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(RESEARCH ARTICLE)

Understanding biosecurity measures of seaweed farmers in Caloco, Tinambac, Camarines Sur, Philippines

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Abstract

The study was conducted to assess seaweed farmers' understanding of biosecurity in Caloco, Tinambac, Camarines Sur. Data were collected using well-structured questionnaires administered in the identified area. A total of 30 identified seaweed farmers participated in the study; most were aged between 51 to 60 years old, 70% were male, and 90% were married. The highest educational attainment reported was high school graduates which was 60% of the respondents. Fishing was identified as the primary source of income with 60% of respondents earning a monthly income ranging from PhP. 6,000 to 10,000. The most commonly cultured species in the area was *Eucheuma alvarezii* due to its fast growth rate, high market value, and suitability for longline technique. The on-farm biosecurity practices revealed that seaweed farmers harvested their crops earlier than the set scheduled time due to the occurrence of ice-ice disease. In managing diseased crop, 55% of the farmers dried and marketed the affected seaweed crop, while 36% were disposed of outside of the farming area and transported them to land. Furthermore, after the disease occurrence, about 64% of the farmers treated seedling by washing them with soap, rinsing them thoroughly, and returning them to the farm the seedlings.

Keywords: Biosecurity Measures; Disease; Farm Technique; Seaweed Farmers

1. Introduction

The Philippines accounts for approximately 80% of the total world demand for seaweeds, making it the world's largest supplier of this product. Seaweeds serve as a major raw material for the production of carrageenan, and provide livelihoods for about 350,000 Filipinos. The current seaweed industry is largely based on *Eucheuma* species, particularly *Eucheuma cottonii*, due to its fast growth rate and high market value. Seaweed farmers generally experience favorable harvest from January to June, which are considered the peak months for seaweed farming. Seaweeds are exported either in raw form (fresh and dried seaweeds) or processed form such as carrageenan and kelp powder. The major products derived from seaweeds utilization include agar, algin or sodium alginate, and carrageenan. Despite increasing eucheumatoid production, several challenges significantly reduce production capacity, including the persistent occurrence of ice-ice disease or syndrome and the epiphytic pests that continue to affect eucheumatoid aquaculture. These challenges can cause significant economic losses in major seaweed-producing countries, such as Indonesia, Malaysia, Philippines, and Tanzania (Ward et. al, 2021; Hurtado et al. 2019; Valderrama, et al., 2015). However, biosecurity measures have been either absent or inadequately implemented from the point of origin to final out-planting sites (Mateo et al. 2020). This lack of biosecurity has contributed to the spread of diseases and pest introductions, alongside intentionally introduced algae, with impacts often becoming evident only several years after their arrival (Vairappan et al. 2008; Tsiresy et al. 2016). The study aims to understand the biosecurity measures of seaweed farmers

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in the area and to enable the development of scientifically based strategize to minimize the introduction and spread of pests and diseases in the farm, thereby promoting long-term socio-economic sustainability.

2. Materials and methods

Study area. The study adopts a quantitative approach to assess seaweed farmers' concerns regarding the biosecurity measures in the Municipality of Tinambac, Camarines Sur. The Municipality is geographically located between 13 37'' 16'' to 14' 15'' latitude and 123 16'' 57'' to 123 26'' 30 longitude. It is bounded on the north by the Municipality of Siruma, on the northeast by the Pacific Ocean. The municipality is known for its rich natural resources, having the widest coconut plantations in the Province of Camarines Sur and rich fishing ground in San Miguel Bay. Along the Pacific side, Lamit Bay and San Vicente Bay are also known for mud crabs and seaweeds (*Eucheuma alvarezii*). Root crops such as sweet potatoes, cassava are abundant. Rice and corn are also one of the main agricultural products of the town.

Respondents and Data Gathering. The respondents were identified through the a provided by the Municipal Agricultural Office (MAO), agricultural/fisheries technologists (AT/FT) of Tinambac, Camarines Sur. Data were gathered through survey questionnaires consisting of information on household identification, production and sales, seaweed farming, on-farm biosecurity, and extension services. This study identifies the existing problems and provides a comprehensive understanding of biosecurity practices taken by the seaweed farmers in the area.

3. Results and Discussion

3.1. Background Information

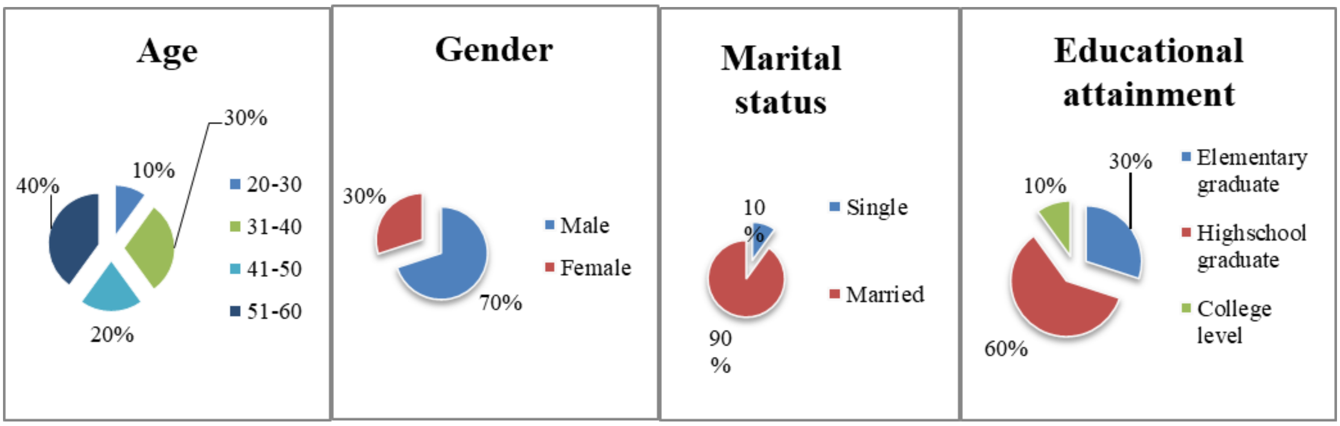

Figure 1 Demographic Profile of Seaweed Farmers in Tinambac

The socio-demographic profile of seaweed farmers in Tinambac includes the age, gender, marital status, and educational attainment. A total of thirty respondents were interviewed, with the majority of the seaweed farmers aged between 51 to 60 years old, representing an older age group. This suggests that knowledge and techniques have been accumulated and refined over time through the continuity in seaweed farming. The age distribution also reflects a deeply rooted livelihood tradition in which experience and long-term engagement play a vital role in farm productivity and sustainability. According to Fabinyi (2010), such intergenerational knowledge transfer is typical in small-scale fisheries and aquaculture, contributing to cultural and economic resilience in coastal communities. In terms of gender, 70% of respondents were male, confirming the male-dominated nature of seaweed farming in the area. The physical demands of the work—such as the installation and maintenance of longline systems, boat operations, and freediving—require significant strength and stamina. This finding aligns with Hurtado, Agbayani, and Sanares (2014), who noted that the longline method, commonly used in seaweed farming involves intensive manual labor and technical skills often performed by men. While women are actively involved in post-harvest activities and seaweed drying in other regions (Lambeth et al., 2002), the lower participation of women in farming operations in Tinambac reflects the persistent gender-based division of labor in primary production. Furthermore, 90% of the seaweed farmers were married, indicating that seaweed farming served as a household-supporting activity in the coastal areas and is often undertaken by individuals with household responsibilities. According to the study of Ellis (2000), married individuals in rural areas tend to rely on stable income-generating livelihoods to sustain household needs. This suggest that seaweed farming provides a dependable, though modest, source of income for family support in Tinambac. Based on the educational attainment, 60% were high school graduates, 30% had completed only elementary education, and only 10% reached the college level. This relatively low level of formal education highlights the socioeconomic barriers in coastal rural communities, including limited access to tertiary education and financial constraints. Despite this, seaweed farming remains an accessible livelihood option, as it relies more on hands-on experience and indigenous knowledge than on formal education. As noted by Asfaw et al. (2012), although formal education enhances decision-making and market engagement, non-formal and practical knowledge remains crucial in traditional aquaculture settings. However, limited higher educational attainment may limit farmers' access to technical innovations, entrepreneurial training, and broader market linkages by the seaweed farmers.

3.2. Source of income

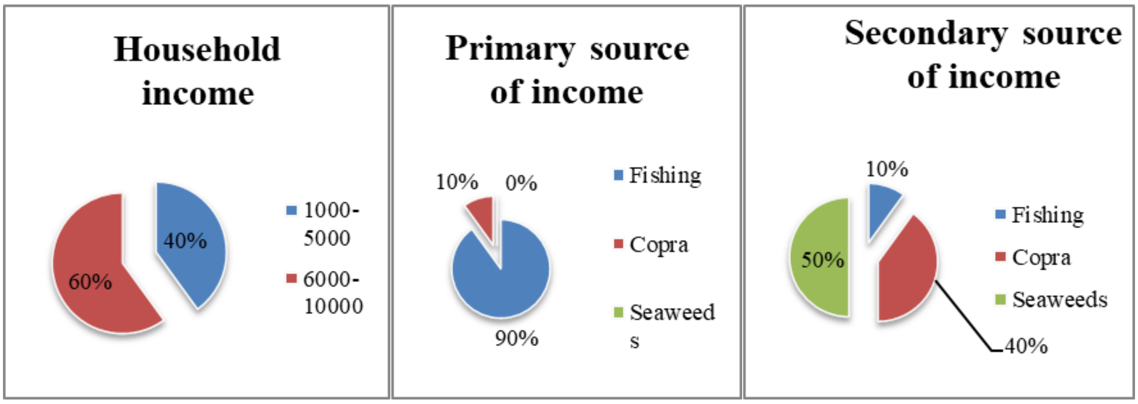

Figure 2 Source of income of the Seaweed farmers

In terms of income sources, 60% of the seaweed farmers reported a monthly household income ranging from PhP 6,000 to 10,000. Fishing was identified as the primary source of income for 90% of the respondents, while seaweed farming served as a secondary source of income for 50% of the farmers, as shown in Figure 2. Fishing remains the main livelihood in the area due to the naturally rich fishing grounds of Lamit Bay, which faces the Pacific Ocean and is also known for its abundance of mud crabs and seaweeds. Moreover, seaweed farming functions as a supplementary livelihood, providing additional income during periods of limited fishing catch caused by unfavorable weather conditions. Copra farming was also identified as an additional source of income, as Tinambac is known for having the widest coconut plantations in the Province of Camarines Sur.

3.3. Production and Sales

Table 1 Production, Sales and Farm Technique

Species cultured	Percent composition (%)	Average kilogram produce (Kg)	Average Sales (PhP.)	Farm technique use
Eucheuma alvarezii	60	1,010	74,000.00	Longline
Kappaphycus spp	40	2,070	50,450.00	Longline

Table 1 presents the production levels, average sales, and farming techniques employed by seaweed farmers in Tinambac. Two species are cultured in the area: *Eucheuma alvarezii* (60%) and *Kappaphycus* spp. (40%). The preference for *E. alvarezii* among farmers is attributed to its fast growth rate and high carrageenan yield, which contribute to its higher market value, as detailed in Table 1. According to Largo et al. (2017), this species thrives well in Philippine coastal waters and exhibits strong resistance to environmental fluctuations, thereby enhancing production stability. The average production of *E. alvarezii* was recorded at 1,010 kg, with corresponding sales amounting to ₱74,000.00, indicating a relatively higher market value despite a lower yield compared to *Kappaphycus* spp. In contrast, *Kappaphycus* spp., although comprising a smaller proportion of total cultivation (40%), registered a higher average production of 2,070 kg. However, this yield generated only ₱50,450.00 in sales, suggesting a lower unit price per kilogram compared to *E. alvarezii*. This trend indicates that market value is influenced not only by production volume but also by product quality and species-specific end-use. While *Kappaphycus* spp. is highly productive, it may have a lower carrageenan extraction yield or reduced demand in certain export markets (Trono, 2017). Both species were cultivated using the longline technique, a widely adopted method in seaweed farming due to its cost-effectiveness and adaptability to various environmental conditions. This technique secures seaweed propagules onto lines suspended in the water column, minimizing substrate contact and promoting better growth. Seaweed farmers in Tinambac followed recommended spacing practices, including a one-meter distance between lines, 12 inches between hills, and an approximate planting density of 150 grams per hill. These practices are consistent with the guidelines set by the Bureau of Fisheries and Aquatic Resources (BFAR, 2021). Furthermore, adherence to these technical protocols demonstrates a high level of awareness and technical capability among local farmers. Respondents reported being well-informed and regularly updated by both BFAR and the Municipal Agriculture Office, ensuring the adoption of species and farming methods suited to local environmental conditions and market trends. This reflects a strong linkage between institutional support and community-level capacity building, which contributes to the overall success of seaweed farming operations in the area.

3.4. On-farm biosecurity

Figure 3 shows that the majority of the seaweed farmers harvested their crop earlier than the standard 45 days of farming period due to the occurrence of ice-ice diseases, which accounted for 55% of early harvesting, while 45% was attributed to weather disturbances in the area. In addition, epiphytes and ice-ice disease were identified as the main problems and pressures experienced by the farmers.

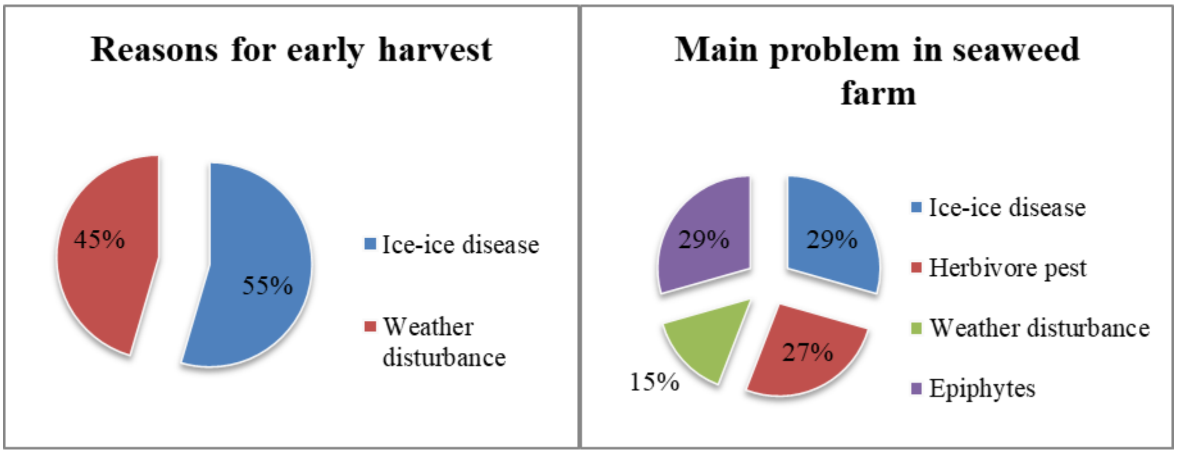

Figure 3 On-farm biosecurity

Typically, ice-ice disease is caused by low salinity, temperature fluctuations, and reduced light intensity, particularly during the summer season. These environmental stressors weaken seaweeds and make them more susceptible to bacterial infections in the surrounding water. Epiphytes, on the other hand, are filamentous benthic algae that proliferate under high-temperature conditions and may be introduced through human-mediated activities, such as the transfer of materials from one farm to another or the use of seaweed seedlings purchased from nearby farmers without proper inspection prior to planting. Mixing infected seedlings with healthy crops can further accelerate the spread of epiphytes. The present findings corroborate earlier studies by de Castro et al. (2017) and Holbech and Pedersen (2018), which reported that epiphytes can be transmitted between farms through contaminated boats and farming equipment. These problems have adversely affected seaweed farmers' income and capital and may also pose a broader ecological risk, as affected areas can serve as pathways or reservoirs for pathogens that may spread to other seaweed farming sites. On-farm biosecurity serves as a preventive control practice implemented by seaweed farmers, including the washing and disinfection of ropes, buoys, bancas, and other operational materials used in farming activities, as well as restricting movement between farm sites. Moreover, Karreman (2006) and Alvial et al. (2012) emphasized that strict limitations on the sharing of equipment between farms are key biosecurity measures for minimizing disease spread. These practices are typically carried out before and after replanting and are particularly crucial during disease outbreaks within the farm.

3.5. Source of seaweed crop

Figure 4 illustrates the sources of seaweed seedlings and the years of farming experience of seaweed farmers in the area. The results show that 71% of the seedlings were obtained from nearby farmers, while 29% were sourced from the Bureau of Fisheries and Aquatic Resources (BFAR). This practice is attributed to the farmers' harvesting strategy, wherein not all seaweeds are harvested; instead, a portion is retained on the farm to ensure the continuous availability of seedlings, particularly during the planting season, and to maintain good seed quality. Additionally, survey results indicated that BFAR Region V also provides seaweed seedlings; however, this support is limited to farmers whose available seedlings are insufficient for their planting areas. Consequently, farmers purchase additional seedlings from nearby farmers at prices ranging from PhP 25 to 30 per kilogram to supplement those obtained from BFAR Region V. In terms of farming experience, 42% of the respondents reported having 30–39 years of experience in seaweed farming. This extensive experience reflects the long-standing practice of seaweed farming in the area, which continues to grow due to the high market value of seaweeds and their importance as a source of income, food, and raw materials for various industrial applications that benefit human populations.

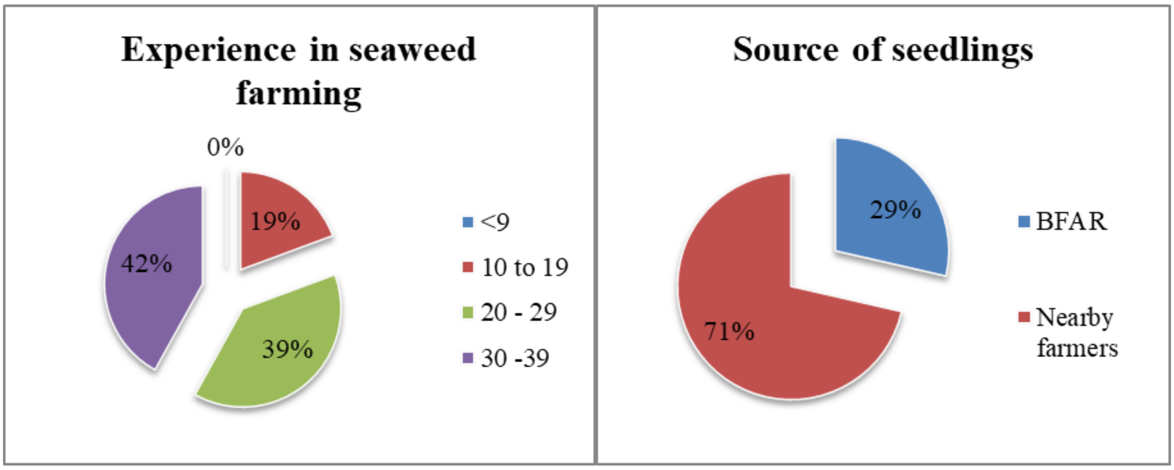

Figure 4 Source of seedlings and years of farming

3.6. Biosecurity measures

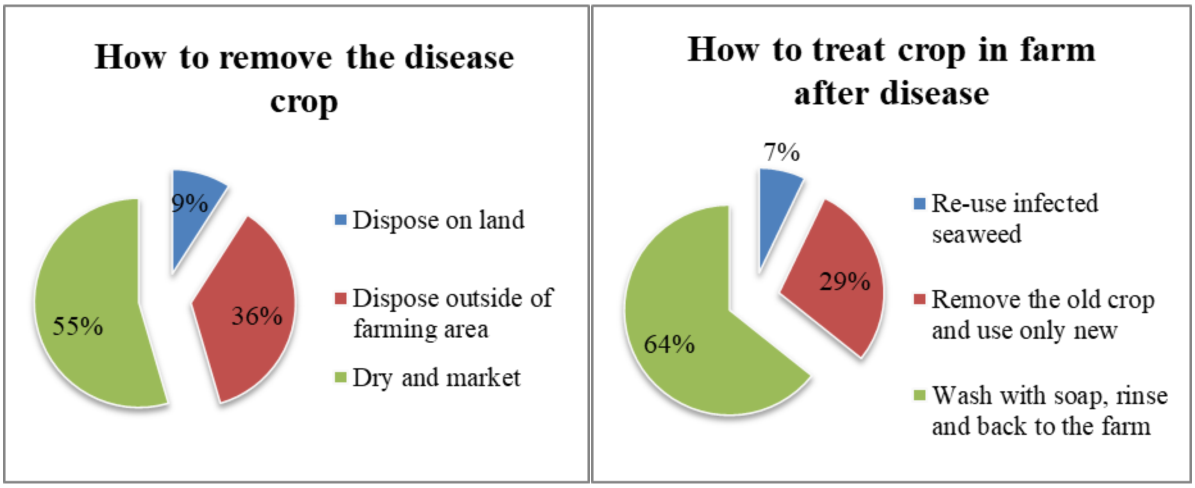

Figure 5 Biosecurity measures to remove the disease crop and how to treat seaweed seedlings

Figure 5 illustrates the biosecurity strategies employed by seaweed farmers in Tinambac in response to crop diseases, focusing on how diseased crops are removed and how farm systems are treated afterward. To manage diseased seaweed crops, 55% of the respondents opted to dry and market the affected biomass, allowing them to recover part of their financial investment during the cropping cycle. Meanwhile, 36% disposed of the infected seaweed outside the farming area, bringing it to land to reduce the risk of contamination to nearby plots. Only 9% disposed of infected crops directly on land, a practice less commonly observed in the area. Regarding post-treatment of the farming area, approximately 64% of farmers reported washing infected seaweed with soap, rinsing thoroughly, and then replanting seedlings. Meanwhile, 29% removed the old crop entirely and planted new seedlings, adhering to more rigorous biosecurity protocols. However, 7% of farmers reported reusing infected seaweed without any treatment, which could contribute to the persistence and spread of pathogens within the farming plots.

Biosecurity policies recommend that farmers should use more sustainable propagule sources that are disease-resistant and tolerant to environmental changes (FAO 2007, Lim et al 2017, Azizi et al 2018). Seaweed farmers in Tinambac also conduct farm monitoring every other day to inspect for pests and disease, allowing for immediate removal or early harvesting of infected crops. Mathiesen (2019) emphasized that maintaining a healthy and resilient host requires a combination of good health, genetics, nutrition (e.g., nutrient enrichment), and effective governance—practices exemplified in the seaweed farming industry. These practices reflect a combination of convenient coping methods and enlightened biosecurity measures, influenced both by the availability of resources and institutional regulation. As stipulated by FAO (2007) and supported by Lim et al. (2017) and Azizi et al. (2018), good biosecurity in seaweed cultivation should include the use of clean, disease-free propagules that are resistant to disease and environmentally tolerant. The use of soap and removing of infected biomass are consistent with these guidelines, though standardization and training must be implemented for effectiveness and safety. Additionally, seaweed farmers in Tinambac conduct farm monitoring every other day to inspect for possible signs of pest infestations. Whereas this monitoring enables immediate removal or early harvest of infected crops, thereby preventing the spread and maintain healthy stock.

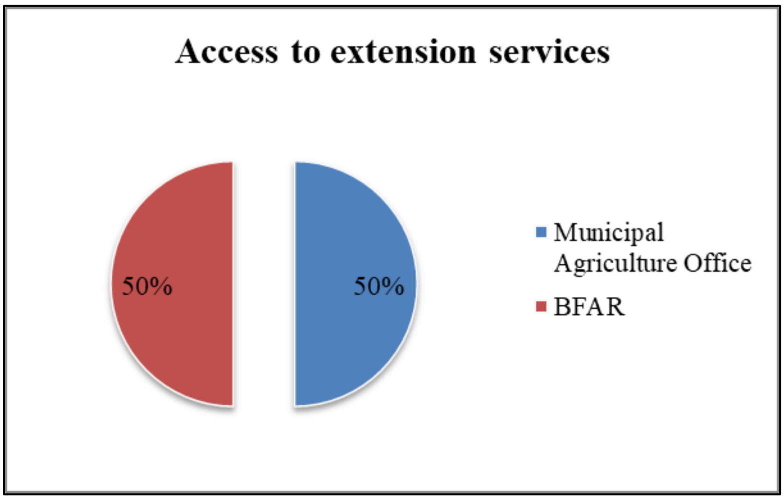

Figure 6 Access to extension services

The access to extension services shows that 50% of respondents receive support coming from the Municipal Agriculture Office, (MAO) while the other 50% received services from the Bureau of Fisheries and Aquatic Resources (BFAR). Both departments provide seminars and workshops that helps seaweed farmers in Caloco, Tinambac improve farm productivity. Through the services offered, it helps them know the crop, farming techniques, and disease prevention strategies. Similar to the findings of Husniah, Fatchiya, A., Amanah, S., et al., 2025, such extension services provide early warning to the seaweed farmers, and helps anticipate potential impacts on production.

4. Conclusion

Extension services play a significant role in educating seaweed farmers in Caloco, Tinambac. Through the efforts of the MAO and BFAR, farmers are able to address challenges in seaweed cultivation effectively. The survey indicated that 40% of farmers are aged 50–60 years, suggesting they are experienced yet open to training and participation in seminars and workshops. The majority of farmers reported harvesting crops earlier than the standard 45-day period due to ice-ice disease (55%) and weather disturbances (45%). They are also aware of biosecurity practices such as washing and disinfecting ropes, buoys, bancas, and other farming materials, as well as restricting movement between farms. Farmers demonstrated knowledge of proper seedling treatment and conduct close farm monitoring every other day to inspect for pests and diseases, enabling prompt removal or early harvest of infected crops. These practices constitute key biosecurity protocols that help prevent large-scale losses and sustain farm productivity. Based on the study's findings, it is concluded that seaweed farmers in Tinambac possess both the knowledge and willingness to implement biosecurity measures, thereby minimizing the introduction and spread of pests and diseases and ensuring the sustainability of their farming operations.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare that no actual, potential or perceived conflict of interest to this article.

Statement of ethical approval

The study ensured ethical compliance by obtaining informed consent from all the seaweed farmers.

Statement of informed consent

Participants were informed about the purpose of the study, voluntary participation and the right to withdraw the interview at any time. Confidentiality was maintained by anonymizing their responses and securing data access. The research posed no harm to participants and respected their time and local practices. Researcher coordinated with LGU, MAO, and Barangay Council to ensure cultural sensitivity and community approval to execute this study.

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