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Describing and analysing the Pacific oyster supply chain in Australia

Final Research Report

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Rural Economies Centre of Excellence

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Acronyms

PO	Pacific oyster
POMS	Pacific Oyster Mortality Syndrome
SA	South Australia
SRO	Sydney rock oyster
TAS	Tasmania

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Executive summary

The Pacific oyster (*Crassostrea gigas*) (PO) industry was established in Tasmania and South Australia in the 1950/60s and has significantly increased in its production volume over time. Yet, there is limited information available about the distribution network of POs as well as potential constraints and prospects for the market supply and how the supply chain of POs compares to other oyster products.

Hence, the aims of this report are to a) to describe the PO supply and value chain, b) to identify potential supply chain issues and opportunities, and c) to compare it to other oyster distribution networks (e.g., the Sydney rock oyster (*Saccostrea glometata*) (SRO)). The comparison of oyster supply chain networks in Australia will help understand the differences in distribution networks and potential reasons for that.

The results suggest that the distribution network of POs is relatively complex with several entities within the chain's processing/wholesale and retail segments being involved. Several supply chain approaches were identified which farmers use to market their product. These include the direct sale model (e.g., farmer sells product directly to retailers or consumers), the agent model, the processor/wholesale model, the export model and the integrated corporate model.

The findings confirmed that farmer's choice of supply chain model(s) appear to be driven by a range of factors including their business objective (e.g., lifestyle farming vs. corporate business), the farm gate price, relationships with downstream entities within the supply chain, the location of the farm and its distance to the market as well as the production volume and product quality.

Several issue and opportunities that affect the distribution of POs were identified. Issues include for example production risks (e.g., POMS), limited value creation in supply chains with a high number of intermediaries, limited product traceability and the low volume of oyster export. Opportunities were identified as improved product marketing/branding, consumer education and the exploration of export markets among other.

The comparison with a previous study which explored other supply chains of oysters produced in Australia (Schrobback & Rolfe, 2020) found that the distribution network of PO resembles the supply network of the SRO with minor distinctions (e.g., role of hatcheries in spat supply, absence of premium oyster wholesale model in the PO network), although is distinct from the supply network for Black-lip oysters (*Saccostrea echinate/Striostrea (Parastriostrea) mytiloides)* and Flat oysters (*Ostrea angasi*). This is mainly due to the commercial scale on which the PO and SRO industries operate, and the volume of oyster produced in comparison to the evolving Black-lip oyster and Flat oyster industries where production volumes are relatively small. The issues and opportunities that were observed to affect the PO supply chain are largely similar with findings for other oyster supply chains in Australia.

Given the findings of the study, the oyster industry may consider addressing the identified issues and opportunities in the light of individual business and industry objectives (e.g., maximisation of profits, consumer satisfaction), particularly strategies for supply chain management that contribute to achieving these goals. This could contribute to increasing the economic growth of aquaculture businesses operating in rural coastal regions of Australia to support economic growth and job creation in the regions.

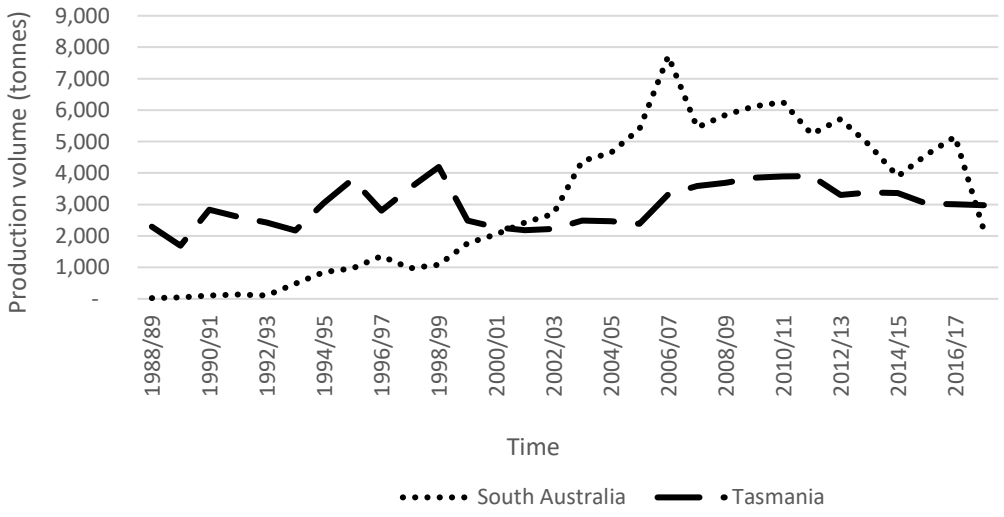
1 Introduction

The Pacific oyster (*Crassostrea gigas*) (PO) is a species used for commercial aquaculture production in Australia. The PO is not native to Australia and was introduced in the 1950/60s to Tasmania (TAS) and South Australia (SA) to supplement the oyster supply of native oyster species (Schrobback et al., 2014; Thomson, 1952), mainly the Sydney rock oyster (*Saccostrea glometata*) (SRO) which is grown in New South Wales (NSW) and Queensland. The production volume and value of POs has increased over time (Figure 1) and the industry is an important contributor to economic and community development in rural coastal regions of TAS and SA (Pierce & McKay, 2008; Pierce & Robinson, 2013).

The Australian PO industry was recently challenged by the Pacific Oyster Mortality Syndrome (POMS) (e.g., NSW in 2010, TAS in 2016), a disease which led to high stock mortalities and subsequently affected the supply of POs to the market (e.g., de Kantzow et al., 2017; PIRSA, 2020; Whittington et al., 2016). While the oyster industry in SA was not directly affect by a POMS outbreak, SA's biosecurity regulation prohibited the import of live POs, including spat, from TAS to prevent the spread of the disease (PIRSA, 2020). Since the SA oyster industry was reliant on spat supply from hatcheries in TAS, the lack of access to production input significantly affected production and subsequently the supply of oysters to the market.

The economic success of oyster farming businesses is influenced by the supply and value chain that farmers choose to distribute their product to the market as well as general seafood market conditions. Yet, there is limited information available about the distribution network of POs as well as potential constraints and prospects for the market supply and how the supply chain of POs compares to other oyster products. While Comiskey (2009) previously examined the oyster supply chain in Australia, this study was conducted on an aggregated basis by combining SRO and PO and the research is dated. Also dated is a previous report by Graham et al. (1993) who conducted a study for the development of a strategic marketing plan for PO industry in TAS which includes supply chain aspects.

Figure 1: Pacific oyster production volume over time



Source: ABARE (1991), ABARES (2020).

Hence, the aims of this report are to a) to describe the PO supply and value chain, b) to identify potential supply chain issues and opportunities, and c) to compare it to other oyster distribution networks (e.g., SRO).

To achieve these aims, semi-structured interviews with stakeholders of the PO industry in TAS and SA were undertaken. The interviews were complemented by a review of the existing literature about features of the PO supply chain as well as an internet search for relevant information, such as retail and wholesale price data and individual oyster growing businesses supply chain approach. Data for this study was collected during June - August 2020. While data collection took place during the COVID-19 health crisis, the interviews specifically focused on the status of the oyster supply chain during the post-POMS and pre-COVID-19 period (October 2019-March 2020). The data collection explicitly did not aim to investigate the impact of the COVID-19 crises on the supply chain of the Pacific oysters and stakeholder adaptation to these challenges since such assessment would be more appropriately undertaken after the crises to fully capture its implications for the industry and supply chain.

Although a small volume of POs is grown in NSW, the focus of this study is on PO produced in TAS and SA. Furthermore, the study focuses on the supply of fresh oysters only and does not consider the import supply chain of frozen product from New Zealand.

Information about the supply chains such as the structure of the supply network and value created within (e.g., monetary value, value created through marketing and relationships) is important for producers since their choice of distribution network can affect their business revenue (e.g., through the farm gate price) and the demand for their product (e.g., consumer awareness through marketing and branding).

This study is part of a larger project which aims to assess the supply chains for all four segments of the Australian oyster industry, including the Black-lip oyster (*Saccostrea echinate/Striostrea (Parastriostrea) mytiloides)*, the Flat oyster (*Ostrea angasi*), the SRO and the PO. Findings from the supply chain assessment of the PO will allow a comparison across all segments of the Australian oyster industry, which will help to better understand potential differences in the distribution networks, as well as issues and opportunities relevant to the development of future industry strategies. As a case study, the research presented in this report will also be of interest for other seafood industries in Australia for which a detailed supply and value chain assessment has not been conducted.

2 Methods

This study uses a mixed-method approach to derive information about the PO supply and value chain. This approach consists of a literature review, an internet search for price data on restaurant menus and individual oyster businesses supply chain approach, and semi-structured interviews of supply chain stakeholders (e.g., oyster farmers, agents, hatchery operators).

A literature review about oyster supply chains and seafood supply chains in Australia was used to establish a basis for the investigation in this study. Of particular interest was the contribution by Comiskey (2009) who has previously conducted research in this area and provided the baseline for the present study.

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. 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 use of semi-structured interviews, which were aligned with the questionnaire, allowed the interviewer to deviate from initial questions depending on the responses given by participants, allowing new ideas and perspectives to be brought into the discussion. This was considered as useful given the exploratory nature of this study. The interview was targeted at oyster farmers and other supply chain stakeholders (e.g., hatchery operators, agents, fishery managers).

Participant were recruited randomly depending on their role within the supply chain 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 June and August 2020 via telephone. Participants were interviewed individually and were not identifiable by other participants. The interviews took between 30-60 minutes. Ethical approval for the data collection involving humans was obtained from Central Queensland University (approval number: 0000021959) and the University of Tasmania (approval number: H0018593). Table 1 offers a summary of the interviewees who participated in this study. All interviews were recorded and transcribed for analysis. Major themes and ideas were identified and analysed.

An internet search in August 2019 and August 2020 for oyster price data at the wholesale and retail level complemented the interviews to develop information about the value chain. For example, oyster price data was collected from restaurants online menus, and seafood mongers', food chain retailers' and wholesalers' websites.

Table 1: Descriptive information about the sample

Identifier	Supply chain role	State	Years of experience in handling oysters	Species
ID1	Farmer	Tasmania	32	PO, FO
ID2	Farmer	Tasmania	34	PO
ID3	Farmer	Tasmania	32	PO
ID4	Farmer	Tasmania	32	PO, FO
ID5	Farmer	Tasmania	28	PO
ID6	Farmer	Tasmania	15	PO
ID7	Farmer	Tasmania	33	PO
ID8	Farmer	South Australia	30	PO
ID9	Farmer	South Australia	18	PO
ID10	Farmer	South Australia	16	PO
ID11	Farmer	South Australia	20	PO
ID12	Oyster hatchery	South Australia	3	PO
ID13	Agent	South Australia	1	PO
ID14	Fishery manager	South Australia	~25	PO, FO

Notes: Interviewees includes state representatives at Oyster Australia, the national peak body of the oyster industry. To ensure individual respondents remain unidentifiable, as provided by participant's consent, these details are not provided in the table. "PO" for Pacific oyster, "FO" for Flat oyster.

3 Results

3.1 Supply network structure

The derived structure of the supply network for POs is shown in Figure 2. The segments of the PO oyster supply chain include production input, production, processing, wholesale, retail, and consumption. Within these segments one or more entities may be present. For example, within the wholesale segment of the distribution network, entities such as seafood agents, seafood wholesalers, seafood exporters and overseas seafood importers were observed. Each of these entities typically comprises several businesses.

Production input

Figure 2 illustrates that oyster spat (juvenile oysters at a size of 2-4 millimeter or larger) is an essential production input which oyster farming businesses purchase from hatcheries. No spat is caught in the wild due to the non-native characteristic of this oyster species. Brood stock which commercial hatcheries use for oyster spat production is typically supplied by Australian Seafood Industries (ASI), a research and development company specialising in an Australia-wide Pacific Oyster selective breeding program.

Interviewees emphasised the dependence of SA oyster farmers on the spat supply from hatcheries in TAS prior to 2016 (pre-PMOS) and the significant impact that the ban of live oyster imports to SA in responds to the POMS disease outbreak in TAS had on the spat supply in this state and subsequently on the entire supply chain of oysters. With substantial support by the SA government, the previously existing two small hatcheries and two newly developed hatcheries are now providing spat to the industry. Yet, issues relating to quality and reliability of spat supply persist in SA which are expected to be overcome in the near future.

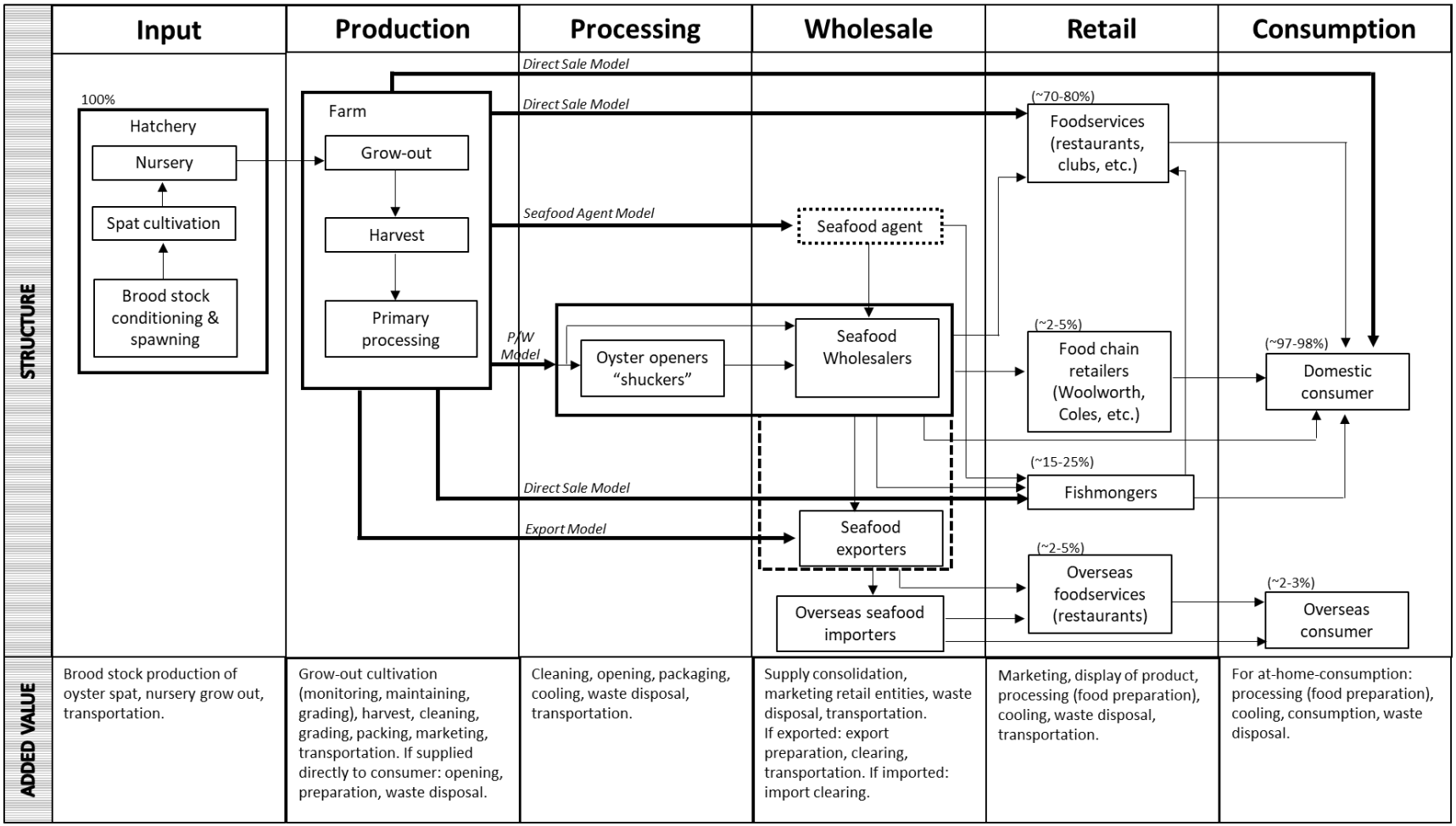
Oyster aquaculture lease areas on which spat is grown out are another important input to production. These areas within the estuaries are licensed for oyster cultivation by the respective state authorities, typically for a typical duration of 20-30 years after which a renewal of the lease agreement may be negotiated (Government of South Australia, 2019). Farm infrastructure such as barges, lines, poles, and basket systems are used for growing the oysters on the aquaculture leases to a marketable size. A land base is typically needed for equipment storage and on-farm primary processing (e.g., clearing, grading, bagging/packaging).

Production

There are currently about approximately 67 oyster producing businesses operating in TAS, and 140 in SA. The grow-out of POs on aquaculture leases takes about 18 months to 2 years. During this period oysters need to be regularly tended (e.g., grading, cleaning from overgrow 3-4 times during their life). POs are predominantly grown in intertidal areas using a long-line rack and rail basket systems. Production systems are continuously being optimised at the farm level, and if successful changes may be adopted on broader industry level.

Selected PO farmers in SA have adopted multi-bay grow out systems where either farmers hold leases in several bays or have a partnerships with other growers in other bays and translocate oysters after the initial grow out period (1-12 months), for conditioning/fattening into bays like Coffin Bay or Smokey Bay from where the product is then harvested and sent to the market. After harvest, farmers typically clean, grade and bag/package the oysters and store them until pick-up and transport from the farm.

Figure 2: Pacific oyster supply chain network



Note: Black boxes around multiple entities within the supply chains indicate integration of processes or entities. Black dotted box indicates a broker, no physical flow through this entity. 'P/W' for processor/wholesale model. Integrated corporate supply chain model is not included here, refer to Figure 3.

POs are sold in three different sizes/grades which include bistro (50-60 mm), buffet (60-70 mm), standard (70-85 mm), and large (85-100 mm). This oyster species has an average shelf life of 7 days if unopened and stored at 5-10 degrees Celsius but can extend to 10 days depending on the handling of the product within the distribution network. Shucked oysters are recommended to be stored at 4 degrees Celsius and to be consumed with 3 days after opening (Madigan, 2014).

Processing/Wholesale

Results reveal that there is diversity in how PO growers supply their product to the market. Observed supply chain models include direct sale from the producer to consumers (e.g., online shop, on-farm retail shop, shucking events) and to the retail sector (i.e., food services, fish mongers), distribution through seafood agents, processors/wholesalers and export of oysters (see Figure 2). Forms of a vertically integrated corporate supply chain model have also been observed in SA and TAS (see Figure 3).

The findings suggest that farmers use combinations of the identified supply chain models for the distribution of specific product qualities and volumes that they produce. For example, the direct sale model to restaurants is commonly used for the sale premium quality oysters, while the agent and processor/wholesale model is used to supply the bulk product volume to the interstate oyster market.

Farmers' decision about which supply chain model(s) to adopt appear to be driven by their business objective (e.g., lifestyle farming vs. corporate business), the farmgate price, relationships with downstream entries within the supply chain, by location of the farm and its distance to the market as well as the production volume and product quality.

Based on the information which participants provided in the interviews it is estimated that a minor proportion of the total PO production volume is distributed directly from farmers to either the retail sector (e.g., restaurants, fishmongers) or consumers (e.g., though a online shop, farm shop, shucking events). The reasons for this relatively small proportion of direct sales may include a bulk commodity characteristic assigned to the product, the high transaction costs for farmers to market the product themselves (e.g., time, skills in branding/marketing) and the small scale of the local oyster market in SA and TAS.

Processors/wholesalers (including specialty oyster wholesalers or seafood wholesalers) have historically held a dominant role in the oyster supply chain, and it is estimated that this supply chain model continues to hold a large market share. Processing (e.g., cleaning, opening) and wholesale functions are often found to be integrated in the oyster supply chain.

The seafood agent model is another form of distribution channel for POs. In this model the product is typically not physically handled directly by the agent. The agent's roles are to link up farmers with downstream supply chain entities such as processors/wholesalers (for opening the oysters) and retail segments (mostly fishmongers). For example, in TAS there are at least two major seafood agents operating (Blue Harvest, Seafood Unlimited). Respondents mentioned that agents offer oyster growers reliable terms of payment and reduce variability in farm gate prices. It is estimated that Australia-wide the agent model together with the processor/wholesale models take up approximately 75-85% of the market share in the distribution of POs from the farm gate.

There is typically a spot market relationship between farmers and their customers (e.g., foodservices, agents, wholesalers), meaning there are no contractual agreements but supply and demand at a point in time coordinates the relationship between entities as well as previous experience or relationships.

Oysters destined for the interstate market are transported on pallets by trucks on roads and sea (i.e., between TAS and Melbourne). In SA, Adelaide appears to be the initial consolidation hub from where consignments from multiple farmers is transported to interstate markets.

The export volume of POs is relatively small with an estimated 2-3% market share of total production volume identified for this supply chain model, with some variability around this estimate. Export of oysters is mostly undertaken through an accredited seafood exporter, that are commonly integrated in seafood wholesale entities. POs are mainly exported to Hong Kong, China, Singapore and Japan and are predominantly sold in restaurants. Due to the relatively short shelf life of live oysters they are typically transported as airfreight.

Retail

It is estimated that most of the oysters produced in TAS and SA are sold by the retail sector interstate due to larger population in Victoria, New South Wales, and Queensland. The domestic retail segment within the PO supply chain includes foodservices (e.g., restaurants, pubs, clubs), food chain retailers (e.g., Coles, Woolworths) and fishmongers (e.g., fish shops) (Figure 2). About 60-80% of POs are sold through foodservices, 20-30% by fishmongers, 2-3% by domestic supermarkets.

Corporate integrated supply chain model

In addition to the distribution network illustrated in Figure 2, forms of vertically integrated corporate supply chain models were observed in TAS and SA. An example is shown in Figure 3. This model can be distinguished from the supply chain model in Figure 2 as the level of vertical integration across the segments of the supply chain is high, including production, processing and distribution of POs. Another observed form of vertical integration includes the incorporation of input supply and production (not shown in Figure 3).

Transportation and food safety

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

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 consumption (Food Standards Australia New Zealand, 2005). Standards that specifically apply to the oyster industry are outlined in the Australian Shellfish Quality Assurance Program (ASQAAC, 2019).

3.2 Value chain

The findings about the value created within the distribution network of POs was restricted to details collected for the processor/wholesale model and the direct sale model (see Figure 4 and Figure 5).

Collected data revealed that the average price of 4-millimeter sized oyster spat was about $5.62/dozen (or $0.47 for each oyster, including GST). The average farm gate price per dozen varies with the size of the product from $8.58 for bistro, $9.96 for buffet and $11.22 for standard within the processor/wholesale model (Figure 4). Processors add for their services (e.g., cleaning, opening, packing) a margin of about $1.50 to $2.30 per dozen to the product value and wholesalers an

additional $3.00 to $4.00 which includes the added value of transportation and coordination with retail sector. The retail price for POs varies according to the outlet and location. For example, at foodservices the price for a dozen of PO can ranged from $24.00 to $69.00. Table 1 offers an overview about the prices for POs advertised at online restaurant menus.

Table 1: Comparison of oyster prices at restaurants (per dozen) across Australia

Location/statistic	Pacific oysters		
	Tasmania	South Australia	Major Australian cities*
Minimum	$ 28.00	$ 24.00	$ 36.00
Median	$ 43.00	$ 39.95	$ 51.25
Average	$ 40.55	$ 41.36	$ 52.58
Maximum	$ 51.80	$ 60.00	$ 69.00

Note: *Only includes oysters labeled as “Pacific oysters”, “Tasmanian oysters”, “Tassie oysters” or “Coffin Bay oysters”. Prices were collected randomly for “natural oysters” from online menus. The sample includes 12 for Tasmania, 18 for South Australia, and for major Australian cities: 12 for Brisbane, 15 for Sydney, and 14 for Melbourne. Data collected during August 2020 was compared to price data collected in August 2019. While some of the previously reviewed restaurants closed or are not offering oysters anymore, the average prices remain unchanged.

Oyster prices in major Australian cities are on average significantly higher than in Adelaide and Hobart which may be explained by transportation costs, higher fixed cost for food services in larger cities as well as higher demand for the product and household income in these locations.

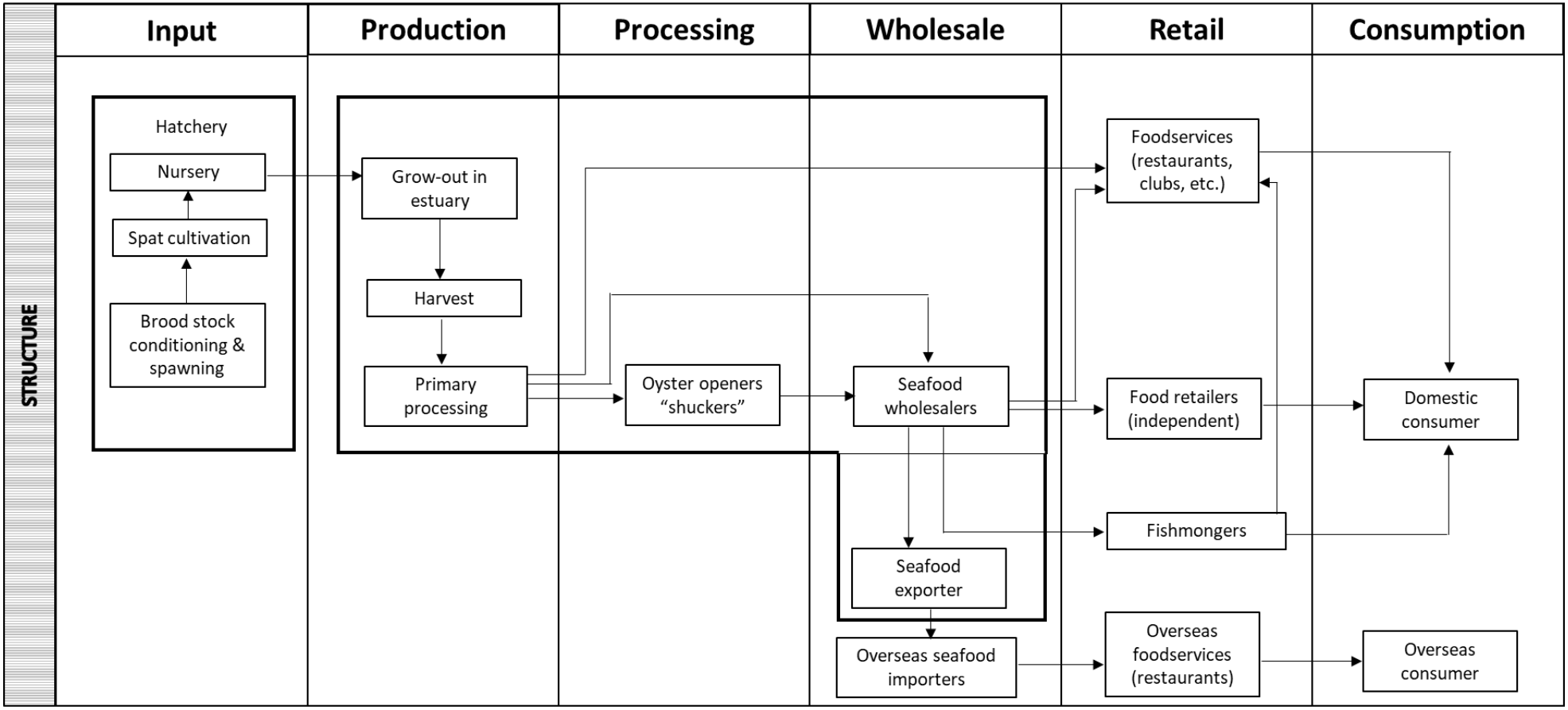
The value created in the direct sale supply chain model for oysters (Figure 5) shows that the farm gate price is typically higher compared to the processor/wholesale model, ranging from $12.00 to $22.00. However, respondents also mentioned that the direct distribution of oysters to either consumers (e.g., online) or the retails sector (e.g., restaurants) is associated with higher transaction costs (e.g., time and effort to establish and maintain relationships with customers) and transportation costs per unit.

Respondents identified that the value created within the agent model is similar to the value in the processor/wholesale model. The agent either charges a commission of 5-10% for the consignments from farmers or pays a price similar to the farm gate price which wholesalers offer.

Values in non-financial forms are also created within the supply chains, including relationships with downstream supply chain entities (e.g., restaurants, wholesalers, agents) or marketing (e.g., promotion of oysters through restaurants which farms have close connections).

Unfortunately, there was not enough information available from this study to be able to estimate the value created in the corporate integrated model or the export model.

Figure 3: Vertically integrated corporate supply chain model



Note: Black boxes around multiple entities within the supply chains indicate integration of processes or entities.

Figure 4: Value chain form processor/wholesale model

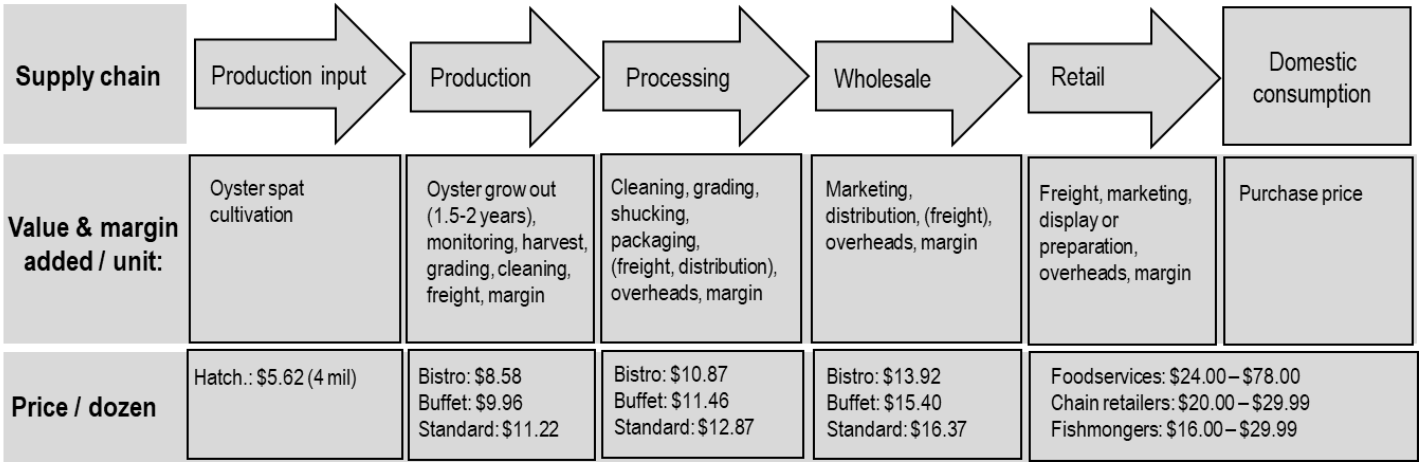
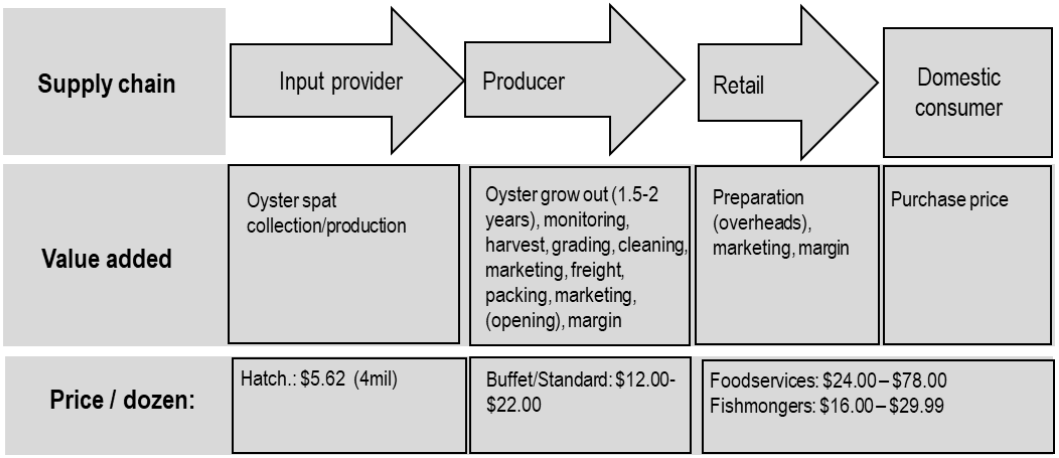


Figure 5: Value chain for direct sale model (restaurant)



3.3 Issues and opportunities

The interviewees were asked to name issues and opportunities that they perceive to be linked to the supply chain of POs. Table 3 summarizes the findings.

Issues linked to the supply chain of POs include production risks (e.g., disease, high rainfall events), limited value creation and product traceability within longer supply chains (e.g., processor/wholesale model, agent model), and the small export volume (e.g., due to limited access to Asian markets, lack of trust, strong domestic market). Furthermore, the structure of the supply chain network suggests a high dependence of most distribution models on the foodservice sector which carries high risks for all other entities in case of disruptions affecting the foodservice industry. Logistics and high freight rates were also named as issues which are linked to production in remote areas and the long distance to the market. A further issue is the access to financial capital for small and medium sized farming businesses which was also seen as an entrance barrier to the industry. In addition, the use of marine area in TAS for oyster production is currently limited by the lack of ability of growers to locate on-land infrastructure (e.g., sheds, office buildings, etc.) nearby to marine lease sites.

There were a range of opportunities for the supply chain of PO raised by participants. These include the need for continued investment into disease resistant brood stock, the potential to expand aquaculture lease area in SA, and the scope for oyster and aquaculture production diversification (e.g., native oyster species or filter feeding species). Increased creation of value within the supply chains could be achieved through improving consumer awareness/education (e.g., industry marketing initiative, social media presence), better marketing/branding (e.g., strategies that link business objective with supply chain), offering consumers an oyster experience (e.g., integration with local tourism, partnership with wineries), shorter and integrated supply chains and better coordinated distribution (e.g., incentivise middleman to promoter the product better, greater traceability). Participants agreed that export opportunities should be explored more rigorously and potentially at an industry level; and also mentioned that there could be an opportunity in developing a frozen oyster market segment as such products are imported from New Zealand. This could offer farmers the opportunity to clear stock from leases when the product is at its prime condition (during July/August) while the demand for oysters is low (demand for oysters is high during spring carnival and Christmas holiday season). Yet, respondents who supported product diversification mentioned that the development of a frozen oyster market should not compromise the demand for the fresh oyster product as fresh product is considered superior to the frozen product.

Table 2: Perceived issues and opportunities linked to the PO oyster supply chain

Theme	Issue	Opportunities
Production risks	-Disease (e.g., POMS) can affect oyster supply -Temporary lease closure due to high rainfall events	-Continued research focusing on disease resistance, survival, and resilience of oysters -Advancing the production systems (e.g. Flip Farm system) -Explore wet storage potential within supply chain -Recognition of carbon credits from carbon capture & storage within oysters' shell structure
Value creation	-Farmers' value proposition is not reaching the consumer -Lack of market oversight ("middle-man issue")	-Increase of consumer awareness/education (e.g., industry marketing initiative, social media presence) -Increased marketing/branding (e.g., strategies that link business objective with supply chain) -Offering a consumer experience (e.g., integration with local tourism, partnership with wineries) -Shorter or more integrated supply chains -More coordinated supply chains (e.g., incentivise middleman via commission-based payments and real-time traceability) -Better supply chain structure to focus on live oysters and traceability, i.e. compares to oyster markets in Europe, USA -Online ordering systems for direct sale of oysters (less intermediaries, closer link to consumers)
Product traceability	-Very limited traceability in longer supply chains, e.g., agent model, processor/wholesaler model -Limited traceability offers ground for seafood fraught	-Explore technologies to increase seafood traceability (e.g., tag system), needs seafood industry support -Improved traceability could support value creation (e.g., offer product's provenance characteristics to consumers)
Sustainability		-Promote the oyster industry as a sustainable seafood industry -Net-benefit of organic or sustainability certification to be explored -Explore sustainability of supply chain models, not only oyster production
Export	-Market access barriers (e.g., lack of trust, lack of links) -Consolidated supply required -Strong international competition (PO is grown worldwide) -Strong domestic market/demand -High freight costs	-Further explore potential alternative markets with seafood industry support
Retail sector	-Reliance on food service sectors as main retail outlet for oysters -Limited focus on distribution through chain retailer as quality of oysters sold at chain retailer is typically low	-Explore potential to increase distribution through food chain retail and to improve quality (e.g., shorter supply chains, fewer intermediaries), product presentation and packing of the product sold at supermarkets -Increased direct sale to consumers if economically feasible (e.g., freight costs for small consignments) - More market research, focused on understanding what makes people *not* want to buy oysters (e.g. asking questions like "are there occasions when you do not buy oysters, and what don't you like about oysters in those situations?")
Logistics	-High freight costs linked to distance between production area and market	-Streamlining logistics, e.g., package traceability using mobile phone apps such as done by Amazon & transparency on freight routes, training of existing logistics operations to deploy this system

Table 3: Perceived issues and opportunities linked to the PO oyster supply chain *(continued)*

Theme	Issue	Opportunities
Product innovation		-Explore frozen oyster market without compromising fresh product reputation and market -Explore oyster production as an ingredient to products, e.g., oyster sauce or meal-ready oyster-packs with already dressed oysters (Kilpatrick, etc.) via modified atmospherics -Provision of training to chefs, restaurateurs, individual consumer) about how to shuck oysters and sale of oyster opening tools as a complimentary product at oyster sales points to support a market for live product -Opportunities to extend shelf life e.g. wet storage, frozen product
Access to financial capital	-Financial institutions do not lend financial capital against lease value (intangible assets), this affects mostly small and medium sized farming businesses -Lack of access to capital is considered as an industry entry and exit barrier to the industry	-Consider alternative sources to attract funding for farm infrastructure upgrades or production expansion (e.g., shareholder business model) -Improved access to financial literacy training for farmers
Production volume & diversification		-New aquaculture area can be made available in SA (on application) which can help to increase production volume -Production diversification, e.g., other oyster species or filter feeding organisms on existing or new leases in SA -Expansion of existing lease areas (further water lease area is available, but in some jurisdictions the integration between potential marine farm sites and access to shore-based sites is needed). In SA some local governments have established 'aquaculture parks' to integrate development of such lease sites. This model may warrant further exploration.

4 Discussion

Summary and comparison

The results of this study suggest that the PO supply network is relatively complex with several entities in the processing and wholesale segments that influence the distribution of large volumes of oysters to the consumers. As such, the structure of the PO supply chain resembles the distribution network of SROs more than those for Black-lip oysters or Flat oysters (Schrobback & Rolfe, 2020). This is mainly due to the commercial scale on which both commercial oyster industries are operating in comparison to the evolving Black-lip oyster and Flat oyster industries where production volumes are relatively small. However, minor differences were noted between the PO and SRO supply chains. For example, as a non-native species the PO production is entirely dependent on hatchery spat production while the spat for SRO cultivation is mostly obtained from the wild with hatcheries providing back-up in input supply (Schrobback & Rolfe, 2020). Production systems of both oyster species are similar although the multi-bay production approach that is popular for PO cultivation is not adopted by SRO producers.

Similar distribution models (e.g., direct sale model, processor/wholesale model, agent model, export model) were observed for POs and SROs, yet market shares of the identified approaches may vary slightly which may be due to the differing distance to major domestic market. The export model currently accounts for only a very minor share oyster production but was identified as having potential for expansion.

The premium wholesaler model which was observed in the SRO supply chain (i.e., an agent focusing on sourcing and distribution of premium quality product only) (Schrobback & Rolfe, 2020) was not observed within the distribution network for POs. This may likely be due to the long distance to the market and relatively high freight price for small consignments which may make the premium wholesaler model economically inviable for POs.

The results confirm previous findings that farmers' choice of supply chain model(s) depends also on their business objectives (e.g., lifestyle farms vs. corporate integrated business) and the net benefit from engaging in a particular model (e.g., farmgate price, maintaining long standing relationships, opportunity to promote their product) that farmers perceived (Schrobback & Rolfe, 2020). From a business perspective, the strategic choice of supply chain model(s) is important for oyster farmers to gain a competitive advantage within the industry to achieve their individual business goals (e.g., profit maximisation, consumer satisfaction) (Ensign, 2001).

The value chain analysis also showed that prices for both oyster species sold at food services are very similar (Schrobback & Rolfe, 2020). It should also be noted that there is limited seafood labeling of on menus of foodservices in Australia due to the food services sector being exempt from clear seafood labeling. This offers consumers limited transparency about the products (e.g., species) and its origin.

The analysis also suggests that prices at sold at fishmongers and chain retailers are higher for POs than SROs, which is likely due to transportation costs as PO production regions are located more remotely than SRO production areas.

Recommendations

Very similar categories of both challenges and opportunities affect the supply chains of the POs and SROs (e.g., production risk, limited product traceability, export potential) (see Table 2) (Schrobback & Rolfe, 2020) which should be addressed in both industries.

For example, an expansion of the production volume in SA can be considered with aquaculture lease area being available. While there is limited potential for extending cultivation areas in TAS, offshore oyster farming options may be explored in more detail.

Different options were identified to create higher value within the selected supply chain models, such as marketing, branding, consumer education and by offering consumers a valuable experience (e.g., shucking events, farm tours that an integrated in local tourism initiatives). Moreover, informing consumers about sustainability of oyster production could be used for marketing and branding. Shorter supply chains (fewer intermediaries) could be beneficial in increasing the traceability within the supply chain, improve the relationship between farmers and consumers (e.g., offer provenance feature of the product to consumers, and obtain direct feedback from oyster consumers) and enhance value creation.

While a higher level of supply chain integration typically implies improved distribution performance and profitability (Kumar et al., 2017), the establishment of business models such as the corporate integrated supply chain model requires significant financial capital investment to which small- and medium-sized oyster farmers have limited access. Unless farmers strive to attract private investment through innovative business plans which focus on increased supply chain integration, it is unlikely that the integrated corporate supply chain model will be adopted on a larger scale in the industry.

At an industry level, farmers would benefit from access to regular market information which could be provided through industry associations on a regular basis. Export markets may be explored as a backup for domestic market downturns as farmers were generally interested in product export and differentiated products. However, support from industry bodies will be required to further explore these opportunities. Furthermore, improved consumer awareness through a marketing campaign at an industry level may raise the profile of the industry, the demand for oysters and subsequently the farm gate price.

A major innovation within the industry would be to consider the implementation of live oyster value and supply chain models, with more high-speed/frequency product traceability modes such as found in the USA or Europe (and also used in the delivery of other on-line products). Such models might open opportunities for product integration/innovation that does not currently exist in the industry and could be supported by training and engagement with retail and hospitality sectors to encourage value for the live shellfish products.

COVID-19 challenges

Although this study aimed to assess the structure and processes of the PO supply chain during the post-PMOS and pre-COVID period (2019-early 2020), participants commented on the impact of the COVID-19 health crisis on the distribution of oysters. Farmers mentioned that the mandated closure of restaurants in response to social distancing requirements let to a significant decrease in the demand for oysters. These validates the supply chain risks identified above from distributing seafood primarily through the foodservice sector. Yet, farmers appear to have adapted their supply chain by focusing more on direct sales through online shops and pop-up stalls. Participants also noted that a switch towards sales through the food chain retail sector would be beneficial while restrictions to the foodservice sector in Australia apply. However, they also stated that more efficient procedures to trade larger volumes of oysters through the food chain retail sector will need to be established, which may require time for infrastructure and relationships to be formed. Farmers mentioned that farmgate prices have decreased during the COVID-19 crisis, yet retail prices remained stable compared to the pre-COVID situation. This is causing concern within the industry about the farmgate prices for oysters

in the long run, and the flow-on effects on cash flow and business profitability of oyster farmers. Furthermore, the decreased demand for oysters may also affect the demand for oyster spat and the commercial viability of hatcheries.

Since the COVID health crisis had not been resolved by the time this report was finalised, it is recommended that further assessment be undertaken post-COVID-19 to investigate the adaptation of the oyster supply chain to the change in demand for the product and to compare findings to the results of the present study (pre-COVID). Information gathered from such study could reveal insights about supply network innovations and potential barriers to supply chain adaptation. Furthermore, it would be interesting to assess whether changes adopted were only temporary or if adjustments persisted in the longer run. Findings could help oyster industry and other seafood industries in Australia to adapt to potential future demand challenges.

Limitations

A limitation of this study is the relatively small sample size which was used to derive the structure of PO supply network, in comparison to the analysis of the SRO industry also conducted as part of this study. Consequently, the estimations of market shares at different segments in the distribution network presented in this study should be treated cautiously. Furthermore, the collection of additional socio-economic data about farmers would have been beneficial in exploring behavioral aspects of farmers choice of distribution model.

5 Conclusion

The aim of this report was to a) to describe the PO supply and value chain, b) to identify potential issues and opportunities linked to the supply chain, and c) to compare it to other oyster distribution networks (e.g., SRO).

Findings about structure confirm a presence of a complex distribution network. However, the results also confirm that the PO supply chain is very similar to the supply chain of SROs. Minor differences were identified in the dependence on and reliability of hatchery spat supply as production input and the absence of the premium oyster wholesaler in the PO distribution network.

Furthermore, issues (e.g., production risks, low export volume, limited diversification) and opportunities (e.g., value creation through marketing/branding, consumer education, shorter and integrated supply chain) that affect the supply of the product are shared across the two main commercial oyster industries in Australia.

The study did not investigate the impact of the COVID-19 health crisis on the supply chain of the PO, but a suggestion is made to examine how the distribution network adapts to the challenges caused by the mandated closure of restaurants in the short and long run.

The report also identified a range of issues and opportunities and a number of suggestions to address these were proposed. This may offer basis for further discussion and effort, both by individual businesses and industry-wide bodies, to develop and/or refine both micro- and macro-level strategies for supply chain management that can contribute to increasing the economic growth of shellfish mariculture in rural and regional areas in Australia.

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