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RESEARCH ARTICLE

Farming Systems of Eucheumatoid Seaweeds in Western Visayas, Philippines

Anne Brigette B. Ledesma[1]* and Harold M. Monteclaro[2]

[1] *Institute of Fisheries Policy and Development Studies, College of Fisheries and Ocean Sciences, University of the Philippines Visayas, Miagao, Iloilo 5023 Philippines*
[2] *Institute of Marine Fisheries and Oceanology, College of Fisheries and Ocean Sciences, University of the Philippines Visayas, Miagao, Iloilo 5023 Philippines*

ABSTRACT

This study investigated the various seaweed farming methods in Western Visayas, Philippines. Data were gathered through workshops, focus group discussions (FGD), key informant interviews (KII), and secondary sources, and were subsequently analyzed. Results showed that four out of six provinces in the region serve as the major suppliers of fresh and dried seaweeds namely, Antique, Iloilo, Guimaras, and Negros Occidental. The eucheumatoids species widely farmed in production sites across Western Visayas include *Kappaphycus alvarezii* (Doty) L.M. Liao 1996, *K. striatus* (F. Schmitz) L.M. Liao 1996, and *Eucheuma denticulatum* (N.L. Burman) Collins and Hervey 1917. Although farming techniques vary per province and mainly rely on culture sites, the simple long line (fixed-off bottom and floating line) is the most common method utilized throughout the region. Other methods employed are broadcast, floating bamboo raft, spiderweb, octopus, and single vertical floating (*tumbo-tumbo*). Significant roles and activities performed by key actors and the enabling environment were discussed. While seaweed production in Western Visayas is still considered a minor industry, the documentation and analysis of the present farming methods and status of seaweed production are crucial in crafting initiatives and strategic directions for improving the quality and production of eucheumatoid farming in the region. Efforts to boost eucheumatoid production include research focused on improved spore production, nursery establishment, and utilization of tissue culture technologies. These strategies will ensure a sufficient supply of healthy seaweed seedlings for culture. Capacity building and promoting best aquaculture practices (BAP) to key stakeholders are also vital for proper coordination and optimizing programs, projects, and initiatives that foster a supportive environment for seaweed farming in the region.

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1. INTRODUCTION

In 2022, seaweed was the top-producing fishery commodity in the Philippines, comprising 35.61% of the total fisheries production (Philippine Fisheries Profile 2023). About 3.82% (1.34 million MT wet weight; farmed and wild) of the global aquatic plant output (including seaweeds) came from the Philippines, making the country the fourth largest producer, following China, Indonesia, and the Republic of Korea (FAO 2022).

In terms of export and import performance, seaweed was the second most exported and fifth most imported commodity in the Philippines. The International Trade Center Trade Map reported a total export volume (65,440.68 MT) of seaweeds and carrageenan valued at PHP 6.92 billion (USD 120.98 million) in 2023 (International Trade Centre 2024). Moreover, miscellaneous fishery products and other by-products of seaweeds and carrageenan were exported at a volume of 48,891 MT, valued at about PHP 19.21 billion (USD 349.26 million), mainly to the US, China, and European countries (Philippine Fisheries Profile 2023).

Meanwhile, the import volume of seaweeds and carrageenan in 2023 reached 14,756.27 MT, valued at PHP 1.22 billion (USD 21.37 million) (International Trade Centre 2024). Additionally, 7,391 MT of total miscellaneous fishery products and other byproducts were imported, valued at PHP 2.61 billion (USD 48 million). The Philippines imported seaweeds and carrageenan mainly from Indonesia, South Korea, and China (Philippine Fisheries Profile 2023).

Production of seaweeds in Asia, including the Philippines, accounts for 97.38% of the global yield (Zhang et al. 2022). Seaweeds in this continent are mainly produced by cultivation, a small portion of which is harvested from the wild (Cai et al. 2021). In the Philippines, more than 60,000 ha of coastal waters are used for seaweed farming (Bureau of Fisheries and Aquatic Resources 2022). In 2022, farmed seaweed production in the country yielded about 65.76% of the total aquaculture production (Philippine Fisheries Profile 2023).

Since 1996, there has been a steady increase in Philippine seaweed production. The highest volume was achieved in 2011 (1.84 million MT wet weight) as high market demands, technological improvement, better prices, and good weather conditions encouraged the expansion of seaweed culture areas. However, the occurrence of ice-ice disease and extreme weather events hampered production such that in 2023, production declined to 1.63 million MT (Philippine Statistics Authority 2024).

Among the many types of seaweeds in the Philippines, *Kappaphycus* spp., *Eucheuma* spp., *Gracilaria* spp., and *Caulerpa* spp. are the predominantly cultured and collected species. The most popular among seaweed farmers are the eucheumatoids or carrageenophyte seaweeds, particularly *Kappaphycus* spp. and *Eucheuma* spp., which are produced through mariculture. Raw dried seaweeds are supplied to carrageenan processors and exporters across the country. Eucheumatoids have a wide variety of commercial purposes as an additive, particularly in food (i.e., thickener, emulsifier, and stabilizing agents), pharmaceutical (e.g., antiviral, antibacterial, biomaterials for drug delivery, tissue engineering), cosmetics (i.e., moisturizer and conditioning agents), and other industrial applications (e.g., cleaning of industrial effluents) (Necas and Bartosikova 2013; Tasende and Manriquez-Hernandez 2016; Loureiro et al. 2017; Pacheco-Quito et al. 2020).

To meet the growing global demand, farming of eucheumatoids in the country became progressive. More than 90% of the total annual seaweed production is comprised of *Kappaphycus* spp., which is primarily grown in major farming sites in the southern Palawan, Bohol, Leyte, Zamboanga, Tawi-Tawi, and Sulu provinces (Hurtado et al. 2017; Trono and Largo 2019; Zhang et al. 2022). The *Kappaphycus alvarezii* (Doty) L.M. Liao 1996 (commercial name, *"cottonii"*) is extensively farmed by most seaweed farmers due to its high market price (DA-PRDP 2014; Wenno et al. 2015), rapid growth rate, and source of pure kappa carrageenan (hard gel) with stable composition and high polysaccharide yields (Jiao et al. 2011; Hurtado et al. 2014; Pacheco-Quito 2020; Tuvikene 2021; Rupert et al. 2022). However, *K. alvarezii* requires more care and farming skill as it is sensitive to infestation by epi- and endophytism and large fluctuations in water temperature (De San 2012). It also needs a specific and established production cycle to produce quality seedlings. *Kappaphycus striatus* (F. Schmitz) L.M. Liao 1996, is another *Kappaphycus* strain widely cultivated in the Philippines that similarly produces kappa-carrageenophyte. Unlike *K. alvarezii*, it has a lower polysaccharide content with a small amount of iota carrageenan (Bhuyar et al. 2021; Hung et al. 2021).

Eucheuma denticulatum (N.L. Burman) Collins and Hervey 1917 (= *E. spinosum* J. Agardh 1852) is likewise a commonly cultured species, as it is easy to produce with less capital needed. Recognized in the industry as *"spinosum"*, it is a good source of iota-carrageenan (soft gel) with higher biological activities (Hayashi et al. 2017; Krstonošić et al. 2021; Dumilag et al. 2022). Compared to *K. alvarezii* and *K. striatus, E. denticulatum* has a lower selling price. Hence, culture practice is less extensive. However, it can withstand temperature variations and parasite infestations, is fast-growing (with a 300–400% growth rate), and can be harvested all year round without replanting (De San 2012; DA-PRDP 2014; Vairappan 2021).

The Western Visayas region in the Philippines has a modest share of farmed and wild seaweed production (volume, 70,071.55 MT wet weight; value, PHP 5.27 million), comprising about 4.31% of the Philippine seaweed production (volume, 1.63 million MT wet weight; value, PHP 12.71 million) in 2023 (Philippine Statistics Authority 2024). In terms of seaweed aquaculture, Antique province has consistently been the leading producer in the past 27 years, accounting for 98–99% of the regional production. Seaweed cultivation in the region started in the early 1970s in Antique province. Since then, the number of farmers engaging in seaweed farming in various regional provinces has continually increased (Neish et al. 2017; Dumilag et al. 2022). Farm expansions in the region due to the growing demand have also accelerated. The farming of *Kappaphycus* spp. and *Eucheuma* spp. has contributed significantly to generating employment, especially in marginalized coastal communities. It has provided socio-economic benefits and is regarded as an essential source of income (Andriesse and Lee 2017; Fitriana 2017; Loureiro et al. 2017; Rameshkumar and Rajaram 2019; Hasselström et al. 2020; Simatupang et al. 2021). Farmers have gained extensive knowledge and familiarized themselves with the different farming methods and techniques that could help seaweed production flourish in the region.

Despite the rapid growth of seaweed farming in Western Visayas, it has experienced the "boom-and-bust" production trend. There is a dearth of information on the existing farming systems and practices, as well as the processes and key stakeholders involved in the seaweed industry in the region. Thus, this paper examined the farming of eucheumatoid seaweeds (*Kappaphycus* spp. and *Eucheuma* spp.) in Western Visayas, Philippines. Specifically, it 1) identified supply areas and seaweed species used in farming, 2) determined input subsystem and culture methods, and 3) documented the processes involved in seaweed farming areas in the region. Results of this study are essential in recommending appropriate interventions and policies to arrest erratic and/or declining seaweed production in the region (except for Antique Province).

2. MATERIALS AND METHODS

The supply areas for seaweed eucheumatoids, including their farming structures and processes, were evaluated across the coastal provinces in the Western Visayas region from February to June 2018. Data on the presence and production of *Kappaphycus* spp. and *Eucheuma* spp. from each province namely, (i) Aklan, (ii) Antique, (iii) Capiz, (iv) Iloilo, (v) Guimaras, and (vi) Negros Occidental were obtained through secondary sources (e.g., government reports, published journals, proceedings), initial scoping through remote method (i.e., phone interviews), site visits, and dialogues with Local Government Units (LGUs).

A series of Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs) were conducted among key stakeholders in major seaweed production sites in Western Visayas. The respondents of this study included the seaweed farmers/growers for the FGDs. A list of seaweed producers, traders, representatives from relevant government agencies, key actors in research institutions, LGUs, funding agencies, local leaders, and members of industry associations was drawn from various sources and referrals for the KII.

The purposive sampling technique was used to identify the respondents. The following criteria guided the choice of respondents for inclusion in the FGD: 1) size of operation (large- or small-scale), 2) length of operation, 3) location, and 4) gender representation. Insights from the review of related literature were used to develop a semi-structured key informant interview and focus group discussion guides. A total of 62 out of 84 seaweed grower respondents were interviewed during five FGD sessions conducted in Iloilo (February 24, 2018), Antique (March 5, 2018), Guimaras (March 9-10, 2018), Negros Occidental (March 14, 2018), and Antique (April 7, 2018). For each FGD, 12-15 participants were targeted with equal gender representation. The FGD session started with a brief introduction to the topic and an explanation of the purpose and scope of the discussions. The facilitator kept the session on track while participants were allowed to talk freely about the issues in question. Each session lasted from 90 to 120 minutes, using the local dialect for a comprehensive and comfortable flow of discussions.

KIIs were undertaken to address data gaps after the series of FGDs and to understand stakeholders' perspectives and experiences to learn more about the issues that confront the seaweed industry. Scheduled interviews were requested based on the availability of the key informants. Data was collected through interviews with 44 key informants (including seaweed growers, local leaders, farm technicians, major traders, industry members, research institutions, and funding and/or national government agencies). Each interview lasted 45–90 minutes and was audio recorded with consent from the key informants.

This study applied value chain analysis (VCA) elements to evaluate the production chain of eucheumatoid seaweed farming in Western Visayas. The VCA framework requires understanding the information on production sites, key stakeholders and their roles, cultured species, cultivation methods, and the processes in seaweed farming. This is to systematically identify potential interventions to improve and increase the benefits of stakeholders involved in seaweed farming (Kula et al. 2006; Webber and Labaste 2009). The FGDs and KIIs were guided by structured and open-ended questionnaires. Data was documented to record the proceedings of the FGDs and KIIs. The primary data collection process strictly followed the research protocols.

A total of 106 individuals were interviewed. Table 1 shows the number of individuals who participated in the FGDs and KIIs.

Table 1. Number of interviewed stakeholders for Focus Group Discussions and Key Informant Interviews.

Respondents	Male n (%)	Female n (%)	Total n (%)
Focus Group Discussion			
Iloilo	6 (31.58)	13 (68.52)	19 (30.65)
Antique	4 (100.00)	0	4 (6.45)
Guimaras	11 (29.73)	26 (70.27)	37 (59.68)
Negros Occidental	1 (50.00)	1 (50.00)	2 (3.23)
Total n (%)	**22 (35.48)**	**40 (64.52)**	**62 (100.00)**
Key Informant Interviews			
Total n (%)	**15 (34.09)**	**29 (65.91)**	**44 (100.00)**

3. RESULTS

3.1 Supply areas

The majority of seaweed farming areas in Western Visayas are located on small islands or in the far-flung areas in the region. The present study identified 30 supply areas of eucheumatoids (*Kappaphycus* spp. and *Eucheuma* spp.) in four out of six provinces across the region (Table 2). The provinces of Antique, Guimaras, Iloilo, and Negros Occidental were confirmed as areas with active presence of seaweed farming (Fig. 1). Other areas in Western Visayas that were surveyed had been producing seaweeds, albeit at a much lesser volume. The municipality of Buruanga in Aklan province, Pandan and Libertad in Antique province, and Barotac Nuevo in Iloilo province had smaller seaweed production due to seasonal occurrences. Further, supply areas for eucheumatoids were not observed in Capiz province.

Seaweed farming areas in the region are mainly small-scale and are often located in coastal villages (barangays) of the city or municipality (83.33%) and can be found in the provinces of Guimaras, Iloilo, Negros Occidental, and some areas in Antique. Large-scale farms (16.67%) are located in the island barangays from two provinces in the northwestern portion of the region (i.e., Batbatan Island in Culasi and Panagatan, Imba, Sibato, and Sibolo islands in Caluya).

Iloilo province was recorded with the highest number of seaweed farms, with 17 barangays (56.7%) located in four municipalities in the province's northern area (i.e., Estancia, San Dionisio, Carles, and Ajuy). The province of Antique had seven island barangays (23.3%) from the municipalities of Caluya and Culasi, where carrageenophyte seaweeds are extensively farmed. Supply areas in the province of Guimaras (10%) were found in Sibunag and San Lorenzo municipalities, and one island barangay in the municipality of Nueva Valencia. The northern part of the province of Negros Occidental (10%), particularly in the cities of Sagay and Escalante, is also known as a seaweed farming site.

Table 2. Profile of key eucheumatoid supply areas (province) with corresponding production area (ha), identified supply areas (including city/municipality and barangays), species cultivated, and farming methods utilized in the Western Visayas region as of 2018. Data are presented as n (%). ha = hectares, nd = no data available.

Province	City /Municipality (Production Area, ha)	Total Coastal Barangays; Total No. of Supply Barangays (%)	Supply Barangays	Species Cultivated	Cultivation Method
Iloilo	Ajuy (**nd**)	**18;** 1 (5.88)	Pedada	*Kappaphycus alvarezii* *Kappaphycus striatus* *Eucheuma denticulatum*	Floating line (floating monoline/hanging long line), Octopus
	Concepcion (**nd**)	**18;** 3 (17.65)	Polopiña Taloto-an Tambaliza		Fixed-off bottom, Broadcast, Single vertical floating (*tumbo-tumbo*), Octopus, Spiderweb Floating line (floating monoline/hanging long line) Floating line (floating monoline/hanging long line)

Continuation of Table 2. Profile of key eucheumatoid supply areas (province) with corresponding production area (ha), identified supply areas (including city/municipality and barangays), species cultivated, and farming methods utilized in the Western Visayas region as of 2018. Data are presented as n (%). ha = hectares, nd = no data available.

Province	City /Municipality (Production Area, ha)	Total Coastal Barangays; Total No. of Supply Barangays (%)	Supply Barangays	Species Cultivated	Cultivation Method
	Carles (**10**)	**32;** 1 (5.88)	Sicogon Island		Fixed-off bottom, Broadcast
	Estancia (**2.5**)	**16;** 1 (5.88)	Gogo		Floating line (floating monoline/hanging long line)
	San Dionisio (**nd**)	**11**; 11 (64.71)	Agdaliran Bagacay Borongon Cubay Naborot Island Nipa Odiongan Pase Poblacion Sua Tiabas		Fixed-off bottom
Antique	Culasi (**250**)	**19;** 3 (42.86)	Maniguin Island Maralison Island Batbatan Island	*Kappaphycus alvarezii* *Kappaphycus striatus* *Eucheuma denticulatum*	Fixed-off bottom
	Caluya (**1,528.04**)	**18;** 4 (57.14)	Panagatan Island Imba Island Sibato Island Sibolo Island		Fixed-off bottom, Floating line (floating monoline/ hanging long line), Spiderweb
Guimaras	San Lorenzo (**1.5**)	**6;** 1 (33.33)	Nadulao Island	*Kappaphycus alvarezii* *Kappaphycus striatus*	Fixed-off bottom, Floating line (floating monoline/ hanging long line)
	Sibunag (**46.69**)	**7;** 1 (33.33)	Sabang	*Eucheuma denticulatum*	Fixed-off bottom, Floating line (floating monoline/ hanging long line)
	Nueva Valencia (**43.3**)	**17;** 1 (33.33)	Panobolon Island		Fixed-off bottom, Floating line (floating monoline/ hanging long line), Floating bamboo raft
Negros Occidental	Escalante City (**10**)	**7;** 1 (33.33)	Washington	*Kappaphycus alvarezii*	Fixed-off bottom
	Sagay City (**21**)	**6;** 2 (66.67)	Vito Molocaboc Island	*Eucheuma denticulatum*	Fixed-off bottom

Note: Based on the results of FGDs and KIIs. Data on production area and total coastal barangays per province are from provincial fisheries profiles (2015, Iloilo; 2016, Antique, Negros Occidental, and Guimaras) provided by local government units in key seaweed supply areas, during the conduct of the study.

3.2 Cultured species

The *Kappaphycus* spp. and *Eucheuma* spp., collectively known as carrageenan-bearing (eucheumatoid) seaweeds, were mostly farmed throughout the region. Interviews with seaweed farmers in Panay Island reported three species of eucheumatoid cultivars: 1) *Kappaphycus alvarezii* var. *tambalangii* (Doty) L.M. Liao 1996, 2) *Kappaphycus striatus* (F. Schmitz) L.M. Liao 1996, and 3) *Eucheuma denticulatum* (N.L. Burman) Collins and Hervey 1917, particularly in the provinces located in northwest Panay (i.e., Antique), northeast Panay (i.e., northern Iloilo), and southeast Panay (i.e., Guimaras). In

Negros Island (i.e., northern Negros Occidental), seaweed farmers used the *K. alvarezii* var. *tambalangii* and *E. denticulatum* in farming.

Among the three eucheumatoid seaweeds, the *K. alvarezii,* locally called "*guso*", *"cottonii"*, or "*tambalang*" by seaweed farmers, was the most well-known species cultivated in farming areas in Western Visayas. The respondents mentioned that despite being vulnerable to ice-ice disease, *K. alvarezii* are widely farmed since most traders prefer to buy *guso* (*K. alvarezii*) because of its greater carrageenan content and higher selling price. A cheaper substitute for *K. alvarezii* was the *K. striatus ("sakol"* or *"flower"* in dialect), which also contains a substantial amount of carrageenan. Results from the surveys and interviews indicated, however, that the *K. striatus* cultivar can be problematic to cultivate at times because it is a slow-growing species that entails additional costs for maintenance with a lower selling price compared to *K. alvarezii*, thus making it an unfavorable option for culture to some seaweed farmers.

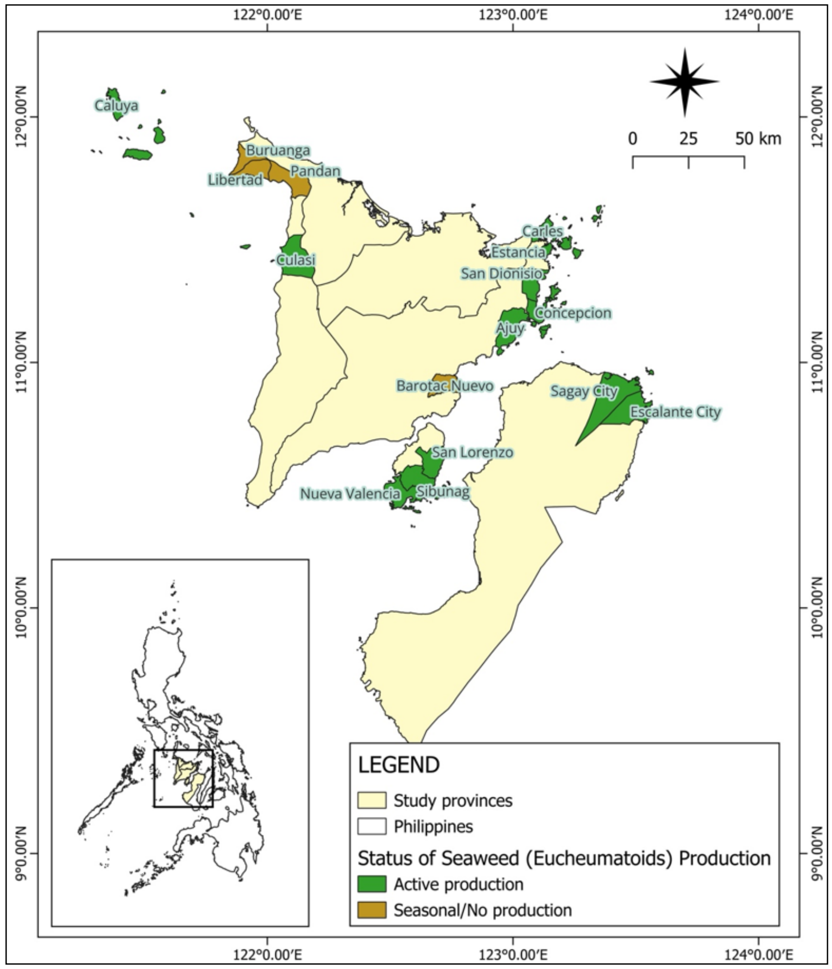

Figure 1. Map of Western Visayas showing the sources of eucheumatoids (*Kappaphycus* spp. and *Eucheuma* spp.) from 2018 to 2019. Areas highlighted in green color show areas with active seaweed production, while areas in gold color have seasonal to no production yield (i.e., Buruanga in Aklan province, Barotac Nuevo in Iloilo province, and Libertad and Pandan in Antique province).

In contrast to *Kappaphycus* spp., the *E. denticulatum* ("*milyon-milyon*" or "*spinosum*") produces iota carrageenan. It was less popular among seaweed farmers because of its cheaper market price. Seaweed farmers related during the focus group discussions (FGDs) and key informant interviews (KIIs) that *E. denticulatum* can be easily affected by diseases and other environmental factors, implying higher capital investment risk. Despite these concerns, it was still being farmed and traded across the region.

3.3 Cultivation methods

Table 3 shows the various cultivation methods being practiced in the different supply areas in Western Visayas. Data gathered from FGDs and KIIs revealed that the fixed-off bottom (FOB) monoline or bottom line was the most utilized culture method in seaweed farms in the region. The FOB technique was applied in 28 supply areas across four provinces (53.85%). These supply areas were barangays or villages in different municipalities in each province. Seaweed farmers reported during the survey that the FOB method is simple to construct and maintain. It also involves low capital investment with high economic returns; thus, it is extensively applied to seaweed farms in the Western Visayas region.

FGD and key interviews with the seaweed farmers in Antique, Iloilo, and Guimaras also showed the use of the floating line (floating monoline/hanging longline) method in seaweed farming (23.08%). Despite its high input cost, this method was employed in some supply areas due to the faster growth rate of

Table 3. Comparison of different seaweed cultivation methods in the Western Visayas region used by seaweed farmers in different provinces with the combined number of supply areas. Data are presented as n (%).

Cultivation method	Province/s	Number of supply areas (%)	Advantages	Disadvantages
Fixed-off bottom	Iloilo, Guimaras, Negros Occidental, Antique	28 (53.85)	Simple to construct; can be easily managed by family labor (also women). Easy to manage. Lines can be prepared on the shore. Deemed as the least capital-intensive farming system. Input supply can be cost-efficient; you can use local wood to prepare the stakes. The farm is easy to reach at low tide. Has high economic efficiency. Less seed capital expense.	Difficult to locate a good area; subject to the competition of other sectors (tourism and urban development). Damage and loss of crops during rough weather. Difficulty in relocating the farm setup. High risk to fish grazers and rope breaking. Additional costs for the construction of the drying rack. Needs high-intensity plot maintenance. Threatened by industrial and urban effluents. The use of non-motorized boats tends to be inconvenient and costly. The use of motorized boats may be uneconomical for small-scale farmers.
Floating line (floating monoline/ hanging long line)	Iloilo, Guimaras, Antique	12 (23.08)	Promotes faster growth of seaweeds. Longlines can be transferred to another area. Easy location for the planting site. Can be moved to another location to avoid fish grazing or even removed from the water during bad weather conditions.	High input cost (i.e., ropes, floaters). Planting and harvesting cannot be easily done on shore. Demanding to construct.
Floating bamboo raft	Guimaras	1 (1.92)	Low-cost technology. Provides substantial profit. Suitable for use in areas with calm to minimal current. Accelerates gaseous exchange, lessens sedimentation.	Heavy yield reduction due to grazing, high temperature (installed in shallow areas). Yield loss due to epiphyte attachment (results in stunted growth). Damage to bamboo rafts; additional expense for inputs during the rough season.
Spiderweb	Iloilo, Antique	5 (9.62)	Easy to maintain. Seedlings can be prepared and planted during both low and high tides.	Has a high capital cost. Requires a professional to install the system. Labor-intensive.
Broadcast	Iloilo	3 (5.77)		
Octopus	Iloilo	2 (3.85)	More resilient to rough weather conditions (i.e., typhoons). Easy to install and requires less maintenance.	Needs a large area to plant seaweeds. conditions (i.e., typhoons).
Single vertical floating (*"tumbo-tumbo"*)	Iloilo	1 (1.92)	Promotes high yield and faster growth of seaweeds, especially in wider areas. Less breakage of plants and lines during rough weather conditions (i.e., current, wind, typhoons). Flexible, environment-friendly.	Difficult to set up. Poses a threat to sea transportation (e.g., can cause accidents).

seaweeds (can be harvested within 30-45 days) and the convenience of relocating the long lines, especially during rough weather conditions.

In Iloilo and Antique provinces, innovative culture techniques such as spider web (SW) (9.62%) and octopus (3.85%) methods were also practiced. The SW method was particularly useful for high seaweed production in small locations, exhibiting environmental advantages, and was feasible with polyculture. On the other hand, the octopus method was ideal for larger areas and required easier installation and less maintenance compared to SW. Local seaweed farmers in Iloilo, particularly in the Concepcion area (Sitio Bat-os and Guinmisahan), implemented the single vertical floating or "*tumbo-tumbo*" as a cultivation technique (1.92%). The '*tumbo-tumbo*' was also installed in wider farming areas, contributing to higher seaweed productivity. It can be flexible and environmentally friendly despite the difficulty of establishing the setup. The SW, octopus, and *tumbo-tumbo* farming methods can be labor- and capital-intensive and are suitable in deeper waters, yet they can withstand typhoons, including strong currents and winds.

During visits to supply areas in the municipalities of Carles and Concepcion in Iloilo province, the broadcast method was usually applied in seaweed cultivation (5.77%). Farmers believe this method was ideal for producing quality seedlings with no input costs (i.e., seedlings are just thrown in shallow areas with a net enclosure in place). On the other hand, the floating bamboo raft method (1.92%) in Panobolon Island, Nueva Valencia in Guimaras province, was utilized by farmers in seaweed cultivation.

3.4 Processes in seaweed farming

In general, seaweed farmers in Western Visayas described six stages involved in seaweed farming: 1) input acquisition/provision, 2) farm selection and establishment, 3) tying of seedlings in soft ties, 4) planting, 5) crops and materials maintenance, and 6) harvest.

The farming of eucheumatoid seaweeds starts with input acquisition and/or provision. Ropes, soft ties, floaters, twines, bamboo posts, and other farm implements were named by seaweed farmers as basic supplies necessary for seaweed farming. These supplies are often bought in town centers or neighboring municipalities. Farmers also mentioned that these input materials included seedlings or cultivars provided by various national government agencies (NGAs), research institutions, private organizations, financers (i.e., big traders and farm owners), and other supply donors. In northern Iloilo for example, most seaweed farmers (30.65%) during the FGD said that they had received input supplies (e.g., seedlings, ropes, soft ties) mainly from local and international humanitarian organizations such as Adventist Development and Relief Agency (ADRA), Cooperative for Assistance and Relief Everywhere (CARE), Zoological Society of London (ZSL), and Iloilo Caucus of Development Non-Government Organizations (Iloilo Code-NGOs). These organizations also implemented livelihood programs in coastal areas in the region with existing and/or suitable areas for eucheumatoid seaweed farming after the onslaught of Super Typhoon Haiyan (Yolanda) in 2014.

Additionally, the Department of Agriculture - Philippine Rural Development Program (DA-PRDP), the Bureau of Fisheries and Aquatic Resources (BFAR) Region VI, through the National Seaweed Development Program, in partnership with local government units (LGUs), as well as Southeast Asian Fisheries Development Center/Aquaculture Department (SEAFDEC/AQD), also provided input supplies (i.e., seedlings grown from culture nurseries and laboratories) to seaweed farmers all over the region.

Seaweed farmers (69.35%) also cited having received support from local networks (i.e., traders and farmers) from nearby areas (e.g., province, municipality, or barangay) that gave capital for input acquisition or sold seedlings at a lower price. Also, during interviews, almost all seaweed growers (87.74%) in the region said they utilized seaweed seedlings sourced from their farms for the next planting season.

FGD and KII results also revealed that seaweed cultivation in the region was generally done in open waters. Depending on the farming site, the production cycle of seaweed farms in the region ranged from two to three planting cycles (cropping) per year (Table 4).

In most cases, a seaweed farmer needed about 0.25 ha (= 100 lines of seaweed) of planting site (i.e., clean with minimal wave action or strong currents). Space for seaweed planting was selected on a first-come, first-served basis. Farmers also reported that planting preparation usually took three to seven days, and the cutting and replanting of cultivars after 15 to 25 days. Seaweeds were grown into maturity with a culture period that ranged from 45 to 120 days for

Table 4. Summary of the production cycle of eucheumatoid farms in Western Visayas.

Supply areas	No. of croppings/year	Planting Season	Harvest Season
Antique			
a. Culasi	2	December; July	April; October
b. Caluya	3 to 5	year-round	year-round
Iloilo			
a. Concepcion	3 to 4	October, June, December, January	after 60 days
b. San Dionisio	2	July to August	after 45 to 60 days
Negros Occidental	2	February and April; September and October	after 90 days
Guimaras	2	September and April	after 60 to 120 days

one cycle. However, it varied depending on the type of cultivation technique used, as well as environmental conditions in the farming site.

The planting season also depended on the supply area. For instance, in Culasi, Antique (i.e., Maralison and Batbatan), the planting season was divided into two cycles. The first cropping was done during December. After 90 days, the seaweed was harvested. The second cropping then started in July, with the harvest season in October. Interestingly, in the island municipality of Caluya and other neighboring island barangays (i.e., Panagatan, Imba, Sibato, and Sibolo), the practice of seaweed farming can reach up to three to five croppings in a year using the *tie* (plant)-*cut* (harvest)-*tie* method after every 25 days with year-round seaweed production.

In Iloilo province, one seaweed farmer in the municipality of Concepcion (Taloto-an Island) can have three to four croppings in a year. October is considered the start of the planting season in the area. June and December/January were perceived as good months for planting seaweeds. Harvesting is usually done after 60 days of cultivation. In the municipality of San Dionisio, the planting of seaweeds started from July to August. During the FGD, farmers did not consider the summer months as an ideal time to grow seaweeds since they were more vulnerable to ice-ice and other diseases.

For seaweed farmers in Negros Occidental (i.e., Sagay City), the first and second cropping started from February to April (peak season) and from September to October (lean season), respectively. Seaweed was then harvested after 90 days. On the other hand, farmers in Sibunag and Nueva Valencia in Guimaras province regarded September and April as the best planting seasons for seaweeds.

Results from the FGDs and key interviews suggest that care for seaweeds and other supplies usually employed family labor, participated equally by both men (89.19%) and women (86.96%), and were frequently assisted by their children. Most of the activities involved in securing and maintaining the seaweeds were (i) tightening the sagging lines, (ii) shaking the lines to remove silts and sediments and drive away the grazers (e.g., sea urchins, fish), and (iii) picking broken and drifting seaweeds and tying them back to monolines.

Farmers typically harvest seaweeds on small-scale seaweed farms with the help of their household family members. In the case of large-scale farms (i.e., Caluya and Batbatan Is., Antique), the seaweed farm owners sought the help of neighbors. Further, additional laborers were sometimes hired to gather large volumes of fresh seaweed. Not all freshly seaweed harvested was dried and sold. Instead, good quality propagules were chosen and cut into small seedlings, which will be used as seedling material for the next cycle. Seaweed farmers described good quality propagules as those with abundant and young branches (thalli), no traces of grazing from predators, and no early signs of disease (i.e., whitish color/ initial bleaching and rotten or soft thalli, presence of epiphytic filamentous algae in the thalli, tiny black spots and appearance of bumps).

4. DISCUSSION

This study highlighted seaweed eucheumatoids farming (*Kappaphycus* spp. and *Eucheuma* spp.) in the Western Visayas region by documenting supply areas, cultured species, cultivation methods, and the processes involved in seaweed farming.

Generally, the structure of seaweed farms in most production sites across the region can be characterized as small-scale (village-based). Seaweed farming in the region started more than three decades ago, mainly in the province of Antique. However, after the occurrence of Super Typhoon Haiyan in 2014, seaweed farming in the region was introduced in other areas in the region and has grown to provide additional sources of income for affected coastal communities. As of this writing, no carrageenan processing plants exist in the region. Thus, farmers, traders, and processors typically transport and sell their produce to neighboring regions, such as Cebu, where large-scale processing facilities are located.

The seaweed industry in Western Visayas mainly includes farmers, local traders, and small-scale processors (Table 5). Not all seaweed farmers in the region may be actively engaged in production, as some areas, particularly Negros Occidental, Iloilo, and some parts of Antique, experience seasonal supply. Some farmers may also occupy multiple roles within the value chain, participating in trading activities (i.e., consolidating, wholesaling, and/or retailing) and post-harvest processing. This process can include drying fresh seaweeds (RDS) or producing value-added consumable products like crackers, noodles, or chips.

The frequency of input assistance may vary. Key informants from research institutions, such as SEAFDEC, indicated that seaweed seedlings are provided to farmers upon request. In the provinces of Guimaras and Antique, farming implements (excluding seedlings) are distributed annually by the BFAR Provincial Fisheries Office in collaboration with the Local Government Unit. However, in Guimaras, unlike in Antique, inputs are given to a limited number of beneficiaries (i.e., 15 farmers per year). This limitation is intended to ensure proper implementation and sustainability of the project in the supply areas. Further, farmers in other seaweed-producing regions typically organize themselves into associations or cooperatives to be considered significant project recipients or to receive support from the enabling environment (BFAR 2022).

In other supply areas, particularly in Iloilo province, where inputs are financed by private institutions, individual traders, and other sponsors, seaweed farmers receive support based on the market demand for Raw Dried Seaweeds (RDS) and the commodity's seasonality.

In 2018, a total of 2,924.60 ha of existing seaweed areas in Western Visayas, with 2,014.31 ha of coastal areas, were identified as potential sites for farming; with the current utilization rate for farming of seaweeds across the region estimated to be around 59.21% (DA-PRDP 2018). Among the four identified major seaweed production sites, the province of Antique has utilized a considerable number of farming locations suitable for the growth and culture of seaweeds, attributing to the abundant yield of the commodity in the area (99.84% of total regional seaweed production) and deemed as one of the top provincial seaweed producers with a 4.30% contribution to the total volume of the Philippine seaweed production (Philippine Statistics Authority 2024). Smaller productions in other culture sites (0.16% of the total output from the other three supply areas; Philippine Statistics Authority 2024) were notable despite the claims from the respondents of having a continuous annual harvest (i.e., northern Iloilo and Guimaras).

Seasonal productivity has been recounted to occur, constraining the growth rates of farmed eucheumatoids in the region. Variability in eucheumatoid production is highly linked to supply and type of species farmed (i.e., sporadic growth due to crop seasonality and geographic preference of cultivars), together with the fluctuating environmental conditions (Selvavinayagam and Dharmar, 2017). Further, the seasonal and environmental variations (e.g., monsoon) were most likely to affect the growth rate, survival, and product quality (i.e., carrageenan yield) of seaweeds (Hung et al., 2009; Kotiya et al., 2011; Hayashi et al., 2017; Simatupang et al., 2021).

Like in other Southeast Asian countries (i.e., Indonesia and Malaysia), vegetative propagation is primarily used for growing eucheumatoids in the Philippines (Simbahon and Ricohermoso 2001; Rimmer et al. 2019; Suyo et al. 2021). Farmers in the Western Visayas region also rely heavily on this

Table 5. Key seaweed stakeholders and enablers in the Western Visayas region as of 2015–2018.

Stakeholder type	Total
Farmer/Grower	4,305
Local Trader (includes consolidator, wholesaler, retailer)	15
Local Processor (fresh and dried value-added seaweed products, i.e., RDS, seaweed crackers, noodles, etc.)	24

Note: Total seaweed farmers based on official sources (provincial fisheries profiles of LGUs); some may assume multiple roles (farmer-processor, farmer-trader, farmer-processor-trader). Number of traders and processors are based on reliable estimates during the conduct of the study planting technique, which repeatedly uses young cuttings from the same plant from preceding harvests (Buschmann et al. 2017). While the method may seem relatively simple and convenient due to readily available propagules in the next planting season, it can contribute to decreased growth rates and reduced production capacity of farmed seaweeds (Yong et al. 2014; Jiksing et al. 2022). The use of vegetative reproduction to produce seedlings may also lead to lower genetic variability, limiting the ability of the cultured stocks to adapt to the fluctuating conditions in the farming environment. This genetic diversity reduction can compromise seaweeds' robustness, making them more susceptible to infestations and diseases (Valderrama et al. 2015; Porse and Rudolph 2017; Hurtado et al. 2019).

Although there have been several recent advances developed to produce good quality eucheumatoid seedlings such as seaweed tissue culture (Tibubos et al. 2017; Hurtado and Critchley 2018), use of biostimulants and plant growth applicators (Yunque Yap et al. 2011; Neves et al. 2015; Luhan and Mateo 2017; Ali et al. 2018; Mo et al. 2020), and acclimatization and grow-out systems of tissue cultured seaweeds (Luhan and Sollesta 2010; Kasim and Mustafa 2017) among others, the conventional production of seaweed propagules (i.e., vegetative planting) is still dominantly practiced in the region. Government-assisted nursery farms (e.g., BFAR, DENR) and tissue culture laboratories have been developed. However, seedstock production is at the infancy stage and is very minimal. Laboratory-produced seedstocks (propagules) are only enough to supply the test farms (i.e., Iloilo, Guimaras, Antique) where these seedlings are further tested *in situ* for their viability. Hence, more seaweed farmers replant their seaweeds using sexually immature propagules that result in genetically weak strains. These limitations may explain the recurring problems that constantly prevail in seaweed farming in most supply areas in Western Visayas, followed by eventual losses in production yield.

The flourishing trend of seaweed farming in the region, as well as the various factors affecting the viability of farming methods (e.g., biomass production, labor and maintenance intensity, the effect of water depth, average planting distance, and wind patterns), has led to modifications and/or diversifications of cultivation techniques to increase harvest (Blakenhorn 2007; Hayashi et al. 2010; Msuya 2013; Hurtado 2013). It is noteworthy that even with efforts to intensify the farming methods, the present sources of eucheumatoid seaweeds in Western Visayas cannot meet the volume demand and product requirements of traders and processing industries (i.e., Cebu, Manila), except for Caluya in the Antique province. As a result, low farm yield or no production has instigated the seaweed farmers to move and re-engage to other occupations such as fishing, gleaning, or land-based jobs to sustain their basic household needs (i.e., Guimaras, Negros Occidental). The technical (biological) and economic parameters of all culture methods employed in the region, along with the application in commercial farm trials (Msuya et al. 2022), must be documented and/or updated. This could provide feasible means for seaweed farmers to attain sizable income levels whilst valorizing the quality and quantity of eucheumatoid seaweeds without compromising the capital investment.

Moreover, seaweed farmers remarked that farming areas were sequentially expanded to increase their harvest production (i.e., Iloilo, Guimaras). This practice disadvantages other growers, suggesting unequal opportunities to benefit from the resource (Andriesse 2021; BFAR 2022). At the time the study was conducted, stakeholders also emphasized the lack of zoning policies and the preferential issuance of permits for seaweed farms in the region. Such might also elicit conflicts among resource users, thus affecting the sustainability of the resource.

Women's participation in seaweed farming in the region plays a crucial role in resource sustainability, thereby enhancing household financial stability. While gender differentials exist in the seaweed industry, both men and women often perform similar roles, possibly due to the predominantly small-scale and family-operated nature of this industry. Women take on various tasks within the input and production chains, with the same activities as men. These include the preparation of culture lines, the procurement of seedlings, the installation of culture lines, maintenance, and harvesting. Farmers, particularly in Iloilo province, have emphasized the essential support that the women provide to the seaweed industry. The economic benefits of their involvement are evident, as it leads to improvements such as the acquisition of appliances, advancements in technology, better housing, enhanced education, and access to medical care (Gopal et al. 2021; Anderson et al. 2023; Mengo et al. 2023).

Seaweed farmers in the Western Visayas region have acquired technical knowledge and understanding of seaweeds through hands-on training, capability building, and values formation to give importance to best aquaculture practices (BAP) in seaweed farming provided by the government, private organizations, and research institutions. In this study, however, these technical assistance programs only benefited those members of an association or cooperative. It can be observed further that these associations are usually formed to access the inputs that local enablers typically provide. However, the full potential of being an organization that could advance their interests remains loosely structured and fragmented. On the other hand, individual seaweed farmers often rely on years of experience or what other farmers have taught them to modify methods and mitigate the persisting problems of diseases and pests; hence, farming practices and production have not much improved.

Technology development, improvement, and transfer of seaweed farming are not always progressive as evidenced by the poor understanding of farmers on seaweed farming systems and lack of skills to appropriately identify the species of eucheumatoids being provided to them for planting (i.e., Guimaras, Negros Occidental). Conversely, in the municipality of Caluya in the Antique province, proper mentoring on seaweed biology, culture, site selection, and technology transfer was initiated by several private sectors and individual "champions". Seaweed farmers in the area were able to appreciate and apply better farm management skills and utilization of the resource, thus resulting in increased seaweed production levels with high economic returns in the area.

Previous reports have also stated that improved seaweed productivity requires significant development in awareness, skills, and information on technological advancements, financial access, market and social networks in seaweed farming systems, communication, and strong support services (Herr and Muzira 2009; Valderrama 2012; Neish 2015; Neish et al. 2017; Msuya et al. 2022). The productivity of seaweed farming is also accompanied by changes in behavior, along with social and economic costs. In areas where seaweed farming is a lucrative alternative livelihood, higher revenues resulted in the shifting of other people to seaweed cultivation as their primary source of income. Nonetheless, such livelihood activity does not always guarantee a better economic profit. Seaweed growers are always vulnerable to political and social conflicts, natural disasters, and other environmental pressures (Buschmann et al. 2017; Hasselström et al. 2018; Suyo et al. 2020). This has led to many seaweed farmers who are still or routinely disadvantaged. Access to credit facilities offered by formal financing institutions remains inaccessible to most small-scale seaweed farmers, who often rely on humanitarian support and dole-outs for their farming implements. In addition, due to the volatile price of seedlings and input materials in the market, seaweed farmers in Western Visayas still largely depend on the external support provided by the government and private sectors.

5. CONCLUSION

The growing market demand, environmental challenges (e.g., climate change and typhoons), and socioeconomic and political changes have spurred coastal communities in Western Visayas to pursue seaweed farming. *Kappaphycus alvarezii* is the eucheumatoid seaweed species widely cultivated due to its fast-growing feature compared to other species. The high productivity and economic viability of seaweed are achieved using the fixed-off bottom method, which is widely adopted in most cultivation areas in the region. Key factors (e.g., good quality seedlings, suitable farming sites, biological conditions, and effective cultivation methods) must be carefully assessed and considered. Seaweed farming must be viewed as a supplementary occupation for financial stability, supported by a competent and efficient enabling environment that promotes the inclusivity of important key actors in the seaweed production chain. Such linkage will result in effective best management practices and strategies that will be developed to achieve improved and increased productivity levels in Western Visayas.

To enhance the availability of high-quality seaweed seedlings, establishing provincial nurseries in key production areas, advancing technologies, and conducting comprehensive research are recommended. Essential support services are necessary, including local government ordinances on seaweed farming and zoning, the use of information technology to facilitate better information flow, the implementation of best aquaculture practices (BAP), the development of better transport networks, and the provision of targeted training on effective farm management practices. Identifying industry champions or lead firms is vital for improving governance in eucheumatoid production and promoting a thriving, sustainable seaweed industry in the Western Visayas region.

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AUTHOR CONTRIBUTIONS

Ledesma ABB: Data collection and analysis, Validation, Preparation and writing of the original draft manuscript, Editing of manuscript. **Monteclaro HM:** Concept framework, Methodology, Data collection, Supervision, Validation, Review, Editing of manuscript.

CONFLICTS OF INTEREST

The authors indicate no conflicts of interest.

ETHICS STATEMENT

The study required human respondents. All study participants or their legally authorized representative provided informed written consent prior to the interview. The respondents' anonymity was ensured during data analysis.

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