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Macroalgae-Invertebrate Associations in Santa Maria, Ilocos Sur, Philippines: Ecological Survey and Community-based Economic Utility

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ABSTRACT

This study was conducted to determine macroalgae-invertebrate associations in Santa Maria, Ilocos Sur, Philippines: ecological survey and community-based economic utility. Specifically, it determined the macroalgal species in both the intertidal and subtidal zones in terms of percent cover, associated invertebrates and their type of association, and community-based economic utility. The study employed a descriptive and observational method, utilizing transect-quadrat sampling. The study protocol was approved by the University Research Ethics Committee. Results show that Division Rhodophyta (red algae) had the highest percent cover for both the intertidal and subtidal zones, followed by Division Chlorophyta (green algae) and Division Phaeophyta (brown algae) respectively. Ecological associations between the macroalgae and invertebrate species range from commensalism, herbivory, facilitative, indirect mutualism, and predatory. Community-based economic utility for the macroalgae and associated invertebrates include the following: livelihood and income generation, local food consumption and market sales, small-scale aquaculture activities, raw materials for food products, souvenirs, or processed goods. These activities help sustain coastal community livelihoods and contribute to local economic development of the community. It is recommended that community-based coastal resource management (CBCRM) programs involving LGUs, academic institutions, NGOs and fisherfolks may be implemented to promote awareness, conservation, and sustainable use of resources, to sustain the economic, ecological, and social value of macroalgae and associated invertebrates in the community.

Keywords: *Seaweeds, percent cover, descriptive, observational method, transect-quadrat*

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1. INTRODUCTION

Seaweeds have emerged as promising marine living resources globally. With a distribution of over 20,000 species worldwide, only a tiny fraction —approximately 1.1% —are commercially utilized. Among these, 145 species are used for food purposes, while 110 species are utilized for phycocolloid production. Seaweeds' wide range of applications and benefits highlights their immense potential in various sectors (Sobuj-Rahman et al. 2024).

Seaweeds are one of the most economically important fishery products, which comprise 60-70 percent of the total aquaculture production. It consistently ranks as one of the top three exports of the fisheries sector. Carrageenan remains the major product being shipped abroad, comprising 94% of the total seaweed export value in pesos. United States of America (USA), People's Republic of China, Spain, Russia, and Belgium are among the major markets for Philippine seaweed products. Currently, the Philippines is endowed with 1,065 seaweed species (Lastimoso and Santianez 2021) but production is mainly of Eucheuma and Kappahycus. The country pioneered the cultivation of the carrageenan-bearing seaweeds Eucheuma that led to its dominance in commercial seaweeds production and recognition as the top seaweed producer in the international market. The country remains to be one of the major seaweed producers globally with great potential for exploring and developing other economically important seaweeds (e.g. *Gracilaria* which is the source of agar and agarose; Sargassum as a source of alginate, fucoidan, and fucoxanthin; *Asparagopsis* as a feed supplement for cattle to reduce enteric methane emission; and, Caulerpa as a sea vegetable; etc), (DA-BFAR National Seaweed Industry Roadmap 2022-2026).

In the Philippines, seaweeds are one of the most economically important fishery products, which comprise 60-70 percent of the total aquaculture production. It consistently ranks as one of the top three exports of the fisheries sector. Carrageenan remains the major product being shipped abroad, comprising 94% of the total seaweed export value in pesos. United States of America (USA), People's Republic of China, Spain, Russia, and Belgium are among the major markets for Philippine seaweed products. Currently, the Philippines is endowed with 1,065 seaweed species (Lastimoso and Santianez 2021) but production is mainly of Eucheuma and Kappahycus. The country pioneered the cultivation of the carrageenan-bearing seaweeds Eucheuma that led to its dominance in commercial seaweeds production and recognition as the top seaweed producer in the international market. The country remains to be one of the major seaweed producers globally with great potential for exploring and developing other economically important seaweeds (e.g. *Gracilaria* which is the source of agar and agarose; Sargassum as a source of alginate, fucoidan, and fucoxanthin; *Asparagopsis* as a feed supplement for cattle to reduce enteric methane emission; and, Caulerpa as a sea vegetable; etc), (DA-BFAR National Seaweed Industry Roadmap 2022-2026).

Seaweed aquaculture and associated ecosystems have been the subject of growing research interest. Pagaoa et al. (2025) emphasized that oyster farming areas in Ilocos Sur are closely linked to physicochemical and microbiological parameters, suggesting that sustainable aquaculture—including macroalgae–invertebrate systems—depends on maintaining water quality to support both human consumption and ecological balance. Meanwhile, Ilac et al. (2024) demonstrated the potential of *Gracilaria* species cultured using the raft method, highlighting its adaptability, biomass productivity, and economic viability. These findings are relevant to macroalgae–invertebrate associations, as they emphasize both the ecological services of macroalgae and their role as potential livelihood resources when integrated with sustainable aquaculture practices.

Marine invertebrates are crucial for healthy ocean ecosystems and human society. They play vital roles in nutrient cycling, water filtration, and habitat creation, and are also important food sources and a source of potential pharmaceuticals. Their diverse roles in the ocean's food web and their ability to filter water, process organic matter, and transfer carbon make them essential for a balanced and productive marine environment.

In the province of Ilocos Sur, several seaweed species are extensively utilized as part of the local diet, especially in the coastal barangays. Among these seaweeds are the caulerpa, codium, eucheuma, gracilaria, hydroclathratus and others. During peak seasons, these edible seaweeds are dried and stored for days or even months. These are used for future consumption, or as 'pabaon" to balikbayan relatives and friends going back to foreign lands. Aside from utilizing seaweeds as food, locals engage in seaweed collection as an alternative source of livelihood. Edible seaweeds are collected in the wild, sold in local markets or nearby towns, or even nearby provinces (Domingo and Corrales, 2001). Invertebrates are equally important and serve many purpose like sources of food and livelihood.

Seaweeds and marine invertebrates have a strong interconnected relationship, where seaweeds provide vital habitat and food sources for many invertebrate species, while invertebrates contribute to the health and structure of seaweed ecosystems. This association encompasses various symbiotic, commensal, and parasitic relationships, highlighting the importance of these interactions for the overall functioning of marine environments.

Bégin et al. (2004) showed an important relationship between the macroalgae canopy and a collection of invertebrates. Different invertebrate communities can be found in the canopy of different macroalgae species, showing the diversity of invertebrates because macroalgae provide shelter.

It is then the purpose of the study to determine the macroalgae and invertebrate biota and their relationships, and present the community-based economic utility of the resources, in Nalvo, Sta. Maria, Ilocos Sur. Combined with the community-based economic utility of invertebrates, understanding the ecological role of macroalgae and their associated fauna provides a holistic view essential for sustaining coastal livelihoods and ecosystem services

2. MATERIALS AND METHODS

Research Design. The study employed a descriptive and observational method, utilizing transect-quadrat sampling. It documented the macroalgae and associated species, described the percent cover, identified, and described their type of association and economic utility. A literature review was employed to supplement data gathered from the local folks.

Sampling Area. Nalvo is a barangay located in the municipality of Santa Maria, Ilocos Sur, on the island of Luzon. Its coordinates are approximately 17.3661°N, 120.4534°E, and it sits at a low elevation of about 4.9 to 6 meters above sea level (PhilAtlas). The area is part of the western coast of Northern Luzon, directly facing the South China Sea (MIS Ilocos Sur). The intertidal zone in Nalvo features a mix of sandy, sandy-rocky, and rocky substrates, which supports a high diversity of seaweed species. This structural variety allows for a greater number of edible and ecologically important seaweeds compared to areas with only one substrate type (Domingo and Corrales, 2001). The intertidal zone is also traditionally used for gleaning and gathering of seaweeds and invertebrates.

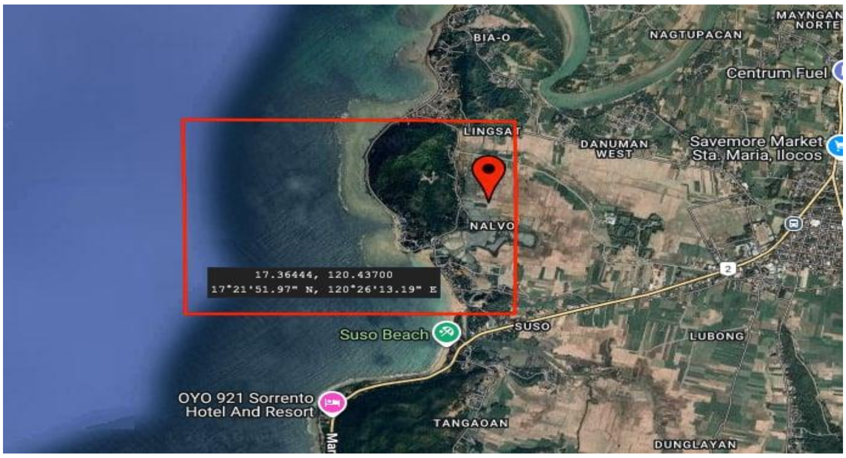

Fig 1. Map of Nalvo, Sta. Maria, Ilocos Sur showing its latitude and longitude coordinates

Sampling Technique. A 15-meter transect line with two quadrats (Quadrat 1and 2) measuring 1m x 1m were laid perpendicular at 5 meters and 10 meters from the starting point from the shoreline into the submerged area of the coast. Quadrats 1and 2 were laid in shallow water in the intertidal zone. Another 15-meter transect line with 2 quadrats (Quadrat 3 & 4) were also laid in deeper area in the subtidal zone but still receive ample sunlight. Figure 2 shows a visual diagram of the set up. The layout follows standard ecological survey methods used in intertidal and subtidal studies (Philippoff and Cox).

Specimen collection, preservation and identification. The specimens were collected in the intertidal and subtidal zones of the sampling area during the low tide when a large expanse of the shore was exposed, by snorkeling or wading through the shallow waters. In the intertidal zone, within each quadrat, all macroalgae were carefully scraped off the substrate using knives or scrapers. Associated invertebrates attached to or living among the algae were collected simultaneously by hand or with small nets. Samples were washed with seawater to remove sediment and loosely attached organisms. Macroalgae and invertebrates are separated for identification.

Subtidal zone collection was conducted through diving or snorkeling. Macroalgae within the quadrat were cut or scraped off carefully using knives or scrapers. Associated invertebrates were collected by hand or with small nets within the quadrat area. Samples are brought to the surface, rinsed with seawater, sorted, and identified in the UNP-MRDC.

Common macroalgae and invertebrate species were immediately identified in the UNP-MRDC and not common species were preserved for later identification following standard procedures from George (2019) and Harris (2016). Species identification followed standard taxonomic books and taxonomic studies by Trono, GC, Jr. (1997), Trono, GC, Jr and Fortes, EG (1998), Trono, GC, Jr (1984) and Domingo and Corrales (2001). Some specimens were identified only up to the Genus level, for further identification of the species.

Ethical Considerations. The researchers adhered to ethical standards in conducting the research. Before conducting the study, the University Research Ethics Review Committee reviewed the protocol and found its ethical appropriateness. Key ethical considerations in the collection of macroalgae and associated invertebrates focused on minimizing harm to the organisms, including their habitats, ensuring compliance with regulations, and promoting conservation. Permission was secured from the Punong Barangay of Nalvo, Sta Maria, Ilocos Sur. The smallest sample size necessary to achieve research objectives, to avoid negatively impacting local populations, was conducted. A non- destructive sampling method was employed, thereby reducing harm to the organisms and their habitats. Associated invertebrates were handled with care to reduce stress injury or mortality. The conservation status of target species was also considered. These principles align with broader ethical guidelines for marine biological research, emphasizing respect for marine life as sentient organisms and the importance of preserving biodiversity and ecosystem integrity.

Statistical Treatment of Data. Frequency count was used to identify the species richness of the macroalgae and associated invertebrate species. Percentages were used in the determination of the percent cover.

3. RESULTS AND DISCUSSION

1. On macroalgae species percent cover in the intertidal and subtidal zones

Division Rhodophyta has the greatest percent cover in the intertidal zone with 42.86%, followed by Division Chlorophyta and Division Phaeophyta, each with 28.57%.

Of the 14 macroalgae species documented, representing the intertidal zone, six (6) species belong to Division Rhodophyta, and four (4) species each belong to Division Chlorophyta, and Division Phaeophyta. The 14 macroalgae species are further divided into 11 families namely: Gracilariaceae (*Gracilaria salicornia*); Rhodomelaceae (*Acantophora spicifera, Laurencia papillosa*); Hypneaceae (*Hypnea sp.*); Valoniaceae (*Valonia* ventricosa.); Halimedaceae (*Halimeda sp.*); Systosiphonaceae (*Hydroclathrus clathratus*); Dictyotaceae (*Padina sp*); Sargassaceae (*Sargassum spp; Turbinaria sp.*); Gelidiellaceae (*Gelidiella acerosa*); Solieriaceae (*Kappaphycus sp.*); Cladophoraceae (*Chaetomorpha crassa*); and Caulerpacea (*Caulerpa sertularioides*).

In the subtidal zone, Division Rhodophyta also has the greatest percent cover with 41.67%, followed by Division Chlorophyta with 33.33% and lastly, Division Phaeophyta with 25%.

Of the 12 macroalgae species documented from the subtidal zone, five (5) species belong to Division Rhodophyta, commonly known as red algae, four (4) species belong to Division Chlorophyta or the green algae, and three (3) species belong to Division Phaeophyta or the brown algae. The 12 macroalga species are further divided into 10 families namely: Rhodamelaceae (*Acantophora spicifera, Laurencia papillosa*); Gracilariaceae (*Gracilaria salicornia*); Sargassaceae (*Sargassum sp; Turbinaria sp.*); Cladophoraceae (*Chaetomorpha crassa*); Caulerpacea (*Caulerpa racemosa,Caulerpa sertularioides*); Gelidiellaceae (*Gelidiella acerosa*); Halimedaceae (*Halimeda sp.*); Dictyotaceae (*Padina sp.*); and Hypneaceae (*Hypnea sp.*).

The dominant macroalgae group in terms of species is consistently reported as Rhodophyta (red algae). Red algae include diverse forms such as calcareous coralline algae, filamentous, and coarsely branched species, which contribute to both species richness and habitat complexity. Studies also show that species richness peaks in mid to low tidal zones and shallow subtidal areas where light and nutrients are optimal (Wang et al., 2025). Brown algae, while often dominant in biomass (e.g. *Sargassum* spp., *Turbinaria* spp), generally have fewer species compared to red algae in subtidal zones.

Table1. Macroalgae species percent cover in the intertidal and subtidal zones

Zone	Scientific Name	Common Name	Division	Family	% Cover
Intertidal	*Gracilaria salicornia*	Kawkawayan	Rhodophyta	Gracilariaceae	42.86
	Acantophora spicifera	Kulot	Rhodophyta	Rhodomelaceae	
	Laurencia papillosa	Kulot tumeng	Rhodophyta	Rhodomelaceae	
	Hypnea sp.	Ragragutirit	Rhodophyta	Cystocloniaceae	
	Kappaphycus sp.	Kanut-kanot	Rhodophyta	Solieriaceae	
	Gelidiella acerosa	Lallali	Rhodophyta	Gelidiellaceae	
	Valonia ventricosa	Lupluptak	Chlorophyta	Valoniaceae	28.57
	Halimeda sp	Coin plant	Chlorophyta	Halimedaceae	
	Chaetomorpha crassa	Pancit-pancit	Chlorophyta	Cladophoraceae	
	Caulerpa sertularioides	Salsalamagi	Chlorophyta	Caulerpacea	
	Hydroclathrus clathratus	Balbalulang	Phaeophyta	Systosiphonaceae	28.57
	Padina sp.	Laplapayag	Phaeophyta	Dictyotaceae	
	Sargassum sp	Aragan	Phaeophyta	Sargassaceae	
	Turbinaria sp	Layog-layog	Phaeophyta	Sargassaceae	
Subtidal	*Acantophora spicifera*	Kulot	Rhodophyta	Rhodomelaceae	41.67
	Laurencia papillosa	Kulot tumeng	Rhodophyta	Rhodomelaceae	
	Gracilaria salicornia	Kawkawayan	Rhodophyta	Rhodophyta	
	Gelidiella acerosa	Lallali	Rhodophyta	Gelidiellaceae	
	Hypnea sp.	Ragragutirit	Rhodophyta	Cystocloniaceae	
	Chaetomorpha crassa)	Pancit-pancit	Chlorophyta	Cladophoraceae	33.33
	Caulerpa racemosa	Ar-arusip	Chlorophyta	Caulerpaceae	
	Caulerpa sertularioides	Salsalamagi	Chlorophyta	Caulerpaceae	

	Halimeda sp.	Coin plant	Chlorophyta	Halimedaceae	
	Sargassum sp.	Aragan	Phaeophyta	Sargassaceae	25
	Turbinaria sp.	Layog-layog	Phaeophyta	Sargassaceae	
	Padina sp.	Laplapayag	Phaeophyta	Dictyotaceae	

2. On the associated invertebrate species in the intertidal and subtidal zone

Modiolus sp. has a commensal/facilitative type of association with *G. salicornia*. In the intertidal zone, *Gracilaria* often forms dense mats or communities attached to substrates such as stones or shells, including those inhabited by *Modiolus* mussels (Asia-Pacific Network for Global Change Research). This interaction is generally considered commensal because *Gracilaria* gains a substrate and possibly some protection from desiccation and wave action, while *Modiolus* mussels are neither significantly harmed nor directly benefited by the algae. However, in some cases, the algae can help stabilize sediments and improve local water quality, indirectly benefiting the mussels, which could suggest a facilitative aspect to the association. *Modiolus* sp. and *Valonia* in the intertidal zone exhibit a commensal to facilitative association, where mussels provide substrate for algal attachment, and algae may offer indirect benefits by modifying the microhabitat, helping both survive in a physically stressful environment(Souza-Cascon et al. 2020). The *Modiolus–Chaetomorpha* association in the intertidal zone is mainly commensal, where mussel beds provide substrate and shelter for the algae, with potential indirect benefits to mussels through habitat modification. This relationship contributes to the complexity and stability of intertidal communities (Mair, et al., 2000).

The association between hermit crabs and *Gracilaria* is primarily commensal, with hermit crabs benefiting from shelter and habitat complexity provided by the seaweed, and potential indirect mutualistic effects through ecosystem interactions. This relationship enhances the ecological complexity and resilience of intertidal and subtidal communities. The hermit crab–*Acanthophora* association in the intertidal zone is mainly commensal, where hermit crabs gain shelter and habitat complexity from the algae without significant impact on the seaweed (Pezzuti-Turra et al. 2002). The hermit crab–*Laurencia* association is mainly commensal, where hermit crabs benefit from shelter and habitat complexity provided by the algae, while *Laurencia* is neither significantly helped nor harmed. Hermit crabs and *Hypnea* have a commensal association in intertidal zones, where hermit crabs benefit from shelter and habitat complexity provided by the algae, while *Hypnea* is neither significantly helped nor harmed. *Kappaphycus* provides shelter and habitat complexity while hermit crabs benefit without harming the algae while *G. acerosa* offers structural habitat for hermit crabs without significant impact on the algae. Hermit crabs may graze on *Valonia*, making that interaction partly predatory, but often use it as shelter, a commensal relationship. With *Halimeda*, the association is mainly commensal, with hermit crabs benefiting from habitat complexity without harming the algae (UltimateReef). Hermit crabs and *C. crassa and C. sertularioides* mainly exhibit a commensal relationship, where the crabs benefit from habitat and associated food resources without causing significant harm to the algae. Hermit crabs benefit from the physical complexity and shelter provided by *Sargassum*, *Padina*, *Hydroclathrus* and *Turbinaria*, while the algae remain largely unaffected, fitting a classic commensalism model Pezzuti et al., 2002).

Linckia laevigata and these red algae species, *Gracilaria, Acantophora, Laurencia, Hypnea, Gelidiella* and Kappaphycus coexist mainly through commensal associations in the intertidal zone, where the algae offer habitat structure and shelter that benefit the sea star without significant reciprocal effects (Baptiste & Jakimovski). *Linckia laevigata* and these green algae species Valonia, Halimeda, Chaetomorpha and Caulerpa coexist mainly through commensal relationships in intertidal zones. The sea star benefits from the shelter and habitat complexity provided by the algae, while the algae experience neither significant benefit nor harm (Baptiste & Jakimovski).

Linckia laevigata coexist mainly through commensalism with the above-mentioned brown algae in intertidal and shallow reef habitats, where the sea star benefits from the shelter and habitat complexity provided by the algae, while the algae remain unaffected.

Culcita sea stars and *Valonia, Halimeda, Chaetomorpha, Caulerpa, Hydroclathrus, Padina, Sargassum, and Turbinaria* coexist primarily through incidental habitat overlap/commensalism. The sea stars benefit from the habitat complexity and shelter these algae provide but do not form specialized or mutualistic associations with them.

Protoreaster nodosus has a commensal type of association with all the macroalgae documented in the intertidal zone, with its role as a habitat generalist in the intertidal ecosystems relying on algae for shelter rather than for direct nutrition, except for *Kappaphycus* (SEAFDEC) with a predatory type of association because it causes tissue damage and branch breakage in farms or areas with the said macroalgae.

Ophiothrix brittle stars and all the macroalgae documented in the intertidal zone coexist mainly through commensal associations in intertidal zones. The brittle stars benefit from the shelter and habitat complexity provided by the algae, while the algae experience neither significant benefit nor harm. This relationship is characterized by habitat use and spatial overlap rather than direct feeding or mutualism. This aligns with general observations that *Ophiothrix* species prefer hard substrata and algal holdfasts for shelter, feeding primarily on suspended particles rather than macroalgae themselves

The relationship between *Asterias* sea stars and these macroalgae in the intertidal zone is predominantly commensal, where the sea stars benefit from the shelter and habitat complexity provided by the algae, while the algae remain unaffected. The sea stars do not feed on these macroalgae but rely on them indirectly by inhabiting the structurally complex environments that support their prey and offer protection (E-Algae).

Canarium interacts with these macroalgae mainly through indirect herbivory, feeding on epiphytic diatoms, biofilms, detritus, and fragments associated with the algae, and algae fragments. The relationship is a form of grazing and habitat association, where macroalgae provide substrate and microhabitats that support the conch's food sources. This aligns with *Canarium*'s ecological role as a grazer in seagrass and algal bed ecosystems, contributing to nutrient cycling and benthic community dynamics (Brillantes et al., 2024).

Strictodactyla sp. in the intertidal zone do not form direct nutritional or parasitic associations with the macroalgae documented from the intertidal zone. The relationship is mostly commensal, where macroalgae provide habitat, shelter, and microhabitats favorable for anemone survival (Erralde & Acuña, 2020).

Conus snails do not directly interact with all the documented macroalgae in the intertidal zone in terms of feeding or symbiosis. Their association with these algae is indirect and commensal, where macroalgae form part of the habitat that supports prey species and offers shelter for the snails. The relationship is primarily spatial and ecological rather than trophic or symbiotic (Childs 2022).

Diadema sea urchins have a keystone herbivore association with macroalgae in intertidal and reef environments. Their grazing controls macroalgal populations, preventing algal dominance, facilitating coral recruitment, and maintaining reef ecosystem balance. This relationship is primarily herbivorous and regulatory, with occasional omnivory under resource scarcity(Edmunds & Carpenter, 2001).

Aplysia eats marine macroalgae, principally red algae, from which it derives pigments that tint its skin a mottled reddish-brown, and also give its ink a purplish color. Their diet influences their coloration and the chemical composition of their ink, which they release as a defense mechanism (Aplysia Web Project).

Tripneustes gratilla is a generalist herbivore that grazes on a wide variety of macroalgae and seagrasses in the intertidal and shallow subtidal zones. Its feeding preferences can vary regionally but include many of the listed macroalgae genera. This broad diet allows it to play a significant ecological role in controlling algal growth and maintaining reef health. It is also a species of interest for aquaculture due to its growth and feeding characteristics (University of Cape Town). Shows significant preference to *Kappaphycus* and *Turbinaria* but grazes generally on other macroalgae documented in the intertidal zone, calcareous algae are less preferred.

In the intertidal zone, sponges and macroalgae have a context-dependent, mostly commensal association. Macroalgae contribute to habitat complexity and release dissolved organic matter that sponges utilize, supporting sponge nutrition and growth. Sponges benefit from the structural habitat and organic matter without directly harming the algae, while macroalgae are unaffected or indirectly benefit from nutrient recycling. This association plays a vital role in maintaining ecosystem function and nutrient dynamics in intertidal marine communities (Gutierrez, 2022).

In the subtidal zone, *Synapta maculata* exhibits a commensal association with the documented macroalgae. The sea cucumber benefits from the habitat complexity and the organic matter (detritus, epiphytes) associated with the macroalgae, which it collects and consumes using its adhesive tentacles. The macroalgae are unaffected directly by this association

Anadara clams have a commensal and indirect association with the collected macroalgae in the subtidal zone. The macroalgae contribute to habitat complexity, organic matter availability, and local productivity, which indirectly support the filter-feeding and survival of *Anadara* (Yurimoto et al.,2021).

Actinopyga sea cucumbers have an indirect, commensal association with the documented macroalgae in the subtidal zone. Macroalgae contribute to habitat complexity and organic matter that supports *Actinopyga*'s detritivorous feeding and ecological functions. There is no direct feeding on or mutualistic/parasitic relationship with macroalgae (ALR Journal).

Synapta maculata has a commensal and indirect trophic association with macroalgae and seagrasses in the subtidal zone.

It benefits from the habitat complexity and organic matter produced by macroalgae like *Padina* and *Halimeda*, feeding on detritus and microalgae on or near these plants. This relationship supports benthic ecosystem functioning without directly harming the macroalgae.

Lambis lambis has a direct herbivorous association with macroalgae, primarily grazing on fine red algae in shallow subtidal and intertidal habitats. This relationship is important ecologically for controlling algal abundance and structurally for providing habitat complexity. The snail's diet influences its chemical composition and ecological interactions (WildSingapore).

Morula species are predatory marine snails that live in rocky intertidal and shallow subtidal habitats rich in sessile invertebrates. Their association with macroalgae is indirect and habitat-based, relying on algae-covered rocky substrates that harbor their prey. They do not feed on macroalgae or form mutualistic or parasitic relationships with them. Macroalgae provide habitat complexity that supports prey species (barnacles, mollusks) which Morula snails feed on, thus macroalgae indirectly influence Morula distribution and abundance.

Overall, association between macroalgae and invertebrates is ecologically important and multifaceted, involving habitat provision, food supply, nutrient cycling, and biodiversity support. The association is fundamental to marine ecosystem structure and function. Macroalgae act as ecosystem engineers that create habitats and food resources, enhancing invertebrate diversity, abundance, and stability. Invertebrates, in turn, contribute to nutrient cycling and algal health, forming complex, mutually beneficial communities essential for coastal marine biodiversity and productivity.

Table 2. Associated invertebrates in the intertidal and subtidal zone

Zone	Scientific name	Common Name	Order	% Cover	Associated Macroalgae	Type of Association
Intertidal	*Modiolus* sp.	Sittil/mussel	Mytilida	9.09	*G. salicornia*	Commensalism/ facilitative
					V.ventricosa	Commensal/ facilitative
					C. crassa	Commensalism
	Unidentified	Hermit crab	Decapoda	9.09	*G. salicornia*	Commensalism/ Indirect mutualism
					A.spicifera	Commensalism
					Hypnea sp.	Commensalism
					Kappaphycus sp.	Commensalism
					G.acerosa	Commensalism
					V. ventricosa	Herbivory/predation/ Commensalism
					Halimeda	Commensalism
	Linckia laevigata	Blue sea star	Valvatida	27.27	*Gracilaria*	Commensalism
					Acantophora	Commensalism
					Hypnea	Commensalism
					Kappaphycus	Commensalism
					Valonia	Commensalism
					Halimeda	Commensalism
					Chaetomorpha	Commensalism
					Caulerpa	Commensalism
					Hydroclathrus	Commensalism
					Padina	Commensalism
					Sargassum	Commensalism
					Turbinaria	Commensalism
	Culcita sp.	Sea star	Valvatida	27.27	*Valonia*	Incidental habitat overlap

					Halimeda	Incidental habitat overlap
					Chaetomorpha	Incidental habitat overlap
					Caulerpa	Incidental habitat overlap
					Hydroclathrus	Incidental habitat overlap
					Padina	Incidental habitat overlap
					Sargassum	Incidental habitat overlap
					Turbinaria	Incidental habitat Overlap
	Protoreaster nodosus	Chocolate chip sea star	Valvatida	27.27	*Gracilaria*	Commensalism
					Acantophora	Commensalism
					Laurencia	Commensalism
					Hypnea	Commensalism
					Kappaphycus	Predatory
					Gelideilla	Commensalism
					Valonia	Commensalism
					Halimeda	Commensalism
					Chaetomorpha	Commensalism
					Caulerpa	Commensalism
					Hydroclathrus	Commensalism
					Padina	Commensalism
					Sargassum	Commensalism
					Turbinaria	Commensalism
	Ophiotrix sp	Brittle star	Ophiurida	9.09	*Gracilaria*	Commensalism
					Acantophora	Commensalism
					Laiurencia	Commensalism
					Hypnea	Commensalism
					Kappaphycus	Commensalism
					Gelidiella	Commensalism
					Valonia	Commensalism
					Halimeda	Commensalism
					Chaetomorpha	Commensalism
					Caulerpa	Commensalism
					Hydroclathrus	Commensalism
					Padina	Commensalism
					Sargassum	Commensalism
					Turbinaria	Commensalism
	Asterias sp	Common starfish	Forcipalutida	9.09	*Gracilaria*	Commensalism
					Acantophora	Commensalism
					Laurencia	Commensalism
					Hypnea	Commensalism
					Kappaphycus	Commensalism
					Gelidiella	Commensalism

					Valonia	Commensalism
					Halimeda	Commensalism
					Chaetomorpha	Commensalism
					Caulerpa	Commensalism
					Hydroclathrus	Commensalism
					Padina	Commensalism
					Sargassum	Commensalism
	Strombus canarium	Dog conch	Littorinimorpha	9.09	*Turbinaria*	Commensalism
					Gracilaria	Commensalism
					Acantophora	Commensalism
					Laurencia	Commensalism
					Hypnea	Commensalism
					Kappaphycus	Commensalism
					Gelidiella	Commensalism
					Valonia	Commensalism
					Halimeda	Commensalism
					Chaetomorpha	Commensalism
					Caulerpa	Commensalism
					Hydroclathrus	Commensalism
					Padina	Commensalism
					Sargassum	Commensalism
					Turbinaria	Commensalism
	Strictodactyla sp.	Sea anemone	Actiniaria	9.09	*Gracilaria*	Commensalism
					Acantophora	Commensalism
					Laurencia	Commensalism
					Hypnea	Commensalism
					Kappaphycus	Commensalism
					Gelidiella	Commensalism
					Valonia	Commensalism
					Halimeda	Commensalism
					Chaetomorpha	Commensalism
					Caulerpa	Commensalism
					Hydroclathrus	Commensalism
					Padina	Commensalism
					Sargassum	Commensalism
					Turbinaria	Commensalism
	Conus sp.	Cone shell	Neogastropoda	9.09	*Gracilaria*	Commensalism
					Acantophora	Commensalism
					Laurencia	Commensalism
					Hypnea	Commensalism
					Kappaphycus	Commensalism
					Gelidiella	Commensalism
					Valonia	Commensalism
					Halimeda	Commensalism
					Chaetomorpha	Commensalism

					Caulerpa	Commensalism
					Hydroclathrus	Commensalism
					Padina	Commensalism
					Sargassum	Commensalism
					Turbinaria	Commensalism
	Diadema sp.	Long-spined sea urchin	Diadematoida	9.09	*Gracilaria*	Herbivory/Grazing
					Acantophora	Herbivory/Grazing
					Laurencia	Herbivory/Grazing
					Hypnea	Herbivory/Grazing
					Kappaphycus	Herbivory/Grazing
					Gelidiella	Herbivory/Grazing
					Valonia	Herbivory/Grazing
					Halimeda	Herbivory/Grazing
					Chaetomorpha	Herbivory/Grazing
					Caulerpa	Herbivory/Grazing
					Hydroclathrus	Herbivory/Grazing
					Padina	Herbivory/Grazing
					Sargassum	Herbivory/Grazing
					Turbinaria	Herbivory/Grazing
	Aplysia sp.	Sea hares	Anaspidea	9.09	*Gracilaria*	Herbivory
					Laurencia	Herbivory
	Tripneustes gratilla		Camarodonta	9.09	*Kappaphycus*	Preferred grazing
					Turbinaria	*Preferred grazing*
	Sponge		Haplosclerida	9.09	*Gracilaria*	Indirect commensalism/ facilitative
					Acantophora	Indirect commensalism/
					Laurencia	facilitative
					Hypnea	Indirect commensalism/
					Kappaphycus	facilitative
					Gelidiella	Indirect commensalism/
					Valonia	facilitative
					Halimeda	Indirect commensalism/
					Chaetomorpha	facilitative
					Caulerpa	Indirect commensalism/
					Hydroclathrus	facilitative
					Padina	Indirect commensalism/
					Sargassum	facilitative
					Turbinaria	Indirect commensalism/

Subtidal	*Stichosynapta maculate*	Spotted worm sea cucumber	Actinaria		*Acantophora*	commensalism
					Laurencia	commensalism
						commensalism
					Gracilaria	commensalism
					Gelidiella	commensalism
					Hypnea	commensalism
					Chaetomorp ha	commensalism
					C. racemosa	commensalism
					C sertulariorde s	commensalism
					Halimeda	commensalism
					Sargassum	commensalism
					Turbinaria	commensalism
					Padina	commensalism
	Anadara sp.	Ark clam	Arcida		*Acantophora*	commensalism
					Laurencia	commensalism
					Gracilaria	commensalism
					Gelidiella	commensalism
					Hypnea	commensalism
					Chaetomorp ha	commensalism
					C. racemosa	commensalism
					C sertulariorde s	commensalism
					Halimeda	commensalism
					Sargassum	commensalism
					Turbinaria	commensalism
					Padina	commensalism
	Actinopyga sp.	Sea cucumber	Holoturii da		*Acantophora*	commensalism
					Laurencia	commensalism
					Gracilaria	commensalism
					Gelidiella	commensalism
					Hypnea	commensalism
					Chaetomorp ha	commensalism
					C. racemosa	commensalism
					C sertulariorde s	commensalism
					Halimeda	commensalism
					Sargassum	commensalism
					Turbinaria	commensalism
					Padina	commensalism
	Holothuria scabra	Sea cucumber	Holoturii da		*Acantophora*	Indirect trophic and habitat association
					Laurencia	Indirect trophic and habitat association
					Gracilaria	Indirect trophic and habitat association
					Gelidiella	Indirect trophic and habitat association

					Hypnea	Indirect trophic and habitat association
					Chaetomorpha	Indirect trophic and habitat association
					C. racemosa	Indirect trophic and habitat association
					C sertulariordes	Indirect trophic and habitat association
					Halimeda	Indirect trophic and habitat association
					Sargassum	Indirect trophic and habitat association
					Turbinaria	Indirect trophic and habitat association
					Padina	Indirect trophic and habitat association
	Synapta maculata	Sea cucumber	Apopida		*Acantophora*	Commensalism
					Laurencia	Commensalism
					Gracilaria	Commensalism
					Gelidiella	Commensalism
					Hypnea	Commensalism
					Chaetomorpha	Commensalism
					C. racemosa	Commensalism
					C sertulariordes	Commensalism
					Halimeda	Commensalism
					Sargassum	Commensalism
					Turbinaria	Commensalism
					Padina	Commensalism
	Lambis lambis	Spider conch	Nudibranchia		*Laurencia*	Direct herbivory
					Gracilaria	Direct herbivory
					Acantophora	Direct herbivory
					Hypnea	Direct herbivory
	Morula sp		Neogastropoda		*Laurencia*	Indirect habitat association
					Gracilaria	Indirect habitat association
					Sargassum	Indirect habitat association

3. On community-based economic utility of macroalgae and invertebrate species

Seaweeds and associated invertebrates play several important economic and social roles in coastal communities, including Santa Maria, Ilocos Sur, Philippines, where these resources contribute significantly to livelihoods, food security, community well-being, and environmental stewardship.

The community-based economic utility of macroalgae and associated invertebrate species notably includes sea urchin (*Tripneustes gratilla)* culture as an important livelihood. Fisherfolks in the community have adopted sea urchin cage culture as a major income source, forming an association among sea urchin growers to manage harvesting and prices. Juvenile sea urchins are collected in the wild and grown in submerged cages fed with locally gathered seaweeds, the Sargassum. Culture period takes about five months to reach market size and sold in the local markets or right in the area. The culture reduces fishing pressure on marine resources in the area and provides economic benefits to the community members. Other associated invertebrate species contribute to protein sources for local consumption and markets.

Small scale seaweed culture provides supplementary income to the community, while seaweed collection in the wild provides food, direct income to women and children who sell them in nearby communities and the local market, as raw materials in food like shanghai, dumplings, noodles, pickles, and other food products, trainings of which were provided by the University extension office.

Other species of seaweeds mentioned above provide habitat and food for cultured invertebrates, thus supporting integrated coastal aquaculture that increases community income diversity.

In a coastal community like Santa Maria, Ilocos Sur, Philippines, these interconnected economic uses of macroalgae and invertebrates provide substantial contribution to poverty alleviation, environmental sustainability, and social empowerment in marine-dependent communities. Community impact includes employment, women empowerment, livelihood diversification, market expansion and value addition, integrated aquaculture, protein source, sustainable fisheries, climate resilience, strengthened social capital, and scalable enterprise.

4. CONCLUSION AND RECOMMENDATIONS

This research underscores the critical role of macroalgae and associated invertebrates in fostering community-based economic development in Santa Maria, Ilocos Sur, Philippines. Key findings reveal a diversity of these marine resources which provide not only significant income and livelihood diversification for local fisherfolk but also promote sustainable resource management and environmental resilience. These activities empower marginalized groups and contribute to strengthening social cohesion within the community.

The study highlights the necessity of enhanced technical support, cooperative frameworks, and policy interventions to sustain and expand these benefits. Future research should explore ways to optimize production techniques and improve market access to further maximize these economic opportunities.

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