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Status, supply chain, challenges, and opportunities to advance oyster aquaculture in northern Vietnam

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ABSTRACT

Oyster aquaculture in northern Vietnam is a new and growing industry that brings benefits to coastal communities. By understanding the oyster supply chain, the potential value can be fully explored, and socio-economic and environmental gains targeted. This study surveyed industry representatives – from farm to plate – to examine the industry status, distribution network, challenges, and opportunities. Four broad distribution network models were identified: direct-to-sale, wholesaler, cooperative/processor, and retailer. These models are quite different and comparing them is complex. A reduction in the marketing margin in any supply chain is likely to result in shared economic and/or welfare gains for pre-harvest elements, elements in the value chain, and consumers. Similarly, lower farm production and hatchery costs and increased consumer demand would result in welfare gains shared along the supply chain, although these do not necessarily translate to changes in the marketing margin. Key challenges were associated with spatial and marine development planning, lack of monitoring, collaboration/coordination along the supply chain, market price variation and consumers. Challenges were further explored in the categories of collaboration/coordination, regulation, and export. Opportunities exist to better understand how oyster shell might be used as a by-product such as a livestock mineral supplement, in soil acidity management, and in crop and vegetable growth. Almost half of the survey respondents have oyster shell as a by-product, suggesting the potential for carbon offset schemes could also be explored, at least to the extent to which they ameliorate the carbon footprint of the industry. These opportunities could advance and value-add to oyster aquaculture in northern Vietnam.

1. Introduction

Oyster aquaculture in Vietnam is relatively new but has proven highly successful. The farmed species has been confirmed as the Portuguese oyster (*Crassostrea angulata*) with unexpectedly high genetic diversity among Vietnamese hatchery stock (In et al., 2017; Van In et al., 2017). *C. angulata* is very closely related to the Pacific oyster (*Crassostrea gigas*) and is morphologically similar (Van In et al., 2017). Conservative estimates of commercial production were 15,000 t/annum in 2018, and farming now occurs in all 28 Provinces that make up Vietnam's coastal areas with 2500 coastal-dwelling families benefiting from the industry (O'Connor et al., 2019). The annual production of Portuguese oysters is rapidly increasing and reached 50,000 t in recent years (Vu et al., 2020a; Vu et al., 2020b). These mostly small-scale businesses have been supported through a series of investments from Australian Centre for International Agricultural Research (ACIAR), beginning in 2005 (O'Connor et al., 2019; O'Connor et al., 2012). The growing industry has enabled diversification into other types of farming and created more jobs, more assets, more protein sources, and improved quality of life for farmers and their families, but these socio-economic benefits also come

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with challenges (Pierce and O'Connor, 2014).

In 2017, Vietnam was ranked the 6th country in the world most affected by climate change according to Germanwatch's Global Climate Risk Index (Eckstein et al., 2019). This vulnerability, particularly in coastal areas, makes the response to climate change in Vietnam of crucial importance (Schmidt-Thomé et al., 2014). The sustainability and ongoing success of oyster production, and aquaculture more broadly, in Vietnam hinges on the ability to rapidly adapt to the major climate change threats, including increasing intensity of storms, warming temperatures, reduced predictability of weather, and rainfall, flooding and drought anomalies (Johnson and Hung, 2020) . These climate threats, in addition to volatile markets and production risks, have led to aquaculture in Vietnam being described as "risky business" (Joffre et al., 2018).

Molluscs could play a role in mitigating climate threats. Oysters are marine bivalves that have two outer shells (valves) such as mussels, clams. These shells trap carbon as calcium carbonate and could, at a small scale, potentially be used to mitigate the effects of climate change, but bivalves also produce CO_2 through respiration. Although the role of bivalves in the carbon cycle has attracted interest in both aquaculture and oyster ecosystem restoration (e.g., Fodrie et al., 2017; Lee et al., 2020), the overall carbon balance of oyster physiology and how industry can economically benefit from this ecosystem service or oyster shell by-product remains unclear.

In northern Vietnam, the Research Institute for Aquaculture No. 1 (RIA1) under the Ministry of Agriculture and Rural Development plays an important role in the establishment and growth of oyster aquaculture. The coastal area for RIA1 is spread across five provinces and all produce seed and commercial oysters (Fig. 1): Quang Ninh, Hai Phong, Thai Binh, Nam Dinh, Ninh Binh. In Ninh Binh (the most southern coastal Province), as of July 2020 there were 267 small-scale hatcheries that collectively produced over 7 billion oyster seed (estimated seed value of over USD 1.05 million) to mainly supply Quang Ninh and Hai Phong (Ninh Ninh Department of Agriculture and Rural Development, 2020). These hatcheries provide about 30% of seed demanded by oyster farms in Quang Ninh (Ninh Ninh Department of Agriculture and Rural Development, 2020). Some seed is, or at least used to be, imported from China to meet demand, but farmers prefer seed from hatcheries in northern Vietnam because it is considered to have better quality and survival through grow-out.

Supply and value chain analyses are useful in identifying challenges and opportunities within a sector and provide a baseline to build a resilient supply network beneficial to both businesses and the industry (Schrobback et al., 2021). Supply and value chains that describe the oyster distribution networks have been done for Australia (e.g., Schrobback et al., 2021) and the United States (e.g. Love et al., 2020), and are more commonly developed for other seafood and a specific purpose such as cold chain storage, traceability, governance, or price development. In Asia, supply chains have been studied for prawns (e.g., Alam and Pokrant, 2009) and fish (e.g., Grema et al., 2020; Kimani et al., 2020), but no comprehensive supply and value chain has been developed for oysters. In Vietnam, only limited investigation of the oyster post-harvest sector has been undertaken, meaning the challenges and opportunities along the oyster supply and value chain are not well documented.

Dung (2021) identified two distinct supply chains for edible oysters in northern Vietnam. In Quang Ninh (the most northern coastal province), the dominant supply chain was through oyster farmers, collectors and sellers of whole oysters, collectors and sellers of raw oysters, oyster

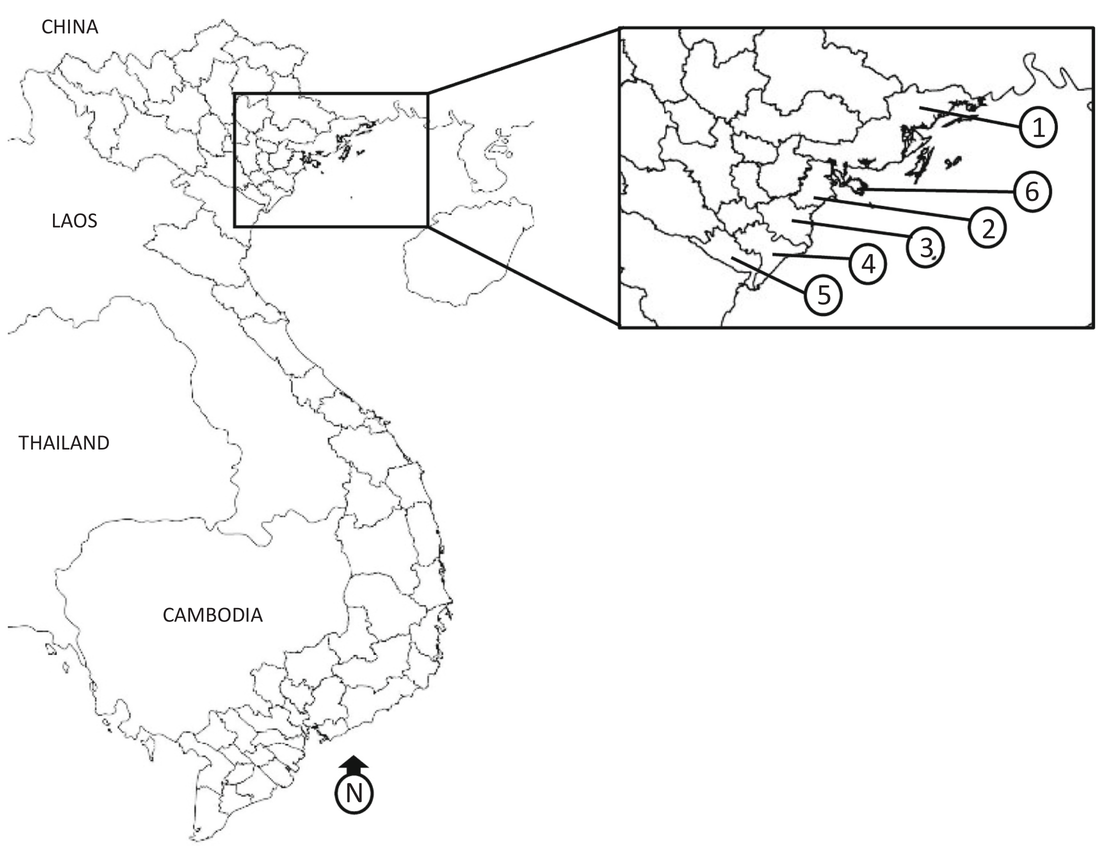

Fig. 1. Map of the coastal Provinces of northern Vietnam: 1) Quang Ninh, 2) Hai Phong, 3) Thai Binh, 4) Nam Dinh, and 5) Ninh Binh, as well as 6) Cat Ba Islands (a part of Hai Phong Province). Image available at Vemaps (www.vemaps.com/vietnam/vn-02#google_vignette).

processors, retailers, and consumers, which accounted for 80–85% of oyster production. The remaining production was through oyster farmers, cooperatives/cooperative groups/oyster processing companies, retailers, and then consumers. In focusing largely on minimising costs, Dung (2021) suggested that the absence of collectors and sellers (i.e., wholesaler "middle-men") in the shorter supply chain meant that farmers could sell oysters at higher prices and achieve higher economic efficiency. But the length of the supply chain is not necessarily an indicator of economic efficiency. Consumers in northern Vietnam have a high demand for seafood as a protein source that is mostly met by shrimp, fish, and molluscs (including oysters). In Quang Ninh, this demand is fed by nine seafood factories capable of processing fresh, frozen, and dried seafood. Frozen products are mostly shrimp, squid, fillet, fish cakes, and molluscs, with an estimated freezing capacity of 380 t/day (Dung, 2021).

This study surveyed industry representatives along the entire oyster supply and value chain in northern Vietnam – from hatcheries to consumers/exporters – to examine the industry status, distribution network, challenges, and opportunities. The aim was to gain an understanding of the oyster supply and value chain as a foundation to identify research and policy interventions of potential value to the entire industry. By understanding the supply, the potential value for oyster aquaculture can be fully explored and target the socio-economic and environmental gains that are beneficial for rural and regional communities of northern Vietnam. This could bring opportunities to rapidly advance and sophisticate oyster aquaculture in northern Vietnam.

2. Methods

2.1. Study area

There are five coastal Provinces with oyster production in northern Vietnam: Quang Ninh, Hai Phong, Thai Binh, Nam Dinh, and Ninh Binh (Fig. 1). All survey respondents were from the Hai Phong and Quang Ninh Provinces. These two Provinces produce the majority of oysters (> 80% of total production in northern Vietnam) and were safely accessible during COVID-19 travel restrictions. Human ethics approval was attained through a Minimal Risk Application from the University of Tasmania Human Research Ethics Committee (Research Ethics Unit), H0026434 (H-82164).

2.2. Farm survey

Survey respondents represented nine elements along the supply chain: pre-harvest (hatcheries and farmers) and post-harvest (wholesalers, cooperative or cooperative groups, processors, retailers, domestic consumers, domestic food services, and exporters). Potential survey respondents were identified through a combination of referral by RIA1 to ensure respondents were representative, random selection, and those who were accessible through COVID-19 travel restrictions. All surveys were conducted in January 2022. Survey respondents were interviewed face to face and were selected based on the accuracy of data collection, accessibility, and representation of the industry, and supply and value chain. Participation was voluntary and confidential, and each respondent was issued a unique identifier code to comply with ethics requirements.

2.3. Survey questions

Survey questions were developed based on similar surveys (e.g., Schrobback et al., 2021) and in discussion with RIA1. There were two available surveys: the pre-harvest sector for hatcheries and farmers (Supplementary Material 1) and the post-harvest sector for those elements beyond the farm gate (Supplementary Material 2). The differences between these two surveys were minor with the pre-harvest survey featuring two questions relating to applied farming practices and spat supply, and the post-harvest survey featuring two questions relating to buying and selling oysters through the supply chain. Respondents completed the survey that they felt was more relevant to their activity within the supply and value chain. Both the pre-harvest and post-harvest surveys had 17 questions that constituted 7 closed-ended questions (checkbox options), 6 open-ended questions, and 4 combined-ended questions (checkbox options and open-ended explanations). All questions were in the context of the respondent's own perception and experience (i.e., their business or operations), except for one question relating to mapping the supply and value chain which was in the context of the whole industry (i.e., question 6 in Supplementary Material 1 and 8 in Supplementary Material 2). Surveys were conducted in person by one or two researchers and took about 15 min to complete. Two surveys were also recorded with permission. Researchers conducting the interviews scribed responses to all questions and undertook a scribe standardization process to reduce bias.

2.4. Data validation

Due to the amount of interpretation required in the data entry (mostly stemming from translation from Vietnamese into English), there was a comprehensive data validation process to ensure accuracy and reliability. There were two levels of data validation: the raw data and the supply and value chain. Validating the raw data required an independent researcher to compare scribed responses (Vietnamese), recorded responses (Vietnamese), translated responses (English), and entered data (English) for two surveys. There was a high level of accuracy and reliability, and therefore, only the scribed responses (Vietnamese) and entered data (English) were checked for the remaining raw data. The supply and value chain data were validated by an independent expert from the Directorate for Fisheries in the Ministry of Agricultural and Rural Development which is responsible for managing aquaculture development in Vietnam. Here, data on the supply and value chain collected through the surveys were compared against current knowledge held within the Ministry. This also showed a high level of agreeance with the survey responses.

2.5. Data analysis

For the analysis, data from the two Provinces were combined. For open-ended questions, data require semi-quantitative content analysis using descriptive statistics in which responses were categorised into topics and expressed as a percentage of total survey respondents. The content analysis was also included in the validation process. Exchange rates from the Vietnam dong (VND) to the United States dollar (USD) were based on ASX calendar year (3 January 2022), about the time of data collection (0.00004375 USD units per VND; sourced from WSJ, 2022).

3. Results

3.1. Background information

There were 22 survey respondents in total, 10 from Hai Phong and 12 from Quang Ninh. On average, all survey respondents (i.e., both pre- and post-harvest survey respondents) had been trading oysters for 10 $\pm$ 3.9 (mean $\pm$ standard deviation) years (range: 3.5 to 20 years). Of the nine elements of the supply chain, only four respondents represented just one element (i.e., only four respondents were just a hatchery, a farmer, a wholesaler, and a processor). All other respondents undertook multiple functions within the supply chain and represented more than one element (Table 1). Thirteen respondents completed the pre-harvest survey, and 9 respondents completed the post-harvest survey. Of the respondents that completed the pre-harvest survey, all used "string" as the most common type of production system (where oysters are strung on heavy monofilament line and suspended from rafts), with four

Table 1
Number of respondents representing each supply chain element.

Supply chain element	Respondents (n)
Pre-harvest elements	13
Hatchery	12
Farmer	12
Post-harvest elements	9
Wholesaler	8
Cooperative or cooperative group	8
Processor	5
Retailer	7
Domestic consumer	2
Domestic food services	2
Exporter	1
Number of elements in chain	
Respondents representing 1 element	4
Respondents representing >1 element (up to 6)	18

respondents using both string and bags. Of the respondents that completed the post-harvest survey, all except one respondent handled oysters daily (the exception handled oysters 6 days a week) with an average volume of 4.5 ± 9.7 t (mean ± standard deviation) handled per day (range: 0.02 to 30.0 t handled per day; total volume from all respondents combined: 49.3 t per day).

3.2. Distribution network: oyster supply and value chain map

Supply chains perform the set of functions required to take oysters at the farm gate and deliver them to consumers in the form they demand (Fig. 2). Oyster supply chains were differentiated, and included all nine supply chain elements (i.e., hatcheries, farmers, wholesalers, cooperative or cooperative groups, processors, retailers, domestic consumers, domestic food services, and exporters), sometimes twice (e.g., oyster moving through two different retailers). Broadly, there were four supply chain modules: direct to sale (23% of production; farm direct to domestic consumer), wholesaler (35% of production; from farm passing

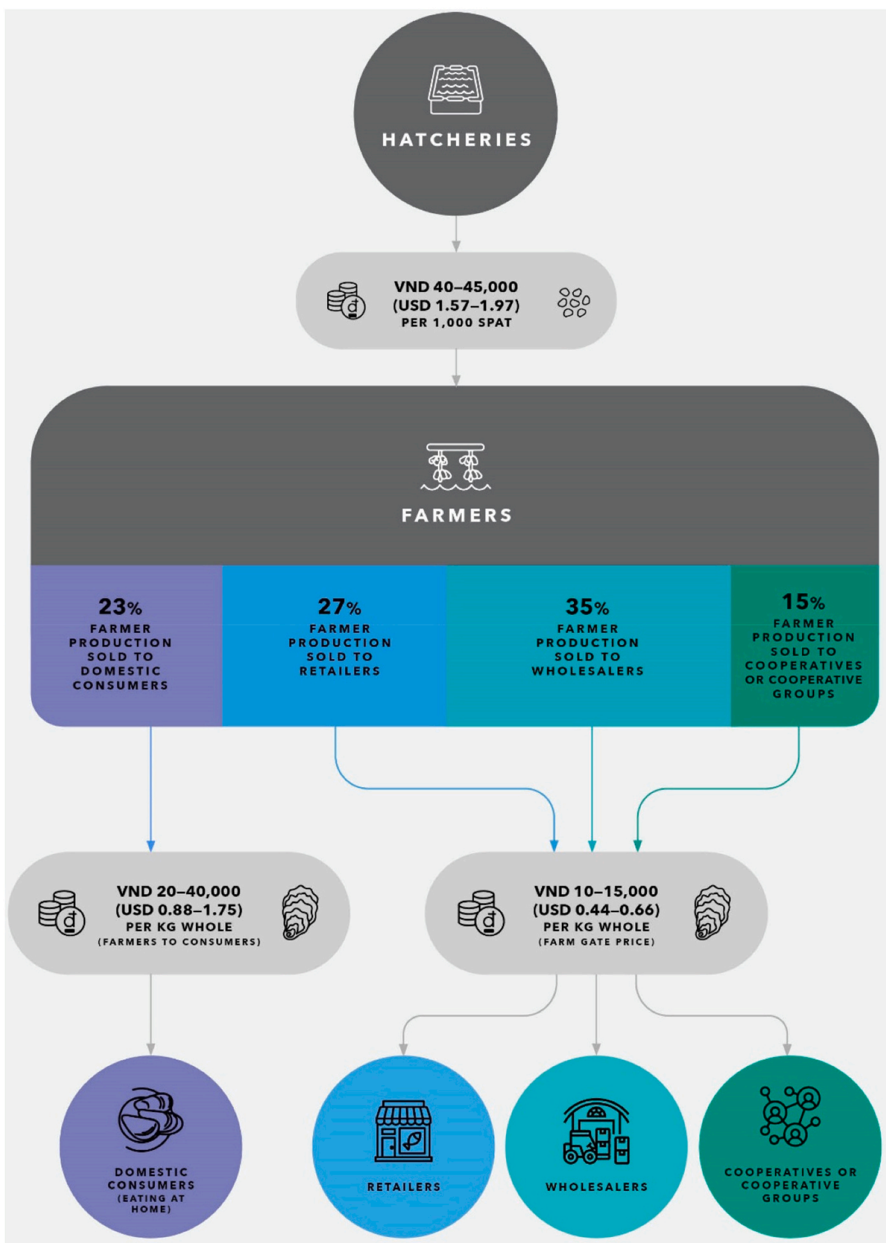

Fig. 2. Supply and value chain of oysters in northern Vietnam.

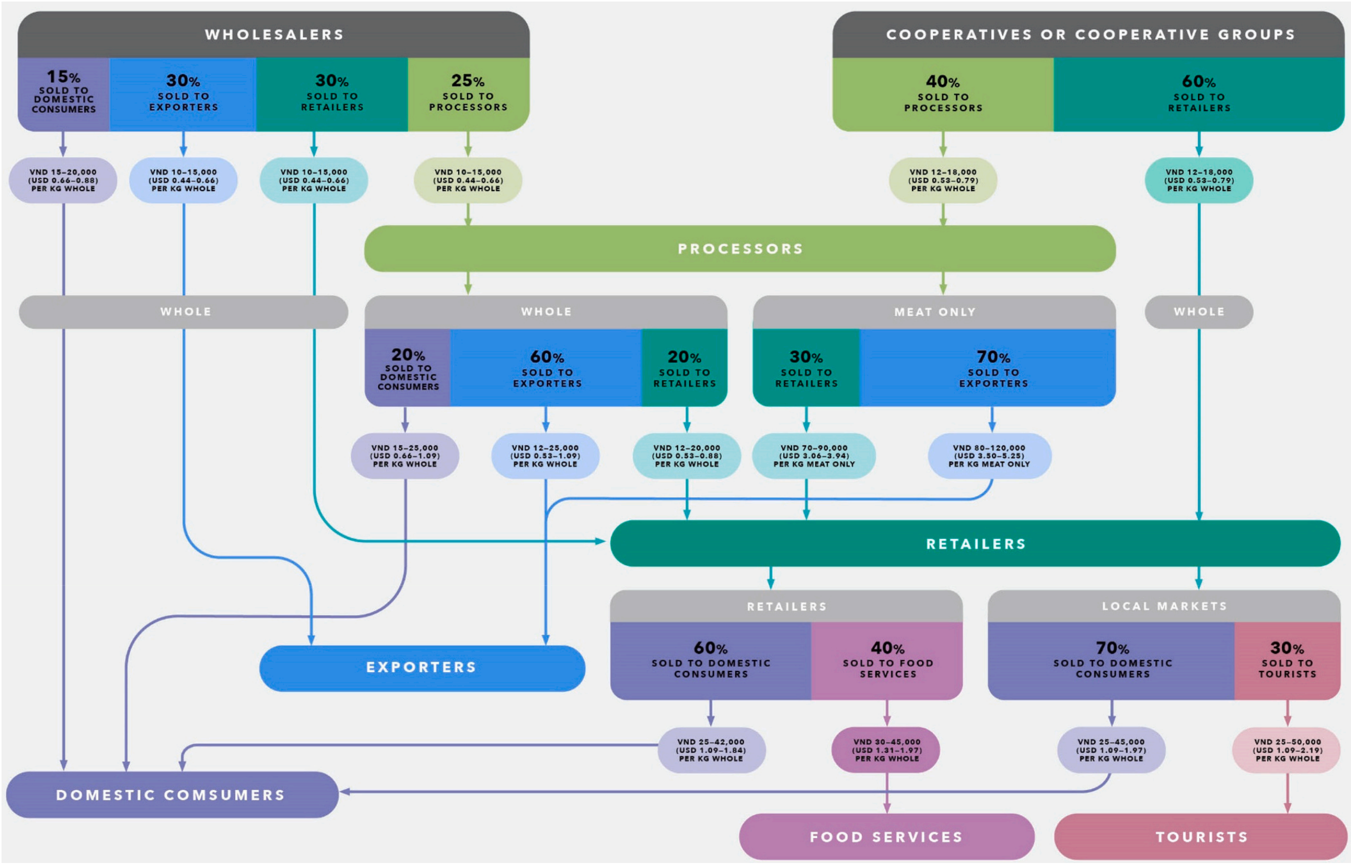

Fig. 2. (*continued*).

through wholesalers to other post-harvest elements excluding co-operatives), cooperative/processor (15% production; from farm passing through cooperatives/processors to other post-harvest elements excluding wholesalers), and retailer (27% of production; oysters passing through retailers to other post-harvest elements excluding wholesalers, cooperatives and processors: Fig. 2). These models describe the supply of oysters having left the farm gate (i.e., oysters from farms to the next element). Beyond this point, each model is not linear, with elements crossing over each other, and potentially oysters being supplied to exporters by three models (excluding the direct to sales model). There were no direct sales from farm to tourist consumer or exporters. All models except direct sales dealt with both whole oysters and meat only (no recorded oysters on the half shell). The highest premium price was for the export market (USD 1.31–1.97/kg), with supply to domestic consumers USD 0.66–1.75/kg, depending on the model), tourists (USD 1.09–2.19/kg), and food services (USD 1.31–1.97/kg) having less value.

The value along the supply chain (Fig. 2) varied greatly depending on the number of elements, the functions undertaken, and the characteristics of the products, such as oyster size (sold as three sizes: 20-35 g whole oyster (unopened) weight, 40 g–65 g whole oyster weight, and over 70 g whole oyster weight), but sometimes the value did not change despite additional elements. For example, the oyster value for domestic consumers was roughly the same with or without an additional local market retailer. Processors also dealt with whole oysters, meaning this element essentially could act as a second wholesaler (presuming no food processing occurred). Although, processing oysters did increase the product value, with selling meat only to both retailers and exporters increases value by USD 2.54–4.38/kg.

3.3. Key challenges: supply, collaboration, regulation, and export

All respondents to the pre-harvest survey identified issues with the

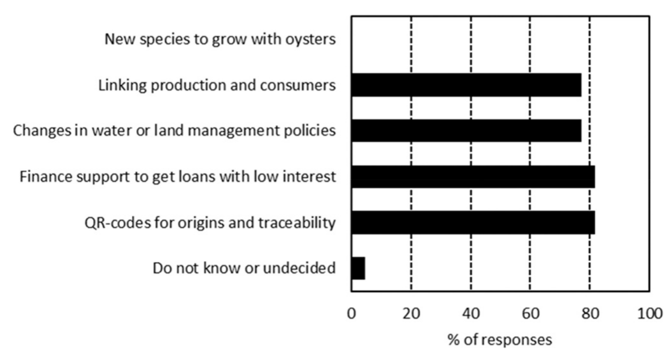

Fig. 3. Survey responses to what technology or policy should be improved to help increase oyster production and price along the supply chain in northern Vietnam.

supply of oyster spat (Fig. 3). These respondents thought there was no lack of spat supply, rather spat supply often exceeds demand (54% of pre-harvest respondents), however, there was a shortage of high-quality spat (77% of pre-harvest responses), especially during peak season. All respondents (22 in total) thought that oyster production and value along the supply chain would increase if technology or policy was improved. The two of the most impactful technology or policy improvements identified were developing QR codes for origin and traceability (82% of responses) and financial support through low interest loans (82% of responses; Fig. 3). No respondents thought that new species diversification would be helpful, and there were no additional technology or policy changes suggested.

Respondents identified 10 key challenges for oyster production, oyster supply and value chains in northern Vietnam (open-ended

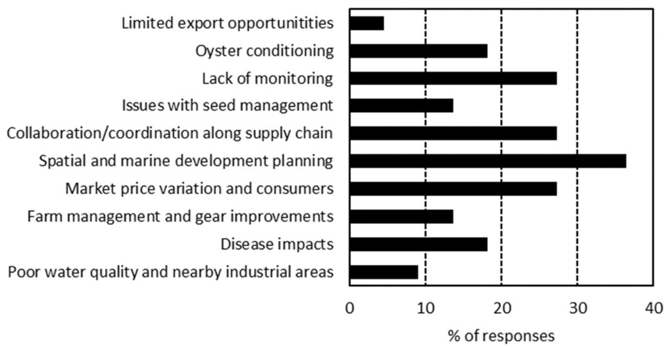

Fig. 4. Survey responses to key challenges for oyster production and oyster supply chain in northern Vietnam.

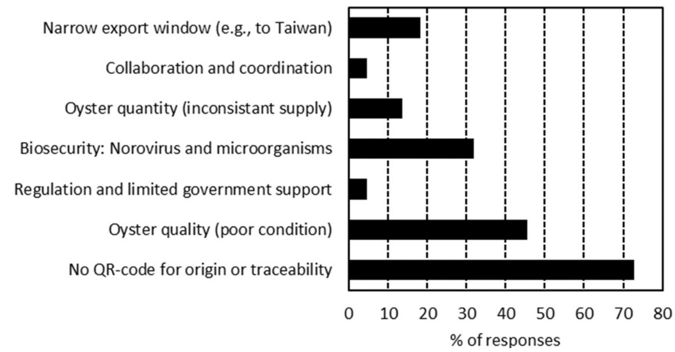

Fig. 6. Survey responses to the reasons for the limited export of oysters in northern Vietnam.

question: Fig. 4). Of those key challenges, the most common issue was spatial and marine development planning (36% of responses) with respondents commenting that there is no plan for farm development, and this often leads to "disorder". Other key challenges were variation in market price or consumer-related challenges (27% of responses, e.g., oysters in poor market condition and market price varying between seasons depending on supply), lack of monitoring (27% of responses, e.g., there is no monitoring in growing areas resulting in over-stocking and poor conditioned oysters, and water quality issues), and lack of collaboration or coordination between elements along the supply chain (27% of responses, e.g., sometimes it is difficult to sell stock).

Most respondents did not operate under a formal contract or agreement (86% of responses). Without this, collaboration and coordination are based on trust and communication with no commitment to oyster quality or quantity. It was noted that this can be "spontaneous" production where local government does not enforce farmers to follow regulations, and this can result in sudden and sporadic oversupply. The remaining respondents operated under a formal contract or agreement (9% of responses) or did not specify the nature of the collaboration or coordination (5% of responses) along the supply chain.

Respondents identified 10 regulatory challenges which affect the supply chain (open-ended question: Fig. 5). The extent of these regulatory challenges mostly ranged from 9 to 23% of responses. The exception was the regulatory challenges of animal health and disease which was identified in 50% of responses. Animal health and disease included the need for spat production with disease resistance (selective breeding) and difficulties in conditioning (fattening) commercial stock. Food safety and accreditation were not identified as a regulatory challenge by any respondents, even though norovirus and bacteria were seen as an impediment to export (Fig. 6).

Respondents identified 7 reasons for the limited export of oysters (open-ended question: Fig. 6). Of these reasons, the most common were the absence of QR codes for origin and traceability (72% of responses), poor oyster quality (45% of responses), and restrictions associated with biosecurity (32% of responses). Respondents commented that Taiwan is the main market for exported Vietnamese oysters, but this is restricted to approximately six months (June to December) when Taiwan has a shortfall in its own domestic supply. Laos, Thailand, and Cambodia were identified as current small export markets, and there was a consensus that there are export opportunities to the United States and Europe.

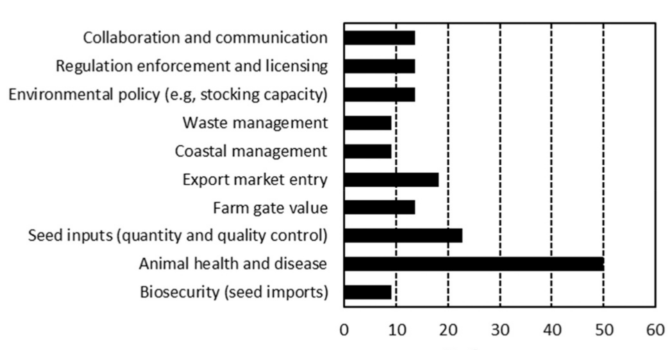

Fig. 5. Survey responses to regulatory challenges which affect the network distribution of the oyster supply chain in northern Vietnam.

3.4. Key opportunities: environmental sustainability and by-products

Most respondents (68%) thought that oysters are an environmentally sustainable seafood product. The remaining respondents did not know or were undecided. Following a brief explanation of carbon offset schemes (explained to respondents as relating to the entire distribution network, and not just the initial production), approximately half of the respondents thought that valuing carbon sounded like a good idea (55% of responses), and the remainder did not know or were undecided. No respondents thought that valuing carbon sounded like a bad idea.

Most respondents (13 out of 22 responses) thought that oyster shells should be sold as a by-product to make oyster production more profitable. The remaining respondents did not know or were undecided. One respondent thought that oyster shell should not be sold as a by-product (4% of responses), but no reason was recorded. From the respondents that thought oyster shells should be sold as a by-product, 7 potential uses were identified (Table 2). The most common possible uses were mineral supplements in livestock feed, soil management to reduce acidity, and crop and vegetable growth and vitality (each 92.3% of responses). 76.9% of these responses thought that carbon and carbon offset schemes should be explored as a potential use. 41% of all respondents have oyster shell as a by-product, and of these, 84.6% currently sell oyster shell mostly to hatcheries for between USD 0.13–0.35/kg or in exchange for a lower spat price. The remaining respondents with oyster shell as a by-product discarded it.

Of the nine supply chain elements, hatcheries, farms, cooperatives, producers, and retailers were the only elements recorded as producing shell. Wholesalers, domestic consumers, domestic food services, and exporters were not recorded as producing shell. The total weight of shell

Table 2
Number of responses (from those who thought that oyster shell should be sold as a by-product) for potential uses of oyster shell by-product.

Potential Uses for Oyster Shells	Responses (%)
Carbon and carbon offset schemes	77
Hatchery for spat production	85
Mineral supplements in livestock feed	92
Soil management to reduce acidity	92
Crop and vegetable growth and vitality	92
Building foundations, road manufacture, or artificial stone	69
Water filtration and purification	54

produced was too difficult to estimate, but the percentage of total shell discarded, sold to hatcheries, or sold to other users could be estimated for the supply chain elements (Table 3). Shell was only recorded as discarded or sold to hatcheries (shell was not recorded as being sold to other users). The majority of shell was estimated to be discarded.

4. Discussion

This study surveyed industry representatives along the entire oyster supply and value chain in northern Vietnam – from hatcheries to consumers/exporters – to examine the industry status, distribution network, challenges, and opportunities. To this end, 22 respondents were interviewed from Hai Phong and Quang Ninh Provinces representing 9 supply chain elements: pre-harvest (hatcheries and farmers) and post-harvest (wholesalers, cooperative or cooperative groups, processors, retailers, domestic consumers, domestic food services, and exporters). Many of the respondents carried out multiple functions along the supply chain and were able to efficiently provide insight into more than one area of expertise.

Commercial oyster production in northern Vietnam began in 2006/7 and within four years had reached 7000 t with a reported value of AUD7.0–9.8 million (O'Connor et al., 2019). This rapid development was embraced, but challenges, particularly relating to genetic quality of stock were soon apparent (In et al., 2017; Vu et al., 2021) and became the major focus for research. With interest in genetics, other areas of industry development received less attention. This study is one of the first to address the status and challenges outside genetics for a rapidly developing industry and highlighted six areas with the potential to rapidly sophisticate the industry: distribution networks (oyster supply and value chains), key challenges for oyster production and supply chains, collaboration/coordination, regulation, export, oyster shell by-products and carbon offset schemes.

Oysters in northern Vietnam have four broad distribution networks: direct to sale, wholesaler, cooperative/processor, and retailer (Fig. 2). Understanding and identifying inefficiencies along these networks from hatcheries to domestic and export consumers may lead to gains in efficiency and profit. For the purpose of this study, a network is efficient when the elements in the network are performing their functions at least cost. Dung (2021) reported an estimated 80–85% of oyster production in northern Vietnam moved through a distribution network similar to the wholesaler model, with the remaining through a distribution network similar to the combined cooperative and retail models described in this study. Dung (2021) advised that to improve economic efficiency, the distribution network should shift away from the dominant wholesaler model. However, the extent to which an efficiency gain would arise is unclear because a change is required in the functions undertaken by elements in the networks, making comparisons difficult.

This study indicates that this shift away from the wholesaler model may have happened, with this model only representing 35% of production (Fig. 2). This study also shows that the direct to sale model represents 23% of production (Fig. 2), and this model was not reported to be present by Dung (2021). Elsewhere, oyster businesses have sought to improve profitability by establishing or expanding direct sales (including online sales) and shortened supply chains as strategies to increase resilience to market and supply chain disruptions (Ogier et al., 2020). Adoption of shorter and more integrated oyster supply chain models has also been coupled with recommendations to increase consumer awareness through product market/branding, offer on-farm oyster experiences (e.g., farm tours, shucking events), and closer links and training of chefs and restaurant staff (Schrobback et al., 2021). These changes may increase revenue for pre-harvest producers, specifically farmers, but also require greater management expertise on their part and perhaps more costly inputs in the form of, for example, better quality oysters. Changes must also be tailored to other cultural and socio-economic conditions faced by farm families in northern Vietnam.

Comparing the efficiency of oyster supply and value chain models is difficult. Value chains can be assessed through the marketing margin which is the difference between the price a consumer pays for an oyster product and the price received by a farmer. In a competitive market, the marketing margin approximates the cost of transferring (e.g., freight, handling) and transforming (e.g., removing meat from shell, freezing, packaging) oysters from farmers to consumers. The marketing margin can be reduced and provide gains by, for example, new technologies or regulatory changes that lower the cost of transferring and transforming oysters. This study did not calculate marketing margins because the sample size for each of the four value chains was too small to confidently estimate the margins, and price data was limited. However, Mullen et al. (2016) suggested that the marketing margin might be in the order of 40% of the retail price for the industry as a whole.C.

Lowering the cost of growing oysters or increasing consumer demand could lead to welfare gains shared along the supply chain and still may not narrow the marking margin. Comparing the marketing margin of alternative supply chains is fraught with limitations. For example, if the end product or end consumer is different between supply chains, it is then difficult to judge whether one supply chain is more efficient than the other. At the farm end, one supply chain might require a higher product quality than the other, and presumably, this quality difference might be due to management (which is not cost free) and environmental conditions. At the consumer end, products may have different services embodied, such as convenience packaging and other attributes (e.g., a high level of food safety is required for export). These value chains that differ between supply chain models could also compete with each other for consumer demand, not only for price, but also for quality (e.g., size, freshness, and packaging), and this might explain why the final value of products of each model is similar in this study. This means that the four value chains identified in this study can coexist, and each can be efficient for the functions it undertakes. Shortening the value chain in an attempt to increase product value does not necessarily reduce the marketing margin because the same functions still have to be performed regardless. Sometimes shortening the chain through vertical integration might lead to a lower margin and gains in efficiency if there is greater coordination of the functions undertaken along the chain.

This study highlighted 10 key challenges of oyster production in northern Vietnam. The biggest challenge was spatial and marine development planning, and this is intrinsically linked with other major challenges: lack of monitoring, market price variation and consumers, and collaboration or coordination along the supply chain. Specifically,

Table 3
Supply chain elements producing shell, and the percentage of shell that is discarded, sold to hatcheries, or sold to other users. The amount of shell being sold to other elements was all unknown (i.e., it is unknown if shell is being sold to any other supply chain elements other than hatcheries).

	Shell Production	Amount of shell discarded (%)	Amount of shell sold to hatcheries (%)
Hatcheries	Yes	25–60[1] 50–100[2]	25-40[1] 50–80[2]
Farms	Yes	15-60[1] 30–100[2]	25[1] 40[2]
Wholesalers	No	Unknown	Unknown
Cooperatives or cooperative groups	Yes	30–70[1] 60–100[2]	20[1] 40[2]
Processors	Yes	25-70[1] 50–100[2]	20[1] 40[2]
Retailers	Yes	25-70[1] 50–100[2]	20[1] 40[2]
Domestic consumers	No	Unknown	Unknown
Domestic food services	No	Unknown	Unknown
Exporters	No	Unknown	Unknown

Hatcheries can only use the cupped valve in spat production. Survey participants reported shell either as percentage of all shell or percentage of cupped shell.
[1] All shells (both valves).
[2] Cupped shells (left valve only).

the lack of strict management and monitoring in oyster growing areas has resulted in over-stocking that results difficulties in fattening/conditioning oysters for market. Oysters with reduced and inconsistent condition are then difficult to sell and contribute to variation in domestic market price, as well as limiting access to premium export markets. Spatial and marine development planning is typically underpinned by legislation that stipulates lease conditions, including stocking density on individual leases. In Vietnam, oyster enterprises and farmers decide quantity and density of spat and oysters growing in the lease area they manage. The local government only provides a license for farmers/enterprises to use the lease area and does not strictly manage spat. This can lead to the unavailability of spat and, therefore, oysters are currently being grown outside local government's monitoring and management.

Oyster farming can create multi-user conflicts, including between farmers who impact each other with chosen farming practices, and have impacts in coastal zones, such as social (e.g., employment), economic (e.g., revenue), and ecological impacts (Chen et al., 2013). The industry structure in Vietnam could be challenging to monitor and manage from a governance perspective because it is made up of many small-scale businesses, rather than fewer large-scale businesses. Despite these challenges, the socio-economic value of these small-scale businesses should not be underestimated (Pierce and O'Connor, 2014).

Collaboration or coordination along the supply chain was identified as one of the 10 key challenges of oyster production in northern Vietnam. The lack of formal contracts or agreements between elements of the supply chain means that trust and communication are vital in building and maintaining collaborations and coordination for spat and oyster sales. Particularly for the hatcheries and farms that can have short windows of time to move stock due to factors such as condition, food availability, incoming weather, and labor, having to keep stock longer than what is required or desired has an increased economic cost. For the wholesaler model, "middlemen" can create bottlenecks by restricting direct access to the market and limiting the ability of farmers and other elements lower in the supply chain to negotiate prices (Future of Fish, 2015). However, relying on trust and communication is not necessarily a disadvantage. Specialised supply chain elements (e.g., wholesalers, retails, and cooperatives or cooperative groups) can have greater ability to access markets and consumers not available otherwise and can quickly move perishable or refrigerated oysters, while maintaining product value, safety, and traceability information (Love et al., 2020). Fully integrated businesses (i.e., direct to sales model) can remove or reduce the reliance on supply chain "middleman" and the need for collaboration and coordination (Schrobback et al., 2021). Although some businesses are vertically integrated, in northern Vietnam, this investment is difficult for most smaller businesses, especially those without the expertise and economic ability to create value in this way.

Ten regulatory challenges of oyster production in northern Vietnam were identified in this study. Opinions on these challenges were broad, showing many different perspectives, but animal health and disease was the most reported challenge. This is mostly related to three areas: difficulty in fattening and conditioning oysters, occasional mortality due to disease, and quality of broodstock, with the latter being less associated with regulation. A lack of clear regulation and control can create a perceived disconnect between industry and government, particularly when tackling broad challenges such as environmental policy (e.g., stocking capacity), waste management, regulation enforcement and licensing, and access to the export market. This question, as well as others, was an open-ended question in our survey and interestingly, food safety, accreditation, and cold-chain storage were not mentioned by any respondents along the supply chain. This potentially highlights limited understanding and knowledge of food safety hazards along the supply chain, or that the regulation associated with food safety is perceived to be adequate. Oysters are a high-risk seafood due to their filter-feeding and because they are often consumed raw, and hazards such as heavy metals (Ngoc et al., 2020), *Vibrio* (Banerjee et al., 2012), *Salmonella* (Nguyen et al., 2016), and microplastics (Dang et al., 2022) could potentially pose health risks to consumers in Vietnam.

Oyster export in northern Vietnam is limited and 7 reasons for this were identified. The most reported reason for this was the lack of a QR code for origin and traceability, followed by poor oyster quality and biosecurity (Norovirus and microorganisms). Traceability of oysters in the market is vital to enable a prompt recall if it is deemed that the product is unsafe or unsuitable for consumption. There is a range of technology available to trace a product, and includes traditional labelling, digital tags (such as QR coded tags), hardware, and software, all of which have advantages and disadvantages. Whichever technology and traceability system is adopted, information needs to be made available rapidly to consumers and all relevant elements within the supply chain. Morgan et al. (2018) showed that if the consumers' perceived risk of consuming oysters following a contamination event can be appropriately managed, demand for oysters significantly increases. This low impact is compared to uncontrolled events, such as exported Australian mussels contaminated with paralytic shellfish toxins recalled from Japan in 2012 that cost the local economy more than AUD 23 million (Hallegraeff and Bolch, 2016). But developing and adopting a new traceability system requires a cost, and the potential success of a new oyster traceability system, such as QR coded tags, depends on the implementation costs and the extent to which price increases can be passed onto consumers (Morgan et al., 2018). For northern Vietnam, Taiwan is the main export market, yet this is only for around six months a year when domestic supply is limited. Laos, Thailand, and Cambodia are lesser export markets for northern Vietnam. Without consistency in oyster quality and quantity and an adequate traceability system linked to approved quality assurance monitoring systems, access to other export markets, such as the United States, China, and Japan may be challenging due to competition in the international market.

Oyster shell as a by-product is perceived positively and is already being sold by some elements of the supply chain in northern Vietnam. The only major purchasers of oyster shell presently are hatcheries that use the cupped shell (i.e., one half of oysters' shell – one valve only) as cultch to settle spat. Hatcheries either buy the shell for between USD 0.13–0.35/kg or reduce spat price. Even domestic consumers can purchase whole oysters and subsequently sell the cupped shell back to hatcheries (Vu, S. V., pers. comm.). Historically, other types of cultch have been trialed, such as bamboo, glass, wood and cardboard, but oyster shell, as well as potentially baked clay and slaked lime (Colsoul et al., 2020), work best despite the biosecurity risk of introducing or translocating non-native shell material such as diseases or invasive species (Jeffs, 1999). It is unclear if the shell sold by farmers to hatcheries is a by-product of processing and selling to domestic consumers (i.e., direct to sales model) or the shell is a result of oyster mortality, potentially introducing a biosecurity risk. To mitigate this risk, hatcheries often dry cupped shells under sunlight for several days, soak them in saline water for a week, and then pressure clean before use as cultch for spat. Proportionately, farmers and hatcheries sell the most shell compared to post-harvest supply chain elements. However, recording the percentage, rather than total volume or weight, makes it difficult to ascertain where along the supply chain a targeted and economical shell recycling program would be best placed. Regardless, a shell recycling program should target the meat supply chain (i.e., where the meat is removed from the shell), rather than the whole oyster supply chain. A shell recycling program can be seen as a cost-effective means of extracting value from a by-product normally seen as a waste. Shell recycling programs produce low-value products and rely on a consistent supply of large amounts of shell. In northern Vietnam, all seven proposed oyster shell products were supported by at least 50% of the respondents, with those that benefited primary producers – oyster or livestock farming and agriculture the most popular, highlighting the perceived importance of food production in northern Vietnam.

Oysters are becoming appreciated for their contribution to ecosystem services, and with that, comes opportunities to explore potential economic gains, including carbon offset schemes and other carbon trade mechanisms. Joffre et al. (2018) described aquaculture in Vietnam as "risky business" due to climate-related threats, volatile markets, and production risks, all of which can hamper upscaling of production. By attempting to value and capitalize on ecosystem services, the economic business case for oyster can be substantially improved. Despite most of survey respondents in this study perceiving oysters as an environmentally sustainable seafood product, only about half thought that carbon offset schemes sounded like a good idea. This could reflect a lack of understanding of carbon offset schemes in general, or alternatively, specific uncertainties, such as how such a scheme could be effectively implemented. Van den Burg et al. (2022) developed six feasible economic payment mechanisms for global bivalves and seaweed ecosystem services: tax-payer funded payments, tradeable credits, encouraging subsidies, social licenses to produce, production cost-sharing schemes and increased utility for consumers. Each of these mechanisms have some merit for application in northern Vietnam but would need to be tailored to suit the social, economic, and political framework. In addition, application of these mechanisms would depend on the specifics for oyster carbon balance in northern Vietnam, for which there is limited data and the need for scientific attention and quantification. The sequestered carbon locked in oyster shells can have a relatively short cycle as it soon becomes biologically available again through decomposition and dissolved organic matter, as well as the contribution of oyster respiration and farming practices. Nonetheless, land-based carbon offset projects have a monetary value of around 5€/ton CO_2-equivalent (Hamrick and Gallant, 2018), and this warrants exploration and application for water-based systems.

This study has some limitations worth noting. The sample size, time of data collection, and types of respondents were somewhat limited by COVID-19 travel restrictions and availability, and this was addressed by having the data independently reviewed and approved by the Directorate of Fisheries, Ministry of Agriculture and Rural Development in Vietnam to ensure it was a good representation. Dealing with data in multiple languages could have introduced some error in translation and interpretation, and this was minimised by applying a comprehensive data-checking process. Surveys can also introduce errors through researcher biases (e.g., phrases of questions and leading answers), and this was addressed by having one or two researchers undertake the interviews. The open-ended questions were "qualitative" data collection, and the process of turning this data into "quantitative" data by selecting and grouping key words or phrases can also have researcher biases, and this was also checked during data validation process.

5. Conclusion

The distribution network and value of oysters and shell in northern Vietnam (Hai Phong and Quang Ninh Provinces) was mapped through 9 supply chain elements: pre-harvest (hatcheries and farmers) and post-harvest (wholesalers, cooperatives or cooperative groups, processors, retailers, domestic consumers, domestic food services, and exporters). Supply chains were highly complex, with four broad models identified: direct to sale, wholesaler, cooperative/processor, and retailer. The amount of product moving between these models was relatively even, suggesting the distribution network has potentially shifted away from a "middlemen" dominated network (i.e., wholesaler model). Challenges and opportunities to rapidly sophisticate the growing industry were identified and include aspects of marine spatial planning, animal health and biosecurity, collaborations and coordination, regulation, export, oyster shell by-products and carbon offset schemes. There is justification to explore the potential uses of oyster shell by-products that especially benefit primary producers and food production (aquaculture, farming and agriculture) in northern Vietnam. The potential for carbon offset schemes is complex, as it is elsewhere in the world, but economic mechanisms have been developed and how these may be relevant is an opportunity for oyster aquaculture with growing interest.

CRediT authorship contribution statement

Sarah C. Ugalde: Conceptualization, Methodology, Formal analysis, Writing – original draft, Visualization, Project administration, Funding acquisition. **Sang V. Vu:** Investigation, Resources, Writing – review & editing, Project administration. **Cao Truong Giang:** Investigation, Resources. **Nguyen Thi Hong Ngoc:** Investigation. **Thi Kim Anh Tran:** Validation, Writing – review & editing. **John D. Mullen:** Writing – review & editing. **Vu Van In:** Supervision, Resources. **Wayne O'Connor:** Conceptualization, Methodology, Resources, Writing – review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

The The authors declare the following financial interests/personal relationships which may be considered as potential competing interests.

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Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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References

Alam, S.N., Pokrant, B., 2009. Re-organizing the shrimp supply chain: aftermath of the 1997 European Union import ban on the Bangladesh shrimp. Aquac. Econ. Manag. 13, 53–69.

Banerjee, S., Ooi, M.C., Shariff, M., Khatoon, H., 2012. Antibiotic resistant Salmonella and Vibrio associated with farmed *Litopenaeus vannamei*. Sci. World J. 2012.

Chen, T.-A.P., Chang, T.-C., Chiau, W.-Y., Shih, Y.-C., 2013. Social economic assessment of coastal area industrial development: an application of input–output model to oyster farming in Taiwan. Ocean Coast. Manag. 73, 153–159.

Colsoul, B., Pouvreau, S., Di Poi, C., Pouil, S., Merk, V., Peter, C., Boersma, M., Pogoda, B., 2020. Addressing critical limitations of oyster (*Ostrea edulis*) restoration: identification of nature-based substrates for hatchery production and recruitment in the field. Aquat. Conserv. Mar. Freshwat. Ecosyst. 30, 2101–2115.

Dang, T.T., Le, X.T.T., Nguyen, D.T., Phung, T.V., Vu, D.N., Pham, H.V., 2022. Abundance of microplastics in cultured oysters (*Crassostrea gigas*) from Danang Bay of Vietnam. Mar. Pollut. Bull. 180, 113800.

Dung, N.Q., 2021. Report on the Products Chain Development Project Major Agriculture Products of Provincial Level for 2020–2025, Orientation to 2030. Socialist Republic of Vietnam.

Eckstein, D., Künzel, V., Schäfer, L., Winges, M., 2019. Global Climate Risk Index 2020. Germanwatch. Available online at: https://germanwatch.org/sites/germanwatch.org/files/20-2-01e%20Global%20Climate%20Risk%20Index%202020_10.pdf.

Fodrie, F.J., Rodriguez, A.B., Gittman, R.K., Grabowski, J.H., Lindquist, N.L., Peterson, C. H., Piehler, M.F., Ridge, J.T., 2017. Oyster reefs as carbon sources and sinks. Proc. R. Soc. B Biol. Sci. 284, 20170891.

Future of Fish, 2015. Making Sense of Wild Seafood Supply Chains. A Report Created for The Nature Conservancy. Available online at: https://futureoffish.org/sites/default/files/docs/resources/TNC.SeafoodSupplyChainReport.V10.Web_.pdf.

Grema, H.A., Kwaga, J.K.P., Bello, M., Umaru, O.H., 2020. Understanding fish production and marketing systems in North-Western Nigeria and identification of potential food safety risks using value chain framework. Prevent. Vet. Med. 181, 105038.

Hallegraeff, G., Bolch, C., 2016. Unprecedented toxic algal blooms impact on Tasmanian seafood industry. Microbiol. Aus. 37, 143–144.

Hamrick, K., Gallant, M., 2018. Voluntary Carbon Market Insights: 2018 Outlook and First-Quarter Trends. Forest Trends, Washington. Available online at: https://www.forest-trends.org/publications/voluntary-carbon-markets.

In, V.V., Sang, V.V., O'Connor, W., Van, P.T., Dove, M., Knibb, W., Nguyen, N.H., 2017. Are strain genetic effect and heterosis expression altered with culture system and rearing environment in the Portuguese oyster (*Crassostrea angulata*)? Aquac. Res. 48, 4058–4069.

Jeffs, A., 1999. The potential for developing controlled breeding in the Chilean oyster. Aquac. Int. 7, 189–199.

Joffre, O.M., Poortvliet, P.M., Klerkx, L., 2018. Are shrimp farmers actual gamblers? An analysis of risk perception and risk management behaviors among shrimp farmers in the Mekong Delta. Aquaculture 495, 528–537.

Johnson, A., Hung, P.Q., 2020. Impacts of Climate Change on Aquaculture in Vietnam: A Review of Local Knowledge. Network of Aquaculture Centres in Asia-Pacific. Available online at: https://enaca.org/?id=1089. Available online at:

Kimani, P., Wamukota, A., Manyala, J.O., Mlewa, C.M., 2020. Analysis of constraints and opportunities in marine small-scale fisheries value chain: a multi-criteria decision approach. Ocean Coast. Manag. 189, 105151.

Lee, H.Z., Davies, I.M., Baxter, J.M., Diele, K., Sanderson, W.G., 2020. Missing the full story: first estimates of carbon deposition rates for the European flat oyster, *Ostrea edulis*. Aquat. Conserv. Mar. Freshwat. Ecosyst. 30, 2076–2086.

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.

Morgan, O.A., Whitehead, J.C., Huth, W.L., 2018. Measuring the impact of traceability information on oyster consumer behavior following a contamination event. Mar. Resour. Econ. 33, 387–400.

Mullen, J.D., de Meyer, J., Gray, D., Morris, G., 2016. Recognising the contribution of capacity building in ACIAR bilateral projects: case studies from three IAS reports. In: ACIAR Impact Assessment Series Report No. 93. Australian Centre for International Agricultural Research, Canberra, p. 84 available at. http://aciar.gov.au/publication/ias93. available at.

Ngoc, N.T.M., Chuyen, N.V., Thao, N.T.T., Duc, N.Q., Trang, N.T.T., Binh, N.T.T., Sa, H. C., Tran, N.B., Ba, N.V., Khai, N.V., 2020. Chromium, cadmium, lead, and arsenic concentrations in water, vegetables, and seafood consumed in a coastal area in northern Vietnam. Environ. Health Insights 14, 1178630220921410.

Nguyen, D.T.A., Kanki, M., Do Nguyen, P., Le, H.T., Ngo, P.T., Tran, D.N.M., Le, N.H., Van Dang, C., Kawai, T., Kawahara, R., 2016. Prevalence, antibiotic resistance, and extended-spectrum and AmpC β-lactamase productivity of *Salmonella* isolates from raw meat and seafood samples in Ho Chi Minh City, Vietnam. Int. J. Food Microbiol. 236, 115–122.

Ninh Ninh Department of Agriculture and Rural Development, 2020. Report on the Production and Consumption Situation of Oysters [Translated into English]. Socialist Republic of Vietnam, 15 September 2020. (N. B. D. o. A. a. R. D. Report, ed.).

O'Connor, W., Dove, M., O'Connor, S., Luu, L.T., Xan, L., Giang, C.T., 2012. Project Building Bivalve Hatchery Production Capacity in Vietnam and Australia - Final Report. Project Number: FIS/2005/114. Available online at: www.aciar.gov.au/publication/building-bivalve-hatchery-production-capacity-vietnam-and-australia-final-report.

O'Connor, W., Dove, M., O'Connor, S., In, V.V., Lien, V.T.N., Van, P.T., 2019. Enhancing Bivalve Production in Northern Vietnam & NSW. Project number: FIS/2010/100. Available online at: www.aciar.gov.au/project/fis-2010-100.

Ogier, E., Sen, S., Jennings, S., Magnusson, A., Smith, D.C., Colquhoun, E., Rust, S., Morison, J., 2020. Impacts of COVID-19 on the Australian Seafood Industry. Available online at: www.frdc.com.au/sites/default/files/products/2016-128-Product-Impacts-COVID19-Report-01Mar2021.pdf.

Pierce, J., O'Connor, W., 2014. Impact of oyster farming on rural community sustainability in North Vietnam. In: Linking Local and Global Sustainability. Springer, pp. 207–224.

Schmidt-Thomé, P., Nguyen, T.H., Pham, T.L., Jarva, J., Nuottimäki, K., 2014. Climate Change Adaptation Measures in Vietnam: Development and Implementation. Springer.

Schrobback, P., Rolfe, J., Rust, S., Ugalde, S., 2021. Challenges and opportunities of aquaculture supply chains: case study of oysters in Australia. Ocean Coast. Manag. 215, 105966.

Van den Burg, S., Termeer, E., Skirtun, M., Poelman, M., Veraart, J., Selnes, T., 2022. Exploring mechanisms to pay for ecosystem services provided by mussels, oysters and seaweeds. Ecosyst. Serv. 54, 101407.

Vu, S.V., Knibb, W., Nguyen, N.T., Vu, I.V., O'Connor, W., Dove, M., Nguyen, N.H., 2020a. First breeding program of the Portuguese oyster *Crassostrea angulata* demonstrated significant selection response in traits of economic importance. Aquaculture 518, 734664.

Vu, S.V., Knibb, W., O'Connor, W., Nguyen, N.T., Van In, V., Dove, M., Nguyen, N.H., 2020b. Genetic parameters for traits affecting consumer preferences for the Portuguese oyster, *Crassostrea angulata*. Aquaculture 526, 735391.

Vu, S.V., Gilmour, A.R., Nguyen, N.T., Dove, M., Van Vu, I., Le, T.S., Knibb, W., O'Connor, W., 2021. Does genetic correlation change across environments for harvest whole weight and its uniformity in the Portuguese oyster (*Crassostrea angulata*). Aquaculture 536, 736444.

WSJ, 2022. WSJ Markets: Vietnamese Dong/U.C. Dollar. Accessed October 2022: www.wsj.com/market-data/quotes/fx/VNDUSD/advanced-chart.

Update

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Corrigendum to “Status, supply chain, challenges, and opportunities to advance oyster aquaculture in northern Vietnam” [Aquaculture Volume 572, July 2023]

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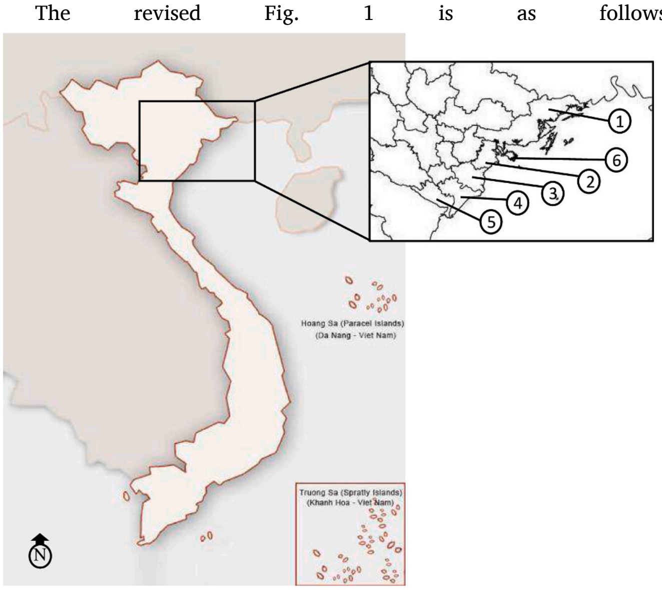
The authors regret an error in Fig. 1 of Ugalde et al. (2023). Unfortunately, the map provided in this figure is missing Hoang Sa (Paracel Islands) and Truong Sa (Spratly Islands). The error is not related to any data collected in the study.

The revised Fig. 1 is as follows:



The authors would like to apologise for the inconvenience caused.

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