

Navigating risks and uncertainties: Risk perceptions and risk management strategies in the Philippine seaweed industry

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ABSTRACT

The Philippine seaweed industry is affected by multiple but interrelated risks. Farmers mainly encountered environment-related risks (e.g. disease, pest infestations) which, if unmanaged, could result to production failure. Traders and processors considered volatility of seaweed supply and poor quality of raw materials as precursors of other risks such as increased competition among local traders and processing companies. Gender differences in awareness and knowledge of risks were more prominent among seaweed farmers but not among traders and processors as roles become more homogenous up the value chain. Poor governance resulted in the adoption of informal and market-driven strategies to prevent or minimise losses. However, this restricted farmers to participating in higher-income trading and processing activities and contributed to increased market inefficiency. The lack of government support has also curtailed the capacity of traders and processors to engage in product development and diversification. Gender and community experiences influence and shape people's understanding of their situations and environment including their coping and adaptive strategies in sustaining livelihoods amidst recurring risk events. Embedding informal structures and the differential needs of the stakeholders in the national institutional framework is therefore essential for the promotion of resilient and sustainable seaweed industry.

1. Introduction

Risk and uncertainty are interrelated concepts used to refer to events with adverse outcomes [1–5]. These terms can be conceptually differentiated based on the extent of knowledge about the nature of event, probability of occurrence, and consequences. Specifically, risk is characterised by an awareness of the probability, distribution and impacts of an event, whereas uncertainty involves the lack of knowledge about its characteristics [6–10]. The risk assessment process involves accounting for quantifiable and non-quantifiable factors such as uncertainties and perceptions (e.g. subjective awareness of risk) in order to obtain a holistic understanding of risk, particularly the values that people assign to the physical, social, and economic impacts of an event [3,4,11–14]. People's knowledge of risks serves as an indispensable source of information about people's safety behaviour, including the manner by which perceptions are translated into practical strategies to eliminate or reduce

the adverse impacts of an event [2–4,15–20]. Using a gender lens in the process of risk assessment further leads to better understanding of the differential impacts of hazards on stakeholders, including the marginalised and vulnerable groups [15,21,22].

A stakeholder approach in analysing risk and risk aversion is of particular importance when understanding the sustainability of the aquaculture industry [23–25]. Based on the report of the Food and Agriculture Organization (FAO), aquaculture constituted 46% of the global fish production in 2018 [26], hence, it is considered as one of the solutions to poverty eradication through provision of livelihood source and food sustainability through increased production of fishery products [27–29]. Within the aquaculture sector, farmed seaweeds is a major commodity among all aquatic algae. Eucheumatoids such as *Kappaphycus alvarezii* (“cottoni”) and *Eucheuma* spp. (“spinosum”) are the two widely cultivated species particularly in Southeast Asia and parts of West Indian Ocean, Pacific Islands, and Caribbean [30,31]. Commercial

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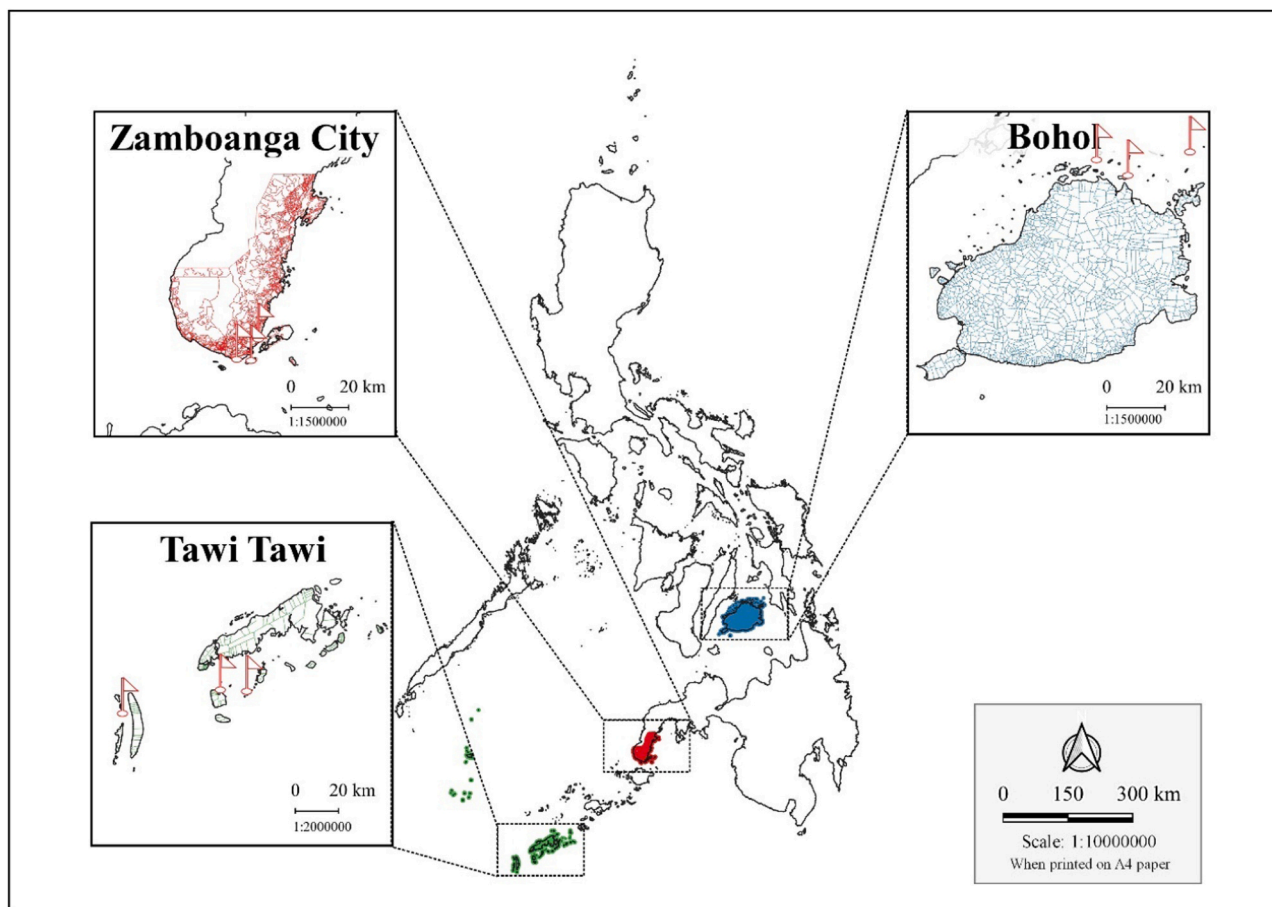


Fig. 1. Geographic locations of the three study sites in central and southern Philippines, Bohol, Tawi-Tawi, and Zamboanga City (Suyo, 2020).

production of eucheumatoids is driven by the increase in global demand for carrageenan as additive for food and non-food products (e.g., cosmetics, pharmaceuticals). Moreover, the use of simple and low-cost technology in cultivation has encouraged even smallholders to engage in seaweed farming [30–33]. Seaweed cultivation has the potential to expand with recent advancements in farming techniques and increased institutional support for the industry [31,34–38].

In the Philippines, the volume of seaweed production has been fluctuating, however, it still comprises a significant portion of the total fisheries production and represents more than half (64%) of the total aquaculture produced between 2016 and 2018 [39]. Seaweed farming is therefore considered as among the major livelihood sources in coastal communities particularly in key production areas which include the Bangsamoro Autonomous Region in Muslim Mindanao (BARMM), Mindoro-Marinduque-Romblon and Palawan region (MIMAROPA), Zamboanga Peninsula, and Central Visayas regions [39,40]. Seaweed farms are mostly owned by families and trading involves several tiers of local traders until it reaches the processors [32,41]. The Philippine seaweed industry mainly caters to *Kappaphycus* and *Eucheuma* species which are then processed as alkali-treated chips (ATC), semi-refined carrageenan (SRC), and refined carrageenan (RC). These seaweed products are mainly exported to Asia, the United States and Europe and used as additives to food and non-food products such as cosmetics and pharmaceuticals [30,31,36,42].

A closer look on the status of the seaweed industry reveals how commercial cultivation of eucheumatoids has been constrained by a multitude of issues such as reduced production due to incidences of disease and pest infestations, limited market access, and lack of institutional interventions [31–34,36,42,43]. Beyond that, there is also a need to examine what other risks constrain the value chain and how

interventions (e.g. infrastructure development, governance measures) can promote or constrain the outcome of the whole industry [44]. For instance, Suyo et al. [41] found that the relationships among the key actors (i.e. farmers, traders, processors) in the industry is highly interwoven and reinforced by economic reliance of farmers on traders and processors for access to credit and information (e.g. seaweed prices). The differential access to resources reveals the socioeconomic imbalances in the Philippine seaweed industry and provides some insights on how the current social network contributes to the emergence of risks at different segments of the value chain (i.e. production, trade, processing/export).

While it is essential to know the issues directly affecting the commodity (i.e., seaweeds), there is also a need to understand the social dynamics and how these have constrained or sustained the industry for more than four decades. This paper examines how the farmers, traders, and processors view risks and navigate the uncertainties associated with specific issues that affect the industry. Specifically, it aims to (i) identify the different risks from the narratives of the farmers, traders, and processors; (ii) know the different risk management strategies adopted and implemented by the stakeholder groups; and (iii) understand how stakeholder relationships shape and influence the structure of the seaweed industry in the Philippines.

2. Methodology

The data used for this study were obtained from a series for Focus Group Discussions (FGD) among women and men seaweed farmers and Key Informant Interviews (KII) with traders and processors from selected sites in key seaweed production areas in the Philippines, namely, Bohol (9.8500° N, 124.1435° E), Tawi-Tawi (5.1338° N, 119.9509° E), and Zamboanga City (6.9214° N, 122.0790° E) within the

Table 1
Number of FGD participants and key informants.

Respondent group	Data collection method	Women	Men
Seaweed farmers	Focus group discussion	64	51
<i>Bohol</i>		25	13
<i>Zamboanga City</i>		15	15
<i>Tawi-Tawi</i>		24	23
Traders	Key informant interview	3	2
Processors	Key informant interview	2	3

period from August 2018 to November 2019 (Fig. 1). Three research sites from each of the regions were selected for the FGDs with seaweed farmers. Site selection was based on the extent of seaweed production in the locality, with reference to information from key informants, published reports of the Philippine Statistics Authority (PSA), and with confirmation from the Local Government Units (LGUs). This process was not suitable in selecting key informants on seaweed trading and processing/export since the location of participants tended to be more dispersed and not necessarily concentrated in villages unlike the farmers. As such, interviews were conducted mostly in towns and cities where seaweed businesses were situated.

Purposive sampling was used in selecting respondents for each category. The parameters for respondents' selection were nature of involvement (i.e., farming, local trade, processing/export) and length of experience in the seaweed industry. Only those who had at least one year's experience in farming, trading, and processing/export were selected for the interviews to ensure that the participants had sufficient knowledge about the seaweed industry in order to facilitate in-depth enquiry of their perceptions and experiences. Two modes of qualitative data collection were used to triangulate data. Among the farmers, separate FGD sessions were conducted for women and men participants

to obtain gender-specific responses on seaweed production. A total of eighteen (18) FGD sessions were conducted with at least five women and five men participants for each session. The total number of seaweed farmers who participated in the study reached 115 from the original target of 90 (which means 10 farmers from each village) since farmers who expressed interest to participate were not excluded from the discussions (Table 1). The variations in the number of participants across the research sites did not compromise the quality of data but rather helped in reaching data saturation in the interview process [45]. Each FGD session lasted from 90 to 120 min and was conducted using the Filipino language with the help of a local translator when necessary. Data on trading and processing/export were collected through individual interviews with major five traders and five processors. Communications were sent to request for interviews and sessions were scheduled based on their availability. Each interview lasted for 60–90 min and was recorded with permission from the key informants. Using a multilevel enquiry, that is, obtaining data from different groups with varying number of samples facilitated a comprehensive understanding of the situation across the seaweed value chain. The use of different tools (i.e., FGD, KII) enabled the collection of information from different stakeholder groups and supported data triangulation. In particular, FGDs helped in accounting individual experiences and social processes among different farmer groups in a way that promoted inclusiveness in an environment where ensuring privacy for one-on-one interviews was limited. KII was the best tool in facilitating in-depth discussions among very limited set of stakeholders such as traders and processors/exporters [46,47].

Three semi-structured interview guides were formulated for the study. The FGD guide included questions on farmers' (1) sociodemographic characteristics; (2) socioeconomic profile (3) perceived risks, and (4) coping strategies. Among the traders and processors, questions

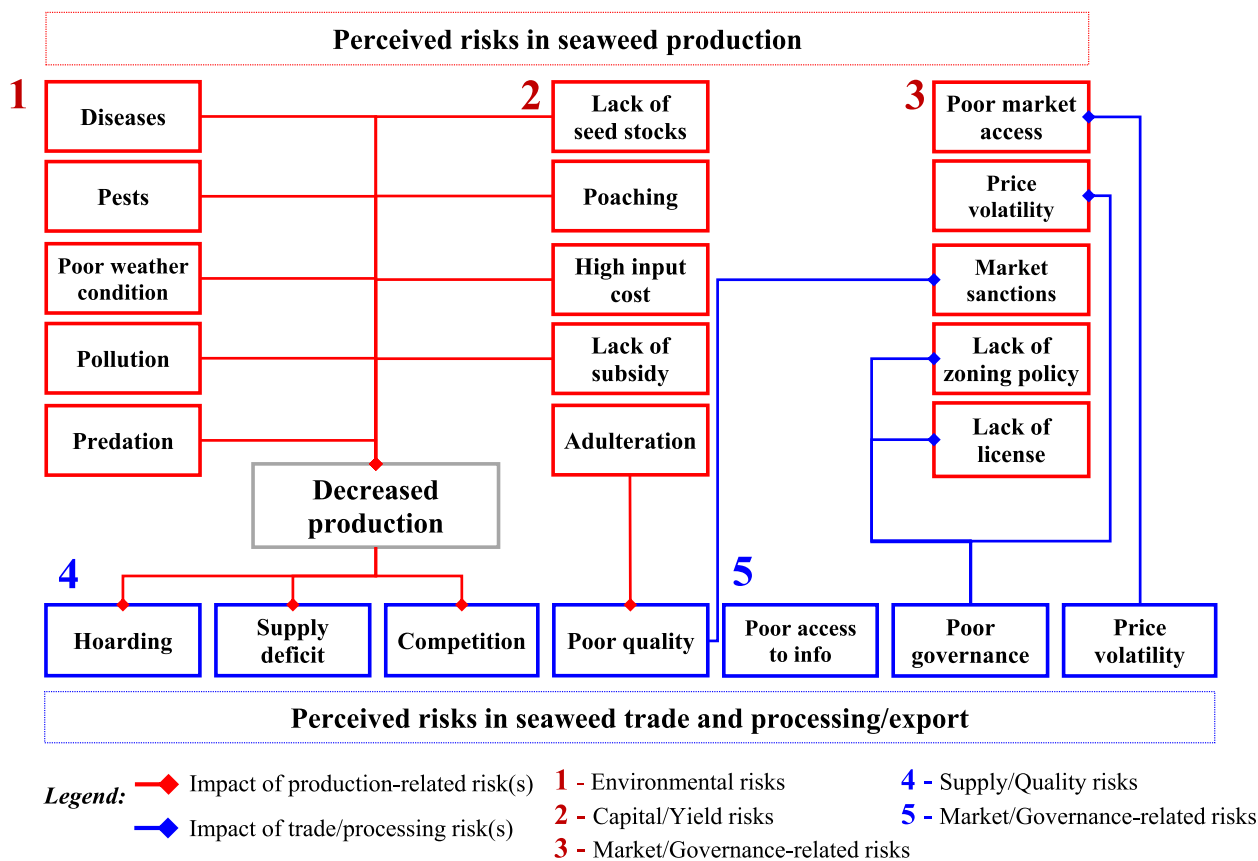


Fig. 2. Summary of perceived risks in seaweed production, trade, and processing segments.

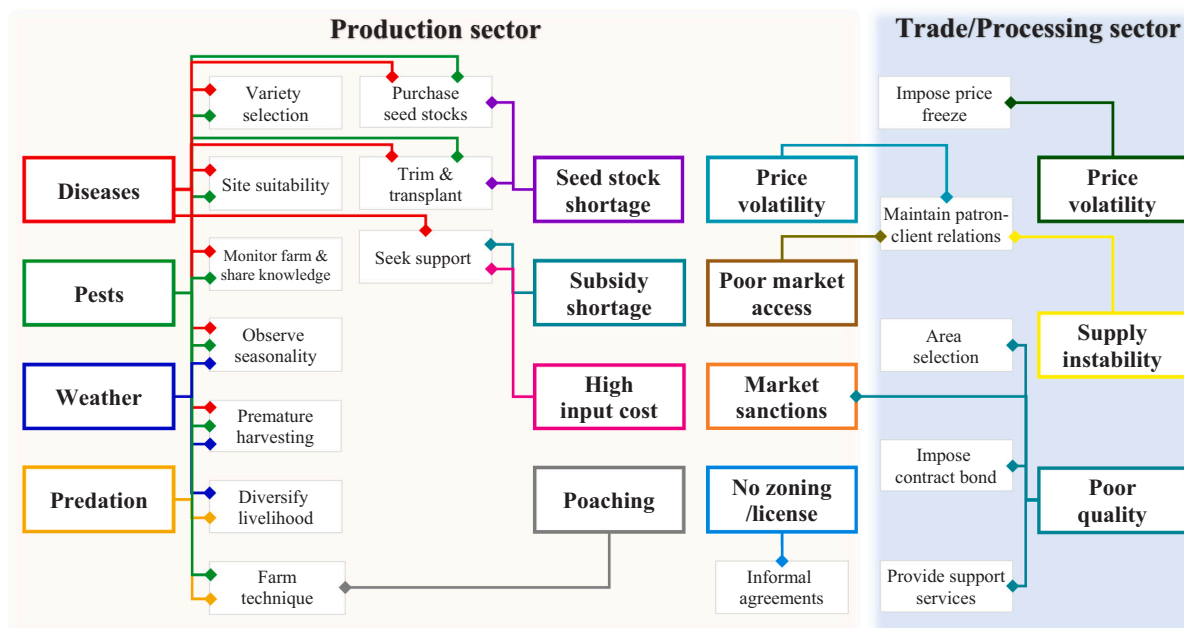


Fig. 3. An overview of risk management strategies in seaweed production, trade, and processing. Notes: (1) Perceived risks are enclosed in coloured boxes; (2) Coloured lines link risks to specific risk management strategy(ies); (3) Risks without corresponding risk management strategy(ies) were not included in the diagram. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

on the following topics were included (1) market structure (e.g., clients, seaweed sources); (2) perceived issues faced affecting trading and processing/export sectors; (3) mechanisms adopted to resolve the identified constraints; and (4) perceptions on socioeconomic mechanisms that govern and sustain the relationships of the different stakeholder groups in the industry. The questions on risk and risk management strategies were non-categorical, that is, the participants were asked to enumerate any types of risks that they have encountered and the corresponding mechanisms they have adopted to mitigate or respond to the impacts. The data were transcribed and content analysis was used to analyse the manifest content (explicitly stated) and latent content (underlying meaning) of the respondents’ narratives. Recurring themes on risks and risk management strategies within respondent groups and across sites were identified and categorised based on risk classifications in published studies [e.g. 24,27,31,36,44,48–50], and coded for analysis [51]. The perceived risks and risks management strategies of farmers, traders, and processors are summarised and illustrated using diagrams (Figs. 2 and 3). Tables showing the frequencies and percentages of responses of farmers (women and men), traders, and processors are found in Appendices A–D.

3. Results

3.1. Perceived risks in seaweed production, trade, and processing

3.1.1. Perceived risks in seaweed production segment

The farmers reported a total of fifteen risks in seaweed production which can be categorised into: i) environmental risks (5), ii) capital investment and yield risks (5), and market and governance-related risks (5) (Fig. 2). Responses that fall into the environmental risk category include disease occurrence, pest infestations, predation, poor weather condition, and pollution while the issues that affected capital investment and yield were high input cost, seed stock shortage, adulteration (e.g. chemical inorganic fertiliser, salt), and poaching. Market and governance-related risks included price volatility, poor market access, imposition of market sanctions for non-compliance to raw dried seaweeds (RDS) standards, and lack of zoning and licensing ordinances.

Disease occurrence and pest infestations were the most frequently

mentioned types of environmental risks across the three sites. The farmers reported that outbreaks of ice-ice disease and epi-endophytic infestations could reduce harvest by 50% or destroy an entire farm if not managed properly. Weather disturbance (e.g., typhoon) was only reported by women (32%) and men (100%) farmers in Bohol owing to the region’s geographical location. Even though none of the respondents in Zamboanga City and Tawi-Tawi reported typhoon as a risk in seaweed farming, seasonal weather changes were believed to affect temperature, water salinity, and consequently, the quality of seaweed growth. For example, exposure of seaweeds to freshwater during the rainy season was believed to contribute to the occurrence of ice-ice disease. The respondents further narrated that disease, pests, and poor weather conditions have forced farmers in some areas to reduce the number of annual cropping cycles from 6 to 4 rounds to avoid experiencing large scale losses. The issue of pollution caused by wastewater discharges from the households was indicated in the responses of women (27%) and men (67%) farmers in Zamboanga City while fish predation (e.g., rabbitfish, parrotfish, mullets, puffers) was only cited by men (39%) in Tawi-Tawi. Gender differences were notable with women’s responses mainly centred on the impact of disease and pest infestations on the seaweed farms. Though the majority of men reported similar incidents, the types of environmental risks they identified were more diverse, spanning from risks directly affecting the seaweeds (e.g., disease, pests) to those with more extensive impacts such as fish predation, weather, and pollution.

For risks pertinent to capital investment and yield, shortage of seed stocks was mentioned by farmers across the three sites. More men (41%) than women (27%) reported lack of seeds as an issue and cross-site comparison shows that it affected farmers in Zamboanga City more than Bohol and Tawi-Tawi. According to farmers, lack of seed stocks becomes a problem when they need to harvest and sell all their crops to recover the cost incurred for farm establishment. Farmers in Zamboanga City were most affected since they needed to purchase seedlings every cropping season. Lack of subsidy (i.e., government) was cited by farmers only in Bohol and Tawi-Tawi, especially women (33%). The farmers said that the Department of Agriculture – Bureau of Fisheries and Aquatic Resources (DA-BFAR) has provided materials for farm construction (e.g., ropes, soft plastic ties), but distributions were done intermittently and

not all farmers were able to avail of its support. High input cost (e.g., ropes, soft plastic ties) and use of additives (i.e., chemical inorganic fertiliser, salt) was only reported by farmers in Tawi-Tawi while poaching was a prominent problem among women (72%) and men (46%) in Bohol.

Among the market and governance-related risks, lack of zoning ordinance was a notable issue especially in Zamboanga City (100%). In Bohol, this issue was identified by 68% of women and 46% of men while only 21% of women and 39% of men in Tawi-Tawi perceived the lack of zoning ordinance as a risk in seaweed farming. The respondents who did perceive it as a risk narrated that it is often a source of conflict between the seaweed farmers and other resource users (e.g., fishers) and one of the factors that contributed to poaching, especially among farmers in Bohol. A majority of women (53%) and 39% of men farmers said that they did not have a license to operate a seaweed farm. The farmers reported they only needed to register their motorboats at their respective Local Government Units (LGUs) but site selection for the construction of seaweed farms was done on a first-come-first-served basis and with consent from other farmers and other stakeholders (e.g., village traders).

Price volatility affected the farmers in the three sites, with men in Bohol (54%) reporting this as a problem. The farmers reported that prices offered by traders vary and there is a lack of transparency about seaweed prices. For instance, farmers said that they only knew the buying price for fresh seaweeds or RDS during trading but they did not have any information as to why prices fluctuate or vary among traders. Only men farmers (22%) in Tawi-Tawi reported imposition of market sanctions (e.g., price reductions for non-compliance to RDS standards) as another risk affecting the production sector and 17% believed that this was further aggravated by lack of option to sell their produce to other traders who can offer better prices. Only one female farmer in Tawi-Tawi and Zamboanga City reported a similar problem.

3.1.2. Perceived risks in seaweed trade and processing segments

Two categories of risks were identified from the responses of the traders and processors: i) supply and quality risks, and ii) market risks/governance-related risks. All respondents believed that instability of seaweed supply was the main problem faced by the trade and processing sectors. The fluctuations were observed based on the volume of seaweeds obtained from the production sites vis-à-vis the capacity of warehouse or processing plant. During peak season, approximately 60–70% of the total storage capacity is utilised, however, the figure drops to about 50% during periods when seaweed supply becomes more limited. According to participants, lack of seaweed supply contributed to increased competition for RDS in the local market. One trader and processor narrated that instability in local seaweed supply is not necessarily caused by a decrease in volume of production but could also be due to hoarding. But since the seaweed market is highly segmented and onsite monitoring of harvest is lacking, the respondents could only presume that this is being practiced in the industry. The processors also reported that the increase in production of eucheumatoids in other countries (e.g., China, Indonesia) also affected the demand for carrageenan products from the Philippines. As one processor recounted, buying decisions become more influenced by price than by quality as consumers opt to get more for what they spend.

Another issue cited by four processors and three traders was sub-standard RDS quality due to improper drying, premature harvest (i.e., not completing the 45 days grow-out cycle), and poor post-harvest procedures (i.e., improper cleaning, adulteration through addition of salt or ash). Among these causes, traders and processors were least concerned about “visible” impurities (e.g., sand, soft plastic tie-tie) but were more particular about grow-out and drying periods since these affect the moisture content (MC) and carrageenan yield of seaweeds. Similarly, most of the traders and processors reported that the local seaweed industry is affected by the volatility of prices of carrageenan products in the global market. The processors said that they adjust the buying price for RDS based on international rates which consequently

affect local prices. Two traders mentioned that prices tend to change on a weekly basis and therefore access to information is crucial so that they can adjust their purchase price and disseminate the information to the farmers.

Two traders and three processors believed that these risks ensue from poor governance measures for monitoring seaweed quality and price control. They narrated that uncertainties in supply and prices result in increased disunity among the industry players thereby hampering the growth of the industry. Like farmers, processors also experience issues concerning access to government support needed for product promotion and development. The processors generally believed that the Philippine carrageenan industry is sustainable, but the failure of the government to respond to the different needs of the key industry players, such as support for product development, has led to industry stagnation.

3.2. Risk management strategies in seaweed production, trade, and processing

3.2.1. Risk management strategies among seaweed farmers

The farmers reported specific risk management strategies for each risk category. A total of twelve strategies were reported by farmers in managing the impacts risks in seaweed production: 1) observing seasonality, 2) variety selection, 3) site suitability, 4) farm technique, 5) trimming and transplanting, 6) farm monitoring and knowledge sharing, 7) premature harvesting, 8) purchase of seedstocks, 9) livelihood diversification, 10) seeking support services (e.g. credit), 11) patron-client relations, and 12) informal agreements (i.e. obtain permissions from traders/farmers) (Fig. 3). Similar strategies were implemented across sites, however, some gender differences in risk management strategies were noted.

Most of the strategies were centred on managing the impacts of disease occurrence, pest infestation, and poor weather conditions. Majority of women farmers (52%) reported site suitability as a commonly adopted strategy in managing disease (e.g., ice-ice disease) and pests (e.g., endophyte infestation) while most men relied on farm monitoring and information exchange with fellow farmers (77%) and selection of seaweed variety (49%). Farmers believed that site condition (e.g., water depth and water movement), type of farming technique, and proper selection of seaweed variety helped sustain seaweed farming. For instance, farmers in Zamboanga City and Tawi-Tawi widely used modified floating techniques (e.g., the “spring method”) because they have access to wider, deeper water areas while variations of fixed off-bottom systems were more preferred in Bohol and some households in Zamboanga City, especially among women, because of the availability of shallow reef areas suitable for seaweed farming. The respondents said that fixed-off bottom system entails lower financial and labour requirements for farm monitoring and allows women to work closer to the shoreline. Lastly, farmers noted that farming techniques affect the growth of certain varieties of *Kappaphycus* spp. and *Eucheuma* spp. The seaweeds were observed to be less prone to disease and pest infestations when using floating methods because it facilitates water movement within the farms which promotes better water quality within the farms and in the surrounding areas. Among men, farm monitoring was not consistently done throughout the grow-out cycle especially among farmers with large seaweed farms because it was time consuming and labour intensive. Farmers usually check their farms twice a week but visits become more frequent when farms are infested with epiphytes or infected with ice-ice disease. Since farm monitoring activities were not done daily, farmers provide each other with updates on the status of farms to prevent further spread of infestation.

Premature harvesting was done by both women (98%) and men (86%) when impacts of disease were no longer manageable. For instance, farmers in Bohol narrated having experienced harvesting seaweeds 15 days shortly after planting just to recover part of their investment. Farmers generally preferred to use seedlings from their own farms, including the trimmings from pest infested seaweeds, to reduce

capital expenditures on propagules. However, when they could no longer get portions of their harvest due to disease occurrence, pest infestation, or weather disturbances (e.g., typhoon), they resorted to purchasing seedlings from adjacent farms. The average cost of seedlings per kilo range from PhP5.00 (~USD 0.10) in Tawi-Tawi and Zamboanga City to PhP10.00 (~USD 0.19) in Bohol. Other strategies such as observing the seasonality of seaweed farming were only reported by men (8%) while livelihood diversification was practiced by women (17%) and men (10%) to supplement income losses due to poor weather condition. Even though farmers were aware of the seasonal variation in production output, very few farmers strictly observe the seasonality in seaweed farming since they believed that there are limited livelihood options in their localities. Farmers continue to cultivate seaweeds even during lean periods because they can still obtain a higher income compared to other jobs (e.g., fishing, food vending). Fishing was commonly done by men to supplement their income from seaweed farming during lean season or as source of food for their families. Women obtained extra income from selling their husband's catch and home-cooked food around the neighbourhood. The majority of farmers sought support from local networks (e.g., traders) or from government agencies (e.g., BFAR) to mitigate severe losses from typhoons and disease infestation.

Both women (77%) and men (77%) farmers reported that patron-client relations governed the local seaweed trading industry. The respondents believed that even though access to market is limited because of the need to maintain market relations with traders, the patron-client system has been beneficial because it enables distribution of support services (e.g., financial) to farmers, thus augmenting the lack of access institutional interventions. Moreover, it also helped in accessing information about seaweed prices. Seaweed farms were established through informal agreements between farmers and traders. All men obtained permission from local traders to establish their seaweed farms while 95% of women obtained their licences from the local traders and 5% leased an area from other seaweed farmers. Traders apply and pay for the permits and taxes to the LGUs and the Bureau of Internal Revenue (BIR) for the utilisation of an area for seaweed farming. Once permits are acquired, these are distributed to the households who are interested in seaweed farming under the auspices of a particular trader. There were no strict zoning guidelines and the only considerations were to secure the availability of the area and to ensure that it does not obstruct the navigational path. Even though pollution and adulteration of seaweeds were recognised problems in the seaweed production sites, none of the respondents reported conducting any measures to prevent or mitigate its impacts.

3.2.2. Risk management strategies of traders and processors

All respondents relied on the patron-client system to resolve issues concerning insecurity in RDS supply. This is mainly done through establishing support systems for seaweed farmers which include provision of funds for farm construction and other needs (e.g., health care). The processors have learned from experience that contract farming (i.e., an agreement wherein processors provide technical and financial support to farmers to be the sole purchaser of the harvested seaweeds) is inefficient because of the high cost involved in monitoring farm activities. As such, seaweed processing and export companies have opted to provide traders with funds to be used for financing farm construction or credit for seaweed farmers. A processor recounted that this set up is more effective in ensuring proper utilisation of funds and sustainable supply of good quality seaweeds because traders interact directly with seaweed farmers. Moisture content was the primary basis for

determining seaweed quality across all segments of the seaweed value chain but processors said that they also test for carrageenan yield to further ascertain RDS quality. All processors adhered to the national standards for raw dried seaweeds for *Kappaphycus* (i.e., 40%) and *Eucheuma* (i.e., 38%) varieties while only two traders reported strictly implementing the RDS specifications. Between the two respondent groups, the traders were less stringent in checking the quality of the RDS because apart from the lack of technology to determine the MC and yield, they needed to maintain good relations with the farmers. Both respondent groups reported imposing sanctions (e.g., percentage deduction from the buying price) for non-compliance which varies across sites. Among traders, price deductions could range from PhP1.00 (USD 0.02) to PhP3.00 (USD 0.06) per kilo of RDS, depending on the condition of RDS. The processors enforce contract bonds to guarantee payment for financial losses in case the RDS fail to meet required standards. The contract involves withholding 20% of the total sales from which penalties for nonconformity will be deducted. Both traders and processors narrated that enforcing market sanctions is challenging because they need to consider the implications of their decision on the welfare of other stakeholders, particularly the farmers. They believed that enforcing standard price deductions would result to large financial losses and could affect relationships with clients (e.g., traders, farmers). However, there were cases when traders and processors needed to terminate market agreements with farmers from certain areas because of improper farming practices (e.g., use of chemical inorganic fertiliser, adulteration practices).

Four processors and one trader cited imposing price freezes as buffers against price volatility. For instance, processors give traders and farmers a one-week notice before implementing price decreases to minimise financial losses across the value chain. In the trade and processing sectors, the processors had more access to information than traders on seaweed prices from local and international sources. The geographical distance between the seaweed farms, warehouses, and manufacturing sites and the poor governance system further contribute to the disparity in access to information sources. Information regarding the seaweed industry (e.g., product demand, prices) is cascaded to traders and eventually to farmers. As such, market decisions are made in a sequential manner with the processors as their primary reference. Prices of fresh seaweeds and RDS vary in the local market because buyers (i.e., traders, processors) impose competitive pricing strategies to obtain more access to seaweed resources in order to sustain their operations. The respondents, particularly the processors, mentioned that competition in the international market is more challenging because the industry has limited access to financial resources and institutional support. The respondents believed that lack of institutional intervention is one of the factors that contributed to the stagnation of the Philippine seaweed industry because it constrained the capacity of stakeholders to adopt new farming technologies and engage in product diversification.

4. Discussion

4.1. Characteristics of perceived risks and uncertainties

This study has been able to demonstrate the different types of risk affecting eucheumatoid production through analysing stakeholders' perceptions of risks associated with seaweed farming, trade, and processing/export. It has highlighted how gender and community experiences shape and influence their understanding of their situations and environment. The risks affecting the Philippine seaweed value chain can be characterised as diverse but interrelated. The different risk categories

that arose from the respondents' narratives show that each group encountered multiple risks and uncertainties. However, risks affecting the production sector adversely impact seaweed trade and processing due to reduction in supply of raw materials (i.e., RDS). Likewise, issues affecting trade and export (e.g., seaweed price fluctuations) affect local market conditions and stakeholder relations (e.g., changes in supply and demand).

In the Philippine seaweed industry, the production sector is affected by more diverse risks, ranging from anthropogenic factors (e.g., adulteration, poaching) to environmental issues (e.g., poor weather condition). Gender differences were notable with women's responses mainly centred on the impact of disease and pest infestations on the seaweed farms. Though the majority of men reported similar incidents, the types of environmental risks they identified were more diverse, spanning from risks directly affecting the seaweeds (e.g., disease, pests, fish predation) to those with more extensive impacts such as weather disturbances and pollution. Utilisation of the seascape is highly gendered [52–54] and the findings in this study exemplify how the perceptions and behaviours of women and men seaweed farmers are influenced by their experiences and roles in the industry. The disparities in perceptions of environmental risks cannot be directly associated with farming practices, but rather on the nature of women and men's involvement in the seaweed farms [43]. Seaweed farming is largely a family-managed livelihood in the Philippines [32], and while tasks are complementary, they also remain largely gendered [55]. Gendered norms and beliefs influenced men and women's participation in livelihood activities [52,53,56] which is also evident in the seaweed farming industry. For instance, more men were able to observe incidence and impacts of predation, pollution, and weather disturbances on site because they were mostly responsible for farm monitoring. Lebel et al. [57] found that these gender differences on risk perceptions become more prominent when the farms are located further from the shoreline where women access is limited as they are mostly confined to shore-based activities.

The evidence that disease and pest infestations are among the major issues faced by the seaweed farmers concur with previous studies in the Philippines and other key seaweed production sites in Southeast Asia and East Africa [30–32,34,36,42–44]. From a technical perspective, disease and endo/epiphytic infestations are caused by extreme changes in environmental conditions (e.g., water salinity, temperature, pH levels, and turbidity) and nutrient deficiency of the eucheumatoids. These lead to increased susceptibility of seaweeds to pathogenic organisms that limit its growth and quality which could eventually result to crop failure [36,58]. Farmers possessed some technical understanding about seaweed diseases and pests from attending professional training and capacity building activities or from experience [41]. However, the industry has been continuously affected by the impacts of poor farming practices [31,36]. Studies show that repeated vegetative propagation is widely practiced in key seaweed production areas in the country [32,41, 43,59–62] and abroad [33,35,42], however, this practice has serious implications on the quality and resilience of the seaweeds and ultimately for the sustainability of the whole industry because it contributes to decreased growth rates and increased susceptibility of farmed seaweeds to disease and pest infestations [30,31,35,36]. Indiscriminate use of vegetative propagules denotes lack of access to technical services and resources such as trainings and capacity building activities [41], however, analysis of the respondents' narratives also revealed that having access to good quality seedstocks may not necessarily lead to the adoption of good farming practices especially if it will require additional budget for purchase of propagules and other materials for farm establishment. Hayashi et al. [31] and Radulovich et al. [35] proposed that traditional farming practices, such as repeated use of vegetative propagation, will improve if accessing more resilient seedstocks will not

significantly increase capital investment needed for seaweed farming. This should also be complemented with good farming practices such as fallowing periods of 2–3 years in heavily farmed sites to allow nutrient recovery [31,36].

The lack of policies on zoning and acquisition of permits for construction of seaweed farms underscores the necessity for revisiting coastal resource management programmes (i.e., integrated coastal management) of local governments. Coastal and marine zonation and regulatory processes (e.g. permits) can help promote livelihood sustainability by ensuring equal opportunities among different stakeholder groups to benefit from coastal resource use [63,64]. Informal arrangements with traders and processors provide opportunities for households to engage in seaweed farming without going through formal licensing procedures. It also strengthens the farmer-trader relationship which is essential for sustaining flows of resources and securing credit access. However, it contributes to the widening socioeconomic gap as traders (and processors/exporters) are able to control distribution of seaweed farm sites while farmers are bounded by the provisions of informal contract agreements [41].

The nature of risks affecting trade and processing sectors demonstrates how risks and uncertainties are interrelated, in particular, how market issues can be attributed to the constraints faced by seaweed farmers. Similar to the findings of Mulyati and Geldermann [44] and Hurtado [32], the issue of RDS quality ensues from the production stage which include poor farming practices (e.g. infrequent monitoring, premature harvest of seaweeds), substandard drying activities (e.g. improper cleaning of harvested seaweeds, use of additives like salt, lack of drying platform, and inadequate drying time), lack of technology, and environmental factors (e.g. disease, pest, weather conditions). However, the adverse impacts of fluctuations in supply and poor seaweed quality become more apparent when traders and processors/exporters associate these with economic losses and market stagnation.

Poor governance affects the whole industry but to varying degrees. Weak law enforcement and lack of monitoring activities in seaweed production sites contributed to inefficient farming and trade practices. In turn, stakeholder groups suffer losses due to economic sanctions from non-compliance with national seaweed standards. The instability of the local seaweed industry is further aggravated by uncertainties that accompany seaweed production (e.g., fluctuations in volume of harvest) and global market trends (e.g., price volatility). Inequality in access to information was only a concern among traders since they serve as intermediaries between farmers and processors. Obtaining up-to-date information is therefore essential in fostering patron-client relations since farmers primarily rely on traders for various forms of information (e.g., price, product requirements) while traders and processors/exporters compete to secure stable supply of seaweeds. However, while Suyo et al. [41] found that farmers have the least access to information, this was not considered as one of key constraints in seaweed production. Information sharing based on loosely coordinated systems constrain product upgrading and market expansion since product quality is based on commercial requirements and not necessarily on standards stipulated in policies [65]. As such, rules tend to vary across seaweed production sites and information about product quality is not clearly communicated to the farmers.

4.2. Risk management strategies and informal relationships

Risk management strategies and coping capacities are inherent and unique to every community since these are composed of combined skills, information, and awareness of certain hazards [24,66]. Women and men farmers showed similar patterns of coping behaviours since information was mostly obtained from community and among farmers that

experience the same types of risk [41]. Informal structures and arrangements (e.g., patron-client relationships) govern decision making processes and behaviour patterns among farmers, traders, and processors. Risk management strategies were intended not just to prevent or mitigate risks but also to safeguard relationships within and across value chain segments. The emergence of informal rules was reinforced by the lack of policies and weak enforcement of existing regulations. Household level strategies were adequate in dealing with small-scale impacts, however, when hazards result in substantial losses (e.g., complete loss of crops due to disease, pests, or poor weather conditions), farmers need external intervention to supplement existing portfolio of coping/adaptation strategies (e.g., access to credit, information). Preparatory and mitigative measures are only feasible for hazards with slow-onset impacts such as disease occurrence and pest infestations but can be ineffective for sudden-onset events (e.g. typhoons) or for unfamiliar risks (e.g. pollution) [67]. For instance, farmers were able to prevent or mitigate impacts of disease and pest infestations because of their familiarity with its causes and progression, however, weather-related disturbances and financial risks prompted support-seeking behaviours. Seaweed farms are mostly family-owned: the low levels of capital investment needed for farm construction and management make it attractive for those with limited income-earning opportunities [32]. However, repeated production risks contribute to financial insecurity among seaweed farmers. The current market structure has provided traders and processors with a certain degree of security in terms of seaweed supply and quality but it leaves farmers in the lower-income section of the value chain with limited opportunities for improvement.

This evidence suggests that upgrading and sustaining the seaweed value chain will entail providing equal access to opportunities among stakeholder groups while considering their different capacities and needs. Adopting a stakeholder-oriented approach in risk and risk management analysis will provide important information about the nature of specific risks encountered in different segments of the seaweed industry, the local strategies implemented to manage the risks, and the loopholes in the current risk management efforts [44,68]. The reported strategies revealed the nature of relationships governing the different stakeholder groups and how these interconnections support and constrain the progress of the specific groups within the industry [41]. Currently, the adaptive strategies employed by farmers, traders and processors compensate for weak regulatory measures, but further improvement can be achieved if informal strategies are complemented by institutional mechanisms. A lack of government intervention provides firms with opportunities to use commercial standards for product evaluation thereby fostering inequalities among stakeholders [65]. The industry will benefit from improved regulatory and institutional support measures that will increase stakeholders' access to services and resources which, in turn, will enhance their capacities for product development [31,36,41].

5. Conclusions

Farmers, traders, and processors experience unique but interrelated risks. Seaweed farmers encounter more varied risks than traders and processors particularly those relating to environment (e.g., disease, pest) and poor farming practices. Knowledge of risks was mostly gained by experience: scientific understanding is lacking particularly about factors that contribute to crop losses (e.g., disease, pest infestations). The issues affecting the production segment contribute to volatility of supply and poor quality of raw materials which consequently pose risks to local traders and processing industries. Instability in the state of the global seaweed industry leads to fluctuations in prices of carrageenan products (i.e., ATC, SRC, RC). International price fluctuations affect the processing segment first and trickle down to other players but with varying degrees of impact. Gender differences in risk perception demonstrate how awareness of risks is influenced and determined by roles played by women and men in the seaweed industry. Specifically, gendered division

of labour in seaweed farming leads to men having more extensive knowledge than women about risks across seaweed production stages. Awareness and knowledge of risks become less gendered in trade and processing sectors as roles played by women and men become more homogenous.

Informal relationships have become the foundation of risk management strategies across the seaweed value chain. Poor institutional mechanisms such as lack of policies and monitoring procedures and weak law enforcement lead to adoption of informal and market-driven strategies to prevent or minimise losses. Commercial standards pertinent to quality and prices of raw materials have been used to bridge the existing management gaps. Stakeholder groups played different but complementary roles in sustaining the seaweed industry amidst risks and uncertainties but the current structure of the seaweed industry reveals where barriers to upgrading across the value chain emanates and where interventions should be directed. From the stakeholders' perspectives, stronger government support is needed to manage impacts of the risks affecting production outcomes and market efficiency. The weakness of institutional interventions has also curtailed the capacity of traders and processors/exporters to engage in product development and diversification. It should also be noted that the stakeholder relations that support the industry pose risks, especially for farmers who lack the capacity and resources to participate in higher-income trading and processing activities. Hence, strategies aimed at supporting and improving the seaweed industry should be able to incorporate gender-specific needs and differential requirements of stakeholder groups across the industry. Local strategies should not be undervalued as these reflect the differential experiences, patterns of behaviour and decision-making processes of stakeholders across the seaweed value chain. These risk management activities should be considered in planning and policy formulation, particularly for the improvement of the competitive advantage of the seaweed industry. In the Philippines, this evidence can serve as reference for updating the Philippine National Standard on the Code for Good Aquaculture Practices (GAQP) for Seaweed of the Department of Agriculture-Bureau of Agriculture and Fisheries Standards (DA-BAFS). At the global scale, the results of this study further highlight the importance of multi-stakeholder-focused risk assessment and its relevance to the formulation of science-based policies and programmes.

CRediT authorship contributions statement

Jeel Grace B. Suyo: Conceptualization, Methodology, Formal analysis, Writing - original draft; Writing - review & editing. **Virginie Le Masson:** Conceptualization, Resources, Writing - review & editing. **Louise Shaxson:** Supervision, Project administration, Writing - review & editing, Resources. **Maria Rovilla J. Luhan:** Writing - review & editing. **Anicia Q. Hurtado:** Supervision, Project administration, Writing - review & editing, Resources.

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Appendix A

See Appendix Table A1

Table A1
Types of risks reported by women and men seaweed farmers in Bohol, Zamboanga City, and Tawi-Tawi (N = 115).

Risk categories	Bohol		Zamboanga City		Tawi-Tawi		Total	
	F	M	F	M	F	M	F (n = 64)	M (n = 51)
Environmental risks								
Disease outbreak	18 (72)	7 (54)	12 (80)	5 (33)	20 (83)	9 (39)	50 (78)	21 (41)
Pest infestation	10 (40)	0 (0)	13 (87)	5 (33)	10 (42)	13 (57)	33 (52)	18 (35)
Predation	0 (0)	0 (0)	1 (7)	0 (0)	0 (0)	9 (39)	1 (2)	9 (18)
Weather disturbances	8 (32)	13 (100)	0 (0)	0 (0)	0 (0)	0 (0)	8 (13)	13 (26)
Pollution	0 (0)	0 (0)	4 (27)	10 (67)	0 (0)	0 (0)	4 (6)	10 (20)
Capital/Yield risks								
High input cost	0 (0)	0 (0)	0 (0)	0 (0)	8 (33)	5 (22)	8 (13)	5 (10)
Seed stock shortage	7 (28)	6 (46)	7 (47)	10 (67)	3 (13)	5 (22)	17 (27)	21 (41)
Subsidy shortage	7 (28)	6 (46)	0 (0)	0 (0)	14 (58)	9 (39)	21 (33)	15 (29)
Use of additives	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	10 (44)	0 (0)	5 (10)
Poaching	18 (72)	6 (46)	0 (0)	0 (0)	0 (0)	0 (0)	18 (28)	6 (12)
Market/Governance risks								
Price volatility	7 (28)	7 (54)	0 (0)	5 (33)	5 (21)	4 (17)	12 (19)	16 (31)
Market access	0 (0)	0 (0)	1 (7)	0 (0)	1 (4)	4 (17)	2 (3)	4 (8)
Market sanctions	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	5 (22)	0 (0)	5 (10)
No zoning policies	17 (68)	6 (46)	15 (100)	15 (100)	5 (21)	9 (39)	37 (58)	30 (59)
Lack of license	10 (40)	6 (46)	8 (53)	5 (33)	16 (67)	9 (39)	34 (53)	20 (39)

- Notes: 1. F – Women farmers; M – Men farmers
- 2. Data are presented as n (%).
- 3. Please refer to Table 1 for the number of women and men participants per site.

Appendix B

See Appendix Table B1

Table B1
Risk management strategies of women and men seaweed farmers in Bohol, Zamboanga City, and Tawi-Tawi (N = 115).

Environmental risks	Disease		Pest		Weather		Predation		Pollution	
	W	M	W	M	W	M	W	M	W	M
Determine seasonality	0 (0)	4 (8)	0 (0)	4 (8)	2 (3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Variety selection	9 (14)	25 (49)	9 (14)	25 (49)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Site suitability	32 (52)	10 (20)	33 (52)	10 (20)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Farm technique	0 (0)	0 (0)	10 (16)	4 (8)	0 (0)	0 (0)	0 (0)	4 (8)	0 (0)	0 (0)
Trimming infected sections	5 (8)	5 (10)	6 (9)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Farm monitoring	7 (11)	5 (10)	7 (11)	5 (10)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Information sharing	14 (22)	34 (67)	14 (22)	34 (67)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Harvest	63 (98)	44 (86)	0 (0)	11 (22)	1 (2)	5 (9)	0 (0)	0 (0)	0 (0)	0 (0)
Purchase seedlings	8 (13)	7 (14)	8 (13)	0 (0)	8 (13)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Transplanting	0 (0)	0 (0)	1 (2)	5 (10)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Loan money	0 (0)	0 (0)	0 (0)	0 (0)	17 (27)	13 (25)	0 (0)	0 (0)	0 (0)	0 (0)
Diversify livelihood	0 (0)	0 (0)	0 (0)	0 (0)	11 (17)	12 (24)	0 (0)	5 (10)	0 (0)	0 (0)
Institutional support	0 (0)	0 (0)	0 (0)	0 (0)	28 (44)	13 (25)	0 (0)	0 (0)	0 (0)	0 (0)
Local support	40 (62)	36 (71)	0 (0)	0 (0)	40 (62)	36 (71)	0 (0)	0 (0)	0 (0)	0 (0)
Capital/Yield risks										
	Seed stock		Subsidy		High input cost		Poaching		Adulteration	
	W	M	W	M	W	M	W	M	W	M
Farm technique	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	3 (5)	6 (12)	0 (0)	0 (0)
Purchase seedlings	8 (13)	7 (14)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Transplanting	56 (87)	44 (86)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Local support	0 (0)	0 (0)	31 (48)	17 (33)	40 (62)	36 (71)	0 (0)	0 (0)	0 (0)	0 (0)
Market/Governance risks										
	Price volatility		Market access		Market sanctions		No zoning policy		No permit	
	W	M	W	M	W	M	W	M	W	M
Information sharing	64 (100)	51 (100)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Patron-client relations	0 (0)	0 (0)	49 (77)	39 (77)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Zoning ordinance	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	28 (18)	7 (14)	0 (0)	0 (0)
Traders' consent	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	61 (95)	51 (100)
Leased from farmers	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	3 (5)	0 (0)

- Notes: 1. F – Women farmers; M – Men farmers
- 2. Data are presented as n (%).
- 3. Please refer to Table 1 for the number of women and men participants per site.

Appendix C

See Appendix Table C1

Table C1

Types of risks reported by seaweed traders and processors (N = 10).

Risk categories	Traders (n = 5)	Processors (n = 5)
Supply/Quality risks		
Supply deficit	5	5
Poor quality	3	4
Competition	4	5
Price volatility	3	4
Information access	2	0
Hoarding	1	1
Governance-related risks		
High production cost	0	1
Poor governance	2	3
Financial insecurity	1	2

Appendix D

See Appendix Table D1

Table D1

Risk management strategies of traders and processors (N=10).

Risk categories	Traders (n = 5)	Processors (n = 5)
Supply instability		
Maintain patron-client relations	5	5
Provision of financial support to suppliers	3	5
Poor quality		
Area selection	4	4
Impose standards	2	5
Impose sanctions	5	5
Impose contract bonds	1	5
Price volatility		
Price freeze	1	4

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