

BE WHAT **YOU** WANT TO BE.



**Describing, analysing and comparing
edible oyster supply chains in Australia**

Final Research Report

June 2020

Peggy Schrobback and John Rolfe

Central Queensland University, School of Business and Law



Rural Economies
Centre of Excellence

Table of Content

List of Figures	2
List of Tables.....	2
Acronyms.....	3
Executive summary.....	4
1 Introduction	6
2 Methodology	7
3 Results.....	10
3.1 Oyster supply chain stages and entities	10
3.2 Development status of the black-lip oyster supply chain	13
3.3 The Sydney rock oyster supply and value chain	16
3.3.1 SRO industry supply network map	16
3.3.2 SRO supply chain models and associated value chains	19
3.3.3 Issues and opportunities associated with the SRO supply chain	28
3.4 The flat oyster supply and value chain.....	30
4 Discussion.....	34
5 Conclusion	38
References	39
Appendix 1: Interview questions	44
Appendix 2: Project communication and engagement.....	47

List of Figures

Figure 1: Supply chain stages.....	10
Figure 2: Black-lip oyster supply network map.....	15
Figure 3: Sydney rock oyster supply network map (industry level)	17
Figure 4: Pricing of oysters at restaurants across Australia	18
Figure 5: Value chain within the traditional processor/wholesaler supply chain model	21
Figure 6: Value chain of within the premium oyster wholesale supply chain model.....	25
Figure 7: Value chain of the direct sale supply chain model	26
Figure 8: Integrated corporate supply chain model	27
Figure 9: Flat oyster supply network map	32
Figure 10: Value for flat oysters – Premium oyster wholesale model	33
Figure 11: Value for flat oysters – Direct sale model.....	33

List of Tables

Table 1: Descriptive information about the sample.....	9
--	---

Acronyms

BLO	Black-lip oyster
FO	Flat oyster
GBMP	Great Barrier Marine Park
ID	Identifier
NT	Northern Territory
PO	Pacific oyster
POMS	Pacific Oyster Mortality Syndrome
QLD	Queensland
QR	Quick response
QX	Queensland Unknown
SA	South Australia
SRO	Sydney rock oyster
TAS	Tasmania
WA	Western Australia

Acknowledgements

This study was funded by the Rural Economies Centre of Excellence (RECOE).

Executive summary

The black-lip oyster (BLO) has been identified as a tropical edible oyster species that could be cultivated on a commercial basis in Northern Australia (Queensland, Northern Territory, and Western Australia). This industry could generate employment, production diversification and economic growth for communities living in northern rural coastal regions of Australia. However, to develop this industry a better understanding about the potential supply chain for this shellfish product is required. Since Australia produces several other oyster species on a commercial basis, information from the oyster supply chains of these industries can be useful in guiding the development of a supply network BLOs.

This study has three main aims. The first is to explore the development status of the BLO oyster supply chain. The second is to map and describe the supply and value chains of other edible oyster species which are currently produced in temperate regions of Australia (e.g., Sydney rock oyster, flat oyster) and to identify potential issues and opportunities associated with their supply chains. The third aim is to synthesize findings from the first two aims and to derive recommendations for the development of a tropical oyster industry and supply chain in Northern Australia.

To collect information about the oyster supply chains a mixed method approach was used consisting of semi-structured interviews with supply chain stakeholders during October 2019 and February 2020 (prior to the COVID-19 crisis in Australia), a literature review and a web search for retail price information.

The scope of this study did not include an assessment of Australia's Pacific oyster (PO) supply chain since this industry has been affected by the Pacific Oyster Mortality Syndrome (POMS), a disease which significantly impacted the industry's production volume and supply chain network. Yet, in a different context, e.g., supply chain adaptation to supply shocks, an analysis of the PO supply and value chain may provide stakeholders with useful insights.

The findings of the present study indicate that:

- the BLO supply chain is currently at a very early stage of its development with only small commercial volumes being produced in Queensland and by two indigenous communities in the Northern Territory;
- the market for this shellfish product is presently mainly local, with the product being supplied by farmers either directly to consumers and restaurants or to processors/wholesalers which distribute to restaurants and fishmongers;
- a major limitation for any increase in the production volume of BLOs is the current lack of hatchery spat supply for this species, as wild spat, although abundant in tropical regions of Australia, appears to be difficult to catch;
- there are several other tropical oyster species present in northern Australia and a clear genetical identification is needed to differentiate these species from each other;
- the current shellfish quality assurance program for temperate oyster species needs to be amended to reflect seafood safety requirements for tropical oyster species; and
- there is limited information available about the potential domestic demand for this oyster species.

The assessment of the flat oyster (FO) supply and value chain suggests that this supply network is more mature than the distribution network of BLOs. The FO can be considered as a niche product due to its distinct taste and low production volume. Although hatchery spat seems to be readily available for this species, the specific environmental and spatial conditions in which FOs thrive appear to limit any expansion of the production volume and subsequently any further increase in the production of this oyster species. The analysis of the supply chains for BLOs and FOs revealed similarities between both networks, such as the requirement for

hatcheries to provide spat as an production input, the current low production volume and the need to further develop the market of these aquaculture products. The similarities suggest that the domestic fine-dining niche market could be a potential target market for the BLO industry.

The findings for the Sydney rock oyster (SRO) supply chain showed that the distribution network for this oyster species is relatively mature and that SROs are almost exclusively supplied to the domestic market. The traditional processor/wholesaler supply chain model was identified as still playing a dominant role, despite criticisms that it does not generate enough value within the supply chain. Over the past five years a range of other supply chain models have emerged with premium oyster wholesalers, a seafood agent and a horizontally and vertically integrated corporation now taking stakes in the processing and distribution of this oyster species. These relatively new entities within the supply chain have more focus on the marketing and branding of the oyster product, on establishing links between farmers and the retail entities and subsequently to oyster consumers. The structure of the SRO supply chain also shows a high dependence on the distribution of oysters through the domestic foodservice sector which carries high risks for the supply of the product in case of disruptions affecting this retail entity.

The results suggest that oyster farmers choose a specific supply chain model based on the net financial value and competitive advantage, as well as other considerations such as: farmers' ability, skills, interest in maximizing profits, knowledge about consumer demand, freight costs, access to market information and capital, time/effort to develop network links, interest in collaboration with other farmers and existing trust-based relationships.

The following recommendations for the development of a tropical oyster industry in Northern Australia are provided:

1. Establish a stable spat supply by hatcheries, with at least one hatchery in each state/territory to reduce dependence on a single input provider that could hamper input supply in situations such as disease outbreaks;
2. Continue research directed at technological improvements, potential pest and diseases and grow-out systems;
3. Improve access to capital by developing more reliable production and supply chain models and reducing risks;
4. Improve production skills and business aspects of oyster farmers, perhaps through mentoring by farmers in existing oyster industries;
5. Ensuring consumer safety of shellfish produced in Northern Australia, and improving food safety infrastructure at which food safety tests can be conducted within short periods of time;
6. Improve market development through consumer demand analysis for BLOs, marketing initiatives, and authenticity/product traceability;
7. The development of export strategies for the BLO may be a longer-term priority, where research into demand testing, branding and export protocols may be necessary;
8. An industry development plan should be established by all stakeholders of the BLO industry and Oyster Australia and may initially be driven by a consortium of Northern Australian Governments.

Overall, the development of a new oyster industry in Northern Australia appears to be challenging with several issues that need to be addressed. Yet, if successfully established, the oyster industry in the northern regions of Australia has the potential to contribute positively to income generation in rural coastal regions where employment opportunities are limited, hence, contributing to the economic growth and community development.

1 Introduction

The aquaculture industry in the northern regions of Queensland (QLD), the Northern Territory (NT) and Western Australia (WA) has been growing gradually over time, particularly in QLD (e.g., prawns, barramundi, red claw, oysters) and WA (e.g., pearl oysters, barramundi, marron, blue mussels) (ABARES, 2018). The further expansion of the aquaculture industry in this region has been identified as a potential source for future employment opportunities, production diversification and economic growth for communities living in northern rural coastal regions of Australia.

The governments of the northern states and territory have recognized the potential to develop a tropical edible oyster industry in this region based on naturally occurring oyster species, such as the black-lip oyster (*Saccostrea echinate*/*Striostrea (Parastriostrea) mytiloides*) (BLO) and the milky oyster (*Saccostrea cucullata*) (MO). Of particular interest is the BLO due to its distinct taste, attractive shell shape, and relatively short grow-out period (18 months - 2 years) (Nowland, O'Connor, Osborne, et al., 2019). Yet, the commercial production of BLOs is currently at a very early stage of development with only very small commercial volumes being produced in QLD and in indigenous communities in the NT (Nowland, O'Connor, Osborne, et al., 2019).

Oyster production in temperate regions of Australia has a long history involving three oyster species: the Sydney rock oyster, the Pacific oyster and the flat oyster (Nell, 2001; Schrobback et al., 2014a). The native Sydney rock oyster (*Saccostrea glomerata*) (SRO) is produced in New South Wales (NSW) and southern QLD where it naturally occurs in estuaries. The non-native and habitat invasive Pacific oyster (*Crassostrea gigas*) (PO) was introduced to Tasmania (TAS) and South Australia (SA) in the 1950/60s to supplement native oyster production in Australia (Nell, 2001; Schrobback et al., 2014b). The SRO and PO are the main commercial oyster species in Australia which together contribute approximately 95-98% of the total edible oyster production volume (ABARES, 2018; Schrobback et al., 2014b). In addition to the two key commercial temperate oyster species the flat oyster (FO), often called Angasi oyster (*Ostrea angasi*) or mud oyster, which is a native species, is also grown on a small commercial basis in NSW, TAS and SA (Nell, 2001; Schrobback et al., 2014b).

Information from the oyster supply chains of the established industries can be useful to guide the development of a supply network for BLOs. Yet, there is currently only limited information available about the existing supply chain of oysters in Australia. For example, Comiskey (2009) provided a broad structure of the existing oyster supply chains without offering detailed information about the processes within the chain (e.g., integration). Other authors have only focused on the consumption stage within the supply chain by investigating consumer demand for oysters in Australia (e.g., Kow et al., 2008; Liu et al., 2006; Mueller Loose et al., 2013).

Hence, the aims of this study are threefold. The first is to explore the development status of the BLO supply chain. The second is to map and describe the supply and value chains of edible oyster species which are currently produced in temperate regions of Australia (e.g., Sydney rock oyster, flat oyster) and to identify potential issues and opportunities associated with these supply chains. The final aim of this study is to synthesize findings from the first two aims and to derive recommendations for the development of a tropical oyster industry and supply chain in Northern Australia.

To achieve these aims, a mixed-method approach was used which included a review of the extant literature comprising scientific and socio-economic aspects of the oyster supply chain (e.g., hatchery spat production, production methods). In addition, semi-structured interviews of oyster supply chain stakeholders in QLD, NSW, NT and WA were conducted during October 2019 and February 2020 (prior to the COVID-19 crisis) to obtain information about the oyster supply chain structure and processes and the value chain. As well, an extensive internet search for retail price information was conducted to collect data about the oyster value chains.

An assessment of the supply chain of Australia's PO industry was not within the scope of this study since this industry has been affected by the Pacific Oyster Mortality Syndrome (POMS), a disease which significantly impacted the industry's production volume and supply chain network in recent years. Yet, in a different context, e.g., supply chain adaptation to supply shocks, an analysis of the PO supply and value chain may offer oyster supply chain stakeholders with useful insights.

The scope of this study was also limited to the fresh oyster supply chain (e.g., opened or unopened) since most of the oysters produced and consumed in Australia are either sold as unopened, fresh-opened (natural) or fresh-prepared (e.g., natural with lemon or Kilpatrick).

This study did not intend to analyse a seafood supply chain from a logistic perspective. Such analysis would require commercially sensitive information from different independent entities within supply chains which are typically difficult to access.

The assessment of the supply and value chains was conducted on an industry scale and from a behavioural and economic perspective to analyse how the oyster farmers manage the distribution of their product to their consumers, and drivers for the adoption of supply chain approaches.

The study is restricted to an assessment of the following supply chain stages: production input, production, processing, wholesale, and retail. An assessment of consumer perception of oyster and their demand for this seafood product was not part of this study since a number of studies have already focused in this supply chain segment (Intuitive Solutions, 2016, 2019; Kow et al., 2008; Lawley, 2015; Lawley & Birch, 2016; Liu et al., 2006; Mueller Loose et al., 2013).

A small proportion of oysters consumed in Australia are imported either as fresh oysters from New Zealand (about 3% of the total volume of oyster consumed) or as prepared oysters (e.g., canned) (ABARES, 2018), neither of which are not included in the scope of this study.

The findings of this study contribute detailed information about oyster supply chains in Australia and summarise issues and opportunities which may need to be addressed within the individual oyster industry segments (e.g., BLO, SRO, FO). As well, this study significantly contributes to the broader literature about seafood supply chains in Australia since only a limited number of studies have been conducted in this area thus far (e.g., e.g., Denham et al., 2016; Farmery et al., 2015; Fleming et al., 2014; Howieson et al., 2013; Lim-Camacho et al., 2015; Plagányi et al., 2014; van Putten et al., 2016).

The report is outlined as following. Section 2 offers a description of the methodology including survey design and information about progression of the sample collection. The results are presented in section 3 and a discussion of the findings are offered in section 4 before concluding in the report in section 5.

2 Methodology

This study uses a mixed-method approach to derive information about the fresh oyster supply and value chains in Australia. This approach consists of a literature review, an internet search about oyster price data sold at retail level, and semi-structured interviews of primary supply chain stakeholders (e.g., oyster farmers, processors/wholesalers, retailers) and secondary supply chain stakeholders (e.g., fishery managers, NGO) in QLD, NSW, NT and WA.

A literature review about oyster supply chains and general seafood supply chains in Australia was conducted to establish a basis for the investigation in this study. Of particular use were the contributions by Comiskey (2009) who has previously conducted research in this area and

provided the baseline for the present study. Other authors have undertaken research about specific components of the oyster supply chain, such as consumer demand in Australia (Intuitive Solutions, 2016, 2019; Kow et al., 2008; Liu et al., 2006; Mueller Loose et al., 2013) and issues in hatchery rearing (e.g., McDougall, 2018; Nowland et al., 2018; Nowland, O'Connor, et al., 2019; Nowland, O'Connor, Penny, et al., 2019; Southgate & Lee, 1998).

A qualitative approach to the data collection for this study was chosen due to the type of information needed (e.g., structural network, network components, processes within the network) and the exploratory nature of the research. Le Bihan et al. (2018) provided a summary of the oyster value chain in France which offered useful insights for selecting the methodology used in the present study. Considering the supply chain assessment guidelines suggested by Schrobback et al. (2019) and Bonney et al. (2009), a questionnaire focusing on broad themes such as the structure of the supply chain (e.g., actors and links among the actors within the chain, dominant elements) and processes within the chains (e.g., presence of forms of vertical coordination, value creation, status of traceability and sustainability within the supply chain) was developed. The questionnaire was supplemented by a draft supply and value chain for fresh oysters which was derived based on the extant literature. The appendix provides an overview of the questionnaire.

The use of semi-structured interviews, which was aligned with the questionnaire, allowed the interviewer to deviate from research questions depending on the responses given by participants which allowed the consideration of new ideas and perspective brought into the discussion. This was considered as useful given the exploratory nature of this study. The interview was targeted at input providers (e.g., hatchery operators, scientists), oyster farmers, processors, wholesalers, retailers, scientists, fishery managers and NGOs.

Random sampling was used to minimise any potential bias in participant selection. To incentivise participation in this study the research team offered a \$50 gift voucher for the completion of each interview. The interviews were conducted during October 2019 and February 2020 via telephone or online video conference. Participants were interviewed individually and were not identifiable by other participants. The interviews took between 30-90 minutes. Ethical approval for the data collection involving humans was obtained from Central Queensland University (approval number: 0000021959). Table 1 offers a summary of the interviewees who participated in this study. All interviews were recorded and transcribed for analysis.

An internet search about oyster price data at the retail level complemented the interviews to develop information about the value chain. For example, oyster price data was collected from menus available on restaurants' websites. An average over 74 restaurants was taken to derive a mean price per dozen oysters. For food chain retailers and fishmongers, the websites of major supermarkets and seafood markets was inspected for price information. Local supermarkets were visited to confirm product pricing and to gain additional information from product labeling in seafood displays.

Table 1: Descriptive information about the sample

Identifier	Supply chain role	State	Years of experience in handling oysters	Species
ID1	Scientist	NSW	>20	SRO, PO, FO, BLO
ID2	Processor/wholesaler	QLD	10	SRO, PO
ID3	Wholesaler	NSW/QLD	5	SRO, PO, FO
ID4	Input provider/farmer	NSW	20	SRO
ID5	Wholesaler	NSW	4	SRO, PO, FO
ID6	Farmer	QLD	>20	SRO
ID7	Fishery manager	NSW	>20	SRO, PO, FO
ID8	Farmer	NSW	>20	SRO, PO, FO
ID9	Input provider/farmer	QLD	>20	SRO, BLO
ID10	Fishery manager	QLD	15	SRO, BLO
ID11	Fishmonger	QLD	15	SRO, PO
ID12	Fishmonger	QLD	15	SRO, PO
ID13	Fishery manager	NSW	10	SRO, PO, FO
ID14	Fishery manager	NT	4	BLO
ID15	Fishery manager	QLD	3	BLO
ID16	Scientist	QLD	2.5	BLO
ID17	Farmer	QLD	20	SRO
ID18	Input provider	WA	~20	SRO, BLO, FO
ID19	Farmer	NSW	12	SRO
ID20	Farmer	QLD	4	SRO
ID21	Scientist	NT	6	BLO
ID22	Processor/wholesaler	QLD	20	SRO, PO
ID23	Farmer	NSW	32	SRO
ID24	Farmer	NSW	5	SRO
ID25	Farmer	NSW	~20	SRO, FO
ID26	Input provider/farmer	NSW	~20	SRO, FO
ID27	Farmer	NSW	10	SRO
ID28	Farmer	NSW	5	SRO
ID29	Farmer	NSW	30	SRO
ID30	Farmer	NSW	40	SRO, FO
ID31	Farmer	NSW	2	SRO
ID32	Farmer	NSW	5	SRO, FO

Note: NSW for New South Wales, QLD for Queensland, SRO for Sydney rock oyster, PO for Pacific oyster, BLO for Black-lip oyster, FO for flat oyster. "Fishery manager" includes government representatives, NGO and industry body representatives. Two representatives of Oyster Australia were interviewed, yet their identity is kept confidential in the table as per data collection agreement between all participants and the research team.

3 Results

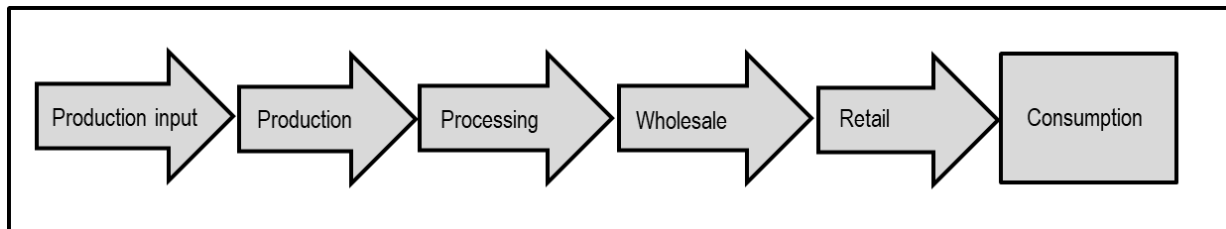
The analysis of the collected data provided information about the entities within oyster supply chains, their role in the network and links between them as well as processes within the chain, such as value creation, collaboration and integration. Interviewees were also asked about their perspectives on supply chain traceability and sustainability.

Section 3.1 provides a description of supply chain entities and their role in the fresh oyster supply chain. Section 3.2 offers findings about the development status of the BLO supply chain. In section 3.3 and 3.4 the supply chain maps and a description of the processes with the chains of the SROs and FOs are presented.

3.1 Oyster supply chain stages and entities

This section offers a brief overview about the stages of oyster supply chain which includes a) production input, b) production, c) processing, d) wholesale, e) retail, and f) consumption (Figure 1). Entities within these supply chain stages (e.g., restaurants, supermarkets, fishmonger which belong to the retail stage) as well as their role within the supply chain are described.

Figure 1: Supply chain stages



It should also be highlighted that not every supply chain stage (e.g., processing/wholesale) or entity (e.g., seafood wholesaler, agent) which will be described in this section may be included in the material following on supply chain maps for each species, yet, for completeness and as a reference a brief overview is provided in the following sub-sections.

Production input stage

The essential input to oyster production is brood stock that produces larvae and develops into juvenile oysters, which is more commonly referred to as oyster spat. For native oyster species, such as SRO, BLO, and FO oyster spat can be caught by farmers in the wild using specific infrastructure (e.g., plastic slats) on which juvenile oysters can settle. Once settled oyster spat is transferred to grow-out furniture (e.g., baskets, bags, trays). Wild collection of oysters spat depends on the environmental conditions (e.g., rainfall), the natural oyster abundance in a location, farmer's awareness of wild spat being available and their ability to collect spat using appropriate infrastructure, and the settlement and settlement density of oyster spat on the collection furniture.

Hatcheries are an additional source for native oyster leave and spat. Farmers of native oyster species consider the use of hatchery spat as a form of production risk management due to the difficulty of collecting spat for native species. The use of hatchery spat also provides the opportunity to develop different seasonal growing schedules compared to being depending on the relatively fixed timing of natural oyster spawning.

Oyster hatcheries are particularly important to produce FOs in NSW due to the limited abundance and difficulties to catch spat for this species.¹

The general process within oyster hatcheries includes brood stock being supplied from wild caught stock by farmers to hatcheries. Hatchery operators condition and spawn the broodstock to produce larvae. Hatcheries which offer selectively bred oyster family lines (e.g., disease resistant, fast growth) also undertake a genetical assessment and selection of the brood stock. Larvae are tended regularly until the end of the larval cycle when they can be placed into settlement tanks (O'Connor et al., 2008). When settled the larvae transforms into spat. At this stage they are either sold to farmers or are transferred into a nursery system at the hatchery before sold to growers (O'Connor et al., 2008).

Production stage

The production stage within the oyster supply chain includes various activities to cultivate the organism from a spat phase to a marketable size in grow-out furniture which is placed on oyster leases in estuaries. The production stage also includes the harvest of the oysters and the supply of oysters to the market.

The selection of grow-out infrastructure (e.g., baskets, trays, bags, long-lines) and production systems (e.g., intertidal, sub-tidal) depends on the location of the oyster lease and the local marine environment (e.g., tidal change, turbidity). Typically, there is a range of other farm infrastructure needed on an oyster farm, such as a barge, grading equipment, a storage/work sheds (and land), and a vehicle for the transportation of the product to the first up-stream entity within the supply chain.

Oyster cultivation is a regulated activity in all Australian jurisdictions meaning that the production of oysters is only permitted on approved oyster aquaculture leases. The respective state and territory governments hold authority over lease approval and allocations. It is common that oyster farmers hold several oyster leases which are suitable for cultivating oysters at different life stages, e.g., spat collection, growing the spat to a mature or semi-mature stage, maturing and fattening the oysters (QLD DAF, 2015). The respective state and territory government also regulates translocation procedures, food safety aspects, enforces compliance with environmental and marine park regulation (QLD), assists with the management of diseases and helps with the review and development of industry management strategies (QLD DAF, 2015).

The grow-out time to a marketable size differs significantly between the oyster species. For example, the SRO requires about 2.5-3.5 years, for FO it is 18 month-2 years, and for BLO it is about 2 years.²

There are several risks which can affect the cultivation of oysters including diseases, such as mudworm, winter mortality and QX (Queensland Unknown) for SROs and *Bonamia ostreae* for FOs, high volume rainfall events which can lead to temporary closures of production areas, and oyster theft and lease vandalism.

Once oysters are grown out to a marketable size, they are harvested by removing them from the grow-out furniture and graded and cleaned (primary processing) before they are distributed to up-stream entities within the supply chain which could include several different channels

¹ The PO industry is entirely reliant on hatchery production spat since this species is not native to Australia, hence, the brood stock does not naturally occur in TAS, SA and NSW. Prior to POMS, hatchery production for PO spat took mainly place in TAS which supplied producers in TAS, SA and NSW. Due to POMS and restrictions on the translocation of live POs including spat, production of POs in SA and NSW reduced significantly as farmers were unable to restock their leases. In response to this issue, the industry in SA is now in the process of setting up two hatcheries to minimise its dependence of oyster farmers in SA on TAS hatchery spat in future.

² The grow-out time for POs is 18 month-2 years.

(see more detail in sections 3.2-3.3). Transportation costs to the first point of product sale within the supply chain is typically paid for by farmers unless other arrangements are made between farmers and first point of sale within the supply chain. Freight costs can vary significantly depending on distance between farm and receiving location (e.g., local market vs. interstate) and the volume of shipment (e.g., one dozen in box vs. one pallet).

As a perishable good with a short shelf-life (approximately 5-14 days depending on the species) the essential features of the oyster supply chain from the point of harvest are cooling and the requirement of short lead-times. The perishable nature of oysters and the health risk associated with unsafe seafood consumption for humans requires compliance with national food safety standards at every stage of the oyster supply chain from harvest (production) to presentation (retail) of the product to consumers (Food Standards Australia New Zealand, 2005). The standards which specifically apply to the oyster industry is the Australian Shellfish Quality Assurance Program (Australian Shellfish Quality Assurance Advisory Committee, 2019).

Processing/wholesale stage

Oyster growers are typically not opening the harvested oysters themselves due to the labour requirements involved. Hence, oysters are transferred from the farms to processors which clean, grade, open (or not), and package oysters before selling them on to up-stream entities within the supply chain. The opening process is referred to as “shucking oysters”. Processors are businesses that are either specialised in oyster processing (which are typically relatively small businesses, also called specialty wholesaler) or are general seafood processors which handle large amounts of fish and seafood species. There are also processors/wholesalers which specialise in the export of seafood, including oysters.

Commonly, processors consolidate oyster supply and therefore take on wholesale functions within the chain by distributing the product on to the retail stage within the chain (e.g., restaurants, food chain retailers and fishmongers). Transportation from the processors/wholesalers to up-stream supply chain is typically organized by the up-stream entities or handled by processors/wholesalers at a cost charged to the up-stream entities. There may be other types of wholesalers present within the oyster supply chain such as seafood agents and premium oyster wholesalers (more detail about these entities is offered in section 3.2.2).

Retail stage

The retail stage within the oyster supply chain includes entities such as foodservices, food chain retailers/independent food retailers and fishmongers.

Foodservices

In Australia, oysters are most commonly consumed in restaurants, clubs, cafes and other food vendors as an entrée dish (Comiskey, 2009; Liu et al., 2006). Restaurants source oysters through different channels (e.g., processors/wholesalers, specialty wholesalers, fishmongers or directly from farmers) (see sections 3.2-3.3). Foodservices offer oysters opened in half-shell as natural or with different dressings and toppings (e.g., lemon, mignonette, Kilpatrick) which can be considered as an added value. Foodservices in Australia are exempt from mandatory country of origin labeling or any other seafood labeling requirements. This means that information about the oyster species offered at restaurants is not required to be made available to consumers on menus.

Food chain retailers

Food retailers are distributors for retail food, including seafood (Spencer & Kneebone, 2012). The food retail channel consists of full-service supermarket chains (e.g. Coles, Woolworths, IGA) and independent grocery stores (Spencer & Kneebone, 2012). Food retailers offer fresh

seafood typically only SROs and/or POs since these industries provide sufficient product volume. Food retailers commonly procure their oyster supply through processors/wholesalers on either a contract basis or spot market basis.

The sourcing of product through the processing/wholesale sectors offer food chain retailers security in supply volume. Supermarkets typically add value to the oyster product through transportation from supplier or customers (for online orders), seafood marketing in form of physical display at the store, preparation advice (e.g., monthly retail magazine, seafood pamphlets) or online marketing. In contrast to seafood sold through foodservices, packed seafood, including oysters, at the retail level in Australia must be labelled with the amount of seafood content, type of seafood, directions to use and nutritional information (IBISWorld, 2019). Yet, fresh seafood does not require the same level of detail as other packaged manufactured food products. Only origin, species and age of seafood needs to be recorded and made available for inspection for retail sales (IBISWorld, 2019).

Fishmongers (seafood markets)

Fishmongers are specialty fish and seafood retailers (IBISWorld, 2019). They offer greater expertise regarding the fish and seafood selection and offer customer advice, such as seafood preparation compared to food retailers (IBISWorld, 2019). Fishmongers rely on the processing/wholesale sector for their supply of opened and unopened oysters to source reliable product volumes.

Fishmongers typically offer a range of retail services, such as, physical display and direct sale of opened and/or unopened oysters, online order opportunity for customers (individual private customers and restaurants), take-away and eat-in services (IBISWorld, 2019). The labeling of seafood, including oysters, is compulsory for fishmongers/seafood markets in Australia (as above for food retailers).

Consumption stage

Detailed information about oyster demand and consumer characteristics are provided by Liu et al. (2006), Kow et al. (2008), Mueller Loose et al. (2013), Intuitive Solutions (2016), Intuitive Solutions (2019) and Lawley (2015). A more detailed analysis of oyster consumption in Australia was not within the scope of this study.

3.2 Development status of the black-lip oyster supply chain

Based on the interviews with stakeholders of the BLO industry a map of its supply chain structure was developed which is presented in Figure 2. The interviews revealed that the BLO industry is at a very early development stage, which is supported by Nowland, O'Connor, Osborne, et al. (2019). There is currently only a very small volume of BLOs produced on a commercial basis in QLD (about 1,000 dozen/per annum (Nowland, O'Connor, Osborne, et al., 2019)) and the NT.

The findings revealed that oyster spat as a production input in QLD is currently collected in the wild, while the small scale commercial BLOs production in the NT is using spat produced in experimental trials. Participants mentioned that wild BLO spat supply is relatively unreliable as this oyster species does not recruit consistently in large quantities. The interviewees highlighted the need to develop protocols to produce BLO spat in hatcheries as the fundamental basis for the development of a commercial BLO industry. At this stage, hatchery spat production of BLOs is at an experimental stage with elementary research about larvae development and settlement having been conducted only recently (Nowland et al., 2018; Nowland, O'Connor, et al., 2019; Nowland, O'Connor, Penny, et al., 2019). Trials about different grow-out systems have been undertaken which revealed that an intertidal production system may be favorable for commercial production, however, these require further optimisation. Further research about hatchery spat production and grow-out techniques is

currently conducted in a fishery research facility operated by the NT Government and a shellfish hatchery in WA. Consequently, no hatchery spat for BLOs is currently being produced for commercial grow-out. Despite research into the development of hatchery protocols for this oyster species currently being funded, participants emphasised the need for future funding in this field of research and the need for incentives and support for commercial hatcheries to take up tropical oyster spat production. It was also mentioned that there may be an opportunity for private investment in the development of hatchery spat production for BLOs but that a long-run commitment by investors would be required since no short term or medium term return can be guaranteed.

Previous research has also shown that there is a lack in the understanding about the genetic taxonomy of tropical oysters (McDougall, 2018). More recent research has found that there are several tropical oyster species present in NA, including QLD, and that these species need to be genetically identified to avoid that several distinct oyster species are categorised as one species. A clear identification of oyster species is believed to also assist with the grading, marketing and with translocation of brood stock.

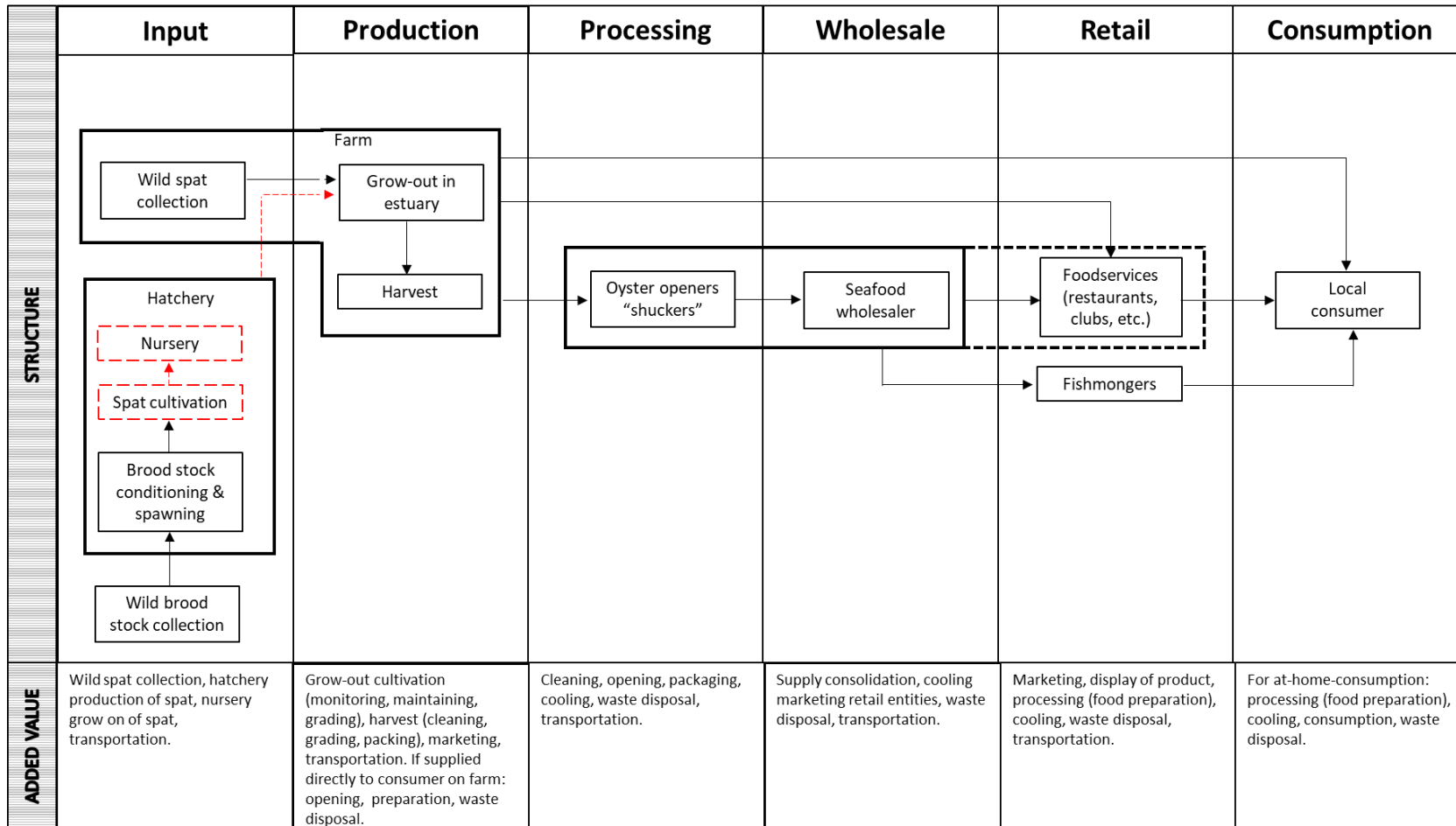
Additional investment is needed to enable the development of the BLO production and its potential supply chain. This will include, for example, licensing and the development of shellfish quality assurance policies. Although the Australian Shellfish Quality Assurance Program (Australian Shellfish Quality Assurance Advisory Committee, 2019) is in place it was noted that this program is directed at temperate shellfish species and would need to be adapted to reflect tropical shellfish quality and safety requirements. For example, tropical oysters may have different cold chain requirements, as they are grown and handled in warmer environmental conditions compared to temperate oyster species.

The respondents mentioned that the infrastructure needed to conduct compulsory food safety tests in laboratories is not currently given in NA which requires producers to send their samples either interstate (for NT) or to capital cities (QLD, WA). Moreover, the lack of access to capital for remote communities to set up a marine aquaculture farms could be a factor which may limit the development of BLO production.

With respect to the production of BLOs in QLD, respondents mentioned that the allocation of oyster leases in tropical regions may be an issue. Potential aquaculture areas that are located within the Great Barrier Marine Park (GBMP) are limited due to the spatial zoning that define which activities can occur in different locations within the GBMP. This may restrict the spatial expansion of BLO cultivation in QLD but may not be an issue for the industry development in WA and the NT. However, it was also mentioned that off-bottom oyster production infrastructure may have very limited impact on the reef and that the net effect of oyster production in the reef environment is likely positive for the reef (e.g., filter feeding organism which removes nutrients from the water). However, there are other potential production risks for the cultivation of tropical oysters which temperate oyster cultivation is not exposed to, for example, crocodiles and cyclones/frequently high winds. Interviewees argued that these risks could be mitigated by using an intertidal grow-out system to avoid issues with crocodiles (e.g., stock monitoring and grading could be done during low tide), and temporal removal of stock from exposed area during extreme storm risks.

The findings revealed that the small volume of BLOs that is produced in QLD and the NT is currently supplied to the market by farmers selling the product directly to consumers or to local restaurants (see Figure 2). A small volume is supplied to local processor/wholesalers which also offers BLO retail services (e.g., integrated foodservice). Yet, the processor/wholesaler component of this entity also distributes BLOs to fishmongers and other local restaurants.

Figure 2: Black-lip oyster supply network map



Notes: Red dashed lines indicate that these entities and processes are in an experimental stage and commercial links between entities are not yet existing. Black boxes around multiple entities within the supply chains indicate integration of processes or entities. Surrounding black box indicates integration of supply chain stages, dashed black box indicates that this is the case in some cases but not all.

Hence, the market for BLOs is currently local in spatial scale, yet interviewees expected that this oyster species could in future also be supplied to the domestic market with more reliable production volume being available. The stakeholders of the BLO industry raised the potential for BLOs to develop into a niche market product targeting fine-dining restaurants in the Australian capital cities. However, it was also mentioned that for the supply chain to develop into an efficient distribution network, the consumer demand for BLOs will need to be investigated further.

Unfortunately, information about the value chain of BLOs were not made available by participants on the bases of the small scale of production and the commercial interests of supply chain stakeholders.

In summary, the findings show that the development of the BLO industry is in a very early phase. There are a range of critical factors (e.g., lack of commercial hatchery supply of spat, food safety policies to be developed, potential limitation to lease area expansion in QLD, production risks, access to capital for potential farmers, need for research funding) which need to be considered for the development of the supply chain for tropical oysters. Respondents mentioned that it might take about 5-10 years to attend to these challenges and to develop the BLO industry from this early stage into a more commercial oyster industry.

3.3 The Sydney rock oyster supply and value chain

The SRO industry has a long history in Australia (Schrobback et al., 2014a), hence, its supply chain structure is relatively mature, specifically in comparison to the supply network of the BLO. The annual production volume and production value at 6.2 million dozen and \$53.6 million in 2018/19 (NSW DPI, 2020) make this sector significantly larger than for BLOs and FOs.

The findings from stakeholder interviews about the structure of the distribution network for SROs at an industry level will be presented in section 3.3.1. In section 3.3.2 supply chain models which were identified within the broader supply chain structure as well as the associated value chains will be presented. Section 3.3.3 offers a summary of issues and opportunities that affect the SRO supply network which were raised by stakeholders.

3.3.1 SRO industry supply network map

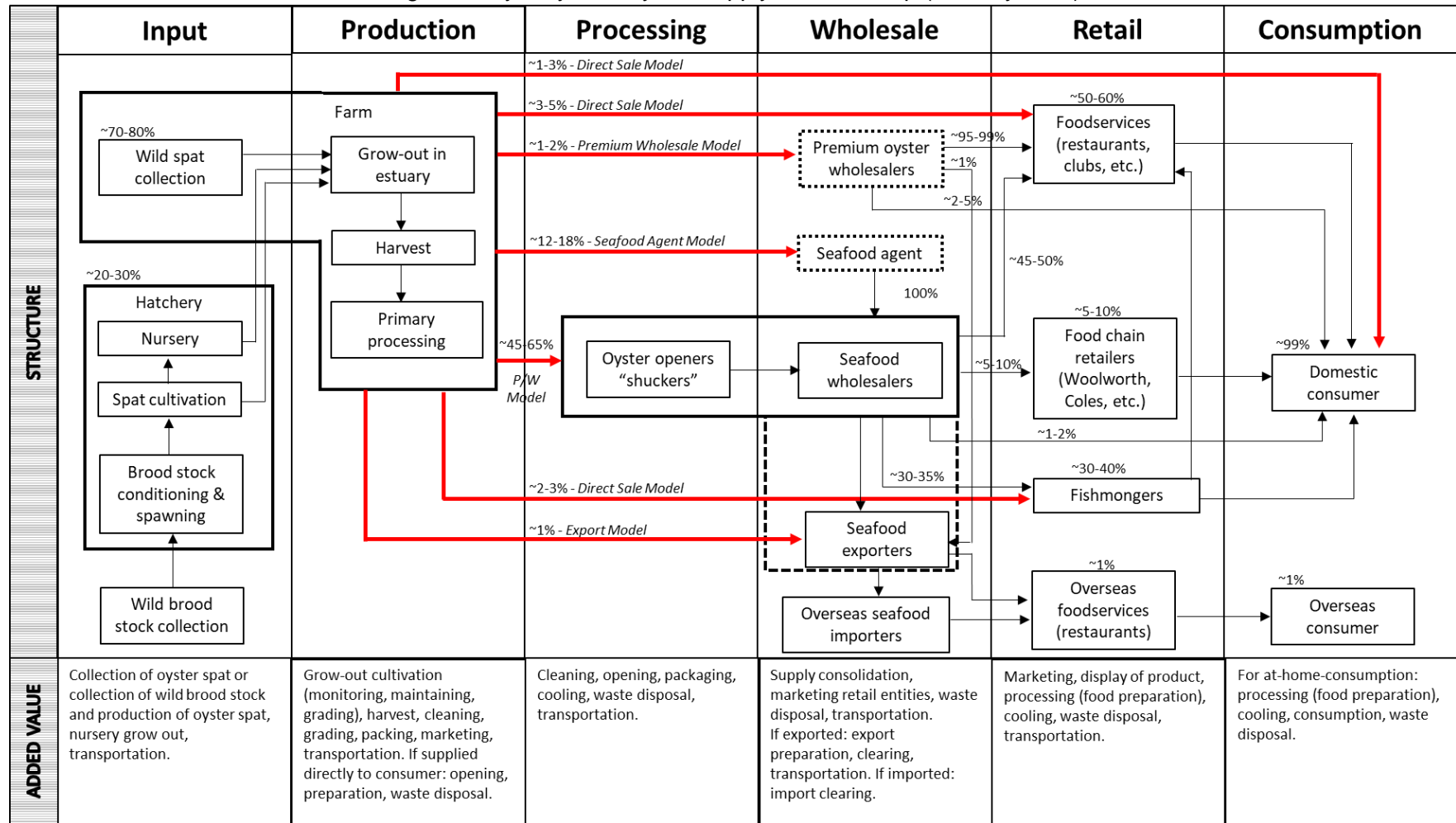
Figure 3 presents a map of the SRO supply chain at an industry level which was developed based on the conducted interviews.

The structure of the distribution network shows that about 70-80% of spat used for SRO cultivation is sourced by farmers from the wild. Only about 20-30% of spat used by the industry is from hatchery production. After cultivation, the spat is typically transferred to a nursery within the hatchery for maturing. Yet, there have also been reports that small spat (~1 millimeter in size) has been supplied directly from hatcheries to farmers who developed their own nursery system.

A form of vertical supply chain integration between input provision stage and production stage was evident for growers who collect their spat from the wild. The grow-out time for SROs to reach a market size is about 2.5 years, which is considerably longer than for POs that can reach market size within 12-18 months (Schrobback et al., 2014b).

After harvesting oysters, the farmers (depurate the oysters depending on lease location), clean, grade and pack/bag the oysters (primary processing) before transferring them to the product's first point of sale. Figure 3 shows that the industry has adopted different approaches (indicated by the red lines) to distribute their product from the farm to consumers, for example, direct sales to restaurants or consumers or supply through processors/wholesalers.

Figure 3: Sydney rock oyster supply network map (industry level)



Notes: Black boxes around multiple entities within the supply chains indicate integration of processes or entities. Black dotted boxes indicate brokers. Red lines indicate identified supply chain models and the estimated market share of respective model in the distribution of the product from the farm gate. "P/W Model" for Processor/Wholesaler model. Integrated corporate supply chain model which accounts for about 12-18% of oyster distribution is not included here, refer to Figure 8.

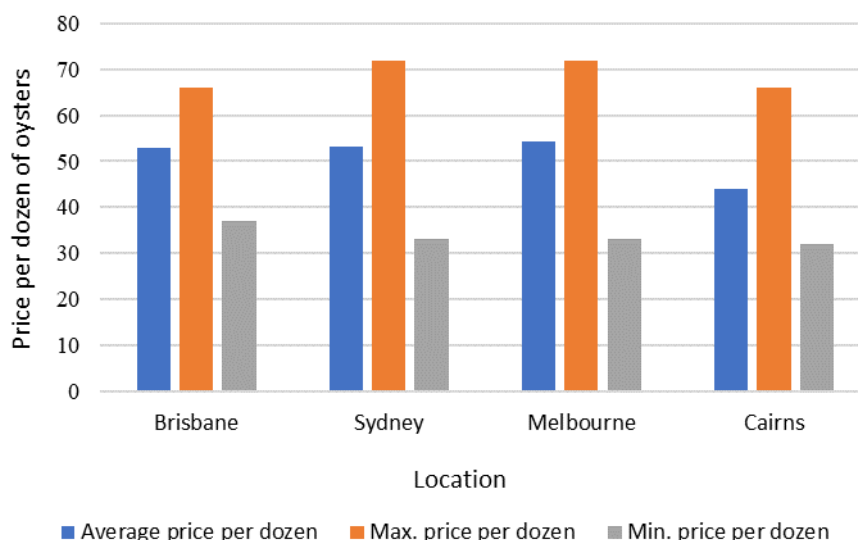
Most of these supply chain models rely on different types of entities in the wholesale segment of the supply chain and are associated with differing value chains. These models will be described in detail in section 3.3.2.

About 50-60% of SROs are sold through foodservices. This includes high-end fine dining restaurants but also less upmarket foodservice providers (e.g., pubs, clubs). The high dependence on foodservices in the retail segment of the supply chain can be considered as a risk within the distribution network of oysters.

The price per dozen oysters sold within the foodservice sectors varies significantly by type of foodservice as well as by location, ranging from \$32.00-\$72.00 (see Figure 4). It should be noted that the data presented in Figure 4 offers limited information about price differentiation between the SROs and POs on menus of foodservice providers. This is due to foodservice providers not being legally required to offer clear seafood labeling or to inform consumers about the species and origin of the seafood they purchase.

Food chain retailers (e.g., Woolworths and Coles) currently only play a minor role within the retail stage of the SRO supply chain, which confirms previous findings by Comiskey (2009). These retailers procure oyster supply from processors/wholesalers which are accredited according to the chain retailers' standards, e.g. Coles Supermarkets Supplies Approval Program, Woolworths Supplier Excellence Program. The advantage for food chain retailers to source oysters through processors/wholesalers includes a consolidated supply of cleaned, opened and packed oysters and economies of scale through procurement of multiple seafood types from accredited suppliers. The price per dozen of SROs sold through food chain retailers ranges from about \$16.00-19.00/dozen (Coles, 2019; Woolworths, 2019). The value that chain retailers add to the oyster product includes product transportation, marketing, display, and cooling. The relationship of food chain retailers with processors/wholesalers is spot market based.

Figure 4: Pricing of oysters at restaurants across Australia



Source: Data collected from menus on restaurant websites in August 2019. 20 samples per city were collected to derive the average price value except for Cairns where only 14 restaurants offered oysters on their online menu (total sample size was 74 restaurants). The selected major cities were chosen as these are considered as the main markets for SRO within Australia.

Fishmongers account for about 30-40% of oyster volume sold at the retail stage within the supply chain. The price for SROs sold through fishmongers ranges between \$17.00-24.50/dozen. Fishmongers sell their product directly to consumers either at the shop or online

and supply oysters to restaurants. The value that fishmongers add to the oyster product includes product transportation, marketing, display, food preparation suggestions, and cooling. The relationship of fishmongers to processors/wholesalers is commonly spot market-based, although in some cases a minimum volume order requirement from side of processors/wholesalers is required.

Only about 1% of SROs are exported. For export, oyster farmers typically transfer their product to certified seafood exporters which are commonly integrated in large processors/wholesaler entities. These certified seafood exporters condition the oyster product according to Australian seafood export regulations, and forward them to overseas seafood importers or directly to foodservice.

It is important to note that the distribution of the product within the SRO supply chain network, such as the physical movement of oysters from one entity within the chain to another, is handled by logistics providers (e.g., freight companies, couriers) or depending on consignment size and distance to the first point of sale within the chain by farmers directly. The logistics providers are not involved in the selling of the product within the chain, only in the transportation of the product.

3.3.2 SRO supply chain models and associated value chains

In this section, a detailed description of the observed supply chain models within the broader structure of the SRO supply chain (see Figure 3) will be provided as well as information about the value generated within these models. It should be noted that farmers tend to adopt one or multiple supply chain models simultaneously for different proportions and qualities of their total production volume.

Traditional processor/wholesaler model

The processor/wholesaler model is a supply chain model (see P/W model in Figure 3) which the SRO industry traditionally adopted to supply oysters to the market (Comiskey, 2009). The structure of this supply chain model illustrates that it relies on a relatively high number of entities which handle the oysters from its production input stage to the consumption stage.

In this model, processing and wholesale functions are integrated, meaning these entities clean, grade, open and package the oysters, consolidated supply and sell them either to foodservices, retailers, fishmongers or directly to consumers. About 45-65% of the total SRO production volume is currently sold by farmers through this supply chain model, which is evidence of its ongoing dominance. Interviewees mentioned that this proportion was previously much higher and has only changed in recent years with new entities becoming involved in the wholesale segment of the SRO supply network.

Within the processor/wholesaler sector the oysters are mostly treated as a bulk commodity due to the range of different product sizes (e.g., small, medium, large), qualities and quantities supplied by producers. Most of the processors/wholesalers are handling other seafood products. However, there are also processors/wholesalers within the chain which exclusively distribute oysters on a bulk commodity basis. Processors/wholesalers can also be accredited for export of seafood, including oysters. Hence, there is a degree of horizontal and vertical supply chain integration observable within the processing and wholesale stages of the SRO supply chain (see black box and black dashed box in Figure 3).

The contractual relationship between farmers and processors/wholesalers is typically spot market based. Farmers pointed out that they would not contemplate a more formal contractual relationship with a processor/wholesaler (e.g., forward selling volume based contract) as they consider this as business risk since production can be variable, e.g., closures of oyster areas due to high rainfall events or water quality issues occur on a regular basis which affects harvesting time.

The value chain of the processor/wholesaler model is presented in Figure 5, illustrating the change in the monetary value of the product within the supply chain. For SROs, the cost for production input varies depending on the type and size of spat is used. The farmgate price for oysters sold through this model during the 2019/20 production season was about \$6.60/dozen (small), \$9.00/dozen (medium), and \$10.40/dozen (large). Processors and wholesalers add a margin of approximately 20-30% and 40-50%, respectively, to the product price. The retail price of SROs sold through the traditional processor/wholesale mode varies according to the retail outlet, ranging from \$16.00-\$17.00 for chain retailers, \$17.00-24.50 for fish mongers and \$32.00-\$72.00 per dozen for restaurants.

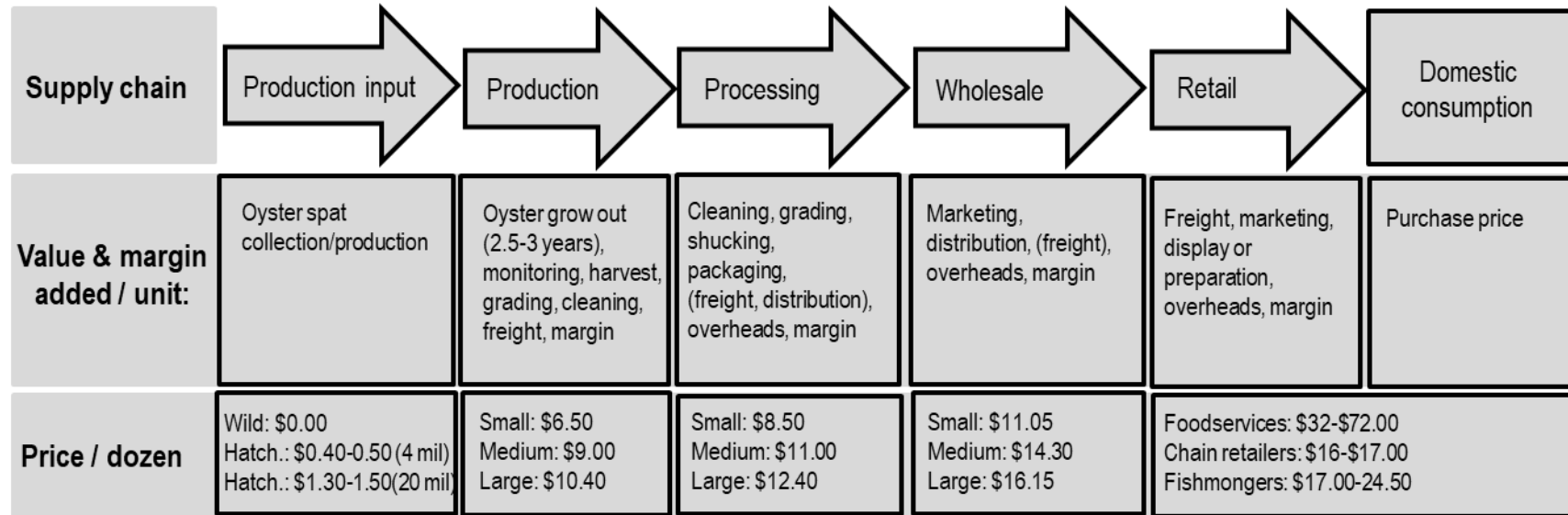
A reason for the large market share of the processor/wholesaler model in the broader supply network of oysters is the need for oysters to be opened before they can be consumed and the relative difficulty of this process for an unskilled person. Furthermore, most oyster producers are small to medium sized businesses and do not have the economies of scale to undertake the processing and distribution of their product to up-stream supply chain entities themselves. Another reason for farmers to choose the processor/wholesaler model is that some growers deliberately opt not to be involved in the marketing of their product as transaction costs of such activities are considered as very high (e.g., time, effort) or they consider themselves as not being skilled in the marketing of their product, hence they prefer to focus on the production of oysters. Farmers who sell their product through this model also mentioned that although they would be interested in exploring alternative supply chain models, they are concerned about how this would affect their trust-based long run relationship with their processor/wholesaler. Furthermore, stakeholders mentioned that the channeling of bulk oyster volumes through processors/wholesalers ensures a constant cash flow which is important for small and medium-sized farming businesses. This suggests that longstanding relationships and associated risk considerations (e.g., trust in timely cash flow) affect farmers' decisions about the continued use of this traditional supply chain model.

Transparency in regard to product flow and value creation within the processor/wholesaler supply chain model was perceived by farmers as very limited, confirming previous findings by Comiskey (2009). Farmers also mentioned the low level of product traceability in this model offers the potential for seafood fraud (e.g., mixing batches of oysters from different farmers and selling them under incorrect labels). It was also mentioned that processors/wholesalers tend not to sell the product in a promotional way and that they act as gatekeepers. Due to the lack of incentives to promote the oyster product processor/wholesaler appear to contribute a limited value in increasing the market for SROs, e.g., increasing consumer experience, farmgate prices, or increasing transparency.

Export supply chain model

A very minor volume of SROs is currently exported (about 1% of total production), mainly to Singapore and Hong Kong. The export supply chain of SROs (see Figure 1) includes farmers who transfer their product to certified seafood exporters (processor/wholesaler). The export supply chain model can be integrated within the traditional processor/wholesaler model depending on whether a processor/wholesaler holds seafood export certification or not. In Australia fish and fish products for export as food must be prepared at an establishment that is registered in respect of the operations for the preparation of the fish and fish products undertaken (Australian Government, 2005). These certified exporters pack the product according to Australian seafood export regulations and from there the product is sent overseas (typically via air). Overseas seafood importers receive the product, obtain local import clearance and from there the product is transferred to the restaurants. Unfortunately, participants were unable to provide information about export prices and current value created within the export supply chain model. The respondents mostly agreed that there is potential in expanding the export volume of SRO. More details about their perceived barriers and opportunities for the export of oysters are outlined in section 3.3.3.

Figure 5: Value chain within the traditional processor/wholesaler supply chain model



Sources: ID2, ID3, ID4, ID11, ID12, ID17, ID20, Coles (2019), Woolworths (2019), Frank's Seafood (2019). Notes: Cost of labour associated with catching spat in the wild was not estimated. Price data for foodservice was collected from menus on restaurant websites in August 2019. Average price are provided for the production, processing, and wholesale segments of the value chain.

Seafood agent supply chain model

The seafood agent supply chain model (see Figure 3) is a relatively new model established in 2014 within the broader SRO supply chain structure. Participants mentioned that this distribution model has significantly gained market share since 2017. Although the seafood agent supply chain model had been adopted historically in other seafood industries seafood agents were previously not interested in representing SRO farmers. This situation changed in 2014 when a group of SRO farmers collaboratively approached a leading aquaculture seafood agent with the request to market their oysters within the domestic market.

Within this distribution model, the agent acts as a marketing institution or broker (illustrated by the dotted box in Figure 3), by linking up all entities within this supply chain models including freight companies. The the agent sources the product from farmers on a spot-market basis and based on product grading standards. Processors/wholesalers are a part of this supply chain model since the seafood agent model handles bulk volumes of oysters which need to be opened before being distributed to upstream entities within the chain. From the processor/wholesaler stage the oysters are distributed using similar market channels as in the processor/wholesaler supply chain model, hence the seafood agent model exemplifies a relatively long supply chain (see Figure 3). Within the agent model, there is currently no export of SROs. The seafood agent model currently has an estimated market share of 12-18% of the total SRO production volume.

Seafood agents are typically specialised in market research to ensure demand and supply of the seafood product can be matched at the highest margin for the seller. The agent has a self-interest in brokering deals that favor producers, e.g., high farmgate prices, since this supply chain entity is commonly acting on a commission basis of about 5%, which farmers pay the agent per consignment volume. The farmgate price of oysters sold through this model was around \$11.00/dozen for medium sized oysters during the 2019/20 production season. Unfortunately, information about farm gate prices for small and large oysters was not made available. The processor and wholesaler margins as well as retail margins of the seafood agent value chain can be assumed to be similar to the processor/wholesaler value chain (see Figure 5) considering the structure of the agent supply chain model.

The level of communication among entities within this model is considered to be relatively high compared to the processor/wholesaler model. This also leads to an increase in supply chain transparency from the perspective of farmers as they gain access to information about where their product is sold to, and conversely the retail sector receives information about the origin of the product. This is seen as an important advantage over the processor/wholesaler supply chain model. Within this supply chain model, the agent has more price negotiation power than individual farmers due to the consolidated supply that this entity represents and due to the access to seafood market information and professional marketing skills.

Premium oyster wholesale supply chain model

The premium oyster wholesale model can be differentiated from the traditional processor/wholesale model since it exclusively focusses on the sourcing, brokering and distributing oysters of premium quality (see dotted box in Figure 3). The model was introduced to the broader oyster supply chain network in 2015 in response to low farmgate prices for oysters and farmer's limited negotiation power within the dominant processor/wholesale model. The model's current market share of the volume traded with within the wholesale stage of the oyster supply chain is estimated at about 1-2%.

In this model, the role of the premium oyster wholesaler is to establish links between fine-dining restaurants and farmers and to broker supply and demand for premium quality oysters between these entities. A very small volume of oysters is exported through this model.

The premium oyster wholesaler established a brand under which oysters from selected independent farmers are sold. This requires a continuous assessment of product quality by the wholesaler to ensure brand continuity. Different to the agent model, the premium oyster wholesaler purchases the oysters from farmers and either requests farmers to send the product directly to restaurants or alternatively consolidates supply from different farmers at a hub, processes and packages the product and distributes it to customers. Hence, this supply chain model is slightly shorter due to fewer entities being involved in handling the product. The relationship between farmers and the premium oyster wholesalers is spot market and trust based. The same applies to the relationship between the premium oyster wholesaler and its customers.

The value chain of the premium oyster wholesale model is presented in Figure 6. Farmers who adopted this supply chain model for their premium product receive a relatively high price for their product of about \$11.00-12.00/dozen. Yet, within this model farmers also receive the added value of marketing for their product (e.g., individual farmer profile on the website of the wholesaler, individual farmer profile cards) which helps to improve product traceability within the chain and contributes to consumer awareness/education. Given that the premium oyster wholesale model focusses on the supply of high quality oysters to fine-dining foodservices it is likely that the actual average value of oysters sold through this supply chain model can be found within the higher price scale of the provided range in Figure 6 (e.g., \$54.00-72.00/dozen).

Direct sale supply chain model

The direct sale of oysters is a supply chain model that has been adopted by the industry traditionally. This model involves the sale of oysters directly from the farm to either consumers, food service providers (e.g., local restaurants, urban fine dining establishments) or fishmongers (see Figure 1). The direct distribution of SROs to consumers includes sale at seafood festivals, on-farm sales at oyster bars or farm tours, as well as oyster shucking events. There is typically a spot-market based relationship established between farmers and their customers. Approximately 6-11% of the total SRO production volume is currently distributed through this model. This model represents the shortest supply chain within the broader oyster distribution network and has the potential to offer consumers the freshest products.

Figure 7 illustrates the value chain of this distribution model. The farmgate price for direct oyster sales depends on the market outlet and the size and quality of oysters. For example, the average price of oysters sold to local restaurants ranged from \$7.00/dozen (medium) to \$15.00 (large), while premium oysters may be sold for \$15.00 to \$30.00/dozen to fine dining restaurants in metropolitan areas. Shucking events attract prices of up to \$4.50-\$5.00/oyster. Direct sale of oysters is considered as an added value to improve supply chain transparency, product traceability, consumer awareness and promotion of the individual oyster business as well as the oyster region.

Yet, the direct sale of oysters is associated with high transaction costs such as time and effort to build and maintain relationships with restaurants and consumers, as well as the continuous search for market information. Within this model farmers are required to balance time required to produce oysters and the marketing/branding and distribution of their product. This also requires the ability to engage with existing and potential customers as well as to provide marketing skills. The high transaction costs linked to the direct supply chain model may explain the relatively low market share of this distribution model.

Integrated corporate supply chain model

A further variant of the SRO distribution network is the integrated corporate supply chain model which was established in 2015 (Figure 8). This model differs significantly from the supply chain models described above (Figure 3) as it holds features of a both horizontally and vertically

integrated distribution network. The model is currently only adopted by one corporate entity within the SRO industry.

The integrated corporate supply chain model builds on a corporate structure in which shares in the corporation are held by private equity investors, corporate management, and a number of individual farmers located across several oyster-growing estuaries in NSW. While the corporation focusses on the production and distribution of three oyster species, which are the SRO, PO and the FO, the SRO remains the major commercial species produced and supplied to the market.

Within this model some of the incorporated oyster farmers produce oyster spat on farm-based hatcheries, yet, spat is also caught wild and bought in from commercial hatcheries. The integration of several oyster farms into one corporate model ensures a consolidated supply of oysters which helps to manage the supply volatility within the market. The supply of oysters through this model is also supplemented by a buy-in of oysters from independent oyster farmers on a spot-market basis which the corporation then sell under their brand and under the condition that the product complies with the corporation's quality standards.

This distribution model also includes processing (e.g., grading, cleaning, packaging) and wholesale functions which together with its production input and production segments form a vertically and horizontally integrated supply network. The supply chain model focusses on branding and marketing of the oyster product to different retail outlets.

The corporation has developed a "hub and spoke" distribution model in which the product is consolidated in different collection points, the "hubs", from where it is then distributed to the retail entities. Like for the supply chain models presented above, distributors (e.g., freight companies) are typically not involved in the selling of the product and only handle the logistics of the market supply. The relationship between the corporation and their customers is mostly trust and spot-market based, although larger foodservice customers, such as hotel chains prefer contract-based agreements with fixed prices and product volumes. Unfortunately, information about farmgate prices within the integrated corporate supply chain model was not made available due to commercial confidentiality.

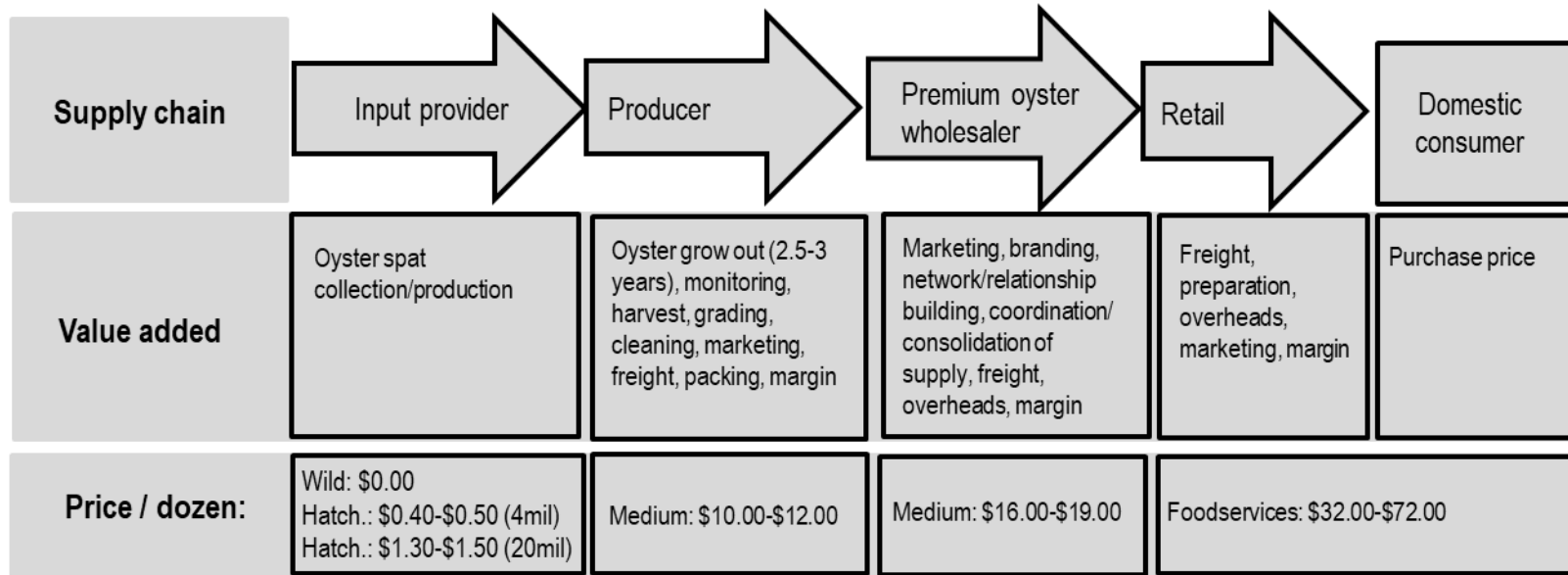
It is estimated that approximately 12-18% of the total SRO production volume is currently traded through this model. The development of this type of supply chain requires significant capital investment (e.g., farm infrastructure, processing infrastructure), skilled labour, marketing/branding and technology.

Summary

The findings from the stakeholder interviews confirm that the SRO industry has experienced a significant change in the way it distributes its product from the farm to consumers. Reasons for increasing competition within the wholesale stage of the supply chain were farmer's dissatisfaction with the dominant traditional processor/wholesale model, increasing availability of information about the adoption of alternative distribution models in other countries, and increasing consumer demand for the product. The findings also show that the shift away from the traditional processor/wholesale model required the initiative by the industry to either develop or support the adoption of alternative supply chain approaches. The diversification of adopted supply chain models also suggests that farmers are increasingly seeking a competitive advantage through supply chain differentiation.

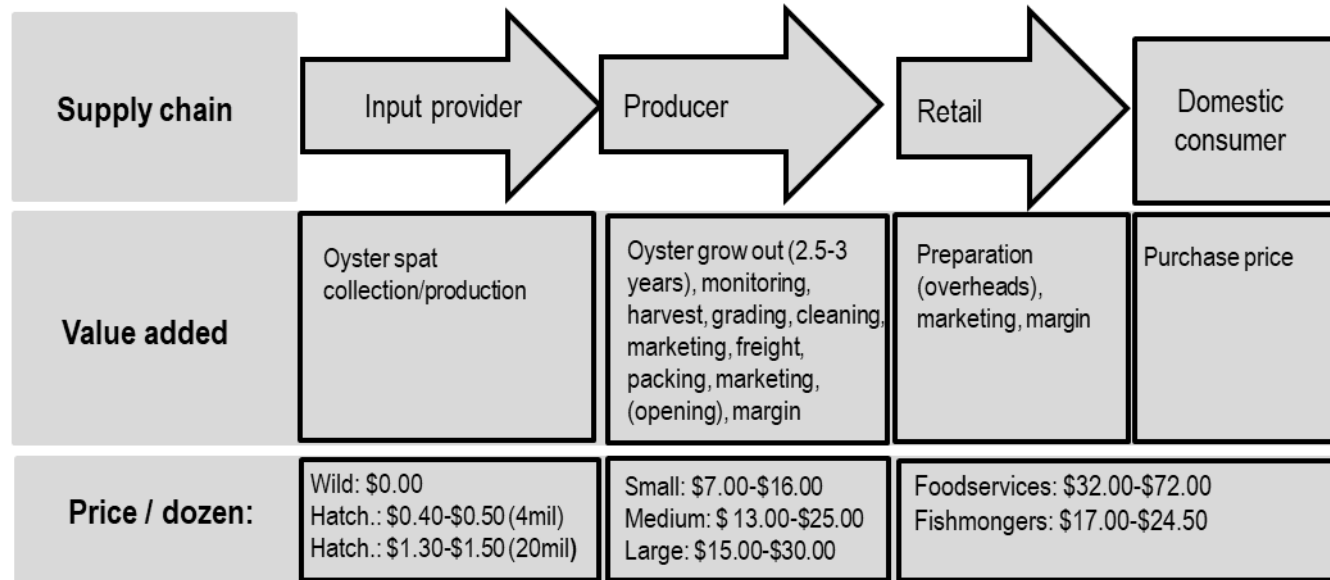
The decision about which supply chain model to adopt is made by the individual oyster farmer and is typically guided by the costs (e.g., transaction costs such as search cost, access to market information; marketing skills, product size and quality, freight costs) and benefits (e.g., higher farmgate price, marketing/promotion) which farmers perceive for different market approaches (e.g., direct sale vs. sale to processors/wholesalers).

Figure 6: Value chain of within the premium oyster wholesale supply chain model



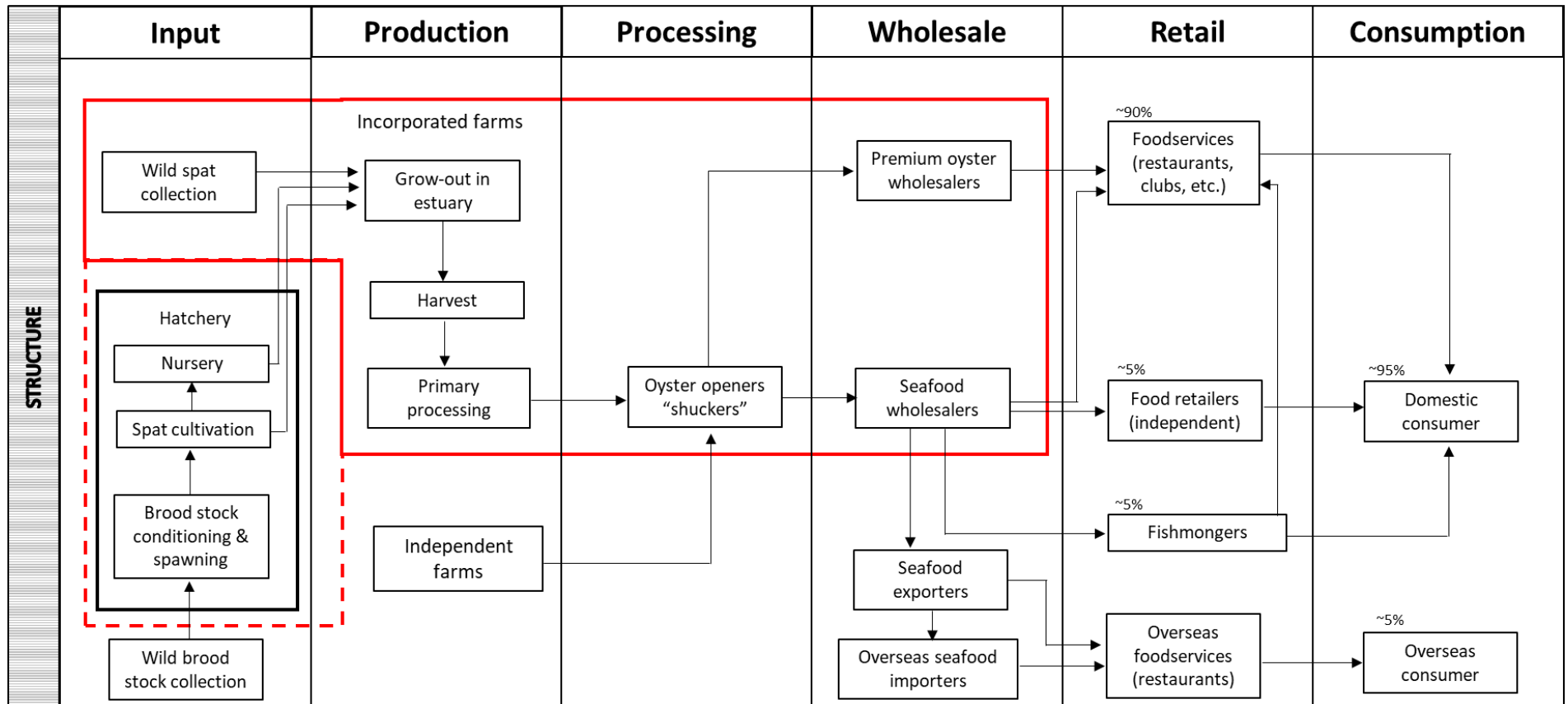
Sources: ID4, ID5, ID26. Note: Cost of labour associated with catching spat in the wild was not estimated.

Figure 7: Value chain of the direct sale supply chain model



Source: ID19, ID23, ID26 and online sources. Notes: Cost of labour associated with catching spat in the wild was not estimated. Excludes values for direct sale shucking events at which oysters are sold for up to \$4.00-\$5.00 per oyster.

Figure 8: Integrated corporate supply chain model



Sources: ID8, ID30

Although a value chain could not be derived for all presented models, the results suggest that farm gate prices may only differ slightly across the identified models, except for the direct sale model which revealed a higher farmgate sale price for oysters that are supplied directly from producers to fine-dining restaurants. However, it appears evident that the models which were introduced more recently (e.g., agent model, premium wholesale model and integrated corporate model) focus on value-adding such as branding, marketing, the developments of linkages, and communication within the chain which increases transparency and information flow among all entities. Producers likely consider these value-adding activities as benefits supporting their decision to adopt these new supply chain approaches.

3.3.3 Issues and opportunities associated with the SRO supply chain

As part of the interviews, stakeholders of the SRO industry were asked about the issues and opportunities that they perceive in relation to the distribution network. The major themes which were identified based on the responses are summarised in this section.

Hatchery spat supply

An issue which was raised repeatedly by the stakeholders of the SRO industry was the lack of reliable supply of hatchery spat as an input to oyster production. Farmers appear to be interested in using selectively bred oyster spat as a production input for a number of advantages (e.g., improved quality over wild collected spat, disease resistance, flexibility in the timing of commencing oyster grow-out) of using this type of spat. Hatcheries seem to grapple with the scientific challenges of reliably producing selected lines for SRO. It was mentioned that more research is needed to improve the existing hatchery protocols for SROs to ensure more consistent supply of selectively bred hatchery spat supply. Furthermore, participants mentioned that communication and coordination between farmers and hatchery operators about demand and supply of spat requires improvement. Given the relatively large interest in hatchery spat production, its potential economic advantages and the current issues in this segment of the supply chain there appears to be a commercial opportunity for investors to become involved in producing reliable supply of oyster spat.

Production risks

Participants mentioned that risks, such as disease, water quality, high volume rainfall events, are ongoing concerns that can potentially impact production and subsequently lead to supply chain disruption.

Product marketing/branding

SRO supply chain stakeholders mentioned that the marketing of SROs has improved over recent years, particularly with new supply chain models being established within the industry. However, interviewees agreed that marketing and branding of SROs within the domestic and export market can be further. Better marketing of the product needs to include consumer and chef education (e.g., master classes, promotional material that can help with forward selling the product within the food service sector). For example, farmers mentioned that consumers should be better informed about how oysters are eaten best, how to identify a good oyster, and how and where oysters are grown. Interviewees suggested that this could be achieved through a national marketing initiative like the “Love Prawns” marketing campaign which was developed collaboratively by the Australian prawn industry. It was also mentioned that consumers and chefs need to be educated about the unique characteristics of the SRO as a species that only occurs in Australia compared to the PO which is cultivated in many other countries. Marketing slogans such as “Sydney rock oysters: Australia’s great secret”, “Bigger isn’t better in the oyster world” or “Favor the flavor: Always insist on Sydney rock oysters” were suggested. Yet, to implement a national marketing initiative for SROs a collaborative approach of farmers would be required. The participants also raised concerns about options for funding such an industry-wide marketing initiative and noted that farmers may not support such an

initiative if funds would be raised through an additional industry levy. Hence, alternative funding options, leadership and collaborative participation would be needed to develop an industry-wide marketing campaign with the aim of raising consumer awareness.

Sustainability

Farmers emphasised that they consider the production of SROs as sustainable since oysters are filter feeding organisms (e.g., filtering of nutrients) which contribute to improved water quality in estuaries. Furthermore, farmers highlighted the industry's efforts over the past decade in removing old, wooden grow-out furniture from the leases and to replace these by non-degradable plastic and off-bottom infrastructure which contribute to minimising the negative impacts of oyster cultivation on the estuarine ecosystem. Although some farmers have opted organic certification for their product, most of the producers currently do not consider sustainability certification as offering a net benefit for their business. This is mostly due to the relatively high costs involved in obtaining and maintaining the certification. However, farmers agreed that the sustainable production process of oysters should be promoted to consumers.

Product traceability

Product traceability was another issue which was raised by the interviewees. SRO supply chain stakeholders agreed that traceability within most supply chain models is limited at the present, particularly within the processor/wholesaler model. Stakeholders agreed that improved product traceability, for example through quick response (QR) coding or blockchain technology, would be beneficial from their perspective to ensure supply chain integrity and as a source of information about product handling at different stages within the chain, particularly in case a food safety issue occurs. Improved traceability would also enhance consumer's ability to obtain information about where the oysters were produced and when the product was harvested. Stakeholders were concerned about the potential high costs involved in establishing such a system for small and medium sized farming businesses which they considered as a disincentive for the adoption of a traceable technology in the absence of any regulatory requirements. It was also argued that a first step towards enhanced seafood traceability would be to improve seafood labeling requirements within the foodservice sector in Australia which are currently exempt from providing information about the origin and species to consumers. Participants mentioned that in the absence of food labeling requirements for foodservice providers, shorter supply chains are beneficial, as producers can build direct trust-based relationships with their retail customers which can incentivise chefs to promote provenance information to consumers.

Export

The interviewed farmer stated that the main reasons for the very low export volume of SROs are the strong and favorable domestic market and the high transaction costs (e.g., search costs, getting access to market information) associated with developing an export supply chain. Yet, participants also mentioned that there is potential for increasing the export volume of SROs to Asia, particularly in a situation in which the market supply of POs increases which may lead to falling domestic prices for SROs. A concern of producers with respect to expanding the export of SROs was that consistent product supply cannot be guaranteed without considerable supply consolidation for oyster export.

A further concern in relation to the export of oysters is the need to improve the branding and marketing of the SROs compared to the POs which is sold in relatively large quantities in export markets (e.g., Singapore, Hong Kong, Japan). Since the SRO is typically smaller than the PO the demand for smaller oysters needs to be created in the Asian seafood market through targeted marketing to justify similar pricing to POs. Highlighting the uniqueness of the SRO, which is only grown in Australia, could be one aspect to be considered in the development of an export branding/marketing strategy. A demand analysis of Asian

consumers' perceptions of the SRO compared to POs or similar seafood could provide useful insights that can inform such a strategy.

Furthermore, trustworthy relationships with seafood wholesalers overseas which can manage the import of oysters (e.g., safe handling, biosecurity clearance) need to be developed. These are tasks that are associated with high transaction costs to individual farmers and potentially require the assistance from oyster and seafood industry bodies or Australian trade organisations. It was also mentioned that it is difficult for farmers to access information about the seafood markets in Asia which may be another barrier for exploring export opportunities of SROs. This highlights the need to engage with Australian trade organizations should the industry intend to expand its export to Asia in future.

Access to financial capital

The interviews also revealed that access to capital remains an issue, particularly for small and medium sized oyster farmers. The lack of access to capital is seen as entry and exit barriers to the oyster industry. Potential new farmers struggle to get a loan from banks since oyster leases and existing lease assists are not considered as security against which financial institutions will lend capital. The issue of capital access as an entry barrier to the industry also affects the exit of farmers from the industry, as in some cases there is a lack of demand for taking over existing oyster farms from growers who wish to retire. However, participants also mentioned that there are oyster farming businesses in the industry which successfully raised financial capital based on the business model (e.g., shareholder model) that they adopted. Hence, innovative business model ideas may be an option for farmers to attract investors. It was also mentioned that with better marketing of the industry, private investors may be attracted in future.

Relationship with processors/wholesalers

SRO industry stakeholders considered the dominant role of the processor/wholesale supply chain model as an issue regarding the creation of an added value within the chain as well as having price negotiation power over farmers (see section 3.3.2). For this model to improve, the current lack of transparency should be addressed by transformation into win-win relationship for all entities within the network. This may require improved collaboration throughout the processor/wholesaler supply chain. Participants mentioned that one approach for encouraging processors/wholesalers to contribute more to value creation within the chain would be to create consumer demand for improved product traceability through the foodservice sector. This may pressure on processors/wholesalers to better engage in value creation for the product. However, to identify further solutions that address this issue, more focused consultations with stakeholders are required.

3.4 The flat oyster supply and value chain

The native FO occurred in relative abundance during the 19th and 20th century in south-east coasts of Australia, yet, severe exploitation of FO reefs, including dredging from the seabed, resulted in a significant reduction in the natural occurrence of this oyster species (Nell, 2001; South Australian Chronicle and Weekly Mail, 1868). In recent years, a small number of oyster farmers in SA, TAS and NSW have started growing FOs on an experimental or small commercial basis to diversify their aquaculture business.

For this study, interviews were only conducted with FO farmers in NSW where the total production volume of FOs was relatively small with production of 3,715 dozen at a total value of \$46,510 in 2018/19 (NSW DPI, 2020). None of the interviewees was producing FOs exclusively. The interviews revealed that FO farmers in this state almost entirely rely on hatchery spat supply as a production input (see Figure 9) The NSW Government has invested into hatchery production of seed oysters for this species in recent years to support farmer's diversification of oyster production (NSW Department of Primary Industries, 2020). The

interviewees confirmed that the spat for this oyster species appears to be more easily produced in a hatchery environment compared to SROs which explains the readily available supply of FO spat. Participants also mentioned that FO producers in TAS and SA predominantly use wild FO spat due to a higher abundance of oyster reefs in these regions (Mitchell et al., 2000). There were also reports indicating that farmers have established small scale on-farm hatcheries for FOs in NSW (NSW Department of Primary Industries, 2020).

Like other oyster species, the juvenile FOs are transferred into grow-out furniture (e.g., floating baskets), following its nursery development stage. FOs thrive best in estuaries that offer high salinity conditions and limited freshwater inflow, which limits the number of suitable growing areas.

FOs are grown on existing intertidal leases developed for SROs or POs cultivation but were found to grow faster in suspended culture on deeper sub-tidal leases (NSW Department of Primary Industries, 2020).

Yet, the cultivation of FOs also appears to be difficult (“They are a tingly thing to grow. [...] They are not as hardy as the SROs. [...] They don’t like to be out of the water.”) which may explain why most oyster farmers whose leases are located in suitable estuaries for FO cultivation prefer to keep their focus on producing either SROs or POs.

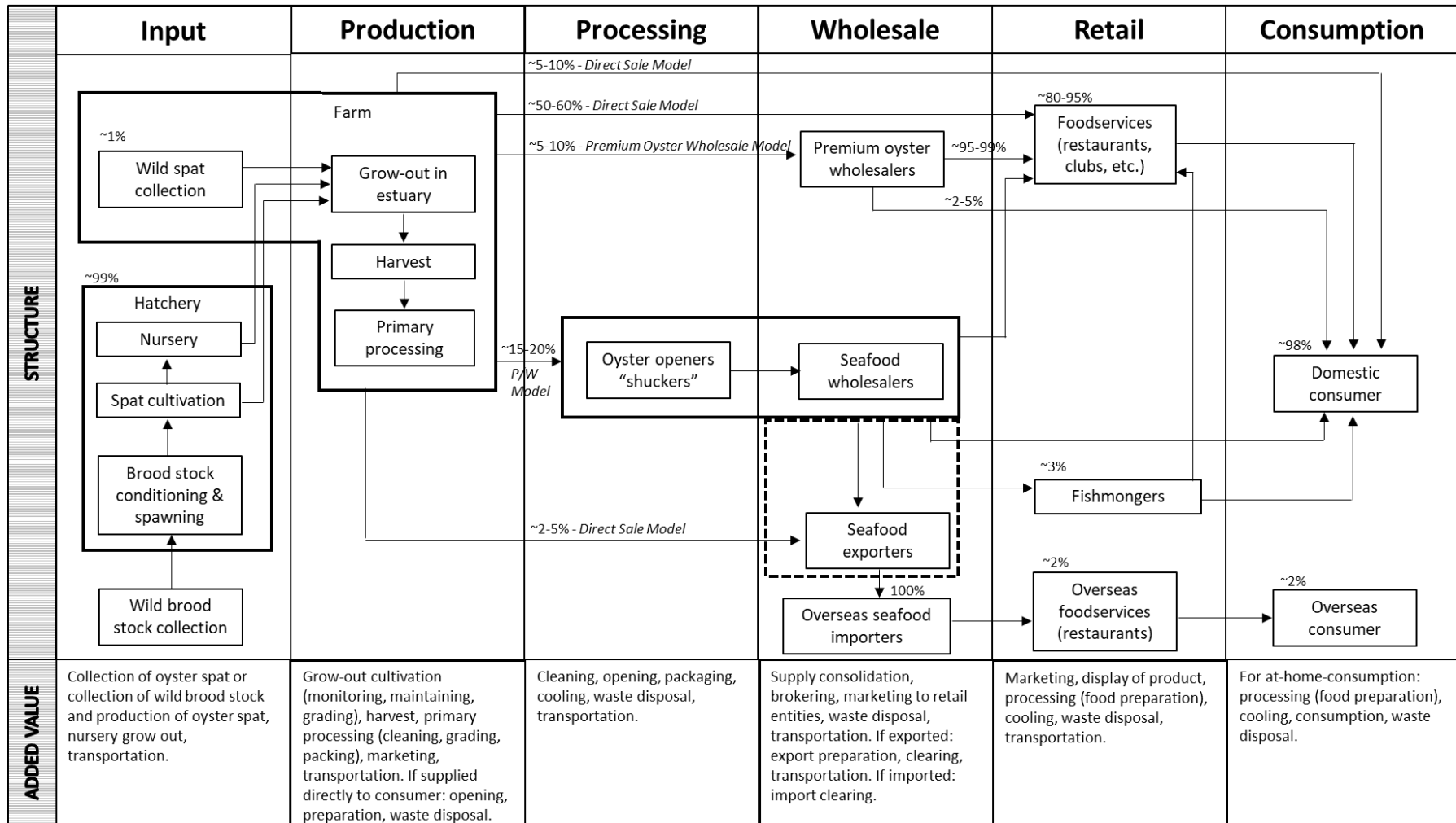
In the past FO production was affected by *Bonamia sp.*, a parasitic protozoan, which also affected flat oyster populations in other parts of the world (Mitchell et al., 2000; Nell, 2001). The FO can grow into a marketable size within 18-24 months, yet, its shelf-life is relatively short with only 5-7 days compared to the shelf-life of SROs (10-14 days).

The taste profile of FOs is considered as significantly different (“They got a rich, beefy, meat pie taste”) compared to the taste profile of SROs and POs. A reason why the consumer demand for this oyster species in Australia is relatively low may be attributed to Australian consumer’s palate preference for SROs and POs. Yet, interviewees also mentioned that there is the potential to develop the domestic market for FOs further as consumers become more aware of this native oyster species. On the hand, participants stated that Asian consumers appear to be interested in the taste profile of FOs which suggests that there may be room to create demand within the Asian consumer segment in Australian for this seafood product and to further develop an export market in Asia.

Value chains for FOs are presented in Figure 10 and Figure 11. The values show that farmgate prices per dozen are significantly higher for FOs compared to SROs (see Figure 5, Figure 6, Figure 7). This is most likely a reflection of the limited supply and the niche market for this seafood product. Although FOs generally attract higher farmgate prices than the SRO, within the fine dining restaurant sector it is sold for a similar price as SROs (e.g., \$4.50-5.50 per oyster) (Fred’s, 2020; Saint Peters, 2020; The Boathouse, 2020).

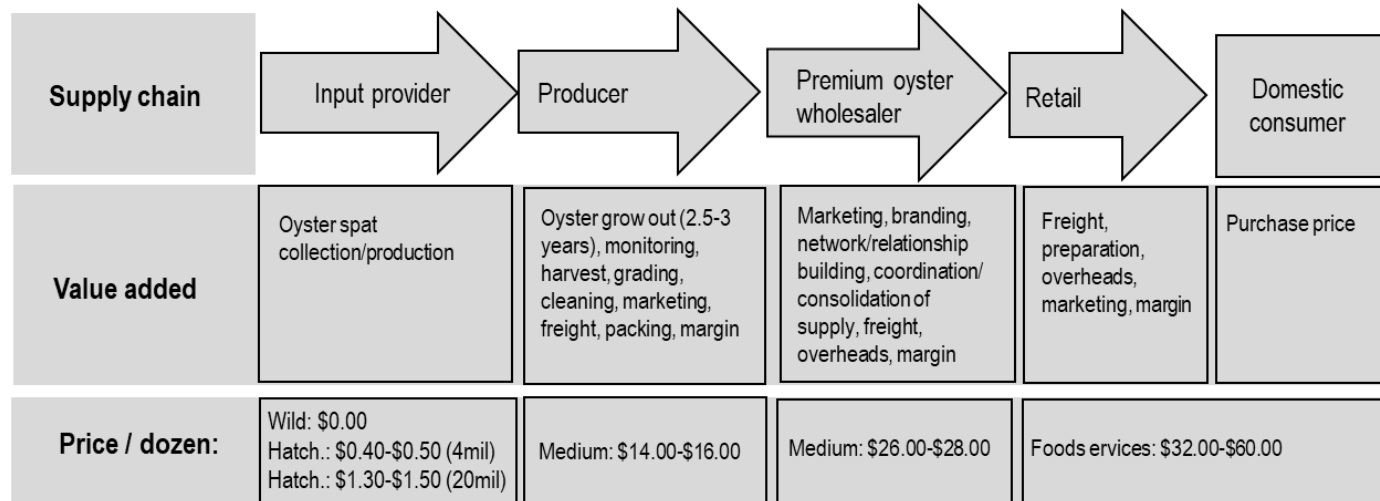
In summary, FOs can be considered as a boutique oyster product which is currently targeting a niche market in Australia due to its distinct taste and its low production volume. While the consumer demand for this oyster species in Australia could be boosted through increased marketing, it is likely that an future increase in the supply of this oyster species will be hampered by limited areas that offer suitable production conditions in which this species thrives. Hence, it is possible that with potential increasing demand for FOs and a small but stable supply volume the farmgate price for this species may increase in future. However, it appears unlikely that FO cultivation will reach the scale of SRO production in NSW so it will remain an option for small scale business diversification.

Figure 9: Flat oyster supply network map



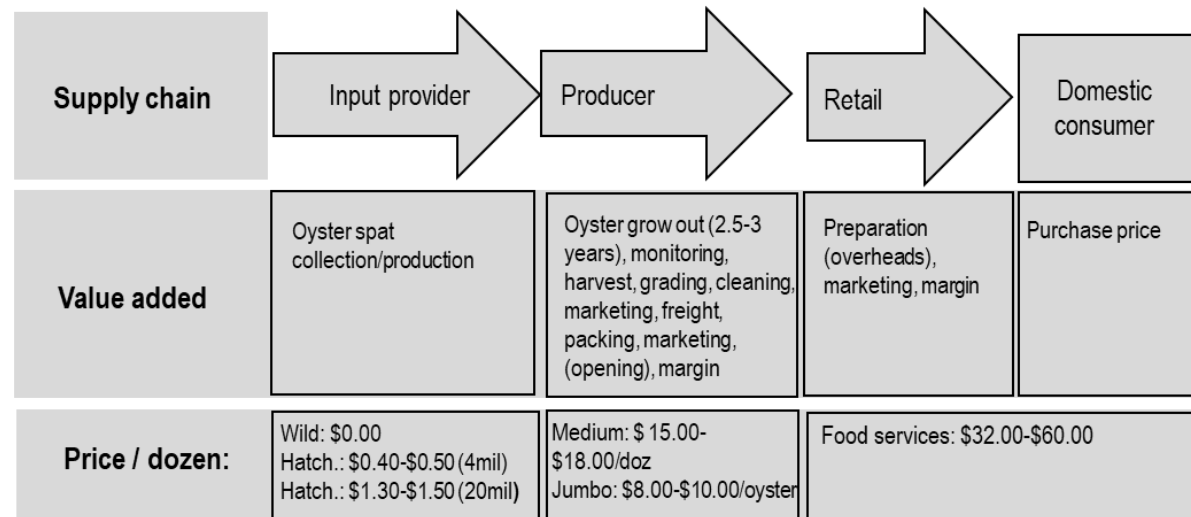
Notes: The map only represents the supply chain structure of FOs produced on NSW. FOs are also distributed through the integrated corporate supply chain model like SROs (see Figure 8).

Figure 10: Value for flat oysters – Premium oyster wholesale model



Sources: ID5, The Boathouse (2020), Saint Peters (2020), Fred's (2020). Note: Cost of labour associated with catching spat in the wild was not estimated.

Figure 11: Value for flat oysters – Direct sale model



Sources: ID25, ID30, The Boathouse (2020), Saint Peters (2020), Fred's (2020). Notes: Cost of labour associated with catching spat in the wild was not estimated.

4 Discussion

Summary and discussion of results

The aims of this study were to explore the development status of the BLO oyster supply chain, to map and describe supply and value chains of oyster species which are currently produced in temperate regions of Australia, and to identify potential issues and opportunities associated with these supply chains.

The findings suggest that the development of the BLO industry is at an early stage. The commercial production of this oyster species is currently very small. A range of critical factors were identified which need to be addressed to progress the development of this tropical oyster industry, including:

- the current lack of hatchery protocols for this oyster species which would allow a commercial production of BLO spat as a fundamental input to production;
- a need for further research into oyster species categorization, potential pest and diseases as well as methods to optimize production systems;
- the need to amend food safety policies/standards to reflect requirements for tropical shellfish;
- demand analysis for BLOs to determine potential domestic markets for this oyster species.

The assessment of the FO supply and value chain in NSW suggests that this supply network is more mature than the distribution network of BLOs. The FO can be considered as a niche product due to its distinct taste and low production volume. Although hatchery spat seems to be readily available for this species, the specific environmental and spatial production conditions needed for FOs to thrive appear to be limited, hampering potential expansion of supply for this species. The limited consumer awareness about FOs and subsequently constrained demand for this species was raised as an area for improvement. Considering the current production volume of this oyster species, the supply network for FOs appears to be relatively well developed. This is not surprising as this species is grown by farmers in NSW who typically produce SROs; hence, producers may be aware about supply chain options for FO from their experience with the other oyster species.

The assessment of the supply chains for BLOs and FOs revealed similarities between both networks, such as the requirement for hatcheries to provide spat as an production input, the current low production volume and the need to further develop the market for these aquaculture products. Since the FO is currently supplying a fine-dining niche market, this could also be a potential target market for the BLO industry.

Given the commercial scale of the SRO industry, its long history and the relatively complex and mature supply chain, the existing literature and conducted interviews offered substantially more information about this oyster distribution network compared to BLOs and FOs. The assessment of the SRO supply network identified a range of distribution models which farmers have adopted to transfer their product from the farm to consumers. The traditional processor/wholesaler supply chain model appears to remain the dominant distribution approach, but which seems to offer farmers the lowest average farm gate price and the creation of limited added value such as marketing or product traceability. Yet, more competition within the wholesale stage of the SRO supply chain in recent years has contributed to increasing the value being created within the network, mainly through improved marketing of the oyster product to raise consumer awareness. The analysis of the retail segment of the SRO supply chain revealed a high dependence on the distribution of oysters through the domestic foodservice sector which carries high risks for the supply of the product

in case of disruptions that affect this retail entity. The market for SROs is almost exclusively domestic due to issues surrounding supply consolidation and export market access. Interestingly, farmers appear to have adopted more innovative supply chain models in recent times in response to issues which they associated with the dominant traditional processor/wholesale model (e.g., limited price negotiation power, lack of transparency). Hence, the motives for change within the broader supply structure were likely driven by farmer's aims to increase their business profits, ensure consumer satisfaction and to expand the market for SROs.

These findings about the structure of the SRO supply chain differ from previous studies for this seafood species (e.g., Comiskey, 2009; Plagányi et al., 2014). The main reasons for this are that the changes to the supply network of SROs since new distribution channels were adopted by farmers only occurred after (around 2015) the earlier studies were conducted.

A range of issues and opportunities were identified from the collected data about the SRO supply chain; for example, there appears to be a need to improve the commercial hatchery spat supply as an input to oyster production. Furthermore, better marketing to improve consumer awareness about SROs as well as the need for more collaboration within the chain to add value to satisfy consumer expectations will remain important in future. Raising the profile of the SRO industry collectively may also assist in increasing its attractiveness from the perspective of potential capital investors.

Product traceability and product assurance is an area which the interviewed supply chain stakeholders considered as becoming increasingly important. This is supported by the broader literature which suggests that seafood producers, consumers and regulators worldwide are recognizing the benefits of traceability along seafood supply chains (e.g., e.g., He, 2018; Leal et al., 2015; Sterling et al., 2015). Yet, for oysters sold in Australia it appears improvement is needed to enhance the product traceability. It was suggested that mandatory seafood labeling for the foodservice sector would be an option to offer consumers improved information about the oysters they purchase. Yet, to achieve a change in seafood labeling regulation in Australia which would benefit producers and consumers, the oyster industry collectively with other seafood industries will need to continue raising this issue with policy makers. Other options to improve seafood traceability (e.g., QR code) should be investigated by aquaculture and fisheries industries on a sectoral level to share potentially high associated research and implementation costs.

Shorter and/or more integrated supply chain models appear to be beneficial for farmers and consumers with respect to value creation. Yet, shorter supply chains typically mean higher transaction costs for farmers or other entities within the chain which coordinate the supply of oysters to the retail sector or directly to consumers. Moreover, while higher supply chain integration implies improved supply chain efficiency it also requires significant capital investment to develop an integrated supply chain business model (Asche et al., 2018).

Overall, the identified segments of the three supply chains described in this study (e.g., production input, production, processing) aligned with studies that have assessed seafood supply chains in other countries (e.g., e.g., Al-Busaidi et al., 2016; Asiedu et al., 2016; Douet, 2016; Howieson et al., 2013; Kaminski et al., 2018; Little et al., 2018; Love et al., 2020; Nguyen et al., 2020; Prompatanapak & Lopetcharat, 2020; Raftowicz & Le Gallic, 2020; Saguin, 2018). Yet, none of these studies offered a detailed analysis of supply chain model as undertaken in the present work which highlights its contribution to the literature.

The findings of the present study also show that the role of the retail sector is relatively small in the farmers' decisions to adopt specific supply chain models as compared to seafood traded in a global supply chains, e.g., shrimp/prawn (Jespersen et al., 2014). This is because oysters are almost exclusively supplied to a domestic market and some entities have dominant roles within the wholesale stage of the oyster supply chain in Australia, despite the increasing competition within that segment of the network.

Recommendations

Given these findings it can be concluded that development of the tropical oyster industry and its supply chain is facing a range of challenges. The following recommendations for the development of a tropical oyster industry in Northern Australia were derived.

1. A priority for the development of the BLO industry should be a focus on establishing a stable spat supply by hatcheries. This need was previously raised by (Nowland, O'Connor, Osborne, et al., 2019). Ideally, at least one hatchery in each state/territory should produce oyster spat to reduce producer's dependence on a single input provider that could hamper input supply in situations such like disease outbreaks and associated biosecurity regulations that limit the translocation of spat. Yet, economies of scale appear to be an issue which may prevent the establishment of several hatcheries to supply only a limited number of oyster farmers, at least initially.
2. Continued research directed at potential pest and diseases and grow-out systems and technologies will also be needed to support the cultivation of this oyster species. Other studies have also highlighted the importance of research and technological drivers (e.g., hatcheries for production input supply) for aquaculture industry development (e.g., e.g., Bostock, 2011; Karim et al., 2020).
3. It will also be critical to attract private investors to the industry for expanding the production scale of BLOs (e.g., investment in farm equipment, skills, technology). Yet, given the current early stages of development in the BLO industry and uncertainties about reliable production input, financiers may consider investment currently as too risky. Recent corporate investments into the SRO industry exemplifies that funding for the development of aquaculture industries is potentially available with Australian and internationally. Developing more reliable production and supply chain models is key to increasing access to capital.
4. The development of production skills and business aspects of oyster farming (e.g., marketing, business development) is a further area which will need to be considered. Mentoring of BLO farmers by farmers in existing oyster industries could be a cost-effective way to increase skills and capacity of tropical oyster farmers in future. The availability of more traditional avenues for skill development (e.g., TAFE or university courses) will also be important.
5. Ensuring consumer safety of shellfish produced in Northern Australia is another priority. There are already actions being considered to amend the existing Australian Shellfish Quality Assurance Program (ASQAP) to assure that the food safety of tropical oysters is managed in accordance with operational guidelines that reflect the conditions in tropical regions of Australia. Improved food safety infrastructure is also required, which includes laboratories at which food safety tests can be conducted within short periods of time.
6. Market development will require a consumer demand analysis for BLOs, marketing which ideally focusses on provenance promotion of aquaculture production in Northern Australia and authenticity/product traceability. The development of links between oyster farmers and the local and domestic retail sector, such as restaurants which would be willing to sell and promote the product, will also be vital. The findings of this study showed that there exist several models to distribute oysters from producers to consumers in Australia and that the choice of channel is determined by producer's cost-benefit assessment for available approaches.
7. The development of export strategies for the BLO may not an immediate priority. Findings from the SRO supply chain show that to establish an oyster export market a consolidated and consistent supply of oysters is needed to establish export channels. Furthermore, oyster branding appears to be important for importers of oysters in Asia,

hence, brands for BLOs may need to be developed prior to exploring export opportunities. In addition, the demand for BLOs in Asian markets should be investigated for example through a palate test with potential Asian consumers. Information about the processes involved in establishing access to export markets and the domestic requirements for seafood export may be obtained from seafood industries or businesses in Australia who successfully supply the Asian market.

8. An industry development plan may support the strategic and gradual growth of the BLO industry, including the development of its supply chain. This plan should outline medium-term and longer-term goals as well as actions to achieve these goals. A strategic plan could be developed by all stakeholders of the BLO industry and may initially be driven by a consortium of Northern Australian Governments such as suggested by Cobcroft et al. (2020). Advice about the industry development plan should also be sought from Oyster Australia, the oyster industry peak body in Australia. To grow the BLO industry into a commercial aquaculture industry in Northern Australia it is important that oyster farmers develop innovative business ideas which ensure continued product supply and promotion of their individual product as well as the BLO industry.

COVID-19 and future work

It should be noted that the findings presented in this study reflect information about the oyster supply chains before the onset of the COVID-19 crisis in Australia. Initial reports from the industry suggest that the crisis has caused a significant decrease in the demand for oysters mainly due to the mandated closure of restaurants, clubs, bars and other foodservices to support social distancing within the society. This has caused a partial break-down of the oyster supply chain. Consumer confidence in spending for luxury seafood outside the foodservice sector may also be impacted by the health crisis and a subsequent economic crisis. This situation requires producers to adapt their supply chain, including adjustments to production (e.g., delay in harvest) and business operations (e.g., minimise labour costs). As an extension of this study, the process of how oyster producers (and aquaculture producers more generally) have adapted their supply chain management in response to the demand shock caused by the COVID-19 crisis would be interesting to investigate. Findings would offer useful insights into how aquaculture industries could prepare strategies that enable them to deal with future supply and demand shocks.

Given the limited knowledge about seafood supply and value chains in Australia, future research should address this gap. This would allow supply and value chains to be compared across seafood industries and to derive information about best practices that could be useful for the industries to develop strategies that increase their economic performance.

Limitations

A limitation of this study is the relatively small sample of interviews that were undertaken to derive the structure of the three supply chains. While it is not expected that the “true” structure of the distribution network may differ significantly from the findings presented in this report, the estimates for the market shares of supply chain models could be biased.

5 Conclusion

This study offers an assessment of three oyster supply chains in Australia with the objective to derive recommendations that assist the emerging BLO industry in developing their supply chain. The complexity of the described distribution networks significantly. The findings of this study suggest that the supply chain of the BLO is at a very early stage of development with only three commercial producers in QLD and the NT who together produce a small volume of this oyster species. Commercial production of FOs has commenced in NSW in during the past decade as a way to diversify SRO or PO production. Production volumes for this oyster species remain low due to difficulties in cultivating FOs. Producer's choice of the distribution channels for FOs builds on their experience with other oyster species but also reflects its limited shelf-life. The findings suggest that the SRO industry has developed the most mature distribution network that has recently experienced significant change with increasing competition developing within the wholesale segment of its supply network. Those changes offer producers more options to choose among supply channels for their product and create different added value.

From the synthesis of the findings about the three oyster supply chains recommendations for the development of the BLO supply chain were derived. These include the development of commercial hatcheries spat production, and continued research about production systems, pests and diseases, and oyster species classification. Producers may need support in developing oyster farming and general farming business skills. Existing food policies will need to be amended to assure seafood safety of tropical oysters and demand for this oyster species within Australia will need to be analysed to underpin better marketing. Establishing a BLO industry development plan would support the further expansion of this aquaculture industry which can generate employment opportunities, production diversification and economic growth for communities living in northern rural coastal regions of Northern Australia.

References

- ABARES. (2018). *Australian fisheries and aquaculture statistics 2017*. Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES). ISBN 978-1-74323-415-0. Retrieved from http://www.agriculture.gov.au/SiteCollectionDocuments/abares/publications/AustFishAquacStats_2017_v1.2.0.pdf.
- Al-Busaidi, M. A., Jukes, D. J., & Bose, S. (2016). Seafood safety and quality: An analysis of the supply chain in the Sultanate of Oman. *Food Control*, 59, 651-662. doi:<https://doi.org/10.1016/j.foodcont.2015.06.023>
- Asche, F., Cojocaru, A. L., & Roth, B. (2018). The development of large scale aquaculture production: A comparison of the supply chains for chicken and salmon. *Aquaculture*, 493, 446-455. doi:<https://doi.org/10.1016/j.aquaculture.2016.10.031>
- Asiedu, B., Failler, P., & Beyens, Y. (2016). Enhancing aquaculture development: mapping the tilapia aquaculture value chain in Ghana. *Reviews in Aquaculture*, 8(4), 394-402. doi:10.1111/raq.12103
- Australian Government. (2005). *Export Control (Fish and Fish Products) Orders 2005 (F2014C01121)*. Retrieved from <https://www.legislation.gov.au/Details/F2014C01121>
- Australian Shellfish Quality Assurance Advisory Committee. (2019). *The Australian Shellfish Quality Assurance Program. Operational Manual. Version 5*. Retrieved from <http://safefish.com.au/reports/manuals-and-guidelines/the-australian-shellfish-quality-assurance-program-manual>
- Bonney, L., Clark, R., Collins, R., Dent, B., & Fearn, A. (2009). *Sustainable Value Chain Analysis: An agri-food chain diagnostic*. National Lamb Value Chain Project. Hobart, Tasmania: University of Tasmania. Retrieved from https://www.researchgate.net/profile/Lawrence_Bonney/publication/251236688_Sustainable_value_chain_analysis_an_agri-food_chain_diagnostic/links/0c96051ef888ad6850000000/Sustainable-value-chain-analysis-an-agri-food-chain-diagnostic.pdf.
- Bostock, J. (2011). The application of science and technology development in shaping current and future aquaculture production systems. *The Journal of Agricultural Science*, 149(S1), 133-141. doi:10.1017/S0021859610001127
- Cobcroft, J., Bell, R., Fitzgerald, J., & Jerry, D. (2020). *Northern Australia Aquaculture Industry Situational Analysis. Project A.1.1718119*.
- Coles. (2019). Coles Deli Sydney Rock Oysters (12 pack). Retrieved from <https://shop.coles.com.au/a/a-qld-metro-noosa/product/oysters-sydney-rock> (20 November 2019)
- Comiskey, S. (2009). *Australian oyster industry supply chain analysis*. FRDC Project No: 2008 / 777. Retrieved from <https://www.seafoodcrc.com/southern-bluefin-tuna/product-and-market-development/2008-777-australian-oyster-industry-supply-chain-analysis-and-improvement-strategy.html>
- Denham, F. C., Biswas, W. K., Solah, V. A., & Howieson, J. R. (2016). Greenhouse gas emissions from a Western Australian finfish supply chain. *Journal of Cleaner Production*, 112, 2079-2087. doi:<https://doi.org/10.1016/j.jclepro.2014.11.080>
- Douet, M. (2016). Change Drivers across Supply Chains: The Case of Fishery and Aquaculture in France. *Transportation Research Procedia*, 14, 2830-2839. doi:<https://doi.org/10.1016/j.trpro.2016.05.349>
- Farmery, A. K., Gardner, C., Green, B. S., Jennings, S., & Watson, R. A. (2015). Domestic or imported? An assessment of carbon footprints and sustainability of seafood consumed in Australia. *Environmental Science & Policy*, 54, 35-43. doi:<https://doi.org/10.1016/j.envsci.2015.06.007>
- Fleming, A., Hobday, A. J., Farmery, A., van Putten, E. I., Pecl, G. T., Green, B. S., & Lim-Camacho, L. (2014). Climate change risks and adaptation options across Australian

- seafood supply chains – A preliminary assessment. *Climate Risk Management*, 1, 39-50. doi:<https://doi.org/10.1016/j.crm.2013.12.003>
- Food Standards Australia New Zealand. (2005). *Safe Seafood Australia. Guide to Standard 4.2.1 Primary Production and Processing Standard for Seafood - Chapter 4 of the Australia New Zealand Food Standards Code (Australia only)*. Retrieved from https://www.foodstandards.gov.au/code/primaryproduction/seafood/documents/Safe_Seafood_Aust_with_cover.pdf
- Frank's Seafood. (2019). Oysters per dozen sucked (Coffin Bay, Tazzie Standard, Sydney rock). Retrieved from <http://www.franksseafood.net.au/product/oysters-per-dozen/> (20 November 2019)
- Fred's. (2020). Menu - To Share (Clair de lune oysters).
- He, J. (2018). From country-of-origin labelling (COOL) to seafood import monitoring program (SIMP): How far can seafood traceability rules go? *Marine Policy*, 96, 163-174. doi:<https://doi.org/10.1016/j.marpol.2018.08.003>
- Howieson, J., Hastings, K., & Lawley, M. (2013). Creating Value in the Supply Chain for Australian Farmed Barramundi: Whole of Chain Perspective. *Journal of International Food & Agribusiness Marketing*, 25(4), 287-297. doi:<https://doi.org/10.1080/08974438.2013.728989>
- IBISWorld. (2019). *Fish and Seafood Wholesaling in Australia-A steady ship: Rising seafood consumption and higher prices have supported revenue growth*. Retrieved from <http://clients1.ibisworld.com.au/reports/au/industry/default.aspx?entid=368>.
- Intuitive Solutions. (2016). *Unpacking the Consumer Seafood Experience*. Report prepared for the Fisheries Research Development Cooperation (FRDC). Retrieved from file:///C:/Users/schrobbp/Downloads/2016%20Unpacking%20the%20consumer%20seafood%20experience%20(1).pdf
- Intuitive Solutions. (2019). *Unpacking the Consumer Seafood Experience - A 2019 Update*. Report prepared for the Fisheries Research Development Cooperation (FRDC). Retrieved from file:///C:/Users/schrobbp/Downloads/2019_Unpackingseafoodexperience_report.pdf
- Jespersen, K. S., Kelling, I., Ponte, S., & Kruijssen, F. (2014). What shapes food value chains? Lessons from aquaculture in Asia. *Food Policy*, 49, 228-240. doi:<https://doi.org/10.1016/j.foodpol.2014.08.004>
- Kaminski, A. M., Genschick, S., Kefi, A. S., & Kruijssen, F. (2018). Commercialization and upgrading in the aquaculture value chain in Zambia. *Aquaculture*, 493, 355-364. doi:<https://doi.org/10.1016/j.aquaculture.2017.12.010>
- Karim, M., Leemans, K., Akester, M., & Phillips, M. (2020). Performance of emergent aquaculture technologies in Myanmar; challenges and opportunities. *Aquaculture*, 519, 734875. doi:<https://doi.org/10.1016/j.aquaculture.2019.734875>
- Kow, F., Yu, L., FitzGerald, D., & Grewal, D. (2008). Understanding the factors related to the consumers' choices of oysters in Australia: an empirical study. *Journal of Foodservice*, 19(4), 245-253. doi:<https://doi.org/10.1111/j.1748-0159.2008.00112.x>
- Lawley, M. (2015). *A Final Seafood Omnibus: Evaluating changes in consumer attitudes and behaviours*. Australian Seafood Cooperative Research Centre. Project No. 2015/702. Retrieved from <https://www.frdc.com.au/Archived-Reports/FRDC%20Projects/2015-702-DLD.pdf> (1 August 2019)
- Lawley, M., & Birch, D. (2016). Exploring Point of Sale Strategies for Improving Seafood Retailing: The Case of the Australian Oyster Industry. *Journal of Food Products Marketing*, 22(7), 792-808. doi:<https://doi.org/10.1080/10454446.2015.1121430>
- Le Bihan, V., Catalo, M., & Bihan, J. L. (2018). Reorganization of the value chain activities of oyster companies on the Atlantic coast following health crises in France (2006–2013). *Marine Policy, In Press, Corrected Proof*. doi:<https://doi.org/10.1016/j.marpol.2018.05.013>.
- Leal, M. C., Pimentel, T., Ricardo, F., Rosa, R., & Calado, R. (2015). Seafood traceability: current needs, available tools, and biotechnological challenges for origin certification.

- Trends in Biotechnology*, 33(6), 331-336.
doi:<https://doi.org/10.1016/j.tibtech.2015.03.003>
- Lim-Camacho, L., Hobday, A. J., Bustamante, R. H., Farmery, A., Fleming, A., Frusher, S., . . . van Putten, I. (2015). Facing the wave of change: stakeholder perspectives on climate adaptation for Australian seafood supply chains. *Regional Environmental Change*, 15(4), 595-606. doi:10.1007/s10113-014-0670-4
- Little, D. C., Young, J. A., Zhang, W., Newton, R. W., Al Mamun, A., & Murray, F. J. (2018). Sustainable intensification of aquaculture value chains between Asia and Europe: A framework for understanding impacts and challenges. *Aquaculture*, 493, 338-354. doi:<https://doi.org/10.1016/j.aquaculture.2017.12.033>
- Liu, Y., Kow, F., Grewal, D., & FitzGerald, D. (2006). Consumer purchase behaviour for oysters: an empirical study in some state capital cities of Australia. *International Journal of Consumer Studies*, 30(1), 85-94. doi:<https://doi.org/10.1111/j.1470-6431.2005.00456.x>
- Love, D. C., Lane, R. M., Kuehl, L. M., Hudson, B., Harding, J., Clancy, K., & Fry, J. P. (2020). Performance and conduct of supply chains for United States farmed oysters. *Aquaculture*, 515, 734569. doi:<https://doi.org/10.1016/j.aquaculture.2019.734569>
- McDougall, C. (2018). Comparative De Novo transcriptome analysis of the Australian black-lip and Sydney rock oysters reveals expansion of repetitive elements in *Saccostrea* genomes. *PLOS ONE*, 13(10), e0206417. doi:10.1371/journal.pone.0206417
- Mitchell, I. M., Crawford, C. M., & Rushton, M. J. (2000). Flat oyster (*Ostrea angasi*) growth and survival rates at Georges Bay, Tasmania (Australia). *Aquaculture*, 191(4), 309-321. doi:[https://doi.org/10.1016/S0044-8486\(00\)00441-5](https://doi.org/10.1016/S0044-8486(00)00441-5)
- Mueller Loose, S., Peschel, A., & Grebitus, C. (2013). Quantifying effects of convenience and product packaging on consumer preferences and market share of seafood products: The case of oysters. *Food Quality and Preference*, 28(2), 492-504. doi:<https://doi.org/10.1016/j.foodqual.2012.11.004>
- Nell, J. A. (2001). The History of Oyster Farming in Australia. *Marine Fisheries Review*, 63(3), 14-25.
- Nguyen, T. A. T., Nguyen, K. A. T., Truong, H. C., & Jolly, C. M. (2020). Collective action governance and benefits distribution in the sturgeon value chain in Lâm Đồng province, Vietnam. *Aquaculture*, 519, 734765. doi:<https://doi.org/10.1016/j.aquaculture.2019.734765>
- Nowland, S. J., O'Connor, W., & Southgate, P. C. (2018). Embryonic, Larval, and Early Postlarval Development of the Tropical Black-Lip Rock Oyster (*Saccostrea echinata*). *Journal of Shellfish Research*, 37(1), 73-77.
- Nowland, S. J., O'Connor, W. A., Penny, S. S., & Southgate, P. C. (2019). Monsoonally Driven Reproduction in the Tropical Black-Lip Rock Oyster *Saccostrea echinata* (Quoy & Gaimard, 1835) in Northern Australia. *Journal of Shellfish Research*, 38(1), 89-100. doi:<https://doi.org/10.2983/035.038.0109>
- Nowland, S. J., O'Connor, W. A., Osborne, M. W. J., & Southgate, P. C. (2019). Current Status and Potential of Tropical Rock Oyster Aquaculture. *Reviews in Fisheries Science & Aquaculture*, 1-14. doi:10.1080/23308249.2019.1670134
- Nowland, S. J., O'Connor, W. A., Penny, S. S., Osborne, M. W. J., & Southgate, P. C. (2019). Water temperature and salinity synergistically affect embryonic and larval development of the tropical black-lip rock oyster *Saccostrea echinata*. *Aquacult International*, 1-12. doi:10.1007/s10499-019-00381-7
- NSW Department of Primary Industries. (2020). Angasi oysters - research information sheet. Retrieved from <https://www.dpi.nsw.gov.au/fishing/aquaculture/publications/oysters/angasi-oysters>.
- NSW DPI. (2020). *Aquaculture Production Report 2018-2019*. Retrieved from https://www.dpi.nsw.gov.au/_data/assets/pdf_file/0008/1198925/Aquaculture-Production-Report-2018-2019.pdf
- O'Connor, W. A., Dove, M. C., Finn, B., & O'Connor, S. (2008). *Manual for hatchery production of Sydney rock oysters (Saccostrea glomerata)*. Cronulla: NSW

- Department of Primary Industries Retrieved from https://www.dpi.nsw.gov.au/_data/assets/pdf_file/0014/261041/Output-1084_Hatchery-Manual_FORMATTED.pdf.
- Plagányi, É. E., van Putten, I., Thébaud, O., Hobday, A. J., Innes, J., Lim-Camacho, L., . . . Thomas, L. (2014). A quantitative metric to identify critical elements within seafood supply networks. *PLOS ONE*, 9(3), e91833. doi:<https://doi.org/10.1371/journal.pone.0091833>
- Prompatanapak, A., & Lopetcharat, K. (2020). Managing changes and risk in seafood supply chain: A case study from Thailand. *Aquaculture*, 525, 735318. doi:<https://doi.org/10.1016/j.aquaculture.2020.735318>
- QLD DAF. (2015). *Oyster industry plan for Moreton Bay Marine Park*. Brisbane: State of Queensland Retrieved from https://www.daf.qld.gov.au/_data/assets/pdf_file/0013/56101/Moreton-Bay-Oyster-Management-Plan.pdf
- Raftowicz, M., & Le Gallic, B. (2020). Inland aquaculture of carps in Poland: Between tradition and innovation. *Aquaculture*, 518, 734665. doi:<https://doi.org/10.1016/j.aquaculture.2019.734665>
- Saguin, K. (2018). Mapping access to urban value chains of aquaculture in Laguna Lake, Philippines. *Aquaculture*, 493, 424-435. doi:<https://doi.org/10.1016/j.aquaculture.2017.01.030>
- Saint Peters. (2020). Menu - Oysters (Petit Clair Rock, Moonlight Kiss Rock). Retrieved from <https://www.saintpeter.com.au/menu> (28/02/2020).
- Schroback, P., Pascoe, S., & Cogle, L. (2014a). History, status and future of Australia's native Sydney rock oyster industry. *Aquatic Living Resources*, 27(3-4), 153-165. doi:<https://doi.org/10.1051/alr/2014011>
- Schroback, P., Pascoe, S., & Cogle, L. (2014b). Impacts of introduced aquaculture species on markets for native marine aquaculture products: The case of edible oysters in Australia. *Aquaculture Economics & Management*, 18(3), 248-272. doi:<https://doi.org/10.1080/13657305.2014.926465>
- Schroback, P., Rolfe, J., & Star, M. (2019). *Describing and analysing agricultural supply chains in Queensland*. Report provided to the Rural Economies Centre of Excellence (Project 3a: Reviewing agricultural value chains in Queensland), Toowoomba.
- South Australian Chronicle and Weekly Mail. (1868). Oyster Culture. Adelaide. Retrieved from <https://trove.nla.gov.au/newspaper/article/90040506?searchTerm=flat%20oyster&searchLimits=>.
- Southgate, P. C., & Lee, P. S. (1998). Hatchery rearing of the tropical blacklip oyster *Saccostrea echinata* (Quoy and Gaimard). *Aquaculture*, 169(3), 275-281. doi:[https://doi.org/10.1016/S0044-8486\(98\)00382-2](https://doi.org/10.1016/S0044-8486(98)00382-2)
- Spencer, S., & Kneebone, M. (2012). *FOODmap: An analysis of the Australian food supply chain*. Canberra: Department of Agriculture, Fisheries and Forestry. Australian Government. Retrieved from <http://www.agriculture.gov.au/SiteCollectionDocuments/ag-food/food/national-food-plan/submissions-received/foodmap-an-analysis-of-the-australian-food-supply-chain-30-july.pdf>
- Sterling, B., Gooch, M., Dent, B., Marenick, N., Miller, A., & Sylvia, G. (2015). Assessing the Value and Role of Seafood Traceability from an Entire Value-Chain Perspective. 14(3), 205-268. doi:10.1111/1541-4337.12130
- The Boathouse. (2020). Meuns - Oysters (Clair de Lune Bouton Rock, Moonlight Kisses Rock). Retrieved from <https://static1.squarespace.com/static/579589e84402433b8b4a9b62/t/5def2b45ac43c868ac6f7df7/1575955269677/Oysters+Dec+19.pdf> (28/02/2020).
- van Putten, I. E., Farmery, A. K., Green, B. S., Hobday, A. J., Lim-Camacho, L., Norman-López, A., & Parker, R. W. (2016). The Environmental Impact of Two Australian Rock

Lobster Fishery Supply Chains under a Changing Climate. *Journal of Industrial Ecology*, 20(6), 1384-1398. doi:10.1111/jiec.12382.

Woolworths. (2019). Woolworths fresh Sydney rock oysters (12 pack). Retrieved from <https://www.woolworths.com.au/shop/productdetails/99476/woolworths-fresh-sydney-rock-oysters>

Appendix 1: Interview questions

GENERAL QUESTIONS: ALL PARTICIPANTS

Q1: Are you over the age of 18?

- Yes
 No

Q2: Which element within the oyster supply chain do you represent?

- Production input provider
 Producer
 Processor
 Wholesaler
 Retailer

Q3: In which state is your business located?

- Queensland
 New South Wales
 Tasmania
 South Australia

Q4: How many years have you produced/ handled oysters?

Years

Q5: Which of the following oyster species do you produce/ handle?

- Sydney rock oyster
 Pacific oyster
 Flat oyster
 Black-lip oyster
 Milky oyster

INTERVIEW QUESTIONS FOR PRODUCTION INPUT PROVIDERS

Q6: Could you please provide a brief overview about how the oyster spat is produced?

Q7: Are there any issue with the supply of oyster spat to oyster farmers? If so, could you please outline these in more detail?

Q8: A map of the supply chain structure and processes of oysters has been developed by the research team based on previous work, could you please have a look at this draft and provide comments on it? (*Provide supply chain*)

Q9: Could you please have a look at this value chain of oysters and provide any comments? (*Provide value chain*)

Q10: Is there any form of collaboration and coordination taking place between hatcheries and farmers?

Q11: What do you perceive as issues and opportunities of the future or oyster production and oyster supply in [*add state name*]?

INTERVIEW QUESTIONS FOR OYSTER FARMERS

Q6: What are currently the most commonly used production systems which the [*name of the state*] oyster industry uses?

Q7: Are there any issue with the supply of oyster spat? If so, could you please outline these in more detail?

Q8: A map of the supply chain structure and processes of oysters has been developed by the research team based on previous work, could you please have a look at this draft and provide comments on it? (*Provide supply chain*)

Q9: What do you perceive as the issues and opportunities of the oyster supply chain in [*add name of the state*]?

Q10: Could you please have a look at this value chain of oysters and provide any comments? (*Provide value chain*)

Q11: What type of consumer are you targeting? Could you please describe these consumers in more detail?

Q12: What is the current role of tractability and sustainability certification and of oysters is [*add state name*]?

Q13: What kind of proportion/branding of oysters is currently undertaken [*add state name*] to raise consumers awareness?

Q14: What could the industry management do to promote the industry and support the creation of value for oyster farmers?

Q15: What type of collaboration and coordination is there currently existing among oyster farmers and other supply chains stakeholder (e.g., wholesalers)?

Q16: What are the reasons for the limited export of oysters?

Q17: Are there any regulatory challenges which affect the shape of the supply chain?

Q18: Is capital investment (e.g., institutional investors) needed to improve the oyster supply chain?

INTERVIEW QUESTIONS FOR PROCESSORS

Q6: How frequently do you handle oysters and in what volume?

Q7: A map of the supply chain structure and processes of oysters has been developed by the research team based on previous work, could you please have a look at this draft and provide comments on it? (*Provide supply chain*)

Q8: Could you please have a look at this value chain of oysters and provide me your comments? (*Provide value chain*)

Q9: Where do you buy the oyster typically from?

Q10: Do you perceive the trade of oyster differently to other seafood? If so, in what way?

Q11: Approximately how much time does pass from when you receive the oysters to when you sell them on?

Q12: Who do you typically sell the oyster to? Could you please provide proportions?

Q13: What are the characteristics of oysters that your customers demand?

Q14: How much oyster loss is there?

Q15: What kind of collaboration and coordination is there within the oyster supply chain?

Q16: What are the issues and opportunities of the oyster supply chain in [*add name of the state*]?

INTERVIEW QUESTIONS FOR WHOLESALERS

Q6: How frequently do you handle oysters and in what volume?

Q7: A map of the supply chain structure and processes of oysters has been developed by the research team based on previous work, could you please have a look at this draft and provide comments on it? (*Provide supply chain*)

Q8: Could you please have a look at this value chain of oysters and provide me your comments? (*Provide value chain*)

Q9: Where do you buy the oyster typically from?

Q10: Do you perceive the trade of oyster differently to other seafood? If so, in what why?

Q11: Who do you typically sell the oyster to? Could you please provide proportions?

Q12: What are the characteristics that your customers typically look for in oysters?

Q13: How much oyster loss is there?

Q14: What kind of collaboration and coordination is there within the oyster supply chain?

Q15: What are the issues and opportunities of the oyster supply chain in [*add name of the state*]?

INTERVIEW QUESTIONS FOR RETAILERS

Q6: How frequently do you handle oysters and in what volume?

Q7: A map of the supply chain structure and processes of oysters has been developed by the research team based on previous work, could you please have a look at this draft and provide comments on it? (*Provide supply chain*)

Q8: Could you please have a look at this value chain of oysters and provide me your comments? (*Provide value chain*)

Q9: Where do you buy the oyster typically from?

Q10: Do you perceive the trade of oyster differently to other seafood? If so, in what why?

Q11: What are the characteristics that your customers typically look for in oysters?

Q12: How much oyster loss is there?

Q13: What kind of collaboration and coordination is there within the oyster supply chain?

Q14: What are the issues and opportunities of the oyster supply chain in [*add name of the state*]?

Appendix 2: Project communication and engagement

- The preliminary project findings were presented in a seminar at the Queensland Branch of the Australasian Agricultural and Resource Economics Society (AARES) on 3rd December 2019 in Brisbane.
- Presentation about the “Challenges of developing aquaculture supply chains” at the workshop about the aquaculture industry situational analysis organised by researchers of James Cook University in Rockhampton on 5th/6th February 2020.
- Presentation about the “Aquaculture supply chains: The case of oysters in Queensland and New South Wales” at the Australasian Agriculture and Resource Economics Conference in Perth, 12th-14th February 2020.