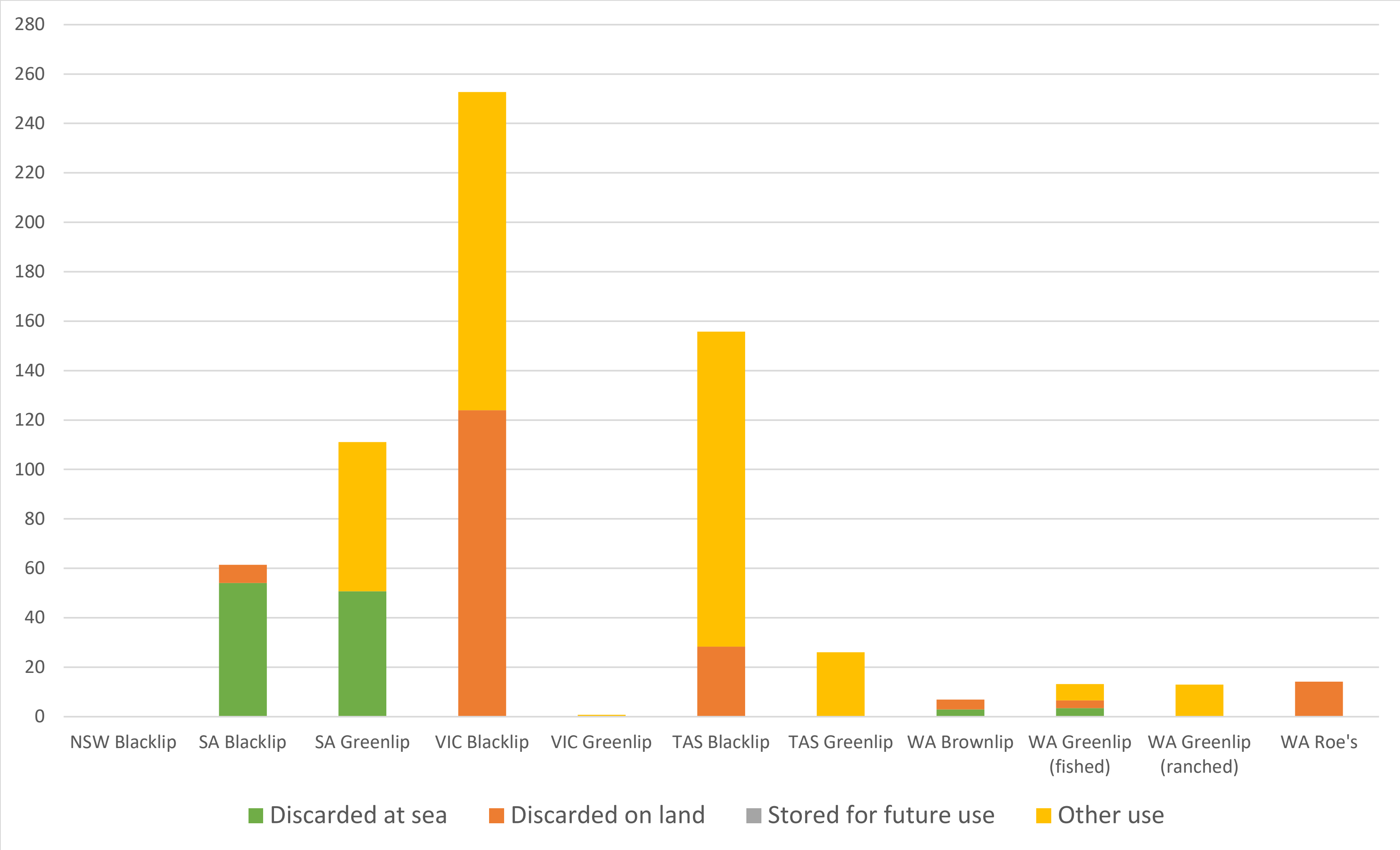

Figure 46. Outcomes of shells (tonnes) generated from primary production and post-harvest stages in each state fishery, on a species-basis.

Mass flow analyses of food waste, particularly at the supply chain-level and focused on specific seafood industries, are limited in the literature. Studies at the micro-level (according to the three food system levels of 'macro', 'meso', and 'micro' which were explained in Section 1.3) have tended to focus on food waste generated within a single firm (Anastasiadis, Apostolidou and Michailidis 2020; Garcia-Garcia, Stone and Rahimifard 2019). Whereas several studies analysing the mass flow of food waste from primary production tend to focus on food waste at a macro- or national-level where seafood is just one broad category amongst others such as fruits and vegetables, dairy, and so on (Bedoya-Perales and Dal' Magro 2021; Beretta et al. 2013; Betz et al. 2015; Caldeira et al. 2019; Dong et al. 2022; Hartikainen et al. 2018; Jiang et al. 2023). Given the imperative to address food waste and to understand the root causes and volumes across supply chains, the lack of mass flow analyses at the supply chain-level constitutes a prominent gap in the literature (Parfitt, Croker and Brockhaus 2021; Xue et al. 2017).

Furthermore, there is a need to maintain the sustainability of seafood production generally, in terms of environmental health, but also where using discards and by-products are concerned (Farmery et al. 2015; Fleming et al. 2014; Tlusty et al. 2019; Venugopal 2021). The results from this phase of the research have both practical and academic significance since specific waste hotspots have been identified (i.e. largest categories of waste and points of waste creation along the supply chain). As explained in Sections 1.3.1 and 1.3.2, identifying waste hotspots along the supply chain allows for targeted action and tailored management interventions; which, in turn, are more likely to result in reduced or prevented food waste outcomes. Furthermore, the focus of this research on improving abalone by-product outcomes aligns with the contemporary literature on sustainable seafood production.

6.1.2 Species as a Factor in By-Product Usage

The outcomes of shells (i.e. disposal versus use) vary depending on species, rather than fishing practices, across the five fisheries. However, species did not appear to have a bearing on the usage or disposal of abalone viscera. For this reason, the outcomes of shells presented in Figure 46 were presented according to species and state as separate categories; and the outcomes of viscera in Figure 45 were only presented according to state with all species combined.

Taken as a proportion of shells generated, rather than nominal volume, 65% (106.4 tonnes) of Greenlip shells were retained versus 50% (236.9 tonnes) of Blacklip shells, 0% of Brownlip shells, and 0% of Roe's abalone shells. Greenlip shells were retained more often than Blacklip shells owing to their higher value (up to AU$15/kg, see Appendix J, Response xxvi) and use for mostly non-food applications such as furniture inlays, decorative display items, and jewellery. Blacklip shells appeared to be sold for use in traditional Eastern medicine, though participants did not reveal the specific market value of Blacklip shells. Rather, it was implied that Blacklip shells are not as highly sought-after as Greenlip shells and are therefore subject to a lower market value.

Current uses of abalone shells and their economic value have not been documented in the literature based on empirical evidence, as is the case in this research. Decorative use of abalone shells in indigenous cultures has received some attention in the literature, but not within a contemporary context (Sloan 2003). Furthermore, studies focused on the technical feasibility of valorising abalone shells for therapeutic uses have asserted the potential economic benefits of utilising the shells in this manner but have not specified current or potential economic value of extracting compounds of interest (Li, Wen, et al. 2019; Wang et al. 2021). Additionally, the extent of usage and discards of abalone shells has not been formally documented in studies focused on valorisation outcomes of the shells (Chen et al. 2015; Li, Wen, et al. 2019; Wang et al. 2021). As explained in Section 2.2.8 the economic feasibility of any valorisation pathways for by-products is an essential accompaniment to technical research from a pragmatic and business management perspective. Quantifying volumes of by-products – the shell, in this case – and providing existing market values are first steps to conducting an economic feasibility assessment. From this perspective, the quantitative phase of this research has contributed to knowledge by bridging the gap between the technical and economic feasibility of improving outcomes for abalone shell waste.

6.1.3 Selective Versus Non-selective Fishing

As a wild, biological product (as opposed to farmed or manufactured goods) the variation in abalone attributes affects the volume of by-products generated. It emerged from participant responses that abalone vary in meat and blood quantity throughout the year, whereas viscera and shell size and volume remain relatively stable. This has supply chain implications in terms of customer expectations of product quality (i.e. size, volume of blood retained in the product); and timing of supply through the year which will be discussed in more detail in this section.

Participants' assertions regarding the fluctuation in abalone meat and blood was supported by two South Australian studies (Stobart, Mayfield and Chick 2018; Stobart, Mayfield and McGarvey 2013) that indicated Blacklip and Greenlip abalone composition does indeed vary throughout the year, potentially depending on spawning patterns or availability of food, for example. An earlier study by McShane, Smith, and Beinssen (1988) on Victorian Blacklip abalone also suggests fluctuation in abalone size and weight throughout the year.

Participants from South Australia's Western Zone, and Area 2 and 3 in Western Australia reported use of selective fishing practices on both Blacklip and Greenlip abalone which account for the fluctuations in meat and blood composition through the year. 'Selective fishing' is used in this research to refer to harvesting that occurs during months where abalone are at their highest meat weight (i.e. mass of the meat once shucked). However, participants in other fishing zones (e.g. Tasmania, Victoria, New South Wales) practiced non-selective fishing, where abalone are harvested at all times of year regardless of the meat/blood ratio. Furthermore, participants commented that ranched abalone tend to have a lower meat yield compared to wild abalone overall (Appendix J, responses lxii and lxv). Thus, it was deemed important that variation in abalone composition for all species be accounted for when assessing waste volumes across the five fisheries.

Based on the knowledge of distinct harvesting practices across the various supply chains gathered from the semi-structured interviews (Appendix J) and literature (Stobart, Mayfield and Chick 2018; Stobart, Mayfield and McGarvey 2013) three scenarios for estimating the constituent parts of the abalone and resultant by-product volumes were devised:

- **Average meat weight scenario:** where abalone are harvested year-round, regardless of size. Abalone meat is assumed to constitute an average of one-third (0.33) of the abalone.
- **Maximum meat weight scenario:** where abalone are harvested only during certain months of the year to yield maximum meat weight. In this scenario the meat component is assumed to constitute approximately 35% (0.35) of the abalone.
- **Ranched abalone scenario:** where meat recovery is generally lower than fished abalone regardless of the time of year harvesting occurs. Meat weight is assumed to constitute approximately 30% (0.3) of the abalone.

Caution was taken in extrapolating South Australian abalone composition that was investigated in the literature (Stobart, Mayfield and Chick 2018; Stobart, Mayfield and McGarvey 2013) to other species of abalone harvested in Australia and to the other state fisheries. As such, the maximum weight scenario was only applied to abalone from fishing areas where participants reported use of selective fishing; the average meat weight scenario was applied to abalone fished in a non-selective manner; and, the ranched abalone scenario was applied to product harvested in Western Australia's Greenlip ranch.

The variance in all components of the abalone, including the meat, across the three aforementioned scenarios are visualised in Figure 47. As shown in Figure 47, the viscera component was assumed to constitute approximately 25% (0.25) of the abalone in all scenarios. Where the shell component was concerned, participants (OP-B3, FS-B1) and Stobart, Mayfield, and Chick (2018) confirmed that abalone shell length and weight do not correlate with meat size and weight; meaning an abalone with a large shell may not possess a correspondingly large foot (meat component, as explained in Section 1.1.2). As such, the shell component was assumed to constitute 33% (0.33) of abalone in both average and maximum weight scenarios; and 35% (0.35) in the ranched abalone scenario. Finally, Figure 47 shows how the blood component fluctuates with the meat between the average and maximum meat weight scenarios but, overall, both components constitute up to 42% of the abalone.

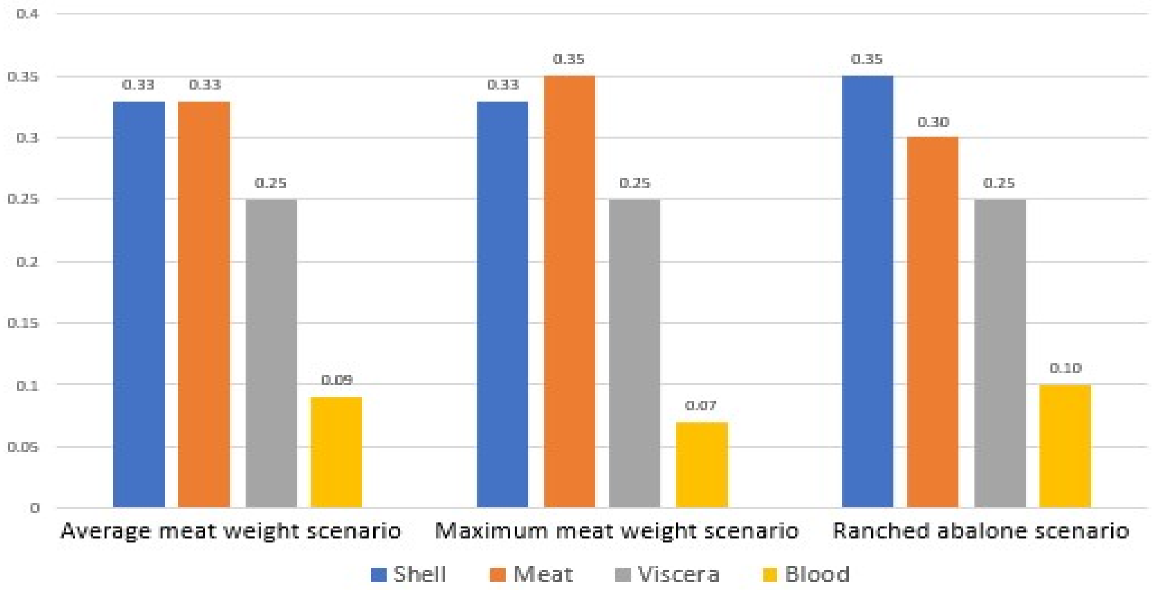

Figure 47. Assumed average, maximum, and ranched abalone composition scenarios employed in this research.

Overall, the fluctuation in components between the three scenarios does not have a significant impact on the total amount of waste generated; particularly given the majority of blood is retained in the meat as explained earlier (Section 6.1.1), and the viscera and shell components do not vary greatly. However, the potential effect of certain supply chain practices (e.g. selective fishing, non-selective fishing, and ranching or cultivation) on seafood waste volumes was a key finding from a methodological perspective and may have relevance to other seafood products. This research demonstrates that these practices have some effect on the composition of seafood (e.g. meat yield compared to other components of the product), and in turn, the quantity of resultant by-products; and, therefore, deserve consideration when estimating product flows which is essential in supply chain planning and control.

The knowledge derived from this aspect of the framework is applicable to other seafood species since selective fishing and aquaculture are prevalent in other seafood industries worldwide, not just within Australian abalone fisheries (Fenberg and Roy 2008; Kennelly 2020; Sørdalen et al. 2018; Zhou et al. 2010). Furthermore, the importance of accurately measuring the composition of food waste as a means to enabling valorisation outcomes has received attention in the literature from a technical perspective, but not from a volume perspective as in the case of this research (Carmona-Cabello et al. 2020; de Abreu et al. 2023; Li et al. 2017). The importance of quantifying waste volumes in addition to technical research of food waste was explained in Section 1.3.2.

6.1.4 Interstate Movement of Product

Where the quantification of food waste hotspots was concerned, this research revealed that in some states TACC quotas and actual catch data become decoupled from waste volumes when interstate movement of product occurs. This primarily concerned Blacklip harvested in South Australia's Southern Zone. According to participants (*n*=4) a significant portion of South Australia's Southern Zone Blacklip abalone (approximately 83% or 109 tonnes) are brought across the border into Victoria where they are landed live and whole in shell, and shucked by licensed processors in Portland, Victoria. From a supply chain perspective, these findings are noteworthy because the interstate movement of abalone products is not sufficiently reflected in existing secondary datasets (ABS 2021; Stevens, Mobsby and Curtotti 2021) and has not been documented in the literature on Australian abalone fisheries (Mayfield et al. 2012), despite the heavily-regulated nature of the industry and level of reporting that is required of divers, quota owners, and processors to ensure products are traceable through the supply chain.

The decoupling of production volumes from processing volumes is noteworthy from a methodological perspective because it highlights that food waste hotspots cannot be identified based on extant secondary datasets alone. Knowledge of practices gathered in Phase A were essential to estimating the volumes of waste by location more accurately. Specifically, food waste is more accurately measured against total processing volumes rather than catch volumes.

Discards relative to total whole weight catch are skewed for South Australian Blacklip (40%) compared to discards relative to catch processed (63%). This is highlighted in yellow in Table 30.

Table 30. Comparison of discards relative to total whole weight catch and discards relative to catch processed.

2019	NSW	SA		VIC		TAS		WA				All States
Species	●	●	●	●	●	●	●	●	● (fished)	● (ranch)	●	● ● ● ●
Total by-products discarded (tonnes)	0.0	121.6	161.3	271.0	0.7	49.8	3.6	13.7	19.4	0.0	24.9	**666.0**
Total catch harvested (whole weight, tonnes)	99.8	302.3	356.7	689.0	6.0	1140.0	109.2	21.5	42.3	55.0	47.0	**2868.7**
A: Discards relative to total whole weight catch (%)	0%	40%	62%	64%	36%	24%	42%	64%	61%	40%	53%	42%
Total catch processed (whole weight, tonnes) *	97.5	193.1	354.8	800.4	11.2	1140.0	105.9	21.5	42.3	55.0	47.0	**2868.7**
B: Discards relative to catch processed (%)	0%	63%	63%	55%	19%	24%	43%	64%	61%	40%	53%	42%
Variance (A less B, %)	**0%**	**-23%**	**0%**	**9%**	**17%**	**0%**	**-1%**	**0%**	**0%**	**0%**	**0%**	**0%**

Comparing discards to total whole weight catch is not a significant issue in other states and for other species because majority, if not all catch, are shucked within the state. Nevertheless, the South Australian case demonstrates that waste hotspots are created where catch is processed rather than where it is harvested. Furthermore, this level of detail is lost when analysing data at a macro-level (i.e. nationally or globally). These findings confirm what has been asserted in the literature regarding the importance of primary and supply chain-level data in eliminating broad and inaccurate assumptions about the extent of food waste (Parfitt, Croker and Brockhaus 2021; Xue et al. 2017).

6.2 Mass Flow Analyses for Individual States

The mass flow analyses for each of the individual state fisheries will now be presented. An understanding of the market share of processors on a state-by-state basis was essential to the mass flow analysis. As explained in Section 3.5.3, this approach to quantifying food waste assumes inputs (i.e. throughput of catch at the processing stage or shucking at sea) equal outputs (i.e. abalone products, by-products, and food waste). Knowledge of processors' market share was elicited from participants in Phase A and a summary is provided in Appendix H. Altogether, the mass flow analysis for individual states and knowledge of processors' market share were essential to the product flow mapping and addressing RQ2. Arguably, improvements to food waste management practices ('performance') can be measured by the volume of food waste produced along the supply chain; and in order to do this knowledge of the current extent of food wastage is key.

6.2.1 New South Wales

There were no by-products (0 tonnes) generated nor discarded in New South Wales in 2019. As explained in Section 5.3.1 there were no licensed processors in New South Wales until 2020, and only abalone receivers.

It is possible that a small portion of catch (2-3%, ≤ 2.5 tonnes) is moved interstate to Victoria before being shucked. This assumption is based on the knowledge (Appendix J, Response iv) that one abalone receiver operates a licensed abalone processing facility in the neighbouring state of Victoria; and the ABS (2021) export data indicates that between 2018 and 2020 approximately 760 kilograms of abalone (~33.3% of 2.5 tonnes) originating from New South Wales was exported in a 'prepared' format (i.e. cooked, canned, frozen, or dried). The small portion of shucked abalone (2-3%, ≤ 2.5 tonnes) originating from New South Wales has been captured in the Victorian estimates of by-products.

Information concerning the number of processors in New South Wales, their activities and outputs, and market share have not previously been captured in publicly available literature or data. This research has contributed to knowledge in this regard, since the harvesting and distribution of live abalone is economically-significant to the state. Literature focused on the New South Wales abalone fishery is limited and has been focused on the sustainability of the fishery from a stock management perspective rather than processing or distribution activities (Chick, Worthington and Kingsford 2013; Worthington, Andrew and Bentley 1998).

6.2.2 South Australia

In 2019, approximately 82% (282.9 tonnes) of Blacklip and Greenlip by-products generated in South Australia were discarded. This estimate excludes by-products generated from South Australian catch processed in Victoria. Of the total amount of by-products generated (343.3 tonnes), 78% was discarded at sea (267.9 tonnes) and 4.4% was discarded on land (15 tonnes); while 17.6% of by-products consisting of Greenlip shells (60.4 tonnes) were exported for other uses (most likely decorative furniture in-lays and button-making).

A summary of outcomes of by-products generated in South Australia for Blacklip and Greenlip abalone is presented in Figure 48. There was no indication from participants that by-products created from shucking at sea or at the on-land processing stage were being stored for future sale or use.

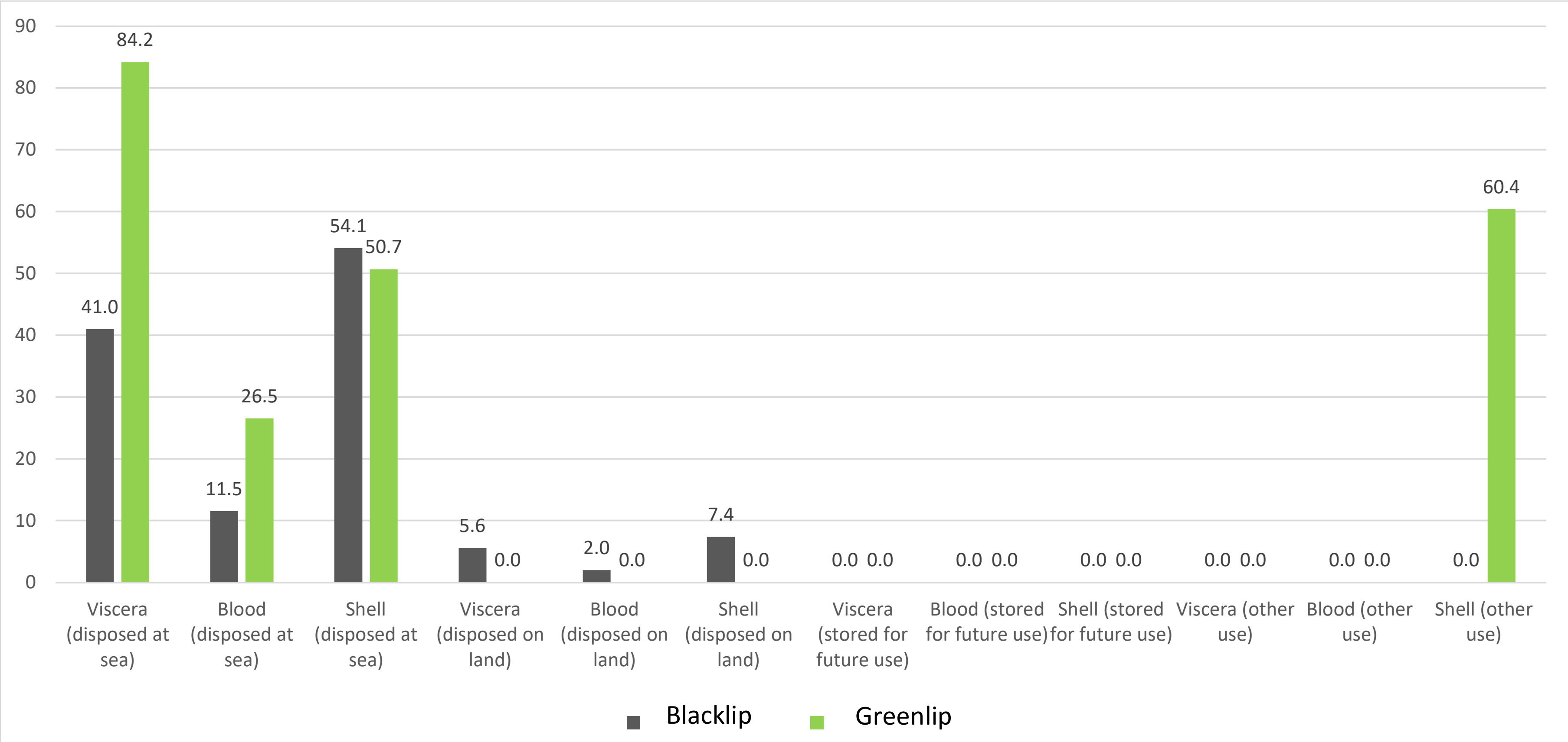

Figure 48. Outcomes of by-products generated in South Australia for Blacklip and Greenlip in 2019.

South Australian discards consisted of viscera (130.7 tonnes), blood (40.1 tonnes), and shells (112.1 tonnes). The relatively low volume of by-products disposed of on land (15 tonnes) is generated from South Australian catch harvested from the Southern Zone, where shucking at sea is not permitted, and is instead pushed down the supply chain to on-land processors based in South Australia. The remainder of discards (267.9 tonnes) occur at sea and are driven by the convenience of shucking at sea in the Western and Central Zones where the practice is permitted.

Shucking at sea practices have been described briefly in fisheries management reports (Burnell, Mayfield and Bailleul 2021; Stobart and Mayfield 2021) and the literature (Mayfield et al. 2012), but the extent of the practice has not been reported on. This research has contributed knowledge by capturing the volume of discards on a zonal basis based on empirical evidence from quota owners, divers, and processors along the South Australian supply chains. Additionally, data on the export and use of Greenlip shells has not previously been reported. This information is significant as it challenges anecdotal comments in the literature about the prevalence of shell discards (Li, Wen, et al. 2019; Suleria et al. 2017c).

6.2.3 Tasmania

Of the 319.5 tonnes of by-products generated in Tasmania from Blacklip and Greenlip abalone in 2019, it was estimated that 16% (53.4 tonnes) was discarded; 10% (32.9 tonnes) was stored for future use; and 73% (233.3 tonnes) was distributed for other uses. Tasmania generates a relatively low volume of by-products to begin with despite its position as the largest fishery in Australia (1249.2 tonnes in 2019). In Tasmania the volume of by-products generated from processing relative to total catch amounts to 26% (319.5 tonnes); whereas in other states such as South Australia and Western Australia, total by-products generated relative to total catch amounts to 52% (343.3 tonnes and 86.7 tonnes, respectively). The lower percentage of by-products generated is as a result of the high export volumes of live Blacklip abalone, typically amounting to approximately half of total catch (53% or 659.2 tonnes in 2019). A summary of outcomes of by-products generated in Tasmania is presented in Figure 49.

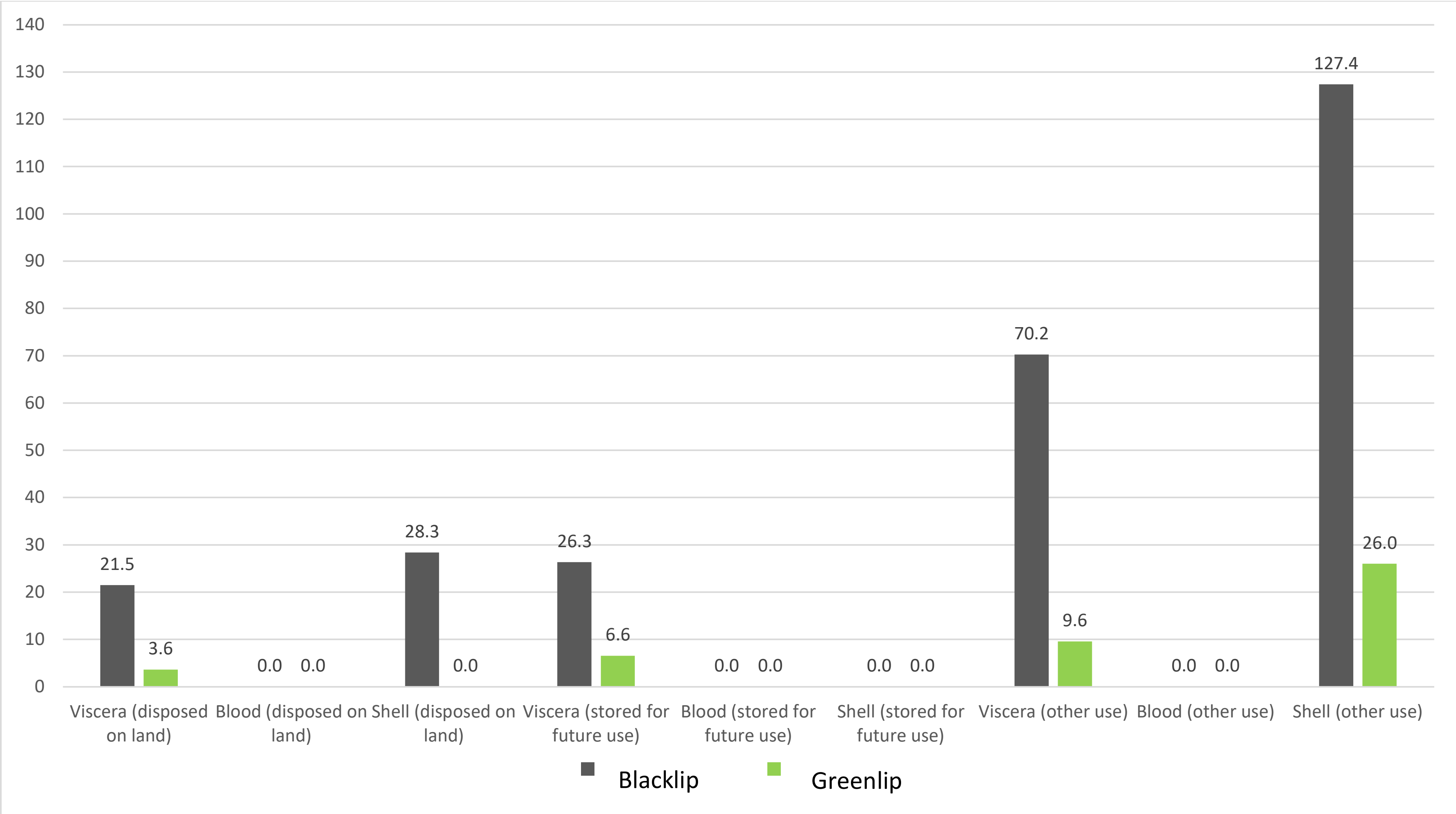

Figure 49. Outcomes of by-produts generated in Tasmania for Blacklip and Greenlip abalone in 2019.

‘Other uses’ for viscera included composting, pet food, and nutraceutical use; whereas other uses for shell were consistent with other fisheries that exported crushed or polished shell for decorative uses. Participants did not specify the volumes directed towards each of the aforementioned outcomes to protect commercial confidentiality. Thus, the mass flow of by-products flowing to these outcomes could only be categorised broadly as ‘other uses’.

Tasmania does not permit shucking at sea and all by-products are generated from processing facilities on land; thereby incurring a disposal cost that shucking at sea does not accrue. This was identified as a driver for processors to find other uses for their by-products even if at a low value (e.g. AU$1-2/kg for viscera) or donated, since the associated operating costs with disposal are eliminated by finding alternative outcomes. Furthermore, abalone meat shucked on land does not tend to be intentionally bled as South Australian and Western Australian products are owing to the relatively quick rate at which abalone are processed after landing to maintain the quality of the meat (Section 6.1). For this reason, the blood component has not been included in the estimates of mass flow.

The empirical data presented in this section on the types and extent of by-product usage by Tasmanian processors challenge existing notions in the literature about the lack of marketability and waste management of abalone by-products (Suleria et al. 2017c). However, responses from participants confirm the use of Australian abalone viscera in research trials for commercial therapeutic use (Suleria et al. 2017a; Suleria et al. 2017b; Suleria et al. 2017c). Although specific volumes could not be obtained, the evidence that some volume of viscera is used for human consumption (condiments) and pet food are new contributions to the literature.

By demonstrating an exception to the commonly-held belief that two-thirds of the abalone are discarded, this research confirms theories in the food waste literature that it is necessary to assess waste management practices at a supply chain-level to more accurately estimate volumes of waste (Amicarelli, Roe and Bux 2022; Parfitt, Croker and Brockhaus 2021). As for the sustainability of the Tasmanian abalone fishery, the literature has been focused on stock health rather than other markers of sustainability along the supply chain such as by-product utilisation (Sanderson et al.

2015; Seger et al. 2020; Temby, Miller and Mundy 2007). This research contributes a new perspective to the literature concerning the sustainability of the Tasmanian abalone fishery, although sustainability performance (e.g. life cycle assessment) was not assessed.

6.2.4 Victoria

Victoria is noteworthy in that it is the only state to process more abalone than is harvested on an annual basis. In 2019, total actual catch of abalone harvested from Victorian waters amounted to 695 tonnes, though approximately 116.6 tonnes of additional catch harvested from South Australia, Tasmania, and New South Wales was processed. The provenance of catch processed in Victoria is illustrated in Figure 50.

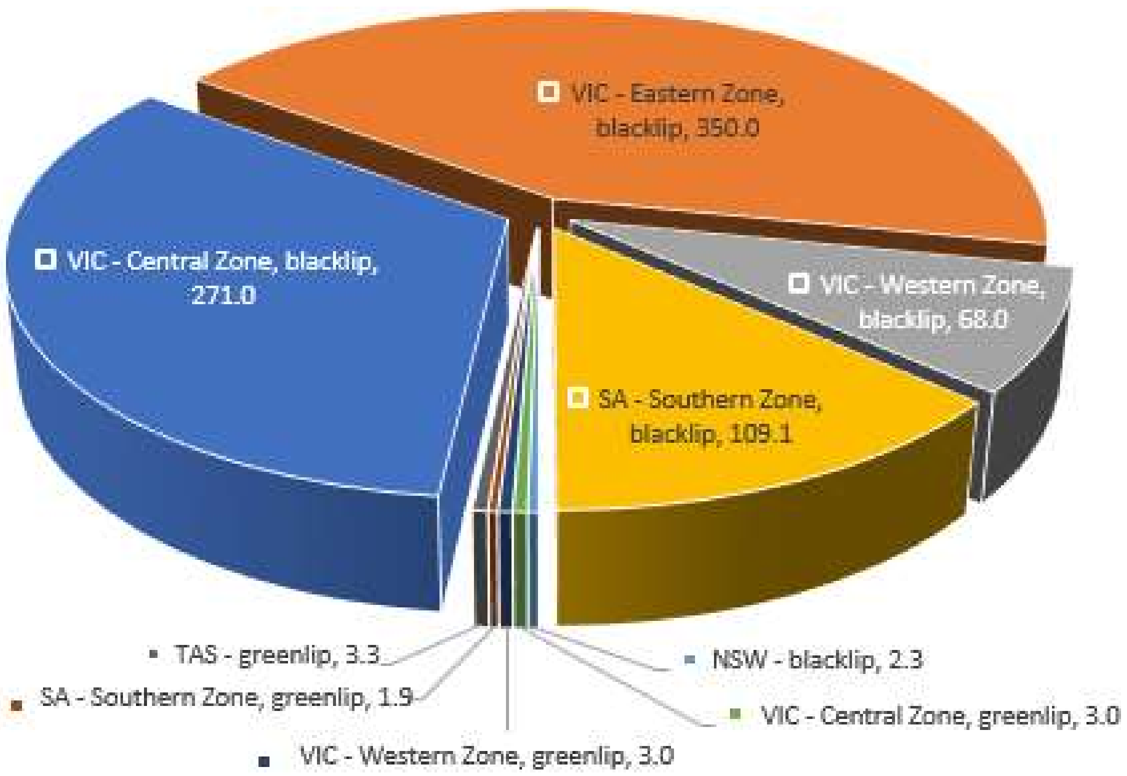

Figure 50. Provenance of abalone processed in Victoria in 2019.

The Victorian abalone fishery was also notable as it generates the highest volume of by-products amongst the five fisheries (444.1 tonnes); of which it discards 60% (268.6 tonnes). All abalone processing in Victoria takes place on land as shucking at sea is not permitted. Whatever is discarded is disposed of in landfill, incurring substantial disposal costs. In contrast to other land-based processors in Tasmania, the volume of discards relative to by-products generated in Victoria has remained relatively high (~268.8 tonnes in Victoria compared to ~53.4 tonnes in Tasmania). This is largely owing to processing plant limitations that prevent the second-largest processor in Victoria from storing and distributing their by-products.

Conversely, reports from participants (*n*=6) indicated that at least three Victorian processors utilise the viscera in nutraceuticals (trials), sauces and beer for human consumption, and pet food. Recruitment of participants, during Phase A, from the three processing firms who could speak to the volumes and utilisation of viscera was attempted but unsuccessful (Appendix D). Estimates of by-product outcomes in Victoria could have been more accurate with data from additional participants. For example, waste produced from the processing of viscera (e.g. off-cuts) and trialling new products could not be obtained and have not been included in the estimates.

Nonetheless, the results of the mass flow analysis were still considered valid based on the consistency of other participants' responses (Appendix J) and estimate of processor market share (Appendix H). Furthermore, in one case, a Tasmanian participant representing a firm with processing facilities in Tasmania and Victoria was able to speak briefly about the Victorian branch practices; accounting for approximately 19% of catch in Victoria. The Tasmanian participant indicated that whatever by-product is not distributed within the same fishing season (approximately 37.3 tonnes of viscera) is stored for future distribution. Arguably, this strategy for managing waste would incur substantial energy and warehousing costs compared to disposal costs; however, the scope of this research did not permit a cost comparison to be estimated or calculated.

In sum, of the 444.1 tonnes of by-products generated in Victoria, it was estimated that in 2019 approximately 60% (268.6 tonnes) was discarded on land, 8% (37.3 tonnes) was stored for future use, and 31% (138.2 tonnes) was put to other uses. A summary of outcomes of by-products generated in Victoria is presented in Figure 51. Although over one-third of by-products are put to use in Victoria, there is opportunity to improve on the volume of by-products currently discarded.

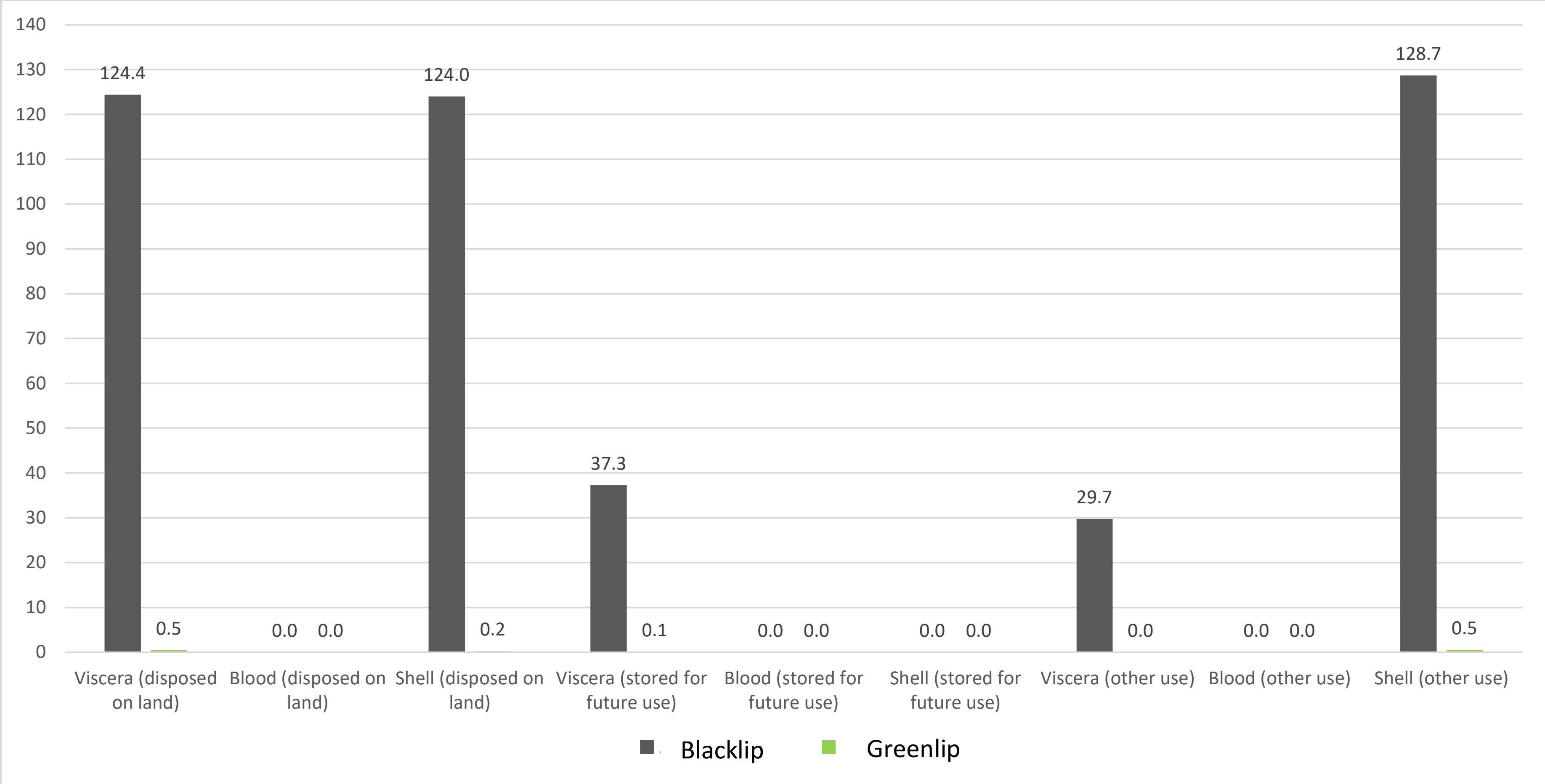

Figure 51. Outcomes of by-products generated in Victoria for Blacklip and Greenlip abalone in 2019.

The literature concerning the sustainability of the Victorian abalone fishery primarily concerns the mitigation of biosecurity threats presented by AVG (see Section 5.3.2 or List of Acronyms) and stock management models (Corbeil et al. 2016; Gilmour, Dwyer and Day 2013; Young et al. 2020). Thus far there has been no focus on other aspects of the sustainability, such as by-product utilisation, of Victorian abalone supply chain and stakeholder practices. Although the estimates of by-product mass flows to uses such as human consumption and extraction of therapeutic compounds were unable to be corroborated by additional processors, this research contributes new knowledge by capturing empirical evidence that abalone viscera are indeed utilised, marketed, and/or sold in Australia's wild-harvest abalone supply chains. As explained in Section 6.2.3 this challenges comments about abalone processing discards in the existing literature.

6.2.5 Western Australia

Western Australia had one of the lowest volumes of discards (58.0 tonnes) amongst the five fisheries when measured by nominal volume. This figure represents approximately 67% of all by-products generated; which is in line with the percentage of discards relative to by-products generated in Victoria (60%). The usage of viscera and shells occurs where abalone are ranched and processed on land (55.0 tonnes in 2019) rather than when abalone are shucked at sea. Thus, when ranched volumes are excluded from the analysis of discards, and only fished abalone from traditional fishing zones are assessed, the percentage of discards relative to by-products generated amount to 90%. This figure surpasses South Australia's volume of discards (82% of by-products generated) because, not only are viscera permitted to be shucked and disposed of at sea, but the shells shucked from Brownlip and Roe's abalone are discarded as a result of low market value. Overall, the majority of catch in Western Australia is discarded either on land (32.1 tonnes) or at sea (25.9 tonnes). A summary of outcomes for by-products generated in Western Australia is presented in Figure 52.

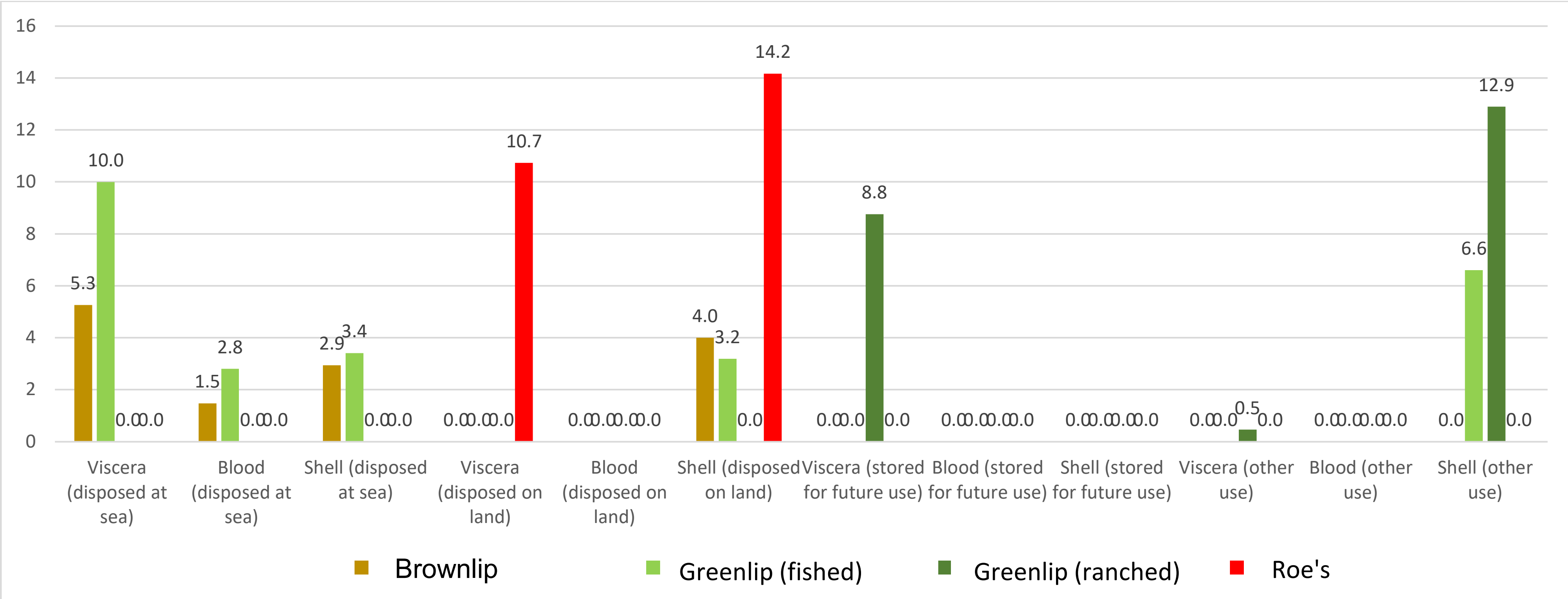

Figure 52. Outcomes of by-products generated in Western Australia for Brownlip, Greenlip (fished and ranched), and Roe's abalone in 2019.

Shells in Western Australia are typically discarded either by landspreading or are transported back to the point of harvest where disposal at sea is permitted. Landspreading and disposal at sea incur no additional operating costs to the operators. Therefore, there is little financial incentive to improve disposal practices to reduce food waste by adopting circular economy principles.

There has been a substantial amount of research conducted on Western Australian abalone. Studies have focused on stock management and biology of the four commercially-harvested species (Caputi et al. 2014; Hart et al. 2008; Wells and Keesing 1990); as well as the impact of ranched abalone on traditional wild-stocks (Jones and Fletcher 2012; Melville-Smith et al. 2013). However, as with the other four state fisheries, sustainability of the Western Australian abalone fishery has not been explored from a supply chain nor by-product utilisation perspective. Thus, this research contributes a new sustainability dimension to the literature concerning Western Australian abalone fisheries.

6.3 Conclusion

In this chapter, the mass flows of by-products were estimated for each of the five abalone fisheries across Australia. The significance of the results presented in this chapter is two-fold.

Firstly, from a research perspective, new knowledge was contributed that addressed several gaps in the literature on food waste that were explained in Sections 1.3.1 to 1.3.3. These gaps concerned the lack of current and accurate data of food waste in upstream stages of Australia’s supply chains, including its seafood sector and abalone industry, specifically. Moreover, mass flows of by-products and their outcomes were categorised according to four categories that emerged from participant responses: disposal at sea, disposal on land, storage for future use, and other uses within the same season. Although more specific measurements on by-products flowing to ‘other uses’ could not be elicited from participants, owing to commercial confidentiality concerns and unsuccessful participant recruitment, the mass flow of by-product discards were estimated with relative detail (i.e. shucked at sea versus shucked on land). Additionally, mass flows were quantified for each of the supply chains (species and state), lending a new dimension to the literature on the sustainability of abalone fisheries in Australia.

Secondly, from a practical perspective, waste hotspots and probable drivers of waste creation were linked to supply chain practices (i.e. convenience of shucking at sea; lack of storage at on-land processing facilities). Thus, targeted management suggestions could be made in the following phase of the research (Chapter 7) as a foundational step to improving waste outcomes for by-products currently flowing to the ‘least preferred’ options as per the food waste hierarchy. Furthermore, the quantified mass flows and market value evidence that was gathered from participants can be used to inform an economic feasibility analysis which is essential to bridging research and ‘real-world’ outcomes (Section 2.3). The by-product quantities and flows identified in this chapter constitute the first time this information has been provided to Australia’s abalone industry. The information will be crucial in decision-making and supply chain design of the industry’s future food waste management initiatives.

Overall, gaps identified in the desktop review (Chapter 4) were filled and depth added to the qualitative results presented in Chapter 5.

7 DISCUSSION OF RESULTS: PHASE C (MIXING 'QUAL' AND 'quan' BY SUPPLY CHAIN ANALYSIS AND MAPPING)

This chapter marks the 'point of interface' of the qualitative and quantitative results. Thus, the aim of this final phase of the research was not to introduce new data but to make broader conclusions about food waste management practices in Australia's wild-harvest abalone supply chains. Principally, relationships are drawn between the themes (from Phase A 'QUAL') and magnitude of waste (from Phase B 'quan') to make conclusions about the supply chain drivers of waste creation, constituting a supply chain analysis on a state-by-state basis. The significance of these conclusions in relation to the literature is also discussed.

The results from the previous phases of this research were integrated by creating 10 current-state maps for each species and state supply chain (i.e. New South Wales Blacklip, Victorian Greenlip, Victorian Blacklip etc.). The current-state maps (*n*=10) integrated knowledge of the supply chain practices, and outcomes of waste that were elicited from participants in Phase A ('QUAL'); and the mass flow analysis of abalone products and by-products, and market share of firms that were estimated in Phase B ('quan'). Supporting data elicited during Phase A concerning supply chain practices, market share, and so on that were not included in Sections 5.3.1 to 5.3.4 but informed the current-state maps are provided in Appendix J. Regulatory information gathered in the desktop review and Phase A were also mapped; such as where shucking at sea is permitted, fishing zones, and licensed operators. In this way, data from the desktop review, Phase A, and Phase B were pieced together to map the parameters listed in Section 3.6.1, Table 8, including: material flows, supply chain structures, governance, and geography, *inter alia*.

Following the current-state maps which are presented on a state-by-state basis in Sections 7.2.1 to 7.2.5, two future-state maps are presented in Sections 7.3.1 and 7.3.2. In the future-state maps the most promising scenarios for making improvements to waste management practices are visualised. The two scenarios were selected based on the current-state maps and supply chain analyses. The proposed changes to product flows and practices are clearly shown in the future-state maps and their accompanying descriptions.

7.1 Supply Chain Mapping Legend

The purpose of this section is to present the legend (Figure 53) used to interpret the current- and future-state supply chain maps (Sections 7.2 and 7.3). The same symbols and conventions were applied to each current- and future-state map to enable a comparative analysis of the supply chains.

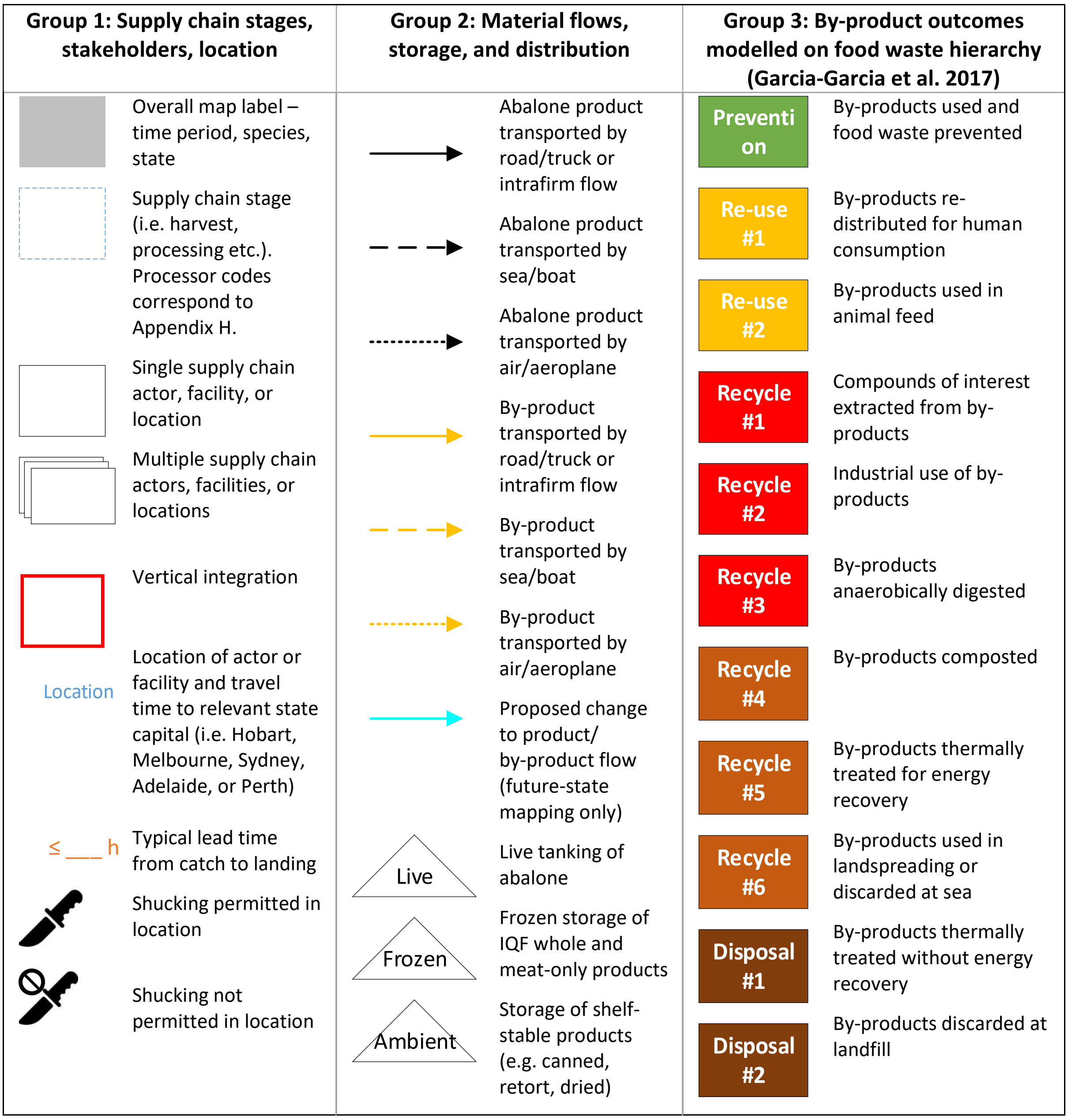

Figure 53. Legend of mapping conventions.

7.2 Current-state Maps

In the following sections, the current-state supply chain maps (*n*=10) for each state and species are presented. As explained in the introduction to this chapter, the purpose of the maps and descriptions are to draw conclusions about the drivers of food waste creation or by-product utilization by drawing connections between the themes of Phase A and the mass flow analysis presented in Phase B.

7.2.1 New South Wales

The current-state map for the New South Wales Blacklip supply chain, presented in Figure 54, shows there were no by-products generated from primary production and post-harvest processing in 2019. This was a result of the lack of processing activity prior to 2020 that was discussed in Phase A (Section 5.3.1) and Phase B (Section 6.2.1).

The minimal processing activity in New South Wales results from two supply chain factors which were discussed in Section 5.3.1: (1) long-established, trusting relationships between abalone receivers and the Japanese market; and (2) regulations that limit operational activities and catch volumes. Specifically where regulatory factors are concerned, the New South Wales TACC quota is limited to a relatively low volume of 100 tonnes per annum; regulations disallow shucking at sea; and licensing for abalone receiving versus processing are separate permits. Supply chain practices and products flows visualised in the current-state map of the New South Wales 2019 fishing season (Figure 54) have remained largely unchanged in 2022 when data were collected for this research.

Participants indicated that Receiver B had commenced processing a small volume of abalone into canned products on a sporadic basis in 2020 or 2021, and approximately 20 to 30 tonnes in 2022 (Appendix J, Response ii). However, attempts to recruit Receiver B for an interview were unsuccessful (Appendix D) and processing activities appear to be generally unpredictable or once-off occurrences in New South Wales (Appendix J, responses ii and viii).

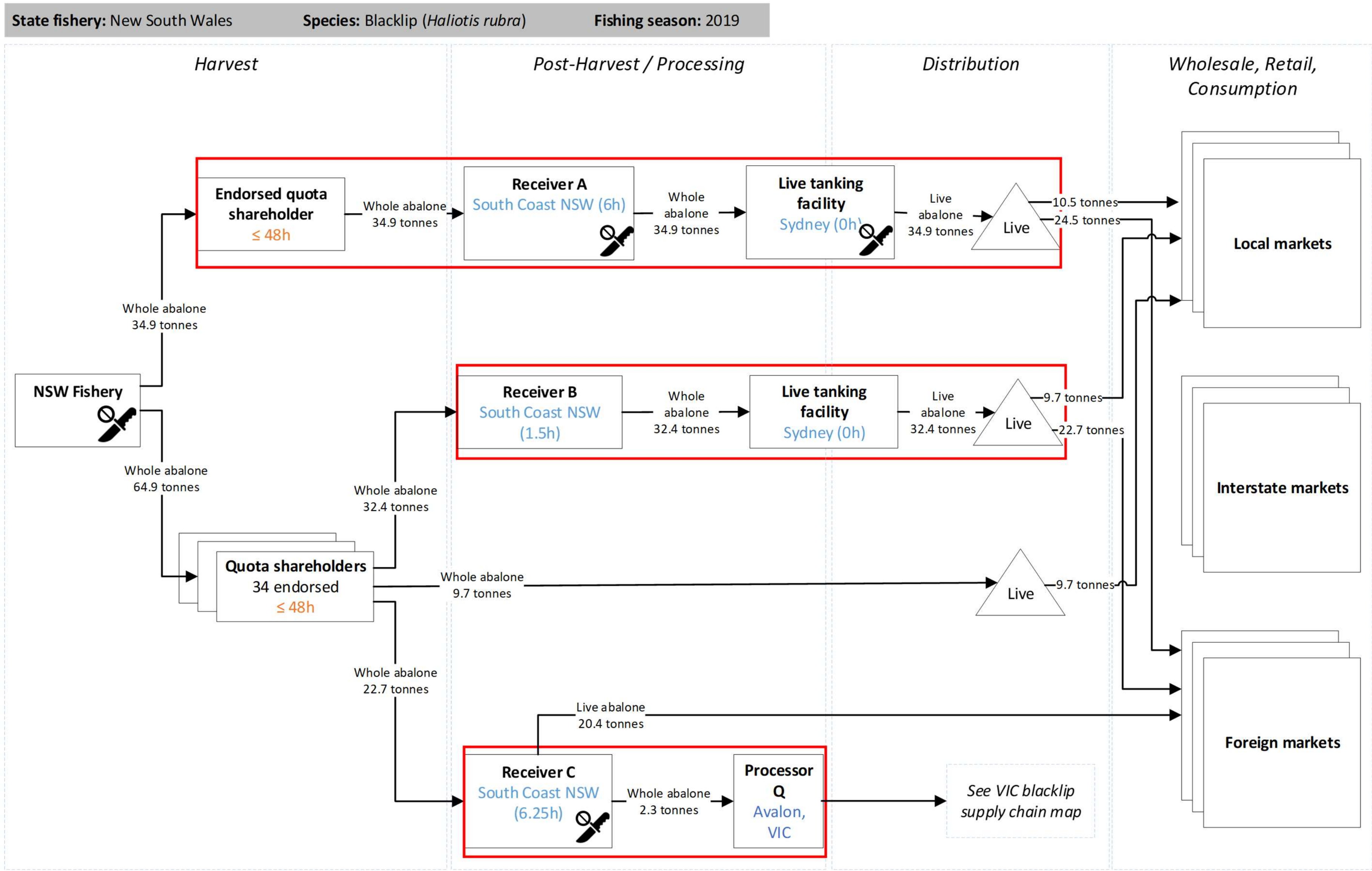

Figure 54. Current-state map of the New South Wales Blacklip abalone supply chain in 2019.

It is probable that New South Wales receivers and processors focus primarily on distributing live abalone because live products generally return a higher margin than processed product formats (i.e. canned, retort, IQF) (Stobart and Mayfield 2021; Mayfield et al. 2012). The higher margin is a result of higher beach prices (price paid for abalone upon landing, before it is processed) and minimised labour costs since shucking and processing activities (e.g. cooking, freezing, packaging) are avoided. Altogether, the focus of receivers and processors on live distribution results in minimal to no by-product creation and waste. According to the food waste hierarchy, food waste is prevented ('most preferred outcome') at the upstream stages of the supply chain. Rather, it is likely that shucking waste is pushed downstream to the consumption stage and dispersed across numerous locations such as individual households and restaurants overseas and within Australia. Since waste produced from downstream consumption was not a focus of this research, the specific volume of by-products generated at this end of the supply chain was not quantified.

In sum, there is limited opportunity to improve outcomes for by-products in the upstream segments of the New South Wales supply chain because of the existing supply chain factors (e.g. long-established, trusting relationships; restricted supply and processing activities owing to state fishery regulations) driving a focus on live abalone distribution. The current-state map and analysis is a contribution to new knowledge as the New South Wales abalone supply chain has not previously been mapped. Additionally, information regarding this fishery is generally scarce in the literature; and focused primarily on stock management (Gilmour, Dwyer and Day 2013).

7.2.2 Victoria

The relatively high volume (249.1 tonnes or 56%) of by-products discarded along the Victorian Blacklip supply chain are driven by two supply chain factors which were discussed in Section 5.3.2: (1) organisational siloing and lack of information sharing; and (2) supply chain actors' focus on other priorities than managing food waste. As supply chain practices have remained largely unchanged in Victoria since 2019 (period mapped), it was determined that there is minimal opportunity to reduce waste for the same two reasons.

The storage (37.4 tonnes) and or diversion of by-products to more preferred outcomes according to the food waste hierarchy (~159.0 tonnes) are driven by firm-specific factors such as organisational motivations and available, existing infrastructure capacity (e.g. cooking equipment, storage). These were discussed in Sections 5.3.1 and 5.3.2, respectively. Additional factors may have influenced the utilisation of by-products, however, owing to difficulties with recruiting participants from Victoria, further conclusions on this front could not be made.

By mapping the Victorian Blacklip supply chain (Figure 55) it was possible to infer that organisational siloing and fragmentation in the Victorian industry (discussed in Section 5.3.2) arises from the segmentation between quota ownership, fishing, and processing. With the exception of Processors J and S (see Figure 55 and Figure 56) there is no vertical integration between harvesting and processing. The intense interfirm competition and lack of information sharing described by Victorian participants in Section 5.3.2 likely arises from the relatively high number of processing firms (*n*=7), compared to fewer than five in all other states) that focus solely on processing abalone and need to compete for a share of limited catch. There do not appear to be any restrictions on the number of abalone processing licenses as there are with quota ownership.

Moreover, results from the desktop review (Section 4.3) indicated that the value proposition offered by most Victorian processors is similar. For instance, most Victorian processors (*n*=5) operate in close proximity to one another (within an hour's travel time to Melbourne as shown in Figure 55 and Figure 56); and each offer similar products and services (e.g. canning, retort processing, live handling). Altogether, these factors may contribute to the pervasive interfirm, rather than supply chain, competitiveness that exacerbates organisational siloing and lack of information sharing.

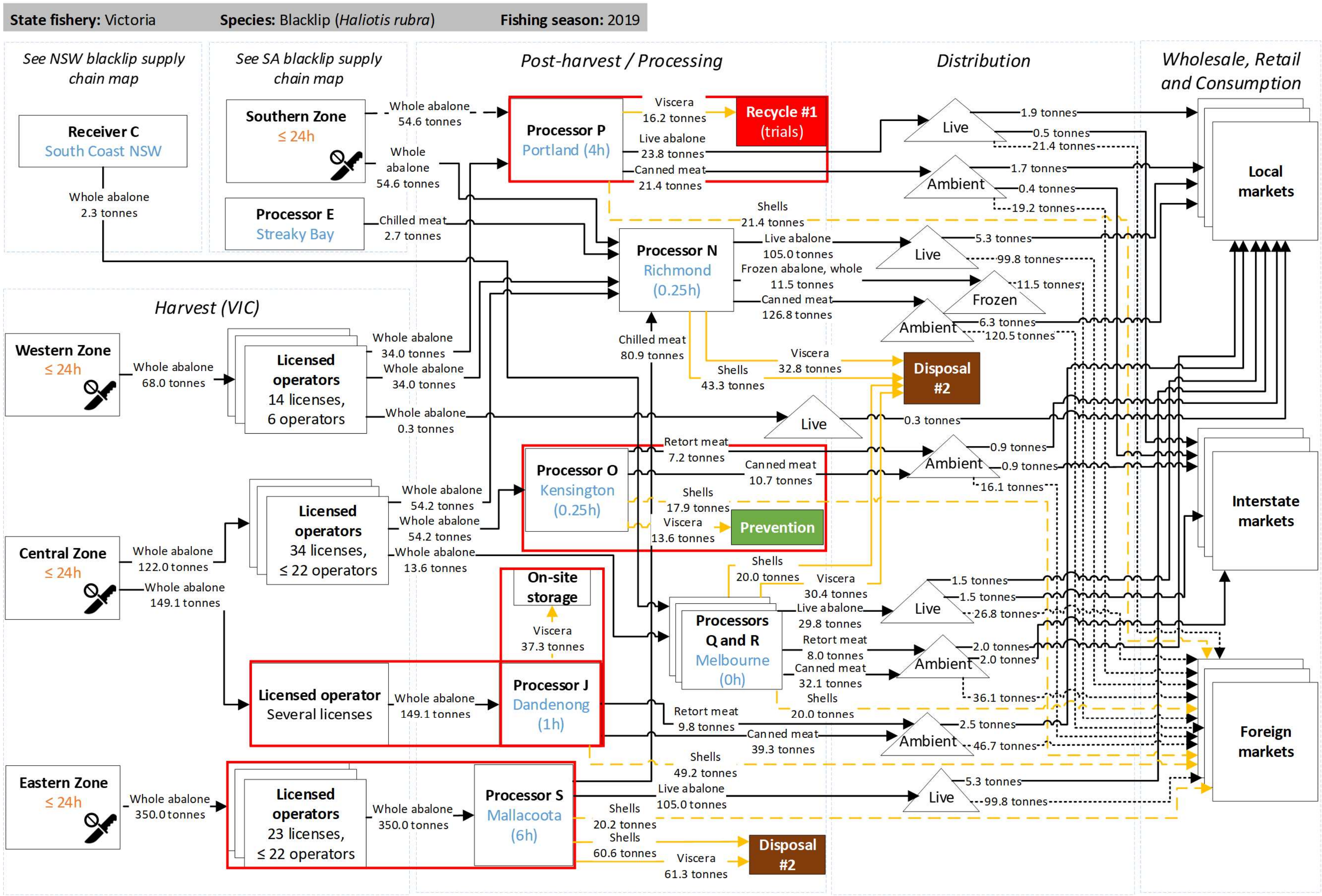

Figure 55. Current-state map of Victoria's Blacklip abalone supply chain in 2019.

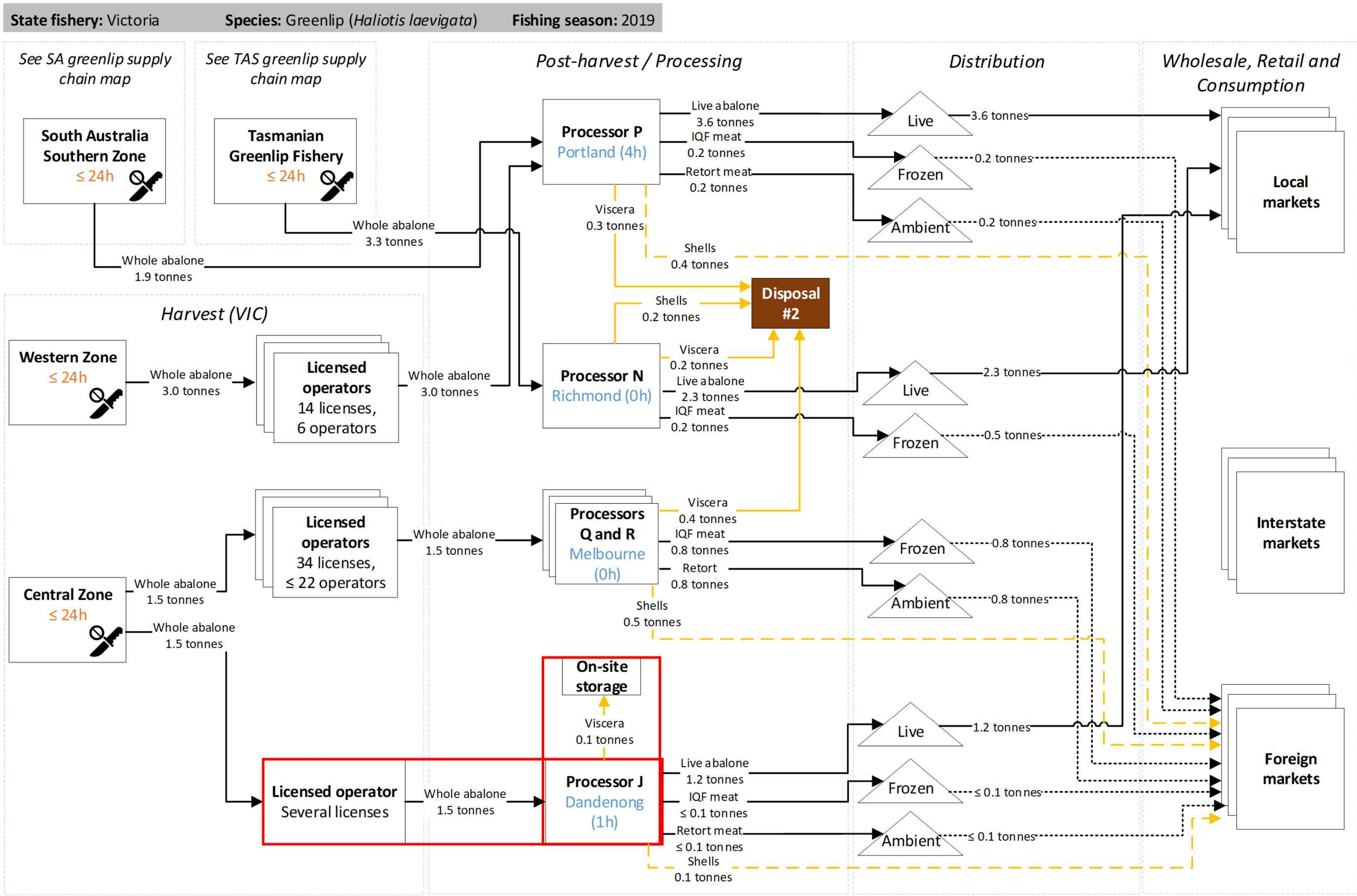

Figure 56. Current-state map of Victoria's Greenlip abalone supply chains in 2019.

From a circular economy perspective, the opportunity to improve outcomes for by-products is limited. For instance, there is no opportunity to improve outcomes for viscera that are currently processed into sauces for human consumption (‘Prevention’). According to the food waste hierarchy adopted in this research, viscera directed towards therapeutic outcomes (‘Recycle #1’ or extraction of compounds of interest) could be better used towards human consumption or animal feed. However, from a practical perspective, the opportunity to improve outcomes for viscera in this way are limited given the commercial potential of therapeutic products and existing resource investment by Processor P that would likely have driven the development of these products. Finally, the outcomes for discarded viscera and shell could certainly be improved from a food waste management perspective. However, barriers that were identified in Section 5.3.2 concerning other priorities and limited storage similarly render the opportunity to divert these by-products from disposal minimal.

The supply chain maps presented in this section are a new contribution to knowledge as the Victorian abalone supply chains have not previously been mapped. The literature has focused on stock management approaches (Gilmour, Dwyer and Day 2013) and the biology of abalone (McShane, Smith and Beinssen 1988) in the Victorian fishery but not on processing practices, distribution of product, nor by-product flows and volumes.

7.2.3 Tasmania

It was determined that the high level (266.1 tonnes, or 83%) of by-product use (or stored for future use) in Tasmania is an indirect result of vertical integration, and a direct result of motivations to maximise catch, and access to existing infrastructure such as storage and required processing equipment. The significance of these factors was discussed in Sections 5.3.1 and 5.3.2. The Tasmanian Blacklip and Greenlip current-state supply chain maps that visualise vertically integrated structures and flow of by-products are presented in Figure 57 and Figure 58, respectively.

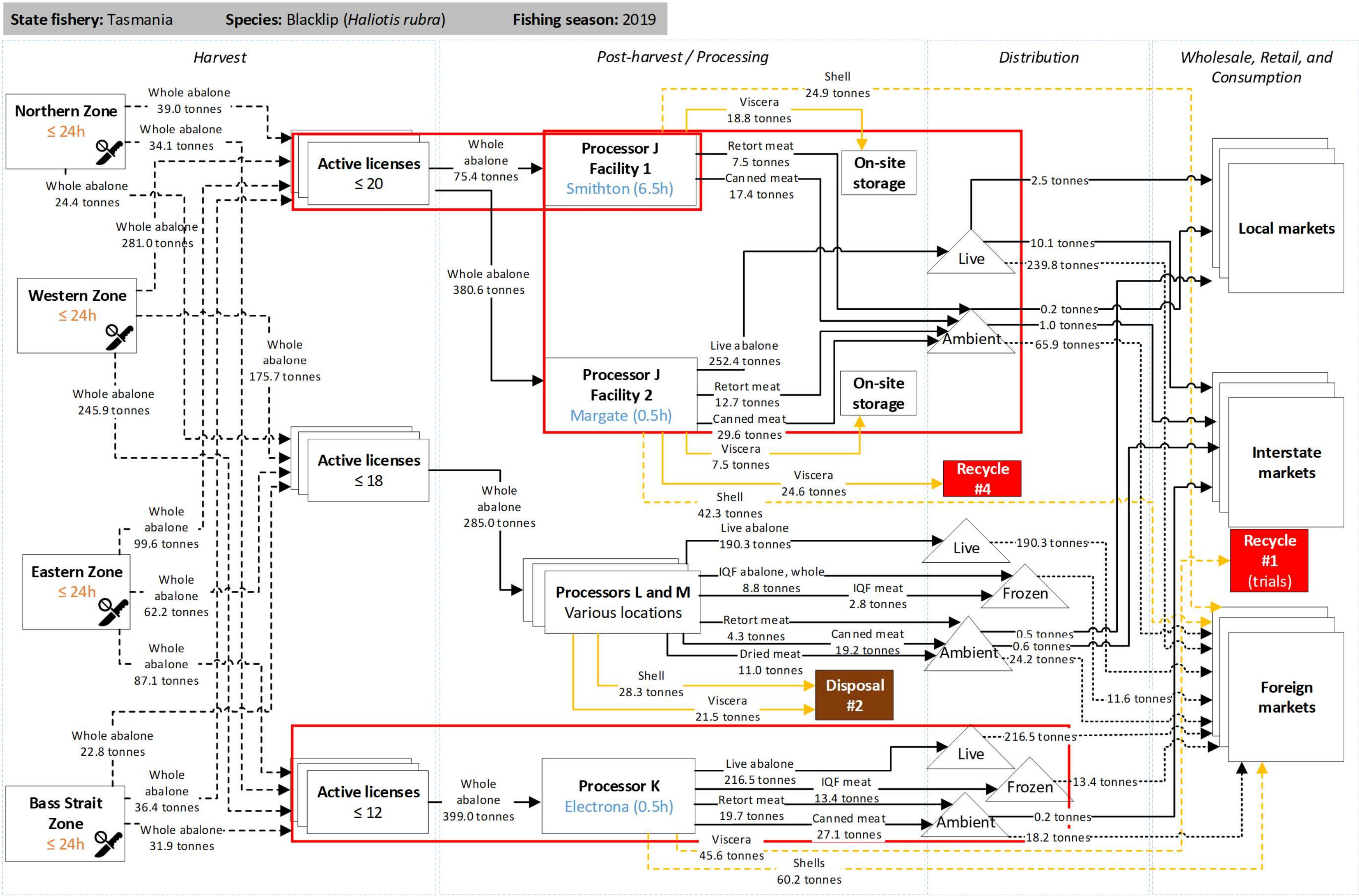

Figure 57. Current-state map of Tasmania's Blacklip supply chain in 2019.

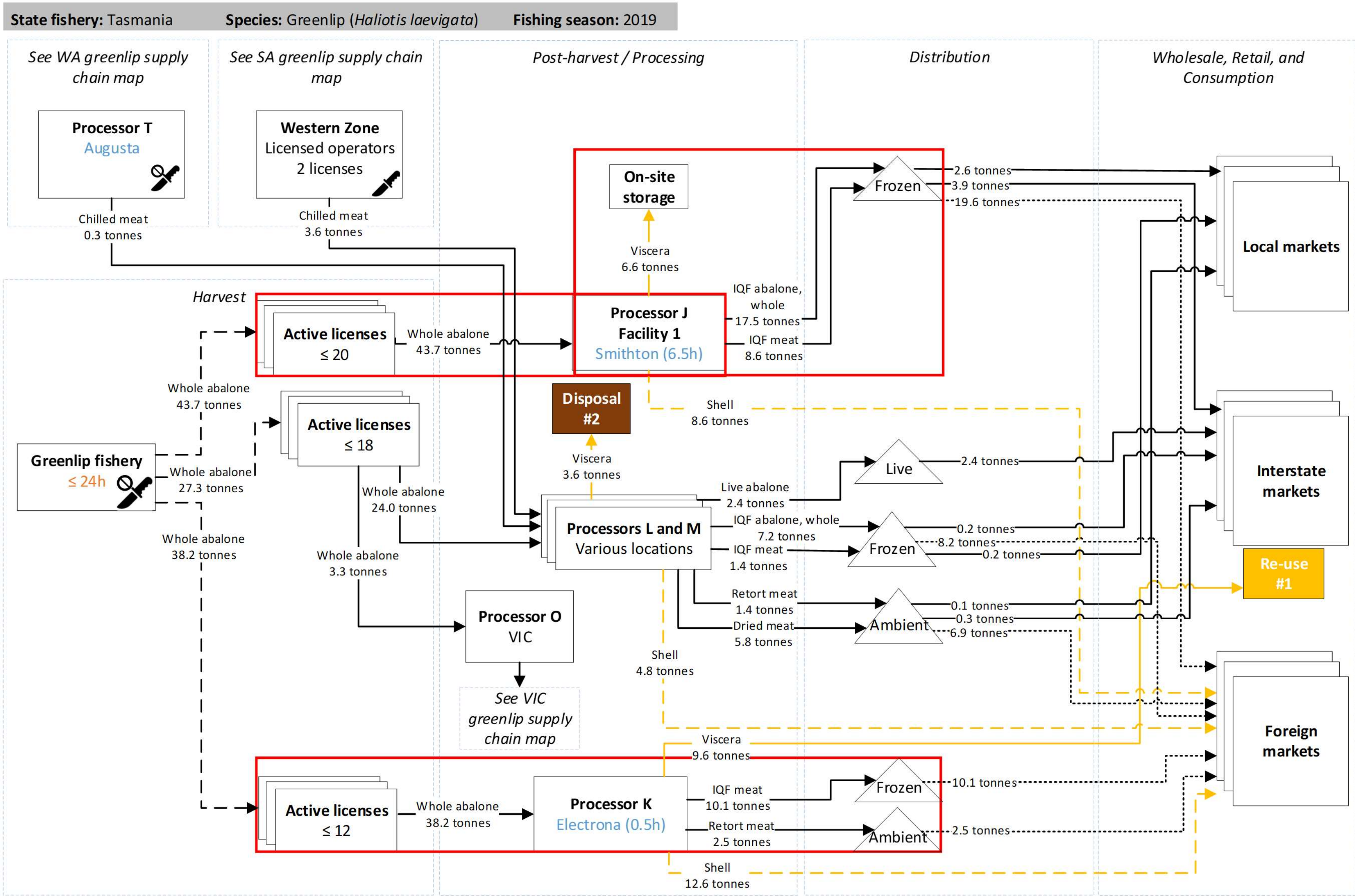

Figure 58. Current-state map of Tasmania's Greenlip supply chain map in 2019.

The structure of the supply chains presented in Figure 57 and Figure 58 contrast greatly to the Victorian supply chains presented in Section 7.2.2. By comparing the current-state maps of both states, it was possible to make some inferences about the reasons for which a greater percentage of by-products is used in Tasmania versus Victoria; given both process abalone on land. In contrast to the Victorian abalone industry, the Tasmanian industry is dominated by two major processing firms that control approximately 75% (936.9 tonnes) of state-wide catch. The firms are also vertically-integrated across quota ownership, fishing, processing, and distribution, as shown by the red outlines in Figure 57 and Figure 58. These two factors mitigate against barriers to utilising waste (Section 5.3.2) such as economies of scale, organisational siloing, lack of information sharing, and labour supply; since access to a large share of catch and communication with their own team of divers (i.e. about timing, location, size and species to be targeted) means both firms can more easily plan product flows and processing capacity.

Finally, the Tasmanian Blacklip and Greenlip supply chains have not previously been mapped and are therefore a contribution to new knowledge. Existing literature has focused on Tasmanian abalone biology and stock sustainability (Haddon, Mundy and Tarbath 2008; Miller, Maynard and Mundy 2009; Temby, Miller and Mundy 2007), but not on the sustainability of its supply chains. By contrast, this research has provided evidence of how major Tasmanian firms, vertically integrated across fishing and processing, are reducing food waste and maximising returns on catch; thereby fostering environmental and economic sustainability in the upstream segments of the supply chain.

7.2.4 Western Australia

The considerable percentage of discarded by-products in Western Australia at sea (30%) and on land (37%) are driven by the economic and logistic barriers raised by some Western Australian participants, which were discussed in Section 5.3.2, including: lack of financial incentives to land viscera and to recover Brownlip and Roe’s abalone shells, remote fishing, use of small vessels, limited boat crew for shucking and handling by-products, and potentially limited cold storage. Western Australia’s current-state maps are presented in Figure 59, Figure 60, and Figure 61.

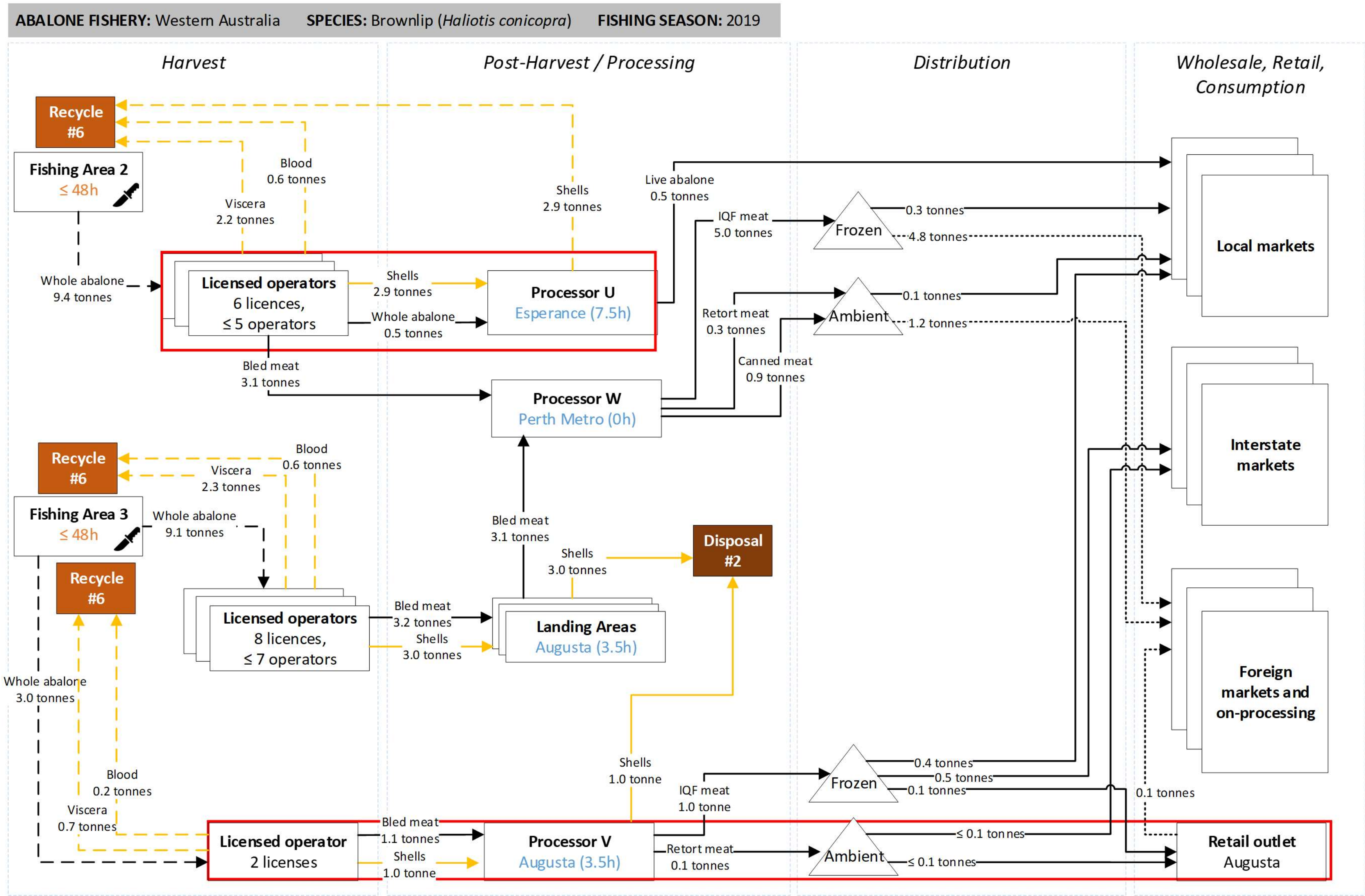

Figure 59. Current-state map of Western Australia's Brownlip abalone supply chain in 2019.

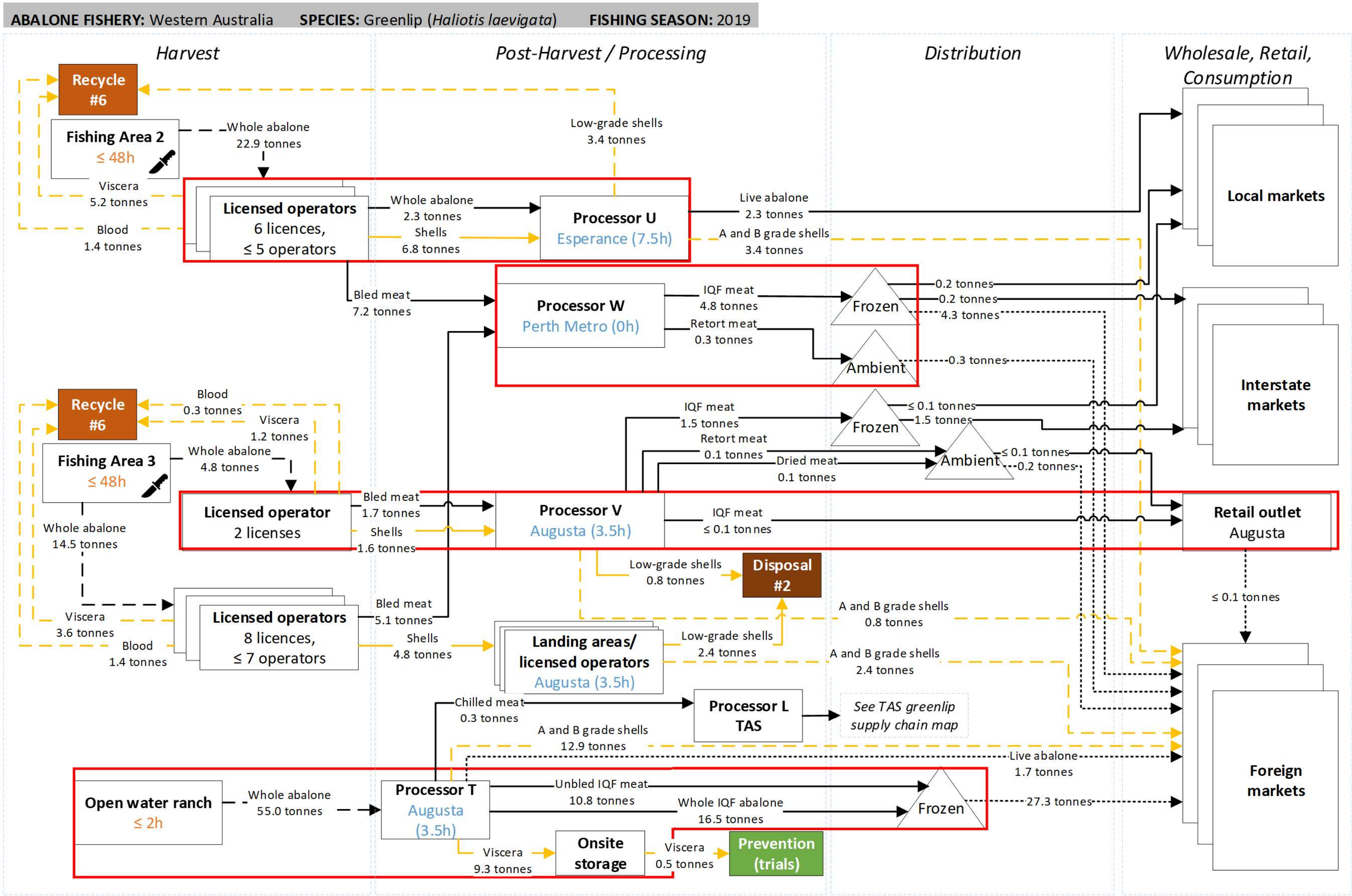

Figure 60. Current-state map of Western Australia's Greenlip supply chain in 2019.

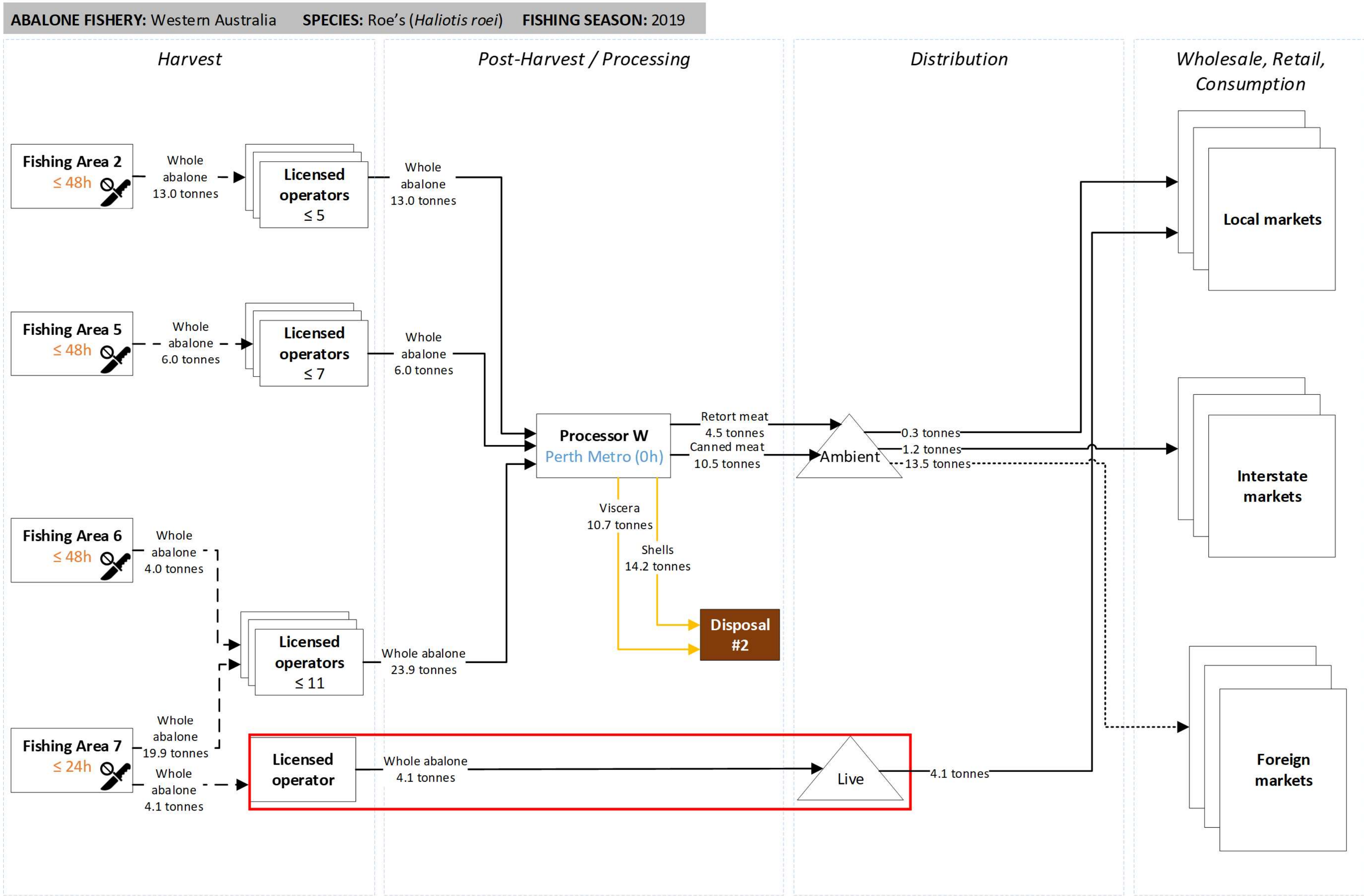

Figure 61. Current-state map of Western Australia's Roe's abalone supply chain in 2019.

Conversely, access to infrastructure (i.e. sufficient cold storage), close geographical proximity between harvesting and processing locations, and regulations that disallow disposal at sea were drivers for the Greenlip abalone ranch in Area 3 to utilise their viscera and shell by-products. Elements that cause the drivers of by-product disposal and utilisation – such as extended lead times (symptomatic of remote fishing), shucking at sea regulations, and vertical integration of fishing and processing activities – are shown in the current-state supply chain maps.

Between 2019 (period mapped) and 2022 (primary data collection period) Western Australia's supply chain underwent some significant changes; however this did not materially affect by-product volumes or outcomes. The changes included:

- Increased production of ranched Greenlip abalone by 33% (81.7 tonnes in 2022, see Figure 62). However, no changes have occurred to the management of by-products since 2019. Viscera are still stored on-site and moved on to research and development trials for new food products; whereas shells continue to be accumulated and exported. The increase in production of abalone would result in an increase in available by-products and, in turn, increase the ability to attain the economies of scale required for commercial uses of the by-products. The significance of economies of scale was discussed in Section 5.3.2.

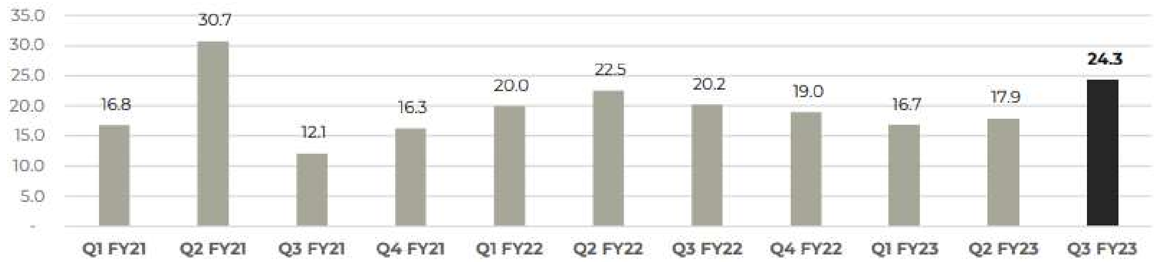

Figure 62. Processor T ranched abalone production volumes from July 2021 to present. Source: Rare Foods Australia (2023, 2).

- Closure of Processor V's processing facility. Bled meat has been landed and transported to Processor T for on-processing since 2021. However, shucking and discarding of by-products have continued to occur at sea; meaning there was no change to waste management practices. The conclusions made about drivers of waste creation (i.e. economic and logistical barriers) are therefore still valid to this scenario.

From a volume perspective, Western Australia does not produce a high volume of by-products (86.7 tonnes), nor a high volume of discards (58 tonnes) compared to other states such as South Australia (282.9 tonnes) and Victoria (249.1 tonnes). This is owing to the increasingly low TACC quotas that have been set for each species and fishing zone for the last decade; which in turn affect catch volumes and the volume of by-products shucked at sea (Strain, Brown and Blay 2023; Strain, Fabris and Blay 2023). Thus, in terms of volume and in comparison to other states Western Australia was not necessarily considered a waste hotspot in this analysis of food waste. Nonetheless, the outcomes of by-products in Western Australia could certainly be improved on the whole regardless of the comparatively low volumes that are generated. For this reason, a future-state map was created, proposing management interventions that were guided by the food waste hierarchy (Section 7.3.1).

The current-state maps of Western Australia's abalone supply chains presented in this section are a contribution to new knowledge as these have not been previously mapped. The literature on Western Australia's abalone supply chains has been focused primarily on stock management and sustainability (Caputi et al. 2014; Boze and Nick 2006; Hart et al. 2008); though fishery management reports have included some economic information in the past (Strain, Brown and Blay 2023; Strain, Brown and Jones 2021; Strain, Fabris and Blay 2023; Strain, Fabris and Jones 2021). However, the sustainability of the Western Australian abalone fisheries has neither been explored from a food waste nor supply chain perspective.

7.2.5 South Australia

The high instance of discarded by-products in South Australia (82% or 282.9 tonnes) is driven by economic and logistic barriers discussed in Section 5.3.1, including: lack of financial incentives to land viscera, remote fishing, use of small vessels with limited storage capacity, and limited boat crew for shucking and handling by-products. However, South Australian participants were highly motivated to change their supply chain practices and improve by-product outcomes (Section 5.3.1) and possessed several of the strengths to be leveraged along the supply chain which were discussed in Section 5.3.3. Strengths specific to the South Australian supply chain included: a high number of Instigators of Change who possessed knowledge of how to initiate changes to practices at the zonal and national levels to improve economic and environmental sustainability performance; and a willingness to collaborate amongst quota owners and processors. Furthermore, the systemic forces with the potential to initiate changes to shucking at sea practices which were discussed in Section 5.3.4 were highly applicable to the South Australian fishery.

Several supply chain factors such as vertically integrated structures, collaborative culture, and few dominant players with control of market share provide favourable conditions for implementing management interventions in South Australia. As shown in the supply chain maps presented in Figure 63 and Figure 64, South Australia’s Greenlip and Blacklip abalone supply chains are highly vertically integrated across the harvesting and processing stages. Furthermore, quota owners in the Central and Western Zones tend to either own several abalone licenses (e.g. Processors E and G) or have aggregated their share of quota by jointly operating processing facilities (e.g. Processor F in the Western Zone). These operator-processors also harvest both species in almost equal volumes, which would assist in attaining the economies of scale likely required for any future commercialisation pursuits of viscera, in particular. Furthermore, the majority of catch is controlled by only three processing firms. Participant responses indicated that at least two of the three firms would be open to collaborating on future waste management interventions; which furthers the potential to attain economies of scale. The opportunities, motivations, strengths, waste volumes, and current disposal practices present in South Australia’s abalone supply chains position it as the most promising of the five state fisheries for reducing waste and improving by-product outcomes by changing supply chain practices.

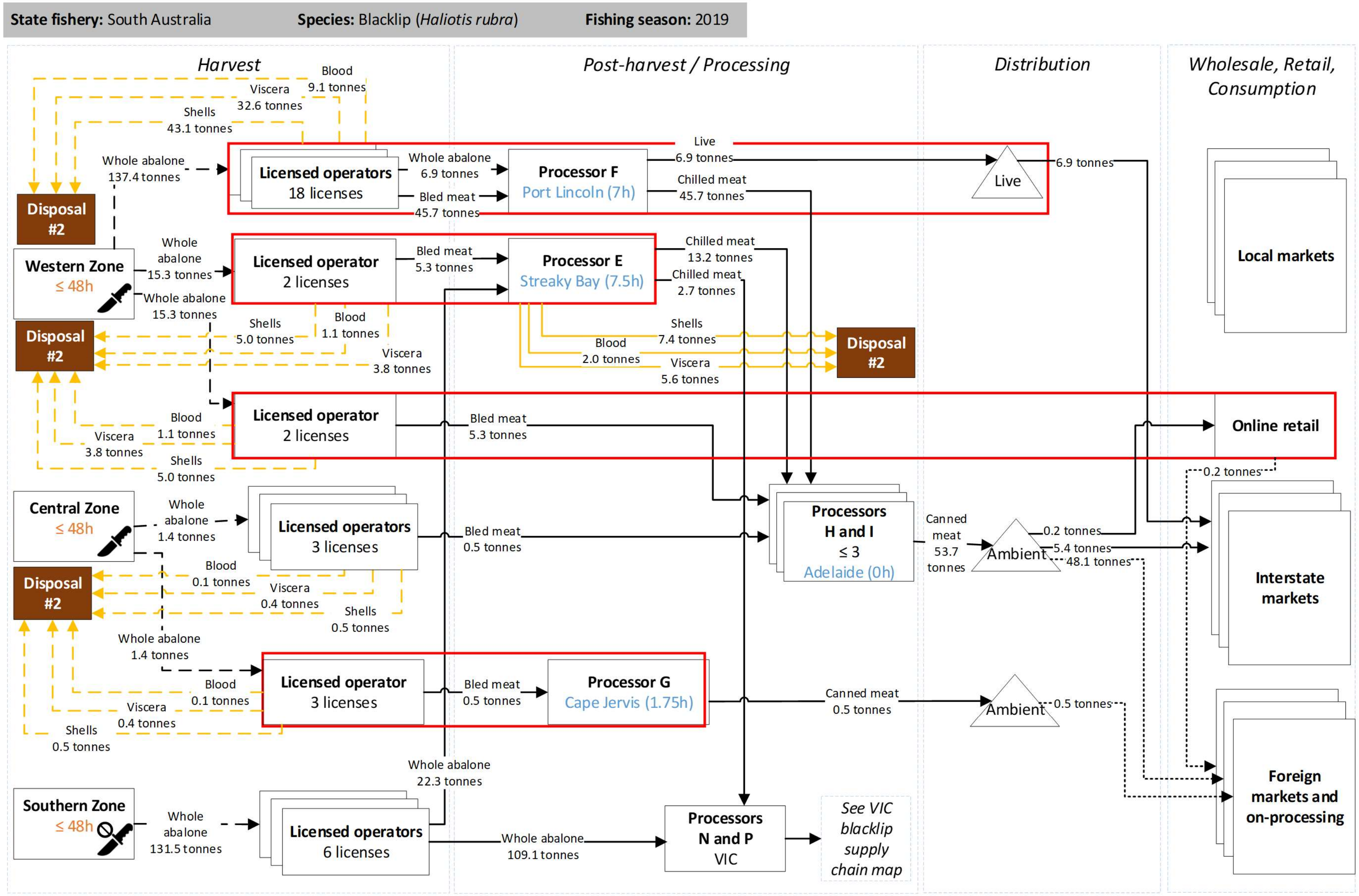

Figure 63. Current-state map of South Australia's Blacklip abalone supply chain in 2019.

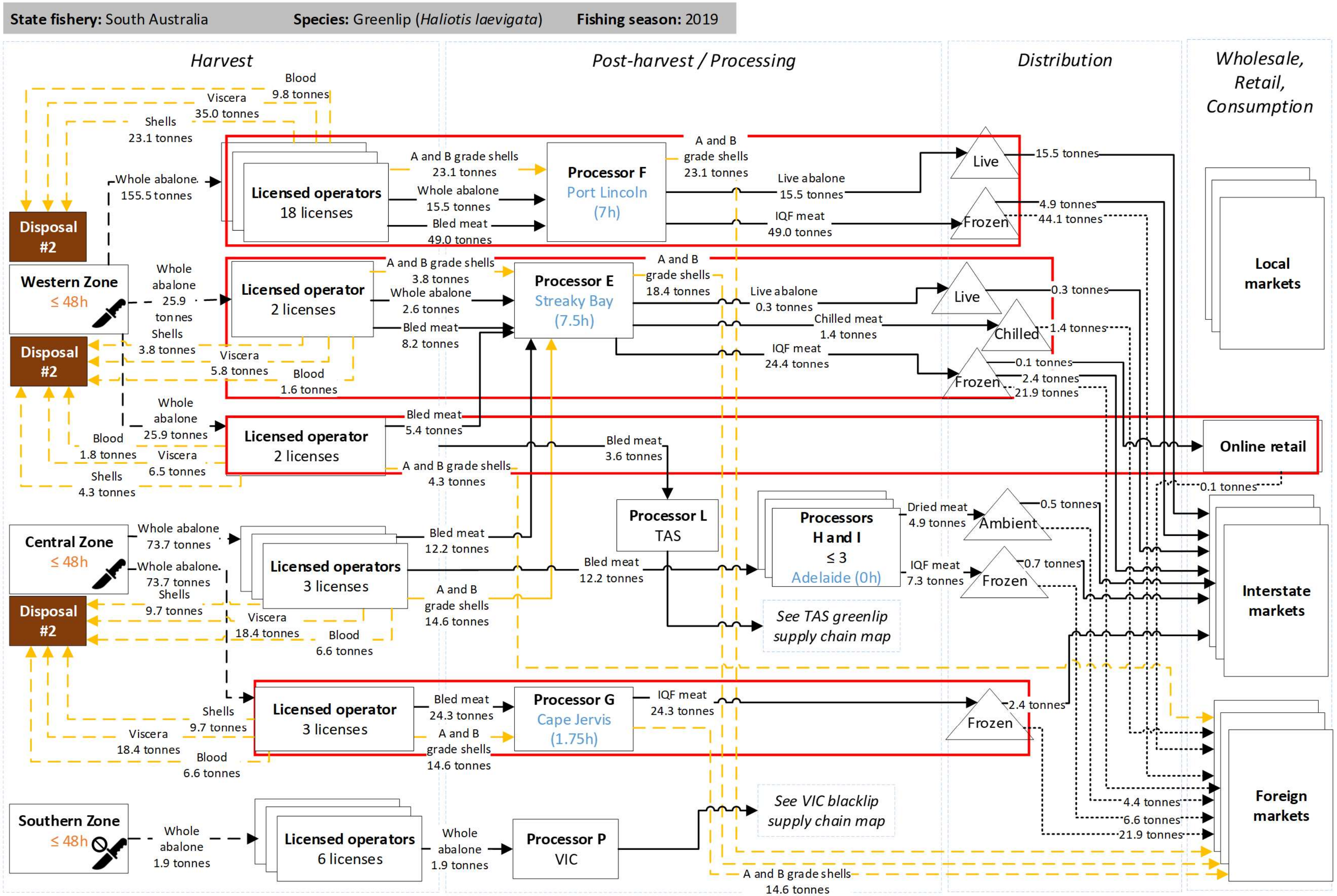

Figure 64. Current-state map of South Australia's Greenlip abalone supply chain in 2019.

The current-state maps and analysis of South Australia's supply chains are a contribution to new knowledge. Literature concerning South Australia's abalone industry has focused on stock sustainability (Sluczanowski 1984; Stobart, Mayfield and Carroll 2016) and biosecurity (Dang et al. 2011; Goggin and Lester 1995; Lester and Davis 1981). However, processing, distribution, and other supply chain issues have not been explored. Similarly, the sustainability of the South Australian abalone industry has not been examined from a food waste perspective.

Owing to the favourable opportunities and conditions for reducing waste and improving by-product outcomes that are present in South Australia, a future-state map was created suggesting management interventions that were guided by the food waste hierarchy. This future-state map is presented in Section 7.3.2.

7.3 Future-state Maps

The future-state supply chain maps presented in the following sections were created to illustrate the proposed management interventions for reducing waste and improving by-product outcomes. The proposed management interventions are guided by circular economy principles that have been adapted to the food waste hierarchy (Section 2.2.8, Figure 13) and theories adapted from general and agrifood supply chain management. Western Australia and South Australia's Greenlip supply chains were selected based on the analyses conducted in Sections 7.2.4 and 7.2.5 which identified the two fisheries as having the most favourable opportunities and conditions for reducing waste and improving outcomes for by-products.

7.3.1 Western Australia's Greenlip Supply Chain

The future-state map of Western Australia's Greenlip supply chain (Figure 65) primarily focuses on diverting viscera from disposal at sea ('Recycle #6') and finding a short- to medium-term use for viscera that has been in cold storage for a prolonged period of time. Greenlip viscera was selected as the category for future-state mapping because of the volumes available for recovery, knowledge of existing firm capabilities that was elicited from the interviews (Phase A), and future scalability across the supply chain.

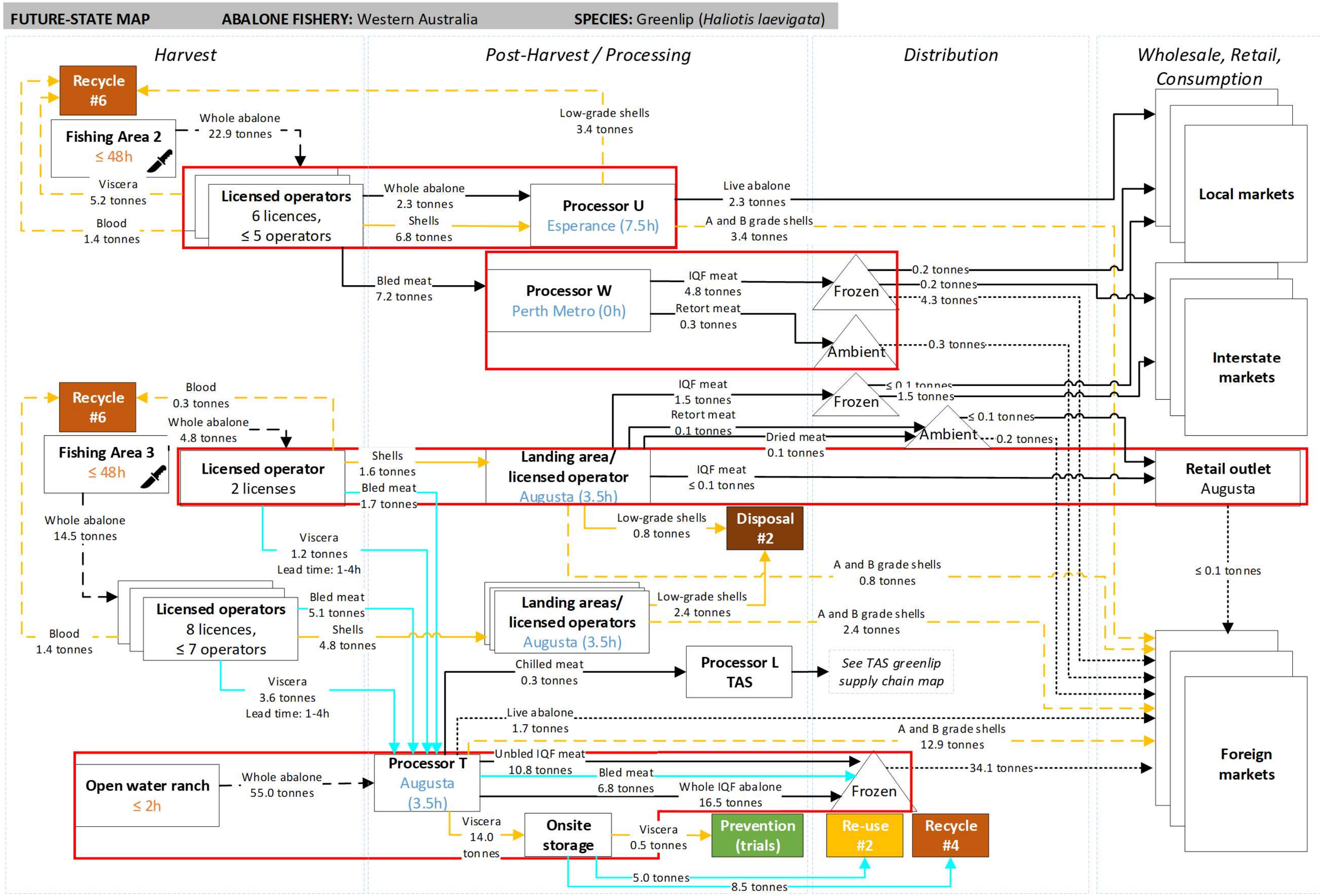

Figure 65. Future-state map showing proposed changes to flows of Western Australian Greenlip viscera to animal feed (Re-use #2) and composting (Recycle #4) uses.

In line with a pragmatic approach to management changes, animal feed (Re-use #2) and composting (Recycle #4) outcomes have been proposed in the future-state map. These specific outcomes were selected given some viscera has already spent a prolonged period in cold storage and would be neither suitable for human consumption nor nutraceutical use. It is likely that this practice will continue (i.e. frozen storage for several months at a time) since sufficient volumes (~10 tonnes, see Section 5.3.2) need to be accumulated to ensure transport is made as cost-efficient as possible. Downstream market requirements for viscera vary depending on the end-product, and this was detailed in Section 5.3.2. Though not the 'most preferred' outcomes according to the food waste hierarchy, the suggested management options of composting and animal feed are improvements compared to disposal at sea.

In the future-state map (Figure 65) it was suggested that all viscera from Area 3 (Albany) be transported for storage and subsequent use by Processor T. This addresses some of the barriers concerning sporadic supply and lack of economies of scale since it is possible that Processor T has sufficient storage capacity at its large, newly-built facility to accumulate volumes of viscera over time. Executing the future-state map scenario would require co-ordination and communication between divers, quota owners, and Processor T regarding landing times and locations. To encourage co-operation between the three parties, the bled meat could also be collected alongside the viscera for further on-processing at Processor T's facility which has the capacity to accommodate all catch from Area 3 (Appendix J, response lxiv). As explained in Section 7.2.4, Processor V has landed their shucked meat at Processor T's facility since 2021; indicating that the future-state map scenario is realistic and viable. The accumulation of viscera by Processor T raises questions of ownership and/or contractual arrangements between quota owners and Processor T that would need to be considered before any changes to practices are attempted.

Only a small portion (~0.5 tonnes) of Processor T's viscera is currently used on an annual basis for research and development (e.g. food product trials) while the balance is stored frozen for future possible use. From an operational perspective, moving the balance of stored viscera to animal feed and composting uses in the interim (i.e. before a commercial product is finalised and developed) would be a more efficient approach to managing the waste; since inventory would be cycled more quickly, warehousing freed up, and some revenue generated.

In this way, food waste is addressed along with operational inefficiencies; partly substantiating theories by De Steur et al. (2016), Folinas et al. (2014) and Wesana et al. (2019), *inter alia*, that lean management principles can be employed to reduce food waste. However, in contrast to the lean paradigm adopted in the aforementioned studies, 'value' is conceptualised in this research as the economic value producers and processors can derive from natural resources rather than the value perceived by the consumers or customers. Furthermore, economic value is maximised by extending the use of products or by-products according to circular economy principles (i.e. the food waste hierarchy). This concept of 'value' substantiates Hedlund et al.'s (2020) framework which adapts lean management principles to a circular economy context but neither uses data nor evidence-based mapping to support their theory as this research has. Rethinking the concept of 'value' and how it can be created by producers and processers addresses the limitations of applying Lean thinking to sustainable agrifood supply chain management that were put forth by Cox and Chicksand (2005).

Incidentally, drying viscera would also be a more operationally efficient means of storing and transporting viscera compared to a frozen product format. A study by Howieson et al. (2017) indicated that abalone viscera can lose up to 79% of its volume through drying. OP-E4 independently corroborated Howieson et al.'s (2017) findings that approximately 80% of abalone viscera consists of fluid (Appendix J, response lxxiii). However, current practices and market information elicited from participants indicated that frozen viscera is a format commonly sought by buyers (Section 5.3.2). As such, distributing frozen viscera may be a suitable short-term or interim solution for diverting Western Australia's Greenlip viscera from disposal outcomes, while other commercial products for human consumption are in development.

In terms of future scalability, Processor T has steadily increased production of ranched abalone over time. This was explained in Section 7.2.4. Based on the company's quarterly reporting to investors, the upward trajectory of production is projected to continue in future (see Figure 62) which may result in an increase in available viscera as well. Furthermore, there is a possibility that viscera from Area 2 (Esperance) could also be accumulated by Processor T in future. This assertion is based on the knowledge that Processor T operates facilities in Esperance and Augusta; and has established road transit arrangements between both locations to transport abalone broodstock on a regular basis (Appendix J, response lxi). However, owing to the estimated transit lead time of eight hours (road transport) between Esperance and Augusta, the expense of cold transport may be a barrier to moving what is currently a low-value by-product (Section 5.3.2). Quota owners' 'other priorities' that were explained in Section 5.3.2 might also act as a barrier to initiating the change of landing viscera for recovery from Area 2. Thus, accumulating viscera from both Areas 2 and 3 may be a long-term objective once commercially feasibility is demonstrated, rather than a pursuit in the short-term.

In sum, the future-state mapping scenario for reducing waste in Western Australia's Greenlip supply chain draws on Batista et al.'s (2021) framework of 'industrial symbiosis'. The concept of 'industrial symbiosis', which extends on earlier work by Chertow (2000), considers co-operation of firms located within certain geographical proximity (e.g. industrial parks, regions) a key factor in moving towards a circular economy. This is because firms can share physical resources such as infrastructure, logistics, and labour (as opposed to intangible resources such as knowledge, for example) that all assist in reducing the cost of transporting and distributing material. The proposed management interventions that were discussed in this section focused on leveraging Processor T's existing storage, processing facility, and logistic systems to accumulate and transport Greenlip viscera across a large swathe of Western Australia (Area 2 in Esperance and Area 3 in Albany). In this way, existing theories of how circular economies can be implemented by changing supply chain practices were used to build the validity of the proposed management interventions in this research (Batista et al. 2021; Chertow 2000).

7.3.2 South Australia's Greenlip and Blacklip Supply Chains

The future-state map of South Australia's Greenlip supply chain (Figure 66) shows the proposed changes to by-product flows for Greenlip viscera in the Western Zone. The proposed changes, indicated by blue arrows (→), could also be applied to the Blacklip current-state map which was presented in Section 7.2.5.

Western Zone Greenlip viscera was chosen as the category for future-state mapping because the three attributes of South Australian supply chain stakeholders which were described earlier (i.e. existing structures, motivations, and strengths) were particularly apparent amongst quota owners and operator-processors in the Western Zone. Furthermore, Western Zone Greenlip abalone constitutes the largest harvest category in South Australia (31% of total catch). It is noteworthy that the proposed changes could potentially be applied to the Western Zone Blacklip supply chain (Section 7.2.5) since Western Zone Blacklip abalone constitutes 25% of South Australia's total harvest. Altogether, the proposed changes depicted in the future-state map (Figure 66) have the potential to affect 87.6 tonnes of viscera (40.3 tonnes Blacklip, 47.3 tonnes Greenlip) discarded at sea in the Western Zone. This portion of viscera represents 33% of all by-products discarded at sea.

In the proposed future-state scenario (Figure 66), Processors E and F would be involved in a collaborative product commercialisation and marketing effort, where processing of viscera is undertaken by Processor E. Processor E was chosen as the facility to undertake on-site drying, rather than Processor F, because this accounts for any future scalability. Specifically, Processor E currently receives catch from the Central and Southern Zones; and as such, the potential to recover viscera from across the whole state in the long-term is considered in this scenario. Incidentally, where scalability is concerned, there may also be the potential to recover aquaculture abalone viscera from processors in the Western Zone (Appendix J, response xiii). However, estimating volumes of aquaculture abalone by-products were beyond the scope of this research.

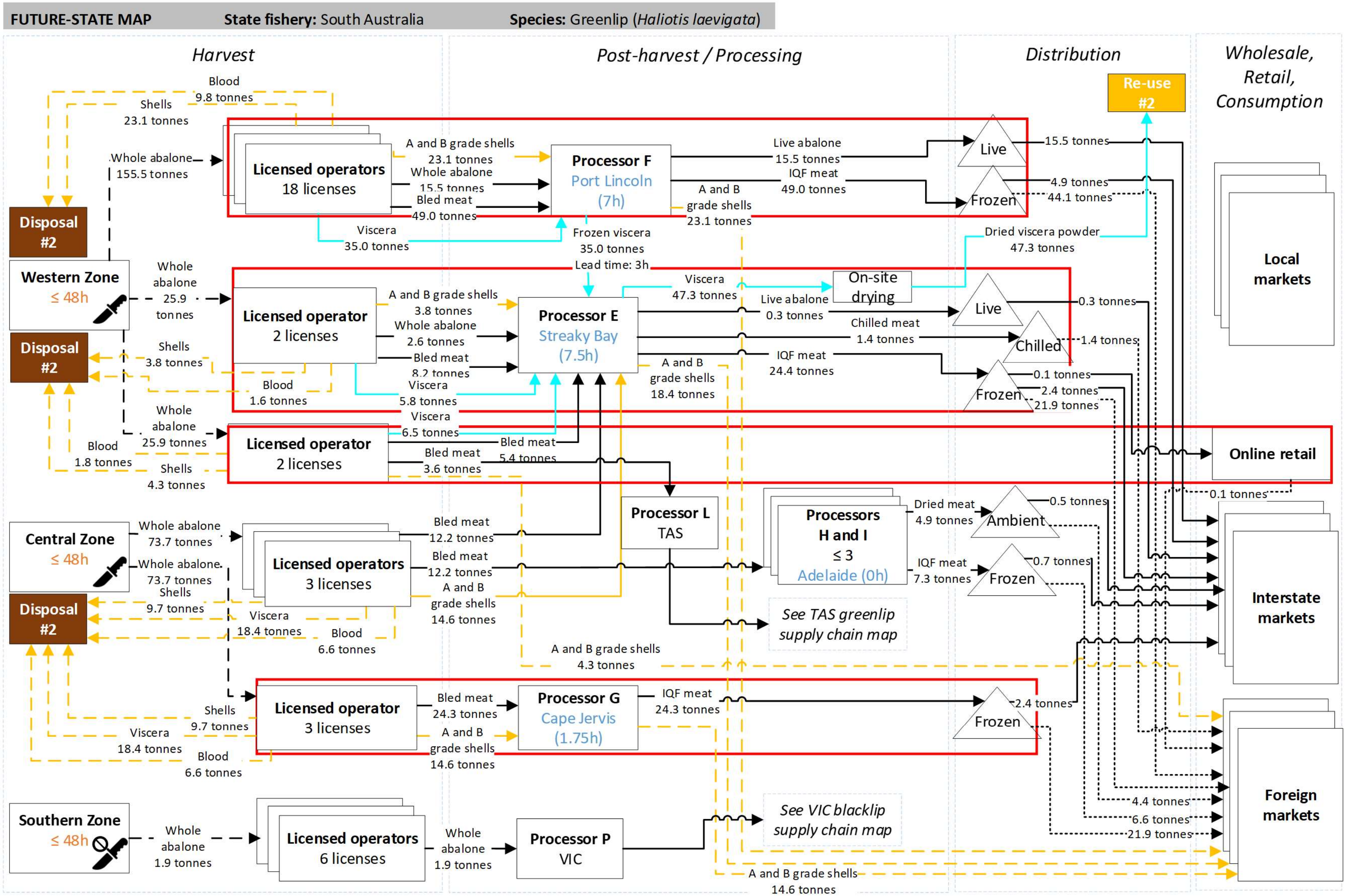

Figure 66. Future-state map showing proposed changes to flows of South Australia's Greenlip viscera to animal feed (Re-use #2).

By approaching the recovery of viscera collaboratively, existing infrastructure (i.e. storage, vessels, processing facility) and strengths along the supply chain are leveraged. In the proposed scenario, viscera would be dried into an animal feed supplement similar to those listed in the Desktop Review (Section 4.4, Table 23). The existing products that were found in the Desktop Review indicate that drying viscera for use as an animal supplement is already technically feasible. From a commercial perspective, powdered abalone supplements for pets derived from Australian wild and/or aquaculture abalone retail online and in traditional bricks-and-mortar pet stores between AU$149.90 to AU$298.80 per kilogram. The Desktop Review findings suggested that there are approximately five to six existing brands of powdered abalone pet supplements derived from Australian abalone currently on the market (Table 23, Section 4.4). These products are marketed as high-end, Australian-made products derived from 100% Australian abalone and no added ingredients; and appear to be targeted to an Australian market.

Furthermore, by integrating the Desktop Review results (Section 4.4) and marketing themes from Phase A (Section 5.3.3, “Wild” and “Brand Australia”) it emerged that there is a potential business case for developing and marketing a powdered abalone pet supplement derived from wild Australian abalone. However, this would need to be explored in-depth by a cost-benefit at the firm-level. As discussed in the theoretical framework (Section 2.2.8), a cost-benefit analysis is beyond the scope of this research. Nonetheless, the potential revenue that could be generated from the proposed future-mapping scenario is presented in Table 31. The estimated revenue scenarios were based on a direct-to-customer approach and 2019 estimates of viscera generated in the Western Zone. A direct-to-customer scenario was used in the revenue estimates since information for wholesale pricing could not be obtained during the desktop review nor by the end of the data collection timeline. Thus, it should be noted that revenues from a wholesale approach would be significantly less than the amounts listed in Table 31.

Table 31. Potential revenue from proposed future-state mapping scenario for South Australia's Western Zone.

By-product Category	Tonnes Discarded (2019)	Minimum Annual Potential Revenue (AU$)	Maximum Annual Potential Revenue (AU$)
Western Zone Greenlip viscera	47.3	$ 7,090,270	$ 14,133,240
Western Zone Blacklip viscera	40.3	$ 6,040,970	$ 12,041,640
Both species	87.6	$ 13,131,240	$ 26,174,880

The future-state scenario depicted in Figure 66 is a short- to medium-term proposal that could be explored while other options mentioned by participants such as nutraceutical or therapeutic uses are still being developed and yet to be commercialised. In this way, viscera are recovered in the near-term, discards reduced, and outcomes improved according to the food waste hierarchy by diverting by-products to animal feed (Re-use #2).

The proposed future-state scenario would require additional infrastructure and changes to supply chain practices by landing viscera alongside the bled meat. There would be no changes to the frequency of landing, lead times, nor landing location where harvesting is concerned; but additional cold storage would be required to chill the viscera onboard the fishing vessels. As suggested in Section 5.3.2 there is some, albeit limited, capacity onboard to accommodate the additional cold storage. Freezer storage would also be required by Processor F to accumulate viscera before transporting to Processor E for drying on a rolling basis. As such, the 35.0 tonnes flowing from Processor F to E is the total amount transported over one fishing season rather than as a once-off consignment. The proposed scenario would also require capital investment by Processors E and F in drying and packaging equipment, staff training, product development (i.e. trials), and marketing. In terms of ongoing costs, Howieson et al. (2017) found that drying can be an expensive approach to processing seafood by-products (AU$3,600/tonne). Notably, this figure (AU$3,600/tonne) may have changed materially in the intervening years. The feasibility of drying was not explored in this research but is noted as a consideration for any future exploration of the proposed scenario.

Similar to the Western Australian abalone industry, some noteworthy changes have occurred along the South Australian supply chains between 2019 (period mapped) and 2022/23 when the semi-structured interviews and future-state mapping were conducted. These changes were considered when devising the management interventions shown in the future-state map. The changes included:

- Ceasing distribution of live Blacklip and Greenlip abalone to domestic markets (i.e. Sydney and Melbourne) and diverting this portion of catch (~3%) towards IQF meat products instead. Participants described this change to processing activities as a direct result of a sharp decrease in tourism and tourist demand for live abalone; which was in turn caused by COVID-19 travel restrictions in 2020 (Appendix J). While noteworthy from a supply-demand perspective, the effect on the volume of by-products generated was not material given the small scale of domestic distribution. As such, flows of abalone products (i.e. live, IQF) were not altered in the future-state map compared to the current-state maps presented in Section 7.2.5.
- A 17% decrease in TACC quota between 2019 and 2023 which potentially reduces the volume of viscera discarded in the Western Zone by 30% (15.4 tonnes). However, no changes to waste management practices and discarding at sea has occurred in the intervening time. As such, the management interventions suggested in the future-state map (Figure 66) would still be appropriate in the short-term given the volumes of recovered Greenlip viscera could be combined with Blacklip viscera.

The proposed management interventions not only draw on the concept of industrial symbiosis (Batista et al. 2021; Chertow 2000), but also on theories of how agricultural co-operatives can be advantageous for helping primary producers and processors to achieve competitive market positioning and access to financing required for funding new commercial projects (Baraka 2022; Ghauri et al. 2022; Hooks et al. 2018; Pesme, Belis-Bergouignan and Corade 2010; Simpson and Bretherton 2004; Zhang, Luo and Li 2021). Agricultural co-operatives are legal structures formed voluntarily by participating primary producers to advance the interests (i.e. commercial, social), skills, and knowledge of its members; and, importantly, are founded based on shared values and co-operative principles put forth by the International Co-operative Alliance (Ghauri et al. 2022; Novkovic 2008;

Zhang, Luo and Li 2021). It is widely-accepted that agricultural co-operatives are beneficial for primary producers in single product industries such as dairy, wine, and beef *inter alia* (Baraka 2022; Hooks et al. 2018; Pesme, Belis-Bergouignan and Corade 2010; Simpson and Bretherton 2004).

Although an agricultural co-operative model was not proposed as a management intervention in this research, several aspects of extant theories were applicable to South Australia's Western Zone. For instance, the largely collaborative nature of supply chain actors; motivations to operate in a manner that maintained social, environmental, and economic sustainability; and voluntary aggregation of catch in South Australia's Western Zone (attributes which were all described in Section 7.2.5) embody several of the co-operative principles (Ghauri et al. 2022; Novkovic 2008). Moreover, the Australian abalone industry is effectively a single-product industry. In this way, several of the conditions of agricultural co-operatives are met by South Australia's Western Zone supply chain; making theories about the benefits of agricultural co-operatives valid and applicable in this context.

7.4 Conclusion

In this chapter, the desktop, qualitative, and quantitative results of the preceding phases were integrated; and, as a result, conclusions about the drivers of waste creation and by-product utilisation along the Australian wild-harvest abalone supply chains could be made. The integration of qualitative and quantitative data culminated in the construction of current-state maps for each state and species (n=10) which visually represented the connections between by-product volumes and drivers of use or disposal. Furthermore, management interventions were proposed by creating future-state maps (n=2) which showed the changes to by-product flows. The management interventions were justified by employing circular economy principles and referring to theories about sustainable agrifood supply chain management and the benefits of participating in agricultural co-operatives.

By conducting evidence-based current-state mapping to understand food waste drivers and volumes; and future-state mapping to apply circular economy principles and some economic feasibility aspects, the theoretical framework (Sections 2.2.1 to

2.2.8) was substantiated. This was a contribution to new knowledge since the theoretical framework was in itself an extension of existing theories and was subsequently substantiated. Specifically the integration of qualitative and quantitative food waste data (Goodman-Smith, Mirosa and Skeaff 2020; Goonan, Mirosa and Spence 2014; Papargyropoulou et al. 2016), demonstration of supply chain mapping to identify food waste hotspots and drivers (Batista et al. 2021; De Steur et al. 2016), and application of circular economy principles to justify management interventions (Garcia-Garcia et al. 2017; Papargyropoulou et al. 2014) had not previously been attempted altogether in the literature, and not at a granular level (Beretta et al. 2013). The contribution is notable since a supply chain perspective was demonstrated as a holistic and practical way of understanding and addressing food waste, which is a nascent but pressing research focus where food waste is concerned (Gorzeń-Mitka et al. 2020; Parfitt, Croker and Brockhaus 2021).

Furthermore, the mapping conventions that were devised in this research (Section 3.6.2) were applied in this phase of the research and found to be useful in the creation of current- and future-state food waste maps. This too was a contribution to new knowledge since existing frameworks were adapted – i.e. Gardner and Cooper's (2003) strategic mapping framework, Value Stream Mapping (Rother and Shook 2003), and general process mapping conventions (Beretta et al. 2013; Gardner and Cooper 2003) – and demonstrated in a food waste context by mapping food waste and incorporating Garcia-Garcia et al.'s (2017) food waste hierarchy model. The conventions were then applied using empirical data. Extant food waste mapping frameworks and examples do not employ supply chain mapping conventions, resulting in either a limited ability to convey information about food waste flows and their drivers (Anastasiadis, Apostolidou and Michailidis 2020; Batista et al. 2021); or, by contrast, an unnecessarily high level of information density (Beretta et al. 2013). The current- and future-state maps that were constructed using reliable conventions from extant supply chain mapping theory resulted in maps that are easy to interpret (Farris 2010; Gardner and Cooper 2003), and clearly signpost the purpose for which they were created – i.e. to illustrate food waste flows, supply chain practices, and proposed management interventions (Donaldson, Brice and Midgley 2020; MacCarthy, Ahmed and Demirel 2022).

In this chapter it was found that the drivers of food waste were highly dependent on context and for that reason, visualisation through current-state mapping was essential to properly comprehend the supply chain drivers in relation to waste volumes. Mapping each supply chain helped to segment, contextualise, and make sense of the large amount of information that was collected over the course of the research (Farris 2010; Gardner and Cooper 2003; Kennedy et al. 2016; Miles, Huberman and Saldana 2020). In terms of food waste volumes, drivers, and their relationship to supply chain context, food waste in Victoria (249.1 tonnes) was primarily driven by a lack of storage, lack of supply chain collaboration, and firms prioritisation of other industry issues (e.g. biosecurity); whereas food waste in South Australia (282.9 tonnes) and Western Australia (58.0 tonnes) was mainly driven by the convenience and lack of costs of shucking at sea. These findings validated widely espoused assertions in academia and practice that food waste must be understood at the supply chain-level to be properly addressed by tailored interventions (Arcadis 2019; FAO 2019; Parfitt, Croker and Brockhaus 2021; Xue et al. 2017).

Western Australia and South Australia's Greenlip supply chains were identified as the most promising scenarios for reducing waste in the near-term. Specifically, Greenlip viscera was selected as a category for focus based on existing attributes such as: infrastructure, processing capability, logistic systems, supply chain relationships, commercial markets, and future scalability. Moreover, management interventions were proposed at a zonal level, rather than across the state. This was based on an analysis of the aforementioned attributes (i.e. infrastructure, logistics, and so on) as well as the knowledge that emerged from the qualitative interviews concerning the unique 'personalities' or set of circumstances that characterise each fishing zone (Section 5.3.3). Thus, changes to by-product flows were only mapped in the future-state maps for Western Australia's Area 3 and South Australia's Western Zone, and tailored interventions were recommended for the two different contexts.

In sum, this chapter drew conclusions that not only contributed to an understanding of food waste along Australian wild-harvest abalone supply chains; but also addressed food waste by suggesting management interventions tailored to the different supply chain contexts. The implications of the conclusions made in this chapter are both academic and practical. From a theoretical perspective, the framework that was developed in this research built on existing theories and was substantiated using empirical data; and the findings demonstrated that practical suggestions for changing food waste management practices can be devised when analysis is performed at a supply chain-level. From a practical perspective, stakeholders in Australia's wild-harvest abalone industry can use the knowledge of volumes, drivers, and the proposed management interventions to reduce food waste along areas of their supply chains in a material way.

8 CONCLUSION

This research has demonstrated a novel, mixed methods food waste mapping framework that was based on extant theoretical constructs, including: how food waste can be reduced by supply chain management practices, how circular economy principles can be adapted to the food waste context to improve food waste outcomes, and how supply chain mapping can be used as an effective tool for understanding and addressing food waste volumes and drivers. Being an industry-driven project a pragmatic worldview was adopted in this research; and this paradigm underpinned the theoretical framework and research design. In this way, it was intended that not only theoretical contributions were made in this research but that practical, managerial outcomes (Section 3.1.1**,** Figure 17) were also yielded. Ultimately the research attained both theoretical and practical outcomes which will be summarised in this concluding chapter, as well as some limitations of the research.

8.1 Limitations and Justifications

There were a number of limitations to this research arising from the limited project timeline and initial scope or drive of the research. These limitations related to: data and participant recruitment, inability to conduct a feasibility analysis, and ability to triangulate some of the qualitative results.

Data and Participant Recruitment

Participant recruitment of typical cases from the Victorian and New South Wales abalone fisheries was unsuccessful despite several attempts (Appendix D); which was mentioned throughout Chapters 5, 6, and 7. As a result, details regarding the extent of by-product use by Victorian processors (e.g. nutraceutical trials and sauces for human consumption) could not be gathered. This information would have served to enhance the accuracy of estimates of by-product use and disposal, since some participant responses in Phase A suggested that only part of the viscera is used in the manufacture of sauces. Nonetheless, analysis of the volumes and outcomes of the majority of by-products generated in Victoria could still be conducted based on the information elicited from participants. Although stronger conclusions could have been drawn with the inclusion of data provided by additional participants, the results are still considered valid.

The relative lack of participants from New South Wales (*n*=2) somewhat affected the analysis of results relating to this specific fishery, but not the overall results of the research. An additional participant from New South Wales with abalone processing or receiving experience would have triangulated some of the claims about market share, recent change in processing/receiving practices, and waste management practices made by the other participants from this subgroup (*n*=2). Instead, secondary data (i.e. TACC quotas, production volumes, export volumes) were used to corroborate the overall finding that New South Wales has low production volumes compared to other states, and is a fishery focused on predominantly live abalone distribution. Thus, the volume of by-products generated was confirmed to be relatively minimal compared to other states. In this way, the lack of participants from New South Wales did not adversely affect the overall results and conclusions of the research but would have better balanced the qualitative data collection and provided greater authenticity to the results.

Recruitment of critical cases that could speak to the commercialisation or marketing of products derived from viscera, shell, or blood was also unsuccessful within the allocated data collection timeline (Appendix D). This affected confirmation of whether theoretical saturation was reached on marketing themes (Section 5.3.3). Though the topic was explored to an extent with ME-1, theoretical saturation would only have been confirmed by interviewing additional critical cases with marketing experience.

Finally, the inability to obtain comparable data for all states for a more recent fishing season that 2019 (i.e. 2021 onwards) was a limitation of the quantification of by-products and current-state mapping. Attempts were made to obtain more recent data as explained in Section 4.2. However, not all fishing authorities were able or willing to provide catch data on an *ad hoc* basis outside of the typical reporting period. More recent catch data would have accounted for the decreases in quota experienced in some fisheries (e.g. South Australia, Western Australia, Tasmania) and led to a more accurate estimate of *current* by-product volumes, use, and disposal. Overall, however, the qualitative data indicated that waste management practices have remained unchanged since 2019 and were captured in the current-state mapping. In this way, the analysis of practices and proposals for change remain appropriate.

Feasibility Analysis

Owing to project timeline constraints, a full feasibility analysis of the suggested management interventions proposed in Sections 7.2.5 and 7.3.2 was not conducted; though the importance of a feasibility analysis was noted in the theoretical framework. Although a feasibility analysis was not conducted, some elements such as existing commercial products, potential ongoing costs and capital outlay, and potential revenue constituting a pre-feasibility analysis were explored in the South Australian future-state mapping scenario (Section 7.3.2).

As suggested by the literature reviewed in Section 2.2.8, a feasibility analysis would be a crucial step in realising any proposed management interventions. In this sense, a feasibility analysis bridges theoretical and practical outcomes. Given the pragmatist worldview that was adopted, a feasibility analysis would have fully realised the theoretical and philosophical underpinnings of this research. Nonetheless, the elements that were explored in Section 7.3.2 relating to economic feasibility (e.g. potential revenue and costs) indicate this may be a fruitful area for future research.

Triangulation of Qualitative Results

The qualitative themes relating to supply chain strengths (Section 5.3.3) would have benefited from triangulation with some quantitative primary data. Specifically, where a number of participants (n=8) attributed sustainable fishing practices and a collaborative approach to business to quota ownership by local families rather than foreign or interstate investors in Theme 3. Though compelling, participants' experiences of the impact of non-local investors on quota ownership, sustainability of wild abalone stocks, and supply chain collaboration could benefit from some quantitative corroboration and deeper investigation, since larger firms in Tasmania (mix of family-owned and non-local investor quota ownership) appear to be operating sustainably in other ways (i.e. using majority of by-products). Given the changing landscape of quota ownership in the seafood industry generally across Australia, as well as pressing concerns about sustainable production and consumption of food that pervade research and practice, this emerged as a noteworthy aspect of the data to include in the qualitative results. However, deeper quantitative investigation such as a survey to better understand the impact of quota ownership type on business practices, sustainability performance indicators and/or levels of supply chain collaboration were beyond the scope of this research.

8.2 Significance

This research has both theoretical and practical significance. The theoretical contributions made by this research will be discussed first, followed by a discussion of the practical implications.

From a theoretical standpoint, a contribution was made by: (1) devising a food waste mapping framework, and (2) substantiating the framework by using empirical evidence. The framework that was construed in this research drew on extant theories, connecting the key constructs from the fields of supply chain management, supply chain mapping – including ideas from operations research – and food waste. This research demonstrated the benefits of adopting a pragmatic and largely inductive (qualitatively-dominant mixed methods) approach to understanding food waste at the supply chain-level. Adopting such an approach allowed for an in-depth and nuanced understanding of supply chain practices, structures, relationships, governance, product flows, and product flow volumes. In turn, an in-depth understanding of the supply chains and waste volumes led to an understanding of drivers of food waste creation and drivers of by-product utilisation. Drivers of food waste creation could then subsequently be addressed in a pragmatic manner by suitable supply chain management theories and circular economy principles drawn from the literature. Notably, such a large amount of information could not have been understood without mapping the supply chains using reliable, intuitive conventions which were also based on a detailed review of extant literature and supply chain mapping theory.

In this way, a theoretical contribution was made since previous food waste mapping examples and frameworks have demonstrated the link between supply chain management, mapping, and food waste constructs but not in a manner that emphasised the role of evidence-based supply chain mapping and use of reliable conventions in effectively identifying the drivers of food waste, volumes of food waste, and drivers of by-product utilisation. Furthermore, mixed methods approaches to supply chain mapping were rare. For instance, Batista et al. (2021) adopt a purely qualitative approach to mapping and do not employ reliable conventions for supply chain mapping. As such, food waste volumes are decoupled from information about the supply chain (i.e. practices, structures, governance, geography) that indicate drivers of waste creation. The inductive approach also contrasts several food waste studies that map and analyse drivers of food waste creation through a pre-determined and limited 'menu' of food waste drivers according to the Lean paradigm (De Steur et al. 2016; Kazancoglu et al. 2021; Shah and Ganji 2017; Wesana et al. 2019); and which is largely suited for analysis of internal firm operations (De Steur et al. 2016; Rother and Shook 2003; Womack, Jones and Roos 1990).

This research also contributed new knowledge by capturing food waste data about an economically-significant seafood industry in Australia. This contributes to filling the gap in food waste data at a supply chain-level for upstream segments of the Australian food system (Arcadis 2019; Ambiel et al. 2019). Furthermore, extant literature regarding Australian abalone fisheries has been limited to the primary production stage; in particular, stock management, regulatory compliance, and biosecurity management. Other aspects such as supply chain collaboration, market share, product flows, processing and distribution activities, and economic sustainability of the industry has not received significant attention in the literature and certainly not from a food waste perspective. Furthermore, the motivations and values of abalone supply chain stakeholders to operate sustainably has neither previously been captured on a national-scale nor in a qualitative manner. In this way, new perspectives and knowledge have been added to the literature on the Australian abalone industry.

From a practical perspective, this research is significant in two ways: (1) the proposed theoretical framework and research design have the potential to be adapted to mapping, understanding, and addressing food waste in other seafood or agrifood supply chain contexts; and (2) the analysis of food waste volumes and drivers, and proposed management interventions that were yielded in this research can be used by Australia's wild-harvest abalone industry stakeholders to instigate better food waste management practices in the near-term. For example, analysis was conducted on a state-by-state basis and used several categories for analysing the mass flow of by-products. South Australia's Blacklip and Greenlip supply chains were subsequently identified as having the most promising opportunity for reducing food waste and improving by-product outcomes based on the volume of food waste that is disposed of. The supply chain analyses of the five state fisheries conducted in this research also revealed strengths (e.g. Instigators of Change, collaborative stakeholders) and areas of weaknesses (e.g. organisational silos, information asymmetry), which is knowledge that can be used by stakeholders to design a more efficient abalone supply chain for the future.

In terms of adaptability to other agrifood supply chain contexts, the proposed theoretical framework is purpose-driven and the scope of parameters consists of broad, core principles informed by general supply chain mapping theory and agrifood supply chain mapping examples. Thus, the purpose and parameters can be adapted to different agrifood supply chain contexts outside of the Australian wild-harvest abalone industry. Similarly, the research design consists of reliable and low-cost techniques which can be adapted to different contexts based on the purpose and parameters of the overarching project. The practical implications are that other agrifood SMEs in primary production and post-harvest processing can adapt and undertake the current- and future-state mapping activities conducted in this research as a low-cost, low-risk first step to addressing food waste in their own supply chains.

8.3 Future Research

A number of suggestions for future inquiry emerged from this research. Firstly, as the scope of this research was limited to wild-harvest abalone supply chains, volumes of by-products generated from aquaculture abalone processing could be investigated using the framework devised in this research. Australian aquaculture abalone production has been increasing incrementally in Western Australia, South Australia, Tasmania, and Victoria and is on a trajectory projected to continue (Mobsby et al. 2021). The volumes of by-product generated from the aquaculture sector could bolster decreasing volumes of wild abalone production to meet the economies of scale and scalability likely required for long-term commercial feasibility. However, aggregating wild and aquaculture products may need to be investigated from a technical perspective to confirm whether by-products from the two production methods possess comparable attributes. Furthermore, employing this framework in another agrifood context (i.e. aquaculture) would test its adaptability to food waste mapping generally. In terms of feasibility, future research could also focus on a techno-economic analysis of the management interventions for by-products that were proposed in Sections 7.2.5 and 7.3.2.

As marketing emerged as an important aspect of improving outcomes for by-products, future research could be conducted on topics such as consumers' willingness to pay for products with 'wild', 'brand Australia', and other credence attributes. Such research would assist in guiding stakeholders' approach to market development and commercialisation. Moreover, marketing research on willingness to pay may adjust stakeholders' current perceptions of abalone by-products as low value commodities.

8.4 Addressing the Research Questions and Concluding Statement

To conclude this thesis, the two research questions put forth in Section 2.4 will be addressed.

RQ1: What are the opportunities for reducing food waste in Australia's wild-harvest abalone supply chains that can be identified by mapping current supply chain practices?

By integrating the themes from Phase A ('QUAL') and results of the mass flow analysis conducted in Phase B ('quan'), it was concluded that there are varying opportunities to reduce waste in each of the five Australian abalone fisheries. The themes and mass flow analysis were brought together in a series of current-state maps (*n*=10), and the opportunities to reduce waste along each supply chain were assessed in terms of volumes and specific by-product outcomes according to the food waste hierarchy. Opportunities to reduce waste were also assessed at a zonal-level, rather than state-wide, and for specific by-product categories (*n*=16, such as species, by-product type, and so on) following an analysis of supply chain capabilities (i.e. strengths, structure, and firm infrastructure), spatial proximity, motivations to change supply chain practices, and future scalability.

Based on the current-state mapping that was conducted, South Australia was judged to have the most opportunity to reduce food waste both in terms of the volume of waste generated along both Greenlip and Blacklip supply chains (82% or 282.9 tonnes of all by-products generated) and outcomes of by-products (discarding at sea or disposal on land). Furthermore, an analysis of the South Australian supply chains – facilitated through mapping – revealed that there were several existing supply chain attributes that created a potentially conducive environment for implementing management interventions for reducing food waste. These attributes included: vertically integrated structures founded on a co-operative ethos, relative geographical proximity of operators, and available volumes were conducive pre-conditions to reducing waste. The opportunity to reduce waste in Western Australia was moderate given relatively low volumes of by-products (86.7 tonnes) and waste (58.0 tonnes) are generated across the state; but the outcomes such as disposal of viscera and shells could be improved.

Conversely, there were minimal opportunities to reduce waste in Tasmania, Victoria, and New South Wales. It was revealed that New South Wales is a pre-dominantly live export fishery; meaning negligible amounts of by-products are generated and, in turn, minimal waste is created. In Victoria, there were several barriers that indicated the opportunity to reduce waste was low despite the relatively high volumes that were generated in 2019 (249.1 tonnes) compared to other states. The barriers included: supply chain actors' focus on other priorities (i.e. biosecurity risks), a fragmented supply chain subject to organisational siloing, lack of storage, and inconsistent labour supply. Finally, in Tasmania there was minimal opportunity to reduce waste since two of the major operator-processors, accounting for ~75% of state-wide catch, were already diverting majority of the by-products in the state (83% or 266.1 tonnes) to other uses such as nutraceuticals, pet food, compost, and sauces for human consumption.

RQ2: How can current supply chain practices be improved to reduce food waste along Australia's wild-harvest abalone supply chains?

It was determined that food waste can be reduced along Australian wild-harvest abalone supply chains by taking a targeted, zone-level approach to changing supply chain practices. This was based on the finding that drivers of waste varied greatly in each state fishery; and, additionally, that each fishing zone within the state fisheries had a unique set of supply chain dynamics, structures, and even governance. Thus, focus was narrowed to proposing management interventions for two fishing zones: Western Australia's Area 3 and South Australia's Western Zone. A future-state map was created for each scenario (*n*=2) which showed the proposed management interventions and changes to the by-product flows. Based on an in-depth literature review, it was determined that supply chain practices could be changed using management interventions drawn from supply chain management theory and by applying circular economy principles (i.e. the food waste hierarchy).

Industrial symbiosis and agricultural co-operative models provided the theoretical basis for the suggested management interventions. In Western Australia's Area 3, it was determined that Processor T's existing infrastructure and logistic systems could be shared amongst quota owners in the region to accumulate sufficient volumes of Greenlip viscera for animal feed and compost uses. In this way, disposal of viscera at sea could be reduced in the short-term by approximately 13.5 tonnes (based on 2019 catch figures). In South Australia's Western Zone, it was proposed that the operator-processors in the area leverage their existing strengths which are reminiscent of agricultural co-operative principles (i.e. voluntary aggregation of catch; motivation to maintain the social, environmental, and economic sustainability of the zone; collaborative mentality, and so on). These strengths could be leveraged if the Western Zone operator-processors were to engage in a collaborative, zone-level commercialisation and marketing effort to accumulate, process, and distribute their Greenlip and Blacklip viscera. This proposed management intervention could have the potential to reduce viscera waste in South Australia by approximately 87.6 tonnes (based on 2019 figures).

In sum, both research questions were addressed by the evidence-based, mixed methods approach to supply chain mapping that was devised in the theoretical framework and research design. This research embodied a pragmatic worldview and remained true to the industry-driven nature of the project by making contributions that were both theoretically and practically significant. Despite the limitations of the research, the findings were still valid and sufficiently addressed the research questions. The current- and future-state maps that were constructed in this research reveal that there are indeed opportunities to reduce waste in Australian abalone fisheries; and the motivations, supply chain structures, interfirm relationships, and strengths exist to enable change in the near future.

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APPENDICES

Appendix A: Interview Guide

Interview Facilitation Guide

From trash to treasure: Mapping waste flows and identifying new opportunities for shell and shucking waste in the Australian abalone industry

Lynne Loo, student researcher; Dr Elizabeth Jackson, Senior Lecturer; and Dr Janet Howieson, Senior Lecturer, Curtin University

<u>Opening Script</u>

Hi [participant name]. Thank you for taking the time to talk to me about supply chain practices in the Australian abalone industry. I'm Lynne Loo, a Master's student at Curtin University; and these are my supervisors, Liz Jackson and Janet Howieson. We would like to speak with you today, for about 40 minutes or so, about mapping waste flows and finding new opportunities to use shell and shucking waste in the Australian wild-harvest abalone industry.

With your permission, I'd like to use this discussion to contribute to my Master's research project.

There are just a few house-keeping points to cover before we start our conversation *[stated verbally]*:

- This discussion will be recorded to ensure the accuracy of the data collected.
- Your contribution will be anonymised when we analyse the data and write up the final results.
- You are free to withdraw from the discussion at any time without prejudice.
- And finally, it would be very much appreciated if you could please complete and return the consent form to me before we get started.

To start things off, could you describe your business and the abalone supply chain?

<u>Facilitator prompts:</u>

- *Quantities harvested*
- *Operating capacity – vessels, workers, licenses/shareholdings*
- *What happens to the harvest*

What are the various product formats that you *[if fisher:]* **fish for /** [if processor:] **produce?**

<u>Facilitator prompts:</u>

- *Domestic sales / export*
- *Approximate breakdown (% or tonnage) of product formats*

At what points in your process are waste generated?

<u>Facilitator prompts:</u>

- *Quality and storage practices*
- *Current practices*
- *Waste streams*
- *Waste end points*

Version 3
10 November 2021

Finally, what are your thoughts about the barriers and opportunities in diverting your shell and shucking waste?

<u>*Facilitator prompts:*</u> • *Financial – costs, dollar value for waste* • *Operational* • *Supply chain factors*

Before we finish, are there any issues that we haven't touched on? Would you like to add any more thoughts?

Are there any others in the supply chain you think would be good for me to contact? If I have any other questions, would you mind if I gave you a call or quick e-mail?

Thank you so much for taking the time to speak to us today. Your contribution has been really valuable for my research project.

We'll be reporting back to Abalone Council Australia Ltd. in a few months, would you like to receive a copy of the report?

If you have any further comments or have any questions about the research, please feel free to get in touch. Our contact details are on the Participant Information sheet that you received.

Appendix B: Template of Contact Summary Sheet

Participant:			
Interview Date:		**Interview Time:**	
Reflection Date:		**Reflection Time:**	

CHECKLIST:

- [ ] Listened back to recording to ensure sound quality etc.
- [ ] Sent participant thank you note

Where did the interview occur and what were the conditions like?

How did the interviewee react to the questions? *i.e. spontaneity, richness, specificity, relevance*

How well did I go asking questions? *i.e. question length vs. answer length; clarification of meanings and other aspects of participant answers; attempts to verify interpretations throughout course of interview*				
Poorly	Unsatisfactorily	Satisfactorily	Good	Very well
Any other info…				

How was the rapport?				
Poor	Unsatisfactory	Neutral	Good	Very good
Any other info…				

Did I obtain the information I really wanted?

Appendix C: Transcription Protocol

- Recording is reviewed to ensure audio and video quality is adequate and that there are no missing parts.
- Recording is backed up (one version in OneDrive, one on PC, and one on hard drive).
- **Audio-video recordings (Webex):** Download the transcription directly from Webex (Webex generates the transcriptions automatically from the video conference recordings). However, if transcription fails then recording is uploaded to Otter.ai.

  Audio-only recordings (in-person interviews): Upload to Otter.ai for transcription.
- **Otter.ai transcriptions:** Interview 'speakers' are identified in the Otter.ai software and assigned automatically to the whole transcript using the 'rematch speakers' feature.
- The original transcript is downloaded from Otter.ai and a copy saved according to the file path:

  C:\Users\19907598\OneDrive - Curtin University of Technology Australia\Documents\Thesis\Data Collection\Interviews\Transcripts\Original Versions - unedited
- The transcription is then 'cleaned up'.
- Any misspellings, grammatical errors, and misinterpretations by the transcription software are corrected
- The paragraphs of spoken word are organised according to speaker, if not already correctly done by the transcription software.
- The transcript is meant to accurately reflect the recording as best as possible, and so far, the decision has been to keep the transcript verbatim.
- As per the transcription protocol proposed by McLellan, MacQueen, and Neidig (2003, 66), the transcript is kept as an exact, verbatim reproduction of the recording such that "elisions, mispronunciations, slang, grammatical errors, and non-verbal sounds (e.g. laughs, sighs), and background noises" are all included in the transcript.
- The edited or 'clean' transcript will be formatted thus:
- Header: the interviewee's name
- Subheadings: meeting date and time, duration, speakers and percentage of word count each,
- A table preceding the 'script' that shows basic interviewee attributes (position, company, state, industry experience)
- 11 point Arial font; speakers' names in bold and set out in a script form; 1.5 line spacing; paragraphs with 6pt before and after; left-justified text; 2.5 cm margins (top, bottom, left, right)
- Timestamps included next to the speakers' names each time they speak
- Non-verbal sounds (e.g. laughs, sighs) and background noises formatted in italics and surrounded by square brackets – e.g. *[laughs]*

Appendix D: Participant Recruitment Log

The following recruitment attempts are listed in chronological order. Recruits were contacted on no more than three occasions.

Recruit	Sample Scheme (Typical or Critical)	Purposive Sampling Technique	State	Gender (F/M)	Role and/or Supply Chain Stage	Interviewed (Y/N)	Contact Attempts
1	Critical case	Expert recommendation	-	1 x F, 1 x M	Existing users of viscera for pet food	N	• Jan 2022: Initial contact by email, recruit agrees to interview • Feb 2022: Meeting falls through • No further contact due to company operational difficulties
2	Critical case	Expert recommendation	SA	M	Fisheries scientist; fishery management; biosecurity expert	Y	• Feb 2022: Initial contact by email, no response • May 2022: Follow up email sent, recruit agrees to interview
3	Typical case	Expert recommendation	SA	M	Operator-processor; quota ownership, harvesting, processing, export, domestic distribution	Y	• May 2022: Initial contact by email, recruit agrees to interview
4	Typical case	Expert recommendation	SA	M	Operator-processor; quota ownership, harvesting, processing, export and retail, domestic distribution	Y	• May 2022: Initial contact by email, recruit agrees to interview
5	Typical case	Expert recommendation	TAS/VIC	M	Operator-processor; quota ownership, harvesting, processing, export; viscera and shell use	N	• May 2022: Initial contact by email, recruit suggests another individual within firm
6	Typical case	Expert recommendation	TAS	M	Operator-processor; harvesting, processing, export, viscera and shell use	Y	• May 2022: Initial contact by email, recruit agrees to interview

Recruit	Sample Scheme (Typical or Critical)	Purposive Sampling Technique	State	Gender (F/M)	Role and/or Supply Chain Stage	Interviewed (Y/N)	Contact Attempts
7	Critical case	Expert recommendation	WA	M	Fisheries scientist; fishery management	Y	• May 2022: Initial contact by email, recruit agrees to interview
8	Typical case	Expert recommendation	WA	M	Operator-processor; harvesting, ranching, processing, export, retail, domestic distribution	Y	• May 2022: Initial contact by email, recruit agrees to interview
9	Typical case	Snowball sampling and expert recommendation	WA	M	Operator-processor; quota ownership, processing, export and domestic distribution	Y	• May-Jul 2022: Initial contact by email, recruit agrees to interview
10	Typical case	Snowball sampling and expert recommendation	WA	M	Operator-processor; quota ownership, processing, export, domestic distribution and retail	Y	• Jun 2022: Initial contact by email, recruit agrees to interview
11	Typical case	Expert recommendation	TAS	M	Operator-processor; harvesting, processing, export, viscera and shell use	N	• Jun 2022: Initial contact by email, recruit agrees to interview • Jul 2022: Recruit does not attend interview; suggests another individual within firm
12	Typical case	Snowball sampling	SA	M	Operator-processor; quota ownership, harvesting, processing, export, domestic distribution	Y	• Jun 2022: Initial contact by email, no response • Aug 2022: Follow up email sent, recruit agrees to interview
13	Typical case	Expert recommendation	NSW	M	Operator; quota ownership, harvesting	Y	• Jun 2022: Initial contact by email, recruit agrees to interview

Recruit	Sample Scheme (Typical or Critical)	Purposive Sampling Technique	State	Gender (F/M)	Role and/or Supply Chain Stage	Interviewed (Y/N)	Contact Attempts
14	Typical case	Expert recommendation	TAS	M	Operator-processor; harvesting, processing, export, viscera and shell use	Y	• Aug 2022: Initial contact by email, no response from recruit • Sep 2022: Recruit re-establishes contact, agrees to interview
15	Critical case	Expert recommendation	-	F	Marketing expert for premium food products	Y	• Aug 2022: Initial contact by email, no response from recruit • Sep 2022: Recruit re-establishes contact, agrees to interview
16	Typical case	Expert recommendation	VIC	F	Industry representative of operator-processors	Y	• Aug 2022: Initial contact by email, recruit agrees to interview
17	Typical case	Expert recommendation and snowball sampling	VIC	M	Operator; harvesting and domestic distribution	Y	• Aug 2022: Initial contact by email, recruit agrees to interview
18	Typical case	Snowball sampling	VIC	1 x F, 1 x M	Processor; processing, use of viscera in sauces, market development, distribution	N	• Aug 2022: Recruit contacted by another participant by email, recruit acknowledges email • Aug-Sep 2022: Follow up email sent, recruit declines interview
19	Typical case	Snowball sampling	VIC	M	Processor; processing, export and domestic distribution	Y	• Aug 2022: Recruit contacted by another participant by phone • Aug 2022: Recruit contacted by phone, agrees to interview

Recruit	Sample Scheme (Typical or Critical)	Purposive Sampling Technique	State	Gender (F/M)	Role and/or Supply Chain Stage	Interviewed (Y/N)	Contact Attempts
20	Typical case	Expert recommendation	VIC	M	Operator-processor; quota ownership, harvesting, processing, export, use of viscera and shell	N	• Sep 2022: Recruit contacted by phone, expresses interest • Sep 2022: Follow up by email, no response
21	Critical case	Snowball sampling	-	F	Scientist; end-use for viscera in nutraceutical products (trials)	N	• Sep 2022: Initial contact by email, recruit expresses interest but requires approval from project partners • Sep 2022: Recruit requests interview guide which was provided for perusal • Oct 2022: No response, no further contact made with recruit
22	Typical case	Snowball sampling	VIC	M	Processor; processing, export and domestic distribution, use of viscera for nutraceutical products (trials)	N	• Sep 2022: Recruit contacted by email and phone, no response and no further contact made with recruit
23	Typical case	Snowball sampling	NSW	M	Processor; processing, export and domestic distribution	N	• Sep 2022: Recruit contacted by another participant by SMS, no response • Sep 2022: Follow up by phone and SMS, no response and no further contact made with recruit
24	Typical case	Expert recommendation	TAS	M	Processor; processing, export	N	• Sep 2022: Initial contact by email, no response

Recruit	Sample Scheme (Typical or Critical)	Purposive Sampling Technique	State	Gender (F/M)	Role and/or Supply Chain Stage	Interviewed (Y/N)	Contact Attempts
25	Typical case	Snowball sampling	NSW	M	Processor; processing, export and domestic distribution	Y	• Nov 2022: Recruit contacted by phone, agrees to interview

Appendix E: FLW Standard Quantification Ranking Tool Survey and Results

Survey Responses to Yield Recommended Methods for Quantifying Food Waste in this Research

Introduction

Purpose: This tool is designed to accompany the *Food Loss and Waste Accounting and Reporting Standard (FLW Standard).* It provides suggested methods for quantifying food loss and waste (FLW).

Instructions: Answer all the questions below to the best of your ability by using the drop-down menus, then press the "Get results" button. This will take you to the Results Tab which ranks all the methods included in the *FLW Standard* (see Chapter 7). You may need to click "Enable macros" when prompted by Excel in order to use this sheet.

Note:
- The "Methodology Tab" explains how this ranking of methods was developed.
- The recommendations provided do not take into account the availability of resources (e.g., budget, staff time). The tool does not consider which methods would work well in combination (see "Methodology Tab" for additional details).
- We welcome your questions and suggestions. Please contact Brian Lipinski at BLipinski@wri.org.

	Questions	Please select answers from drop-down menus
1	How important is it to have a low level of uncertainty (high degree of accuracy in the FLW results)? *Note: A higher degree of accuracy is recommended when monitoring targets.*	Very important (e.g., setting/monitoring targets)
2	Is it necessary to determine the reasons why FLW is generated?	Yes
3	Can you get direct access to the FLW being quantified?	No
4	Is the FLW (whether packaged or not) mixed with other items or materials (e.g. soil, garden / yard waste, non-organic solid waste, etc.)?	No, FLW is separate
5	Is the FLW mainly liquid or solid?	Mixed liquid and solid
6	Does all, some, or no FLW go down the drain/sewer?	Some
7	Are inputs and outputs recorded that could be used for inferring the amount of FLW? (e.g. in a factory, the amount of ingredients entering the site and the amount of product leaving the site)	Yes
8	Is there existing information that describes how FLW varies in response to other factors (e.g. with climate, soil conditions, crop / food type)?	No
9	Do you have existing records that could be used for quantifying FLW? (For this purpose, records are individual pieces of data that have been written down or saved often for reasons other than quantifying FLW, e.g., waste transfer receipts or warehouse record books.)	Yes
10	Do you have access to those records? (The response is automatically "not applicable" to this question if the answer is "no" or "don't know" to question 9.)	Yes
11	Is a material/significant amount of FLW in its packaging?	No

Survey Results of Recommended Methods for Quantifying Food Waste in this Research

Methods in green are recommended for further consideration, based on the responses given in the questionnaire. Those in orange may be appropriate in certain situations and those in red are not recommended. Further guidance in the FLW *Standard* can help you decide which method (or combination of methods) is appropriate. The scores in column R are out of 100 (see "Methodology Tab" for details). If any words appear "cut off" in the table below, set the Zoom feature back to 100%.	The comments include information on why a method is recommended or not for a given context. A user may revise its answers to the questions in light of these comments. Some considerations, such as budget and staff time, have not been accounted for in this tool. Therefore, the recommendations are based on the assumption that the required resources are available.

Methods & Description		**Score**	**Comments**
Records	Using individual pieces of data that have been written down or saved, and that are often routinely collected for reasons other than quantifying FLW (e.g., waste transfer receipts or warehouse record books)	100	This is a good method where records of FLW exist and the user has assess to them. The user needs to understand what has been measured and how it has been measured. It is important that the quality of these records is sufficiently high. Additional methods may be required to gather information on why FLW is generated, e.g., diaries, qualitative interviews, waste prevention audits (e.g. using site visits) or other methods.
Mass balance	Measuring inputs (e.g., ingredients at a factory site, grain going into a silo) and outputs (e.g., products made, grain shipped to market) alongside changes in levels of stock and changes to the weight of food during processing	90	This is a good method for estimating FLW where inputs and outputs to a process or production site are accurately quantified. Furthermore, knowledge of changes in mass (e.g., evaporation of water during cooking) need to be well understood. As the FLW is not being measured directly, mass balance is usually (but not always) less accurate than methods in which FLW is measured. This method may produce highly accurate results if an entity uses very accurate input and output data and also understands well the relationship between the input (e.g., amount of ingredients) required to produce the output (e.g., manufacture of a certain amount of product). Additional methods may be required to gather information on why FLW is generated, e.g., diaries, qualitative interviews, waste prevention audits (e.g. using site visits) or other methods.

Diaries	Maintaining a daily log of FLW and other information	50	This is a good method where insights are needed about behaviors linked to amounts and types of food. However, FLW data collected through diaries are likely to be less accurate than FLW data collected using weight-based methods. This is because quantities are most frequently captured through approximation rather than measurement, and where measurement is used, it is carried out by non-experts which may lead to inaccuracies. FLW may also be under-reported by diarists. This is not an effective method for monitoring targets, as there are moderate biases in the estimates.
Surveys	Gathering data on FLW quantities or other information (e.g., attitudes, beliefs, self-reported behaviors) from a large number of individuals or entities through a set of structured questions	25	This is a good method for gathering data on FLW quantities or other information (e.g., attitudes, beliefs, self-reported behaviors) from a large number of individuals or entities through a set of structured questions. This is not an effective method for monitoring targets as it is subject to biases.
Assessing volume	Assessing the physical space occupied by FLW, and using the result to determine the weight	0	This method requires access to the FLW to be measured.
Direct weighing	Using a measuring device to determine the weight of FLW	0	This method requires access to the FLW to be measured.
Counting	Assessing the number of items that make up FLW and using the result to determine the weight; includes using scanner data and "visual scales"	0	This method requires access to the FLW to be measured.
Waste composition analysis	Physically separating FLW from other material in order to determine its weight and composition; a WCA may also be referred to as a "waste characterization study," or "waste sort"	0	This method requires access to the FLW to be measured.

Assessing volume using COD measurements	Using measurements of chemical oxygen demand to obtain an approximate quantification of FLW in liquid waste streams (e.g., material going to the sewer)	0	This method requires access to the FLW to be measured.
Proxy data	Using FLW data that are outside the scope of an entity's FLW inventory (e.g., older data, FLW data from another country or company) to infer quantities of FLW within the scope of the entity's inventory	0	This is not an appropriate method for monitoring targets.
Modelling	Using a mathematical approach based on the interaction of multiple factors that influence the generation of FLW	0	This method requires information on how FLW varies with other factors.

Appendix F: Ethics Approval Documents

Curtin University

Updated By: Elizabeth Jackson @ 10-Nov-2021 11:36:58 AM

1. INTRODUCTION

Use this form to apply for an ethical review of human research projects conducted by Curtin University staff or students. On submission your application will be triaged as either low-risk or non-low-risk.

Saving and completing the form:

- Click Save as you progress through the form. We recommend that you click Save every 10-15 minutes.
- To close the form, click the Save button then the Close button. You can return to the form at any time. Do not close the window without saving your work.
- To complete the form, tick the white box in the Complete button then click the Complete button itself.

IMPORTANT: The session timeout period is 30 minutes. You will lose unsaved work if the form is idle for more than 30 minutes. Please click the Save button at regular intervals to save your changes.

Completing the investigators section:

- To add an investigator, click the add ('+') button.
- Search for co-investigators by clicking on the first letter of their surname in the alphabet links that appears at the top of the search page. Type the co-investigator's LAST NAME in the 'Search for a particular entry' text box to narrow your search results. Click on the drop-down arrow next to the 'Select' button to display the results.
- Indicate the Chief Investigator by checking the 'Chief Investigator' checkbox.
- Do not enter start or end dates.
- Select appropriate role for each investigator from the drop down menu.

Please email infoed@curtin.edu.au if you cannot find an investigator in the system.

IMPORTANT NOTE FOR STUDENTS AND CO-INVESTIGATORS: Please add yourself in the investigator section before you close the form. You will NOT have access to the form if you are not listed in the application.

2. INVESTIGATORS

Investigator

Name

Howieson, Janet

Chief Investigator	Start Date (DD-MM-YY)	End Date (DD-MM-YY)	Role
☐	05-Nov-2021		Supervisor

* Explain how the researcher has sufficient skills and experience to conduct the proposed research (NS 3.3.5).

Dr Howieson has been conducting mixed-method food science research with human subjects for the past 25 years and has a well-established track record of research projects and research publications related to qualitative work on evaluating attitudes towards change in practices influenced by community values and industry imperatives.

Name

Jackson, Elizabeth

Chief Investigator	Start Date (DD-MM-YY)	End Date (DD-MM-YY)	Role
☑	05-Nov-2021		Supervisor

* Explain how the researcher has sufficient skills and experience to conduct the proposed research (NS 3.3.5).

Dr Jackson has been conducting mixed-method, social science research with human subjects for the past 15 years and has a well-established track record of research projects and research publications related to qualitative work on evaluating attitudes towards change in practices influenced by community values and industry imperatives.

Name

Loo, Lynne

Chief Investigator	Start Date (DD-MM-YY)	End Date (DD-MM-YY)	Role
☐	05-Nov-2021		Student

* Explain how the researcher has sufficient skills and experience to conduct the proposed research (NS 3.3.5).

Ms Loo has successfully completed M1 and has developed a research strategy and data management plan for this project; as well as compiling all of the documents for ethics approval e.g. consent form, participant information sheet, interview guide, etc..

3. GENERAL INFORMATION

* Does the research project have a SCRIPT project ID?

☑ Yes ☐ No

Please enter the 6-digit numeric part of the SCRIPT ID

Enter ID [Get script data]

* SCRIPT ID: RES-SE-SML-SL-63348 [Clear script data]

Project title in Script:
New opportunities for abalone processing waste

Keywords:
abalone, industry processing waste

Funding Details

Funding Scheme:
Grant Funding

Funder Name:
FIGHT FOOD WASTE LIMITED

Funding start year:
2021

Funding end year:
2025

* Indicate the type of project.
Masters by research

* Has this project been peer reviewed?
Peer reviewed means accepted by a granting body that uses a peer review process (e.g. NH&MRC) or if the project has been approved through the candidacy process at Curtin.

☑ Yes ☐ No

Attach a copy of the acceptance/candidacy letter to this application.

* Does this research involve any staff going overseas?

☐ Yes ☑ No

* Does this research involve any students going overseas? (NS4.8.8, NS4.8.18), Curtin WiL

☐ Yes ☑ No

* List the locations research will be conducted. If the research is being conducted on a Curtin University campus please specify the building and room number/s.
Interview data will be collected via WebEx or MS Teams for inter-state participants. Perth-based participants will be interviewed in their places of business or via WebEx or MS Teams (whatever is most convenient to them).

* Provide a lay summary of your project. Include background, aims and hypothesis, methods and anticipated outcomes in your summary.
For assistance in writing in lay language please refer to the Tips for Writing in Plain English.

Background:
The Australian wild-harvest abalone sector is the largest of its kind in the world. An opportunity exists to address a significant waste problem within the industry. Roughly two-thirds of landed abalone catch is disposed of as waste - the shell, viscera (guts), and blood - since only the muscular 'foot' of the abalone is considered edible. Preliminary research has indicated that the shell and shuckings could be used in innovative products for human consumption or agricultural applications. If this can be achieved, tonnes of useful material would be diverted from waste streams and food losses avoided. Additionally, cost savings and new revenue streams may be identified for primary producers and processors. The purpose of this research is to map Australian wild-harvest abalone supply chains, using data collected from industry stakeholders. Particular focus will be paid to food losses in the fishing and processing stages in order to identify possible interventions that could address those food losses. We will also assess the viability of any interventions that are proposed.

Project Objectives:
1) To map Australian wild-harvest abalone supply chains using existing supply chain mapping methods (e.g. Value Stream Mapping), paying particular attention to food losses in the primary production and processing stages.
2) o identify possible interventions using existing waste management frameworks (e.g. waste hierarchy, circular economy principles) to address the food losses identified.
3) To assess the theoretical viability (e.g. cost/benefit) of the proposed interventions.

* Describe how your research will have an impact on the community.

Project Significance:
1) To the best of our knowledge, the supply chain mapping and waste management framework proposed in this research is a novel approach to addressing food losses in the Australian abalone industry. The impact of this research will be in the identification of opportunities to utilise waste in the Australian abalone industry for value-adding.
2) Additionally, this research will fill a number of gaps that have been identified in our literature review:
- A lack of use of real-world case studies and primary data to validate food loss/waste models and frameworks
- A lack of available data on abalone processing activities - specifically, what type and volume of waste is produced
- Few studies analysing Australian abalone supply chains, particularly from a food loss perspective
- A lack of studies that focus on the primary production and processing stages of food supply chains in developed countries, especially those outside of Europe and USA

4. RISK AND MITIGATION

* Outline the potential risks to participants. If potential risks are identified, explain how this research justifies the burden and risk to participants (NS 2.1).

Participation will be restricted to adults who are involved in the abalone industry of Australia. Participants will be fully informed of the project, the anonymity of their contributions (to be audio recorded) and how the data will be used. Data collection will be focused on abalone fishing, processing and distribution practices and will not intrude on any sensitive issues like financial situation, sexuality or religion. Overall, risks to participants is very low.

* If you identified risks in the previous question, outline how you will mitigate the risks identified above and your plan of action for expected adverse events and other identified risks.

Participants will be fully informed of the project, the anonymity of their contributions (to be audio recorded) and how the data will be used. Participation in the research is entirely voluntary and participants are free to withdraw from the study at any time with prejudice. This information will be provided to applicants in their information sheet and consent forms.

* Outline the potential harm or risk to researchers.

The researchers will be collecting data for this project and interacting with strangers for data collection. Interviews that are not conducted online will be conducted in participants' places of business. To manage these risks, the interviews will be conducted in public venues (with the door open) and researchers will collect data in pairs. Mobile phone coverage for emergency situations will be available at all times.

* Outline the potential risk to the University and the research.

Risks to Curtin and the research overall are minimal. The main threat is project management and adhering to time lines as data collection will be during participants' busy work day.

5. PARTICIPANT RECRUITMENT AND CONSENT

* Are you recruiting participants?

☑ Yes ☐ No

* Does your research involve staff and students from Curtin University?

☐ Yes ☑ No

* Describe your target population and sample size.

The target population is members of the Australian abalone supply chain (fishers, processors and distributors). The planned sample size is 20-25 interviews but this is subject to reaching the point of theoretical saturation where the marginal interview does not yield any new information.

Select how you are going to recruit participants (select all that apply)

☐ Database/medical records

☐ Social media including Facebook, Yammer, LinkedIn, Twitter etc.

☐ Classroom or hospital or clinic or community groups etc.

☑ Snowball recruitment or word of mouth etc.

* List:

Through the extensive networks of the research team and the funders of the project (the Abalone Council of Australia).

☐ Print media including flyers, newspapers, newsletters, etc.

☐ Radio/television

☐ Other

* Describe your recruitment process.

Invitations to potential participants will be sent a personalized e-mail four weeks before the interviews. Invitations will include an information sheet on the research and consent form so participants are fully informed of the reserved prior to participation.

* Will participants receive anything in exchange for participating in research? (NS 2.2.10 - 2.2.11)

☐ Yes ☑ No

Participant consent

* Will participants provide consent? (NS 2.2, NS 2.3)

☑ Yes ☐ No

* Describe the process of how you will obtain consent.

Participants will receive an information sheet and consent form with their invitation to join the research. Upon joining the research, participants will sign a consent form which will be held with the researchers. Participants are free to withdraw from the research at any time without prejudice.

* Is there the potential for the participant to be subject to coercion or pressure, including perceived position of power or people in dependent or unequal relationships? (NS 2.2.9 and NS 4.3)

☐ Yes ☑ No

* Does the research use deception, concealment, incomplete disclosure, limited disclosure, an opt-out approach, or use of information, samples, health information etc., without the specified consent from those persons? (NS 2.3)

☐ Yes ☑ No

Commonwealth agencies

* Will you collect or use IDENTIFIED health information held by Commonwealth agencies **without consent**?

☐ Yes ☑ No

Private sector

* Will you collect or use IDENTIFIED health information from the private sector **without consent**?

☐ Yes ☑ No

6. RESEARCH METHODS

* Describe your research methods clearly outlining your study protocol and what each participant will be required to do for the research study (NS 3.1 and NS 3.4).

You may want to attach a flow chart or Standard Operating Procedure.

Research methods are limited to the collection and analysis of interview data. Participation will be voluntary and interviews will be arranged at a time and location convenient to each participant. Participants outside WA (none will be overseas) will be interviewed via WebEx or MS Teams. Participants are required to do nothing other than provide about 40 minutes of their time for the interview to share their knowledge of the Australian abalone industry, read the information sheet and sign the consent form.

* Does your research involve withholding from one group specific treatments or methods of learning, from which they may "benefit" (e.g. in medicine or teaching)?

☐ Yes ☑ No

* Does your research include invasive physical procedures, collection of body fluid, tissue sampling, infliction of pain, psychological interventions, treatments, administration of drugs or other substances or use of a medical intervention device?

☐ Yes ☑ No

* Does your research use medical records where participants can be identified or linked?

☐ Yes ☑ No

* Briefly explain your research outcomes and how do you plan to analyse the data?

Provide sufficient detail in this section to describe the data you collect, how you will analyse it and what the outcomes of the research will be.

The research outcomes will be knowledge about Australia's abalone supply chain the the potential to better manage waste. The interviews will be audio recorded and the recordings will be transcribed verbatim via thematic analysis will be conducted using NVivo software.

* Does your research involve exposing participants to radiation? *Eg. radioisotopes, lasers, x-rays, microwaves, ultra-violet radiation*

☐ Yes ☑ No

* Does your research use health information (including biospecimens) that may reveal information that may be important for the health or future health of the donor(s), their blood relatives or their community? (NS 3.4.10, 3.5.1 and 3.5.2)

☐ Yes ☑ No

* Does your research involve human genetics? (NS 3.5)

☐ Yes ☑ No

7. CLINICAL TRIALS

* Is your study a clinical trial? (NS 3.3)

☐ Yes ☑ No

8. PREGNANT WOMEN AND HUMAN FETUS

* Does your research involve gametes and/or embryos?

☐ Yes ☑ No

* Does your research involve women who are pregnant and/or the human fetus?

☐ Yes ☑ No

9. ABORIGINAL AND TORRES STRAIT ISLANDER PEOPLES

* Does your research involve Aboriginal and Torres Strait Islander Peoples? (NS 4.7)

☐ Yes ☑ No

10. SPECIFIC PARTICIPANT GROUPS

Children and Young People

* Does your research involve children and young people? (NS 4.2).

No

Highly Dependent on Medical Care

* Does your research involve people highly dependent on medical care who may be unable to give consent? (NS 4.4)
People who are highly dependent on medical care refer to those who may be unable to give consent. This may be people who are patients in the emergency department or intensive care, unconscious people or people in termal care.

☐ Yes ☑ No

Cognitive Impairment, Intellectual Disability, Mental Illness

* Does your research involve people with a cognitive impairment, an intellectual disability, or a mental illness? (NS 4.5)
Refer to the Diagnostic and Statistical Manual of Mental Disorders, 5th Edition: DSM-5, and Tables for the Assessment of Work Related Impairment for Disability Support Pension

☐ Yes ☑ No

Illegal Activities

* Does your research involve people who may be involved in illegal activities? (NS 4.6)

☐ Yes ☑ No

Research involving participants in other countries

* Does your research involve participants in other countries? (NS 4.8)

☐ Yes ☑ No

Research involving non-english speakers

* Does your research involve participants whose primary language is not English?

☐ Yes ☑ No

11. CONFLICTS OF INTEREST

* Are there any potential conflicts of interest?

☐ Yes ☑ No

12. DOCUMENTS TO UPLOAD

Attachments can be added when you have saved and/or completed this form. To upload documents:

1. Go back to the main submission screen
2. Click **Add**. A new window will pop open to upload new documents
3. Click **Choose File** to select document to upload
4. Click **Upload**
5. The pop up window will refresh to allow for more uploads

IMPORTANT: Uploaded documents appear in the main submission screen. To see which documents you have uploaded Click **Close** to close the popup window.
Below are a list of documents you may need to add to your application:

- Peer review documents
- Protocol
- Participant information statement and consent form
- Parent information statement and consent form
- Child information statement and assent form
- Questionnaires/survey instruments
- Data Management Plan
- Translations where a language other than English is used
- Recruitment materials
- Approval from the Radiation Safety Officer
- Risk assessment
- Investigator Brochure or Product Information (clinical trials involving drugs)
- SOL Research Integrity Professional Development program certificate (Staff can access certificates from iPerform. Students can take a screen capture of completion in blackboard)
- Curriculum vitae's of investigators
- Approval to access Curtin students and staff for research purposes

Curtin University

Research Data Management Plan

From trash to treasure: Mapping waste flows and identifying new opportunities for shell and shucking waste in the Australian abalone industry

Supervisor	Elizabeth Jackson
Data Management Plan Edited by	Lynne Loo
Modified Date	11/11/2021
Data Management Plan ID	JACKSE-BS09370
Faculty	Curtin Business School
Script project number	RES-SE-SML-SL-63348

1 Research Project Details

1.1 Research project title

From trash to treasure: Mapping waste flows and identifying new opportunities for shell and shucking waste in the Australian abalone industry

1.2 Research project summary

Abstract: The Australian wild-harvest abalone sector is the largest of its kind in the world. An opportunity exists to address a significant waste problem within the industry. Since only the muscular 'foot' of the abalone is considered edible, roughly two-thirds of landed abalone catch is disposed as waste: the shell and shuckings (viscera and blood). Preliminary research has indicated that the shell and shuckings could be used in innovative products for human consumption or agricultural applications. If this can be achieved, tonnes of useful material would be diverted from waste streams and food losses avoided. Additionally, cost savings and new revenue streams may be identified for primary producers, processors, and others in the upstream segment of the Australian wild-harvest abalone supply chain. This research proposes a novel supply chain mapping and management framework that is developed by synthesising existing supply chain mapping and management theory (e.g. Value Stream Mapping and the Global Supply Chain Forum Framework) with food loss and waste management models (e.g. the waste hierarchy). It is then applied to the case study of Australian wild-harvest abalone supply chains using primary data collected from industry stakeholders. The extent to which the proposed framework is useful in identifying food loss interventions, quantifying volumes of food loss, and assessing the cost/benefit of intervention activities is investigated.

1.3 Keywords

abalone, Australia abalone fishery, supply chain mapping, supply chain management, food loss and waste, waste hierarchy, value stream mapping

2 Research Project Data Details

2.1 Research project data summary

Export data, domestic sales data, catch volumes, and waste data will be sourced from online databases such as the Australian Bureau of Agriculture and Resource Economics and Sciences (ABARES), Australian Bureau of Statistics (ABS), and Fisheries Research and Development Corporation (FRDC).

Data addressing business operations, waste management activities and identified data gaps will be collected from industry experts (e.g. primary producers, executive managers, processors, peak industry associations) using interviews. Interviews will be captured on audio recordings and transcribed.

NVivo software will be used to analyse qualitative data. Quantitative data (cost/benefit, waste volumes) will be collated and analysed using Microsoft Excel.

All data will be backed up on an external hard drive, Curtin University's OneDrive cloud storage, and Curtin University's Research network drive.

2.2 Will the data be identifiable

- Re-identifiable — identifiers have been removed and replaced by a code, but it is possible to re-identify an individual

2.3 Will biospecimens or human participant information be sent overseas?

No

2.4 Will novel information about controlled goods or technologies on the Defence and Strategic Goods List (DSGL) be sent overseas?

No

2.5 Data organisation and structure

Folder Structure: folders will be ordered hierarchically - raw data, data analysis and other document files will be separated according to type; and will contain subfolders of relevant documents.

All files will be named according to the following conventions -

File Naming Convention (Secondary Data): [Document Type or Subject] [Source] [Date Published YYYY] [file extension]

Example: Export Data ABARES 2020.xlsx

File Naming Convention (Primary Data): [Document Type or Subject] [Source] [Date Collected/Analysed YYYY-MM-DD] [file extension]

Example: Interview Expert A 2021-02-25.mp3

3 Research Project Data Storage, Retention and Dissemination Details

3.1 Storage arrangements

Data will be stored on the investigator's research laptop, external hard drives, Curtin University's Research network drive and OneDrive.

The laptop and all hard drives / devices are password protected.

3.2 Estimated data storage volume

Most likely no more than 20 GB

3.3 Safeguarding measures

Data will be backed up regularly (weekly basis or more frequently if significant work conducted) using the 3-2-1 method: copies of data will be stored on Curtin University's Research network drive and OneDrive cloud storage, as well as external hard drives and the personal investigator's research laptop).

Once data collection is complete, data will be archived to Curtin's R Drive and destroyed 7 years after the results are published.

3.4 Retention requirements

7 years (All other research with outcomes that are classed as Minor)

3.5 Collaboration

Fight Food Waste CRC, Abalone Council of Australia Ltd., and Australian Abalone Association

3.6 Data dissemination

Presentations made via industry networks; written reports; and workshops facilitated by the Fight Food Waste CRC

3.7 Embargo period

N/A

RECRUITMENT EMAIL

Curtin University

Dear [participant name]

You are invited to participate in a research study on mapping waste flows and finding new opportunities for shell and shucking waste in the Australian wild-harvest abalone industry.

You have been asked to take part in this research because you work in the Australian abalone industry as a diver, processor, business manager, regulator, or other industry stakeholder.

This research is being conducted by Lynne Loo (student researcher), Dr Elizabeth (Liz) Jackson (Senior Lecturer Supply Chain Management & Logistics, Curtin University) and Dr Janet Howieson (Senior Lecturer Food Science, Curtin University). Curtin University Human Research Ethics Committee (HREC) has approved this study (HRE2021-XXXX).

A brief outline of what is involved, should you wish to participate:
You will be interviewed for approximately 40 minutes about your operations and industry practices. We are primarily interested in understanding what kind of waste is produced, volumes, and where it is disposed.
The interview will take place at a mutually convenient location.
You may not benefit directly from participating in this research. However, people sometimes appreciate the opportunity to discuss their opinions and insights.
Your participation will contribute to Lynne obtaining a Masters by research.

Before you decide whether or not you would like to participate in the study, it is important that you understand what the project is about, why we are doing it and what is required from participants. Please take the time to read the attached Participant Information sheet which contains these details.

If you wish to contribute to this research, we have attached a Participant Consent form which you will need to complete and return to us before you commence participation.

Please do not hesitate to get in contact with Liz Jackson (lead contact for this research) if you would like more information about the study or have any questions:
(08) 9266 7706
elizabeth.jackson@curtin.edu.au

We look forward to hearing from you.

Kind regards
Lynne Loo

PARTICIPANT INFORMATION STATEMENT

HREC Project Number:	*To be assigned*
Project Title:	From trash to treasure: Mapping waste flows and identifying new opportunities for shell and shucking waste in the Australian abalone industry
Chief Investigator:	Dr Elizabeth Jackson, Senior Lecturer – Supply Chain Management
Student Researcher:	Lynne Loo
Version Number:	4
Version Date:	11 November 2021

What is the Project About?

Background:

- The Australian wild-harvest abalone sector is the largest of its kind in the world. An opportunity exists to address a significant waste problem within the industry. Roughly two-thirds of landed abalone catch is disposed of as waste – the shell, viscera (guts), and blood – since only the muscular 'foot' of the abalone is considered edible.
- Preliminary research has indicated that the shell and shuckings could be used in innovative products for human consumption or agricultural applications. If this can be achieved, tonnes of useful material would be diverted from waste streams and food losses avoided. Additionally, cost savings and new revenue streams may be identified for primary producers and processors.
- The purpose of this research is to map Australian wild-harvest abalone supply chains, using data collected from industry stakeholders. Particular focus will be paid to food losses in the fishing and processing stages in order to identify possible interventions that could address those food losses. We will also assess the viability of any interventions that are proposed.

Project Significance:

- To the best of our knowledge, the supply chain mapping and waste management framework proposed in this research is a novel approach to addressing food losses in the Australian abalone industry.
- Additionally, this research will fill a number of gaps that have been identified in our literature review:
    - A lack of use of real-world case studies and primary data to validate food loss/waste models and frameworks
    - A lack of available data on abalone processing activities – specifically, what type and volume of waste is produced
    - Few studies analysing Australian abalone supply chains, particularly from a food loss perspective
    - A lack of studies that focus on the primary production and processing stages of food supply chains in developed countries, especially those outside of Europe and USA

Project Objectives:

- To map Australian wild-harvest abalone supply chains using existing supply chain mapping methods (e.g. Value Stream Mapping), paying particular attention to food losses in the primary production and processing stages.
- To identify possible interventions using existing waste management frameworks (e.g. waste hierarchy, circular economy principles) to address the food losses identified.
- To assess the theoretical viability (e.g. cost/benefit) of the proposed interventions.

- To identify possible interventions using existing waste management frameworks (e.g. waste hierarchy, circular economy principles) to address the food losses identified.
- To assess the theoretical viability (e.g. cost/benefit) of the proposed interventions.

Who is Doing the Research?

- This project is being conducted by Lynne Loo, Dr Elizabeth Jackson and Dr Janet Howieson (Senior Lecturer – Food Science, Curtin University).
- This research will contribute to Lynne Loo obtaining a Master of Philosophy.
- This research project is funded by a grant from the Fight Food Waste Co-operative Research Centre (Fight Food Waste CRC) and Abalone Council Australia Ltd. (ACA Ltd.)
- There will be no costs to you and you will not be paid for participating in this project.

Why am I being asked to take part and what will I have to do?

- You have been asked to take part in this research because you work in the Australian abalone industry as a diver, processor, business manager, regulator, or other industry stakeholder.
- You will participate in a semi-structured interview for approximately 40 minutes where you will be asked a set of questions aimed at stimulating discussion about the abalone wild-harvest supply chain in your state.
- The interview will take place at a mutually convenient location.
- We will ask you questions about your operations and industry practices. We are primarily interested in understanding what kind of waste is produced, volumes, and where it is disposed.
- The interview will be recorded so that we can concentrate on the conversation, rather than on taking notes. We will make a full written transcript of the recording after the interview which will be sent to you.
- In the weeks following the interview, you may also be asked for your feedback on the supply chain maps that are created.

Are there any benefits to being in the research project?

- You may not benefit directly from participating in this research. However, people sometimes appreciate the opportunity to discuss their opinions and insights.
- Your participation will be greatly appreciated and valued as it will contribute to developing the sustainability (economic and environmental) of the Australian wild-harvest abalone industry and, potentially, other food industries.

Are there any risks, discomforts, or inconveniences from being in the research project?

- There are no foreseeable risks from this research project.
- We will adhere to all state government COVID-19 guidelines and restrictions (e.g. travel restrictions, social distancing measures, contact tracing) to mitigate any potential risks related to the pandemic.
- Apart from giving up your time, we do not expect that there will be any risks or inconveniences associated with taking part in this study.

Who will have access to my information?

- The information collected in this research will be re-identifiable (coded). This means that we will collect data that can identify you but will remove identifying information on any data and replace it with a code (e.g. Firm A, B, C) when we analyse the data.
- Only the research team have access to the code to match you or your company if it is necessary to do so.

- Any information we collect will be treated as confidential and used only in this project unless otherwise specified.
- The following people will have access to the information we collect in this research: the research team, ACA Ltd., Fight Food Waste CRC, and, in the event of an audit or investigation, staff from the Curtin University Office of Research and Development.
- Electronic data will be password-protected and hard copy data (including video or audio tapes) will be in locked storage.
- The information we collect in this study will be kept under secure conditions at Curtin University for 7 years after the research is published and then it will be destroyed.
- The results of this research may be presented at conferences or published in professional journals. You will not be identified in any results that are published or presented.

Will you tell me the results of the research?

- A summary of the project's overall results will be sent to participants.
- If you are interested in obtaining a summary of the results, please contact the researchers after May 2023.
- We intend to publish the results in journal articles (e.g. the Journal of Cleaner Production) and in reports to our industry partners and funders (Fight Food Waste CRC and ACA Ltd).

Do I have to take part in the research project?

- Taking part in a research project is voluntary. It is your choice to take part or not. You do not have to agree if you do not want to. If you decide to take part and then change your mind, that is okay, you can withdraw from the project.
- If you choose to leave the study, we will use any information collected with your permission.

What happens next and who can I contact about the research?

- The lead contact for this research is Dr Elizabeth (Liz) Jackson of Curtin University. Liz can be reached via the following details:
- (08) 9266 7706
- elizabeth.jackson@curtin.edu.au
- If you decide to take part in this research we will ask you to sign the consent form. By signing it is telling us that you understand what you have read and what has been discussed. Signing the consent indicates that you agree to be in the research. Please take your time and ask any questions you have before you decide what to do. You will be given a copy of this information and the consent form to keep.

Curtin University Human Research Ethics Committee (HREC) has approved this study (HREC number XX/XXXX). Should you wish to discuss the study with someone not directly involved, in particular, any matters concerning the conduct of the study or your rights as a participant, or you wish to make a confidential complaint, you may contact the Ethics Officer on (08) 9266 9223 or the Manager, Research Integrity on (08) 9266 7093 or email hrec@curtin.edu.au.

CONSENT FORM

HREC Project Number:	*To be assigned*
Project Title:	From trash to treasure: Mapping waste flows and identifying new opportunities for shell and shucking waste in the Australian abalone industry
Chief Investigator:	Dr Elizabeth Jackson, Senior Lecturer – Supply Chain Management
Student Researcher:	Lynne Loo
Version Number:	2
Version Date:	11 November 2021

- I have read the information statement version listed above and I understand its contents.
- I believe I understand the purpose, extent, and possible risks of my involvement in this project.
- I voluntarily consent to take part in this research project.
- I voluntarily consent to the interview being audio/video recorded.
- I have had an opportunity to ask questions and I am satisfied with the answers I have received.
- I understand that this project has been approved by Curtin University Human Research Ethics Committee and will be carried out in line with the National Statement on Ethical Conduct in Human Research (2007).
- I understand I will receive a copy of this Information Statement and Consent Form.

Participant Name	
Participant Signature	
Date	

Declaration by researcher: I have supplied an Information Letter and Consent Form to the participant who has signed above.

Researcher Name	
Researcher Signature	
Date	

Note: All parties signing the Consent Form must date their own signature.

Appendix G: First Cycle Codes and Representative Data

Parent Codes	Subcodes	No. of Participants Coded	No. of Passages Coded	Representative Data
Outsiders bringing change		1	3	*FS-B1: We've found that you just chip away at them [implementing change] over a period of time and gradually the benefits are realised and [change] happens. But you always get a bit of pushback at the beginning, until you can really persuade them [the operators and divers] that it's a good idea.*
Competition vs. collaboration	Commercial in confidence	9	11	*O-D2: He's got a use for his [viscera] and he's very – I can understand this – protective of that.*
	Industry relationship with regulator	5	21	*OP-B3: A lot of the change that is imposed on the harvesting teams and processors has traditionally been regulatory burden. All that does is cost you money. Changing is then automatically seen as a pain in the arse.*
				O-D2: If there's an issue in one particular area, you've got a voice as a group [industry association] so it's a lot more powerful. Then we deal directly with the [state] fisheries authority [about] anything abalone related and they're great. They're super supportive of us.
	Intergenerational vs. investor driven quota ownership	9	31	*OP-B2: Tasmania, for example, has a lot of investors. Here, because I think we're sort of fortunate that we're a long way away from most places and most people, it is still mainly family business here.*
	Vertical integration	6	9	*OP-B3: In other states a lot of the investment has occurred from third parties so the link between the harvester, the quota owner – license owner – the processor, and exporter is segmented.*
				OP-A2: A processing facility needs to put through about 100 tonne a year to be financially viable. Anything less than that and it's not worth doing.
	Whole of supply chain thinking	7	31	*ME-1: It is about the competitiveness of the value chain, not about individual company competitiveness.*
Considerations for Using Viscera	Biosecurity and health risks	7	15	*FS-B1: It's still unpublished information but essentially [the viscera] go straight through the fish and they come out as viable parasite. So the fish eating them is not taking [parasites from the viscera] out of the system and it's actually probably making it worse.*
	Compliance and regulation	2	4	*FS-E1: Depends on the operator and what they want to do [with the waste]. There's no real regulation around that.*
	Cost against return for low value product	14	44	*OP-B2: That's the trouble I've had before. I've been trying to push down this line for some time. There are people that take viscera around the place, but it's a very low price and it's a commodity. It's high moisture content and so it's high shipping costs. It really just makes it difficult to actually establish anything worthwhile."*
				P-D3: I've had a couple of different companies wanting to buy the abalone gut. So first of all, they want it at a very low price. And then they don't want to pick it up on the day so we've got to pack it, freeze it, and that's all labour and costs so it doesn't really stack up.

Parent Codes	Subcodes	No. of Participants Coded	No. of Passages Coded	Representative Data
	Economies of scale	7	18	*OP-C1: We're moving 10 or 11 tonne [of viscera] per time to accumulate those sort of volumes, which is what you need to make it efficient. Most processors wouldn't get to that in 10 years. Having volumes that are efficient is definitely a pinch point.*
	Established way of doing things	6	26	*FS-E2: I think number one is 'culture' – probably not the right word – it's just the way the fishery has been. Like, it's just the way it's always been done … I think some operators just continue that way.* *OP-C2: Whereas the other guys are old school. You know, they've been doing it for 50 years and they're gonna do it the same way.*
	Infrastructure	8	16	*OP-C1: At the moment I don't see that it's viable for us to spend the money on the equipment [to valorise viscera]. That's why we ship some to Cairns and they do the treatment and that there, because the infrastructure already exists.*
	Labour supply	5	9	*P-D3: That's the biggest problem in this industry – is to be able to provide consistent work with the ups and downs with weather and availability of quota and whatever else.* *OP-C2: What we found is by bringing in those other product forms and processing flows, we're able to provide casual work to our casuals all year round. Whereas historically they've come in for a season, disappear, come back.*
	Meeting market requirements	2	5	*OP-C1: I've probably been working with the gut in the nutraceutical area for 10, 15 years altogether, trying to get things to work. They've got quite complex processes. The other thing is that a lot of the time they need very fresh product … It's got to be under three months old.*
	Shucking at sea	8	57	*FS-B1: [Shucking at sea] has also caused a significant displacement of catch. So they favour not fishing where there's* Perkinsus *and that catch has been displaced to other parts of the fishery which, essentially, we estimated probably about $11 million of displaced catch over recent years.* *OP-B2: I think that's probably why the waste usage stuff has always stayed off the agenda because – particularly in our area anyway – it's out of sight out of mind. It's thrown back to sea by the boats.*
	Predictability and variability	14	33	*OP-B3: That third/third/third ratio isn't entirely correct because there's a blood component as well … It [the percentage of components] varies through the year, and it depends on the condition of the actual abalone meat.* *OP-E3: [Fishing] is weather dependent, you see .. There's only certain days you can dive. That's the thing when you're looking at utilising waste, is fitting in with that sporadic fishing method.*
	Priority of processing	1	1	*P-D3: It's very difficult to be able to handle the waste and put it into some sort of value-added form because … the quicker you process it [the abalone meat] the better your recovery, the yield, you get. So that becomes your priority in the processing.*
	Risk and proof of concept	3	4	*OP-B3: When we presented that paper and everybody could see it and realise that fishing during the wrong months was not only doing detriment to the resource, but also their back pocket, there was a wholesale change through the industry to fish at the right times of year.*
	Zero waste branding	1	3	*OP-C2: We're very conscious of building a brand. So we know there's important pillars in a brand such as that sustainability … So by us going down that path [utilising waste] where others may not, we sort of position ourselves differently.*
Previous endeavours using viscera and blood		13	56	*OP-E4: We have tried in the past, there's been a couple of attempts to use abalone [viscera] for bait and things like that, but it was always too difficult to do; not profitable enough.*

Parent Codes	Subcodes	No. of Participants Coded	No. of Passages Coded	Representative Data
Incremental Change		1	1	*OP-A2: We've also toyed with the idea of doing a [product redacted] … but I think we're a little bit further away from that because our facility doesn't have that kind of capability – cooking – things like that. So that will be somewhere in the future I would say.*
Perceptions		1	4	*ME-1: The mindset [of the industry] is, "We sell volume, we don't sell value"*
Qualities that lead to change	Learning mentality	7	15	*O-D2: We're very strong on really fine-scale, sustainable fishing and knowing as much about the fishery as we can. That's how we make our decisions. We make very measured decisions.*
	Innovation	5	12	*OP-E1: People say "Oh, you can't export Greenlip abalone live because they're not as strong as the Blacklips or the browns" … Well we've proved these guys wrong … There's a lot of R&D that's gone into that research.*
	Persistence	7	19	*OP-B2: It's something I've been pushing on for a little while here but it's not an easy space to develop.* *O-D2: There's nowhere in the world where they've had that decline that we had through the virus … We were able to rebuild it through our knowledge and being patient*
	Vision	1	11	*OP-E1: Were at our infancy stage when it comes to that side of it [utilising waste]. All we've been doing is just throwing the ideas on paper, then together with the technicians, the food scientists, a bit of market ingenuity to find out what the market will take … It's a work in progress, but it's a starting point.*
Strategy	Pull vs. push	1	2	*OP-B3: There's very little unplanned fishing that occurs. It will always be in mind of who's going to be ending up with a product. And that is to maximise our returns as well.* *OP-C1: Nah, it's [types of products] dependent on where the fish come from … Depending on where the money is, the size of the fish.*
Sustainable thinking	Economic	5	7	*OP-C2: The [quota owners] that work with us are of the perspective that sustainability is really important and for the future they want intergenerational security, I suppose.*
	Environmental	7	17	*OP-B3: It was driven through a group of us that were fishing in what we believed was the correct way. And frustration from us of others that didn't seem to see it that way. It was like "Okay, we'll get the science to prove it."*
	Seeing opportunity in the whole animal	11	31	*OP-B2: The opportunity's there – there is more of our resource that we don't use. So I see it as a waste. … Hopefully there's a financial incentive there to it. But I just think it's the right thing to do that the opportunity is there rather than just throwing it over the side. If we can find a better way of using it, I think we should.*
	Social	1	1	*OP-A2: I try and use locals all the time because I like to look after the local community down there. It's a pretty small community on the south coast.*
The importance of marketing		2	14	*OP-E3: You need a market for anything you do. If you don't have a market don't even bother because it's not worth it.*

Appendix H: Estimated Market Share of Abalone Processors in Australia

State	Processor Code	Estimated Market Share (2019)
NSW	Receiver A	35%
	Receiver B	33%
	Receiver C	23%
	Receiver D	10%
SA	Processor E	18%
	Processor F	53%
	Processor G	14%
	Processor H	8%
	Processor I	7%
TAS	Processor J	40%
	Processor K	32%
	Processors L and M	25%
VIC	Processor J	19%
	Processor N	18%
	Processor O	7%
	Processor P	11%
	Processors Q and R	3%
	Processor S[1]	43%
WA	Processor T	33%
	Processor U	2%
	Processor V[1]	5%
	Processor W	60%

[1] *Processors non-operational from 2020 onwards*

Appendix I: Outcomes of Viscera, Shell, and Blood by Volume and State

Legend

● Blacklip abalone	● Greenlip abalone	● Brownlip abalone	● Roe’s abalone

Outcomes of Viscera

	NSW	SA		TAS		VIC		WA				All States
	●	●	●	●	●	●	●	●	● (fished)	● (ranch)	●	● ● ● ●
Discarded at sea	np	41.0	84.2	np	np	np	np	5.3	10.0	np	np	**140.4**
Discarded on land	0.0	5.6	0.0	21.5	3.6	124.4	0.5	0.0	0.0	0.0	10.7	**166.3**
Stored for future use	0.0	0.0	0.0	26.3	6.6	37.3	0.1	0.0	0.0	8.8	0.0	**79.0**
Other use	0.0	0.0	0.0	70.2	9.6	29.7	0.0	0.0	0.0	0.5	0.0	**110.0**

np = shucking and disposal at sea is not permitted

Outcomes of Shell

	NSW	SA		TAS		VIC		WA				All States
	●	●	●	●	●	●	●	●	● (fished)	● (ranch)	●	● ● ● ●
Discarded at sea	np	54.1	50.7	np	np	np	np	2.9	3.4	np	np	**111.1**
Discarded on land	0.0	7.4	0.0	28.3	0.0	124.0	0.2	4.0	3.2	0.0	14.2	**181.3**
Stored for future use	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Other use	0.0	0.0	60.4	127.4	26.0	128.7	0.5	0.0	6.6	12.9	0.0	**362.6**

np = shucking and disposal at sea is not permitted

Outcomes of Blood

	NSW	SA		TAS		VIC		WA				All States
	●	●	●	●	●	●	●	●	● (fished)	● (ranch)	●	● ● ● ●
Discarded at sea	np	11.5	26.5	np	np	np	np	1.5	2.8	np	np	**42.3**
Discarded on land	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**2.0**
Stored for future use	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Other use	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Retained in meat	0.0	0.0	69.3	42.5	7.1	68.9	0.3	0.0	0.0	3.7	3.0	**194.8**

np = shucking and disposal at sea is not permitted

Appendix J: Supporting Data for Phases B and C

The passages presented in this appendix were elicited from the semi-structured interview conducted in Phase A. The following passages concern supply chain practices, governance, market share, product flows and mass flow estimates, and firm structures relevant to each state fishery. The information presented in this appendix supports the mass flow estimates presented in Phase B (Chapter 6) and the current-state maps presented in Chapter 7. Processor codes (i.e. Receiver A, B, C; Processor N, O, P, and so on) correspond with the processors and market share listed in Appendix H.

New South Wales

Participant	Response ID	Participant Response
O-A1	i.	"Most of [the state's] 100 tonne TAC is supplied live from the boats to the buyers that in turn, export it live. So there's obviously no wastage from that because the shells etc. go overseas."
	ii.	"At the moment [in 2022], [Receiver B] - because of the delays and the I guess the upheaval in the, or the slowness in the live abalone market - he has been processing. He'll probably take about maybe 20 or 30 tonne this year. This is a bit of a one off,"
	iii.	"On a diving day - when everything lines up and the weather's good, we can go diving and supply someone. They'll meet us at the boat ramp and collect the abalone there. So basically the ownership transfers to the buyer at the boat ramp. Because we're live we keep them in tanks on our boat. The trucks that pick them up, they're usually refrigerated … so, from whatever boat ramp back to a holding tank. … Locally, there's three buyers and once it's brought onto the truck, it's in the possession of the buyer. They've got our fishery docket, and that's what we get paid on. So from a fisheries compliance point-of-view, our catches are identifiable. So if fisheries, for example, pulled over the truck and there were, say, undersized or over-quota fish in your truck, they'd deem it back to the diver. Once [the abalone are] in the tank, they get graded out into different sizes so they're basically not identifiable back to the diver. So whatever we weigh in at the ramp is what we expect to be paid on. And that's exactly what happens"
OP-A2	iv.	"there's a processor in Eden, [Receiver C], but they are also in Melbourne. So they're allowed to process product in Melbourne, but their facility in Eden is only a live holding facility. They can't process there. And then you've got [Receiver B] is the only one in New South Wales that actually processes abalone. That's only a recently new thing in the last couple of years [since 2020] because of COVID."
	v.	"we [are] a live export facility that basically exports live abalone to overseas markets"
	vi.	"I think last year we did about 35 to 40 tonnes, so we did about 35, 40% of New South Wales product."
	vii.	"[Receiver B] would probably take maybe 30%. [Receiver C] would probably take 20% and then the other guys would basically sell their own. So you probably have 10% of guys that sell their own fish to wherever they want, basically"
	viii.	"[Receiver B] was buying the majority of that abalone from Mallacoota from Victoria to process [during 2020-2021]. He wasn't buying it from New South Wales … I know he was processing some fish last week but then again, he hadn't processed any abalone for the last probably 10 weeks. So it's really sporadic … It's only when he gets an order that he'll process."

South Australia

Participant	Response ID	Participant Response
OP-B2	ix.	“The fish from the Southern Zone, quite a lot of those go over the border into Victoria … [Processor P] in Portland, and [Processor N] in Melbourne. Between those two, they take a reasonable chunk of the South Australian Southern Zone”
	x.	“Greenlip, has nearly always been frozen meat. So the shucked meat. That's been a strong product in particularly the Hong Kong market, amongst a few others for a long time. So we send a lot of that to Hong Kong, and to a lesser extent, a couple of other places: China, North America, Singapore a little bit. … That would be high-90s percent [across both Blacklip and Greenlip] since the live [export of Blacklip abalone] has dropped right away. That's basically just been moved into the frozen channels. So it'd be 99% frozen Greenlip for our supply chain there. And Blacklip is very similar now. We put a little bit into on-processed products … where in the past a few years ago we were nearly 100% canning. Now we're probably less than 5% canning.”
	xi.	“When the abalone in our fishery are caught, they'll come up to the boat in a bag … Effectively being able to shuck at sea, we process it within less than half an hour of landing the abalone so that helps us with our quality. … We refer to our product from a shucked-at-sea fishery as a fully bled product because it's shucked live more blood comes out. Whereas most fisheries in Australia when the animal is delivered whole and it's shucked the next day or that night, more of the blood stays within the animal - within the muscle.”
	xii.	“Effectively, we use some of the shell, maybe 50% at the most of Greenlip shell. 0% of the Blacklip shell. And 0% of the Greenlip or the Blacklip viscera. So in our [zone], which is what, about 88 tonnes of meat all up? We also have 88 tonnes of viscera that doesn't even make it to shore, and 88 tonnes of shell. Probably 50, 60-plus tonnes [of shell] stays in the water, too.”
	xiii.	"We do everything right from receiving the product and facilitating catch and receiving catch all the way through processing, packing, sales, marketing, and exporting. So that's all done from here in - in our office in Port Lincoln. We are majority export. Pre-[2020] we were probably 90% export. Post-[2020] we’re about 99% export. … We also process farmed abalone. So while wild catch is our core business, we actually do quite a bit of farmed abalone too and they are [purely] Greenlip … Probably, 50-plus tonne we would shuck a year … 50 to 80 tonne."
	xiv.	"Both of our major products Blacklip and Greenlip are both sold as IQF meat [since 2020/21]”
OP-B3	xv.	"We get our abalone contract-processed either through [Processor E], or if we’re canning or retort pouching [Blacklip abalone] it could be through [Processor N] who are actually based in Victoria but not so much of that anymore."
	xvi.	“Being a smaller company we are quite flexible and are focused on premium quality. We provide chilled product to the abalone dryers … We supply [Processor L] with their premium large size Greenlip. We supply [Processor H] with their premium quality and sized Blacklip and some Greenlip. And we, on occasion, also send chilled abalone for drying to Hong Kong.”

Participant	Response ID	Participant Response
	xvii.	“Greenlip meat will be individually quick frozen. For us that would be maybe 50 to 60% of the quota that we have allocated [2 of 22 licenses]. Then the remaining 40% will be provided as a chilled product to other processors who will dry it"
OP-B4	xviii.	“We also contract pack for other divers in our area and other zones as well. So we're packing for Central Zone and Southern Zone divers also. So a mix of product coming in here from our local zone, which is predominantly all shucked meat and also Central Zone’s similar but Southern Zone they land all their Blacklip in shell … The bulk of our product nowadays is sold as IQF or frozen meat-only… It’s a pretty straightforward process and not too complicated. [Abalone are] just graded into sizes and packed in 10 kilo master cartons and shipped out, so there's not too much to it.”
	xix.	“We've been tapping into that supply [from the Southern Zone] just prior to COVID … So, 2018/19 …So we probably get about 20 tonne in shell from down there through our partners.”
	xx.	“There is a small amount of interest in live Greenlip and a little bit of frozen-in-shell Greenlip. But very, very niche markets, so I'd say, well over 90% would be IQF bled meat.”
	xxi.	“I’ll start with the Greenlip because it’s pretty easy. Pretty much, the market only really demands the frozen meat only. Ours is a fully-bled meat-only product unlike, say Tasmania, the Greenlip from there, generally isn't bled because it comes in in shell and then snap frozen out of the shell. So there is a noticeable difference and the market does recognise that. It's probably an advantage for us being shucked at sea. The product comes in after being shucked at sea, held in a chiller overnight, and it's basically fully-bled by the time we handle it the next day [for freezing]. So it's just the way it is for us. It's always been that way. And the clients prefer it that way.”
	xxii.	“Prior to [2020] our Blacklip was pretty much all canned - 100% canned market - and so we would send the product from here just as a chilled product to a cannery either in Adelaide or Melbourne. And - and have it canned to order, to size specifications for our customers. Nowadays there is no real canned market for our product …So yeah, back to basically freezing, IQF with the Blacklip.”
	xxiii.	“We don't play in the export live market at this stage. We're just too remote. And the logistics just aren't there for us for exporting live.”
	xxiv.	“We process both local Greenlip and the central zone Greenlip, pretty much all our Western Zone Greenlip … 98-99% would be exported … Whereas the quality and size of the central zone Greenlip is at times quite a bit lower than ours. Size is quite a bit smaller, and the quality can be very variable … so it's a second grade type product [which is] IQF-ed and sold domestically. A lot of it used to go into the Sydney domestic market.”
	xxv.	“With our relationship with the central zone divers, we’re able to fill a container [of Greenlip shells] each season quite comfortably and move it on each year.”
	xxvi.	“The return on our good A-grade shell that we sell for ornamental use and buttons and jewellery … we're selling that for around, say $15 a kilo, which is considered pretty good return on that product.”

Tasmania

Participant	Response ID	Participant Response
OP-C1	xxvii.	“There's about 90 active [licenses in Tasmania]. And I think in total, we own about 20. So not all are active, but we own about 20. I think there's probably 17 active or something outta that.”
	xxviii.	“When we shift gut around - when we move it for further processing - it's 10, 11 pallets at a time and there's a tonne a pallet”
	xxix.	"Smithton does the majority of the canning product, whereas Margate does virtually all of our live."
	xxx.	“We get a little bit of fall down [abalone] that's damaged broken, weak, slow, dead, that we’ll process; usually recover the meat out of it; and we still have the shell and the gut to deal with there.”
	xxxi.	“Across the industry, [our market share] it’d be about 30% of everything. We’ve got two abalone canneries in Tasmania, but they're the only two that are in Tasmania."
	xxxii.	"We're a couple of hundred tonne of live and Smithton would produce equivalent to around about that same sort of volume out of canning. And then they also do some frozen, they do retort pouches, they do slice pouches. We do a few other products as well."
	xxxiii.	“Live fish come from East and Western Zones … but when you get up to the north, they're not really good enough for live, certainly not to the premium market. So that dictates that they're sold as live at a really a lot lower value, or they're processed into other products. A lot of them have a really poor-quality shell through mud worm and thick, heavy growth. So it's more about where the fish come from, what options you have for them. And they're also different sizes. So live’s all about big, but Northern Zone and Bass Strait, they're small, so they don't fit into that live size zone, predominantly"
	xxxiv.	“[Breakdown of product formats] varies constantly. Depending on where the money is, the size of the fish.”
	xxxv.	“We would be probably 75% export on Greenlip. And if we were talking Blacklip… Yeah, it's - it's a lot higher than that. It would be, you know we don't target the domestic market for canned at all or retort pouches. ... 95% export for Blacklip. For processed Blacklip and obviously live’s all so – probably not – yeah 95% at least overall would all go."
	xxxvi.	“The gut’s all frozen and sold. We have a couple of markets for that. One predominant market and then a secondary market. And it's sold and we're flat out catching up on old stock. We have a lot of old stock that was packaged in cartons and frozen. So it's taken some time to work through that. It was several hundred tonne and we've got that committed now; and we're still producing and packing it the same”
OP-C2	xxxvii.	“We control about 35% of the industry and then [Processor J], they control probably about 40%. So between us we've got the lion's share and majority."
	xxxviii.	“[Live products are] Just Blacklip. Greenlip doesn’t travel live well. So we just do that IQF.”
	xxxix.	“So out of 250 tonne [of catch] per annum, 150 tonne is live and then 100 tonne is processed – IQF or rumbled”
	xl.	“We would sell next to nothing into the domestic market. So maybe 1%, if that. Everything else is exported”

Participant	Response ID	Participant Response
	xli.	“What we do with those is the shell is sold to China as well and it's made into jewellery, it's crushed for soil conditioners, there's some nutraceutical extractions that go on but that's all sort of further down the value chain from where we are. We just put the shell in a shipping container and send it off.”
	xlii.	“The viscera we actually get turned into sauces … There's also some peptide research going on out of Victoria, that we're sort of across as well, looking at sort of nutraceutical extractions, but that's not a commercial, sort of - in a commercial position right now, but we're expecting that to sort of come to life in the next couple of years.”
	xliii.	“We just supply the raw materials [viscera] and another company does the processing [into sauces]”
	xliv.	“We sell the shells … All of it. It's quite high demand for it”
	xlv.	“We accumulate a pallet of [viscera] product and then we send that off. So as opposed to sending one poly box a week off. We just accumulate it, send it. So it could be there for a couple of months.”
	xlvi.	**OP-C2:** “There’s also some peptide research going on out of Victoria, that we're sort of across as well, looking at sort of nutraceutical extractions, but that's not in a commercial position right now, but we're expecting that to sort of come to life in the next couple of years. **Lynne**: Is that with the [*research centre name redacted]*? **OP-C2:** Yeah, yep it is. **Lynne:** With [*recruit name redacted]*? **OP-C2:** Yep and [*processor name redacted*] out of Victoria. **Lynne:** And is that just for Blacklip? **OP-C2:** Correct, yep.

Victoria

Participant	Response ID	Participant Response
OP-C1	xlvii.	"[The Victorian branch of Processor J] sell the shell … sell some of the gut, but a lot of it, we don't. We will be able to sell all of our gut from there in the very near future when we've caught up on our old stock out of Smithton."
	xlviii.	"[Processor J] also have quota and a factory in Melbourne for Victoria … the shell and the gut will usually stay in Victoria."
IR-D1	xlix.	"Not all of [Processor S' catch] go into cans. Maybe 60 to 70% would go into can, and maybe 30 to 40% would be live."
	l.	"What I perceive the supply chain is, is the divers catch [the abalone] … If the owner has shares in the processing facility that we have in Mallacoota, then they're obliged … to provide 90 to 95% of the abalone caught to that facility. … [Processor S have] got these big massive state of the art blue bins, and they export them to Singapore, or Hong Kong, not so much to China now, but they export them with live products, so the product can get over there and it's still live."
	li.	"The co-op in Mallacoota, they got big crates with the shells. So that's what I see as the biggest waste, but I've asked them about the shells. And each processor seems to have a [customer] and the one in Mallacoota has one in China who, once they get a container-full, then that's shipped over to China … They [the customer] do something with it, like break them all down and pulverise them into a powder form … They grind it down and use it into powders."
	lii.	"One of [the Victorian processors] is very, very proactive in utilising the waste [viscera] … The company is called [Processor O]. He's developed the abalone sauces… He's also done an abalone beer."
P-D3	liii.	"It'd be [Processor J] would be number one, [Processor N would] be number two. [Processor O] would probably be number three and [Processor P] would be number four. That's not counting [Processor S], which they're in the Eastern Zone so they can the majority their own product… [however] the factory burned down two years ago [in 2020] at Christmas, we've been doing all the contract canning for them in the last 18 months."

Participant	Response ID	Participant Response
	liv.	“Okay, so give you an example of when we get product in from say, Warrnambool or Portland which has usually got a component of over 650g - over 450g [whole weight] I should say - we would bring them in that night, pick them up from the diver, say, 4:30, 5:30 [pm], depending on the day. [The abalone] would come back to the factory, they would be put into the tank overnight. Next day, [the abalone] would be sorted out – the ones that are under 450[g] which would go either – if it’s a big quantity – they’d go straight to canning, or they might go to IQF meat, or frozen on shell so there, that gives you the live component. And the diver gets paid accordingly – or the quota owner gets paid accordingly - on what's a live component and what’s a canning component. Now if they come from an area, which is, say, not known for bigger fish, which might be like today, they're coming from the back beach at Sorrento, which will be coming off around Cape Schanck, around that area - the back beach of Sorrento. So that will be all canning product. So that will come in tonight, will go into the cool room and the next morning it will be shucked – the gut and the shell separated. It goes into an ice slurry and then it goes into the rumbler and it’s rumbled and cleaned and trimmed for canning.”
	lv.	“Most of the Greenlip we source we sell into the live market. It’s only the product that’s not suitable for live that goes into frozen meat. So we can generate a lot of waste out of the Greenlip but the majority of product that we source is Blacklip. Blacklip would be 95% of our raw material in total.”
	lvi.	“[Processor P] do the same … They've got the ability to store the shell. We're in - we're inner city at Richmond, so we've got nowhere to store the shell.”
	lvii.	Speaking on how much canned product is exported: “It’d be over 90%.”
O-D2	lviii.	"There’s about seven… six to seven active processors in Victoria."
	lix.	"In [the western] zone, I'd say it’d be … 60% live 40% canned. Maybe even a bit higher live, 70/30 … I'd say in the other zones it’d be round the other way, the majority would be canned.”

Western Australia

Participant	Response ID	Participant Response
OP-E1	lx.	"There's [Processor U] … [Processor W] do a little bit just up here [in Hamilton Hill] and to tell you the truth - I don't know of anybody else [who processes abalone other than ourselves] ... There used to be more. Catalano's used to do abalone … or Nancy Reed in the early days, but she's passed away. And then there was Leeuwin Star … but he had a fall out with the divers … he's no longer doing any abalone."
	lxi.	"You've got Augusta down there *[pointing to map]* and [the coastline] sort of goes round to Esperance. So we're getting broodstock from [Augusta] … sending the broodstock to [Esperance and] bringing the [young abalone] back."
	lxii.	"[Ranched abalone] take four to five years to grow to a market size. We've got target market sizes … 250 or 300g [meat weight]."
	lxiii.	**Lynne**: Okay. And so that's all of your viscera at the moment. You're just saving it? **OP-E1**: Pretty much.
	lxiv.	"I designed and had this [facility] built to handle 400 tonne per year. So we're up to 80 tonne … per year at the moment … We've got the opportunity to process for the wild sector as well. … Because their quotas have reduced significantly it's not viable to open up a premises [as an] individual."
OP-E3	lxv.	"Then you've got … the ranch in Augusta. Now I think they said they are producing about 80 tonne a year [in 2021/22] but that's whole weight … their [meat] recovery's not as good because they're smaller abalone - probably looking at about 20 to 25 tonne of meat."
	lxvi.	"[Divers in Area 3] start in April, for the Greenlip and Brownlip quota. That's the bigger species, and that goes into winter. The abalone weigh more then, so the meat weight recovery's good and that's why we try to fish in those winter months"
	lxvii.	"Most of our product was consumed within Sydney and Perth [before 2020] … Most of our [abalone] will be exported now, so it goes over east and they do it. So probably 90%'s exported now. We do have our retail shops in Augusta …But it's only small amounts that would only be 1 to 2% and then the rest is [sent] overseas."
	lxviii.	"There's a processor in Augusta. There's a processor in Perth that's at Hamilton Hill. There's another processor at Catalano's, which is in Perth, and one down in Esperance,"
	lxix.	"I was doing it myself at our own factory up until a year ago. But now we do it down at [Processor T], which is down on the marina. But the actual cutting and the meat, as you understand is done out at sea"
OP-E4	lxx.	"[We're] also shareholders in a processing factory in Esperance which has processed abalone in [Area 2] of Western Australia since we purchased the business in 1987, or '88 … We're not processing at the moment because of we've had a severe cut of our quotas ... So we've stopped processing ourselves, but we're still out outsourcing it to other people and doing the marketing ourselves."

Participant	Response ID	Participant Response
	lxxi.	“The abalone are brought on board the boat, but they’re actually shucked at sea so the meat is removed from the shell; the gut - the viscera - is thrown overboard. The shell - we have to bring all of our shell back to shore as part of the management plan because we have a size limit and so the fisheries want to have an ability to inspect the shell to make sure that you've got the right number of shells for the day’s fishing and that they're all of-size. So all of the shell has to be brought ashore; has to be kept until the abalone has been received with the processors. So that generally means at least a day. Abalone pretty much most of the time is in the processing factory on the day it was caught. Sometimes when we work in the more remote areas it might be on the second day. So it's cold in large eskies for the first day then brought in; and then processed and sold from there. Most abalone [are processed into] IQF - so individually quick frozen - graded in different sizes and sold that way. Sometimes we've done live, chilled and other variants of it but the bulk of it goes in a frozen form.”
	lxxii.	“So generally what would happen would be: when the divers are working at sea – like I say, all the shell has to come to shore but they would have a good-grade bin and a B-grade bin. So once the abalone had been delivered and all the rest of it you could take the lower grade abalone [shell] back to sea and dump it, which is to be encouraged because the abalone shell is actually a settlement area for abalone when they spawn. … So that's the current state of play. The viscera is just all thrown over the side when it’s shucked.”
	lxxiii.	“Most of [the viscera] is fluid anyway. So if you shuck it into a container of some sort, at the end of the day you've got 80% fluid and a bit of gut material, that sort of stuff, left.”
	lxxiv.	On fishing in Area 2: "We do try and modify our fishing to do with the spawning time of abalone. … Abalone in Western Australia spawn around about September/October. When that happens they lose probably 15 to 20% of their meat weight. So you have to take a lot more product to get the same kilos. So we try to avoid that time of year. We try to make sure that our quota starts in April so you try and be finished - you'll have the vast majority of fishing done before the - before the abalone spawn.”
	lxxv.	On the portion of product processed as IQF meat: "[Prior to 2020] it probably was 95%... 90 to 95. At the moment it’s 100%."
	lxxvi.	On the portion of product exported: “In the past it was probably 90% export. Nowadays, I'd say we're probably about 60% export”