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The diversity and traditional knowledge of seaweed in Thai An village, Nui Chua national park, Vietnam

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ABSTRACT

Thai An village is characterized by high seaweed diversity; however, local knowledge regarding its utilization remains limited despite long-term interactions. Seaweed samples collected within 1 meter of a transect line were presented to 33 informants, including traders, gatherers, and consumers, through semi-structured interviews in an ethnobotanical study. A total of 71 species was identified, comprising 28 red, 27 brown, and 16 green seaweed species. Species composition varied across five surveys, reflecting biological seasons and natural conditions. The highest diversity was recorded in March 2024 (39 species), likely due to the favorable conditions for seaweed growth, while the lowest occurred in August 2023 (9 species), when most seaweeds had died off. Sixteen seaweed species were reported to have traditional uses across seven categories: food, beverages, medicine, fertilizers, animal feed, economic activities, and ornamental purposes. Food (10 species) and beverages (8 species) were the most cited uses. Preparation methods varied, particularly in sweet jelly production, mainly depending on the species used. No significant differences were found in seaweed utilization based on gender, education level, occupation, or involvement in seaweed-related activities. Use Values ranged from 0.03 to 2.15, with *Gelidiella acerosa*, *Hydropuntia eucheumoides*, *Sargassum* spp., *Porphyra* sp., *Betaphycus gelatinus*, and *Gracilaria salicornia* scoring highest. Fidelity Level values ranged from 2.3 to 100.0, with the food and beverage categories receiving the highest scores. This study provides valuable insights into traditional seaweed knowledge, contributing to the conservation of indigenous practices and fostering opportunities for local economic development, seaweed aquaculture, food security, and climate change mitigation.

Keywords: Macroalgae; Traditional knowledge; Seaweed; Thai An; Vietnam.

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SIGNIFICANCE STATEMENT

Thai An village in Nui Chua National Park has a long history of seaweed use. Despite this tradition, local knowledge regarding seaweed utilization remains limited. Our ethnobotanical study was carried out to answer two main questions: (1) Do local people still utilize seaweed resources? If yes, for what purposes? (2) Do socioeconomic factors influence traditional seaweed knowledge?. Our findings show that seaweeds continue to be an essential resource for coastal communities and the traditional knowledge is not significantly affected by gender, educational level, occupation. Although seaweed contribute to diversifying household income, creating local employment opportunities, and supporting the local economy, seaweed harvesting currently relies heavily on nature, with no formal regulations in place. Therefore, we recommend implementing seaweed farming programs involving local participation and focusing on selected species. This approach would promote sustainable development while preserving both traditional knowledge and biodiversity.

INTRODUCTION

Seaweeds, or macroalgae, are photosynthetic eukaryotic organisms and vital components of marine ecosystems. They are generally classified into three main groups: red algae (Rhodophyta), green algae (Chlorophyta) and brown algae (Heterokontophyta), distinguished by their dominant colors and pigment chemistry (Dawson 1956). Seaweeds and their derivatives are significant resources for coastal communities and have been utilized by indigenous populations for millennia for a diverse range of purposes, such as food, medicine, flavor enhancers, sources of alginates, carrageenans. Additionally, they have been utilized in clothing, household items, and cultural practices (Abbott 1996; Anggadiredja 2016; Thurstan et al. 2018). In the context of global challenges like food security and climate change, seaweeds are increasingly recognized for their economic and ecological importance (Thurstan et al. 2018, United Nations Conference on Trade and Development 2024). Over the past decade, the annual global production of seaweeds has more than doubled, exceeding 28 million metric tons in wet weight and valued at over 6 billion USD (Thurstan et al. 2018). This highlights the growing recognition of seaweed potential (Tiitii et al. 2022).

Vietnam boasts a rich diversity of seaweed species due to its extensive 3,260 km coastline, spanning from north to south. A recent checklist documented 878 species, including 439 red, 196 green and 156 brown algae (Nguyen et al. 2023). This biodiversity underscores Vietnam's potential for research and sustainable utilization of seaweeds.

Ethnobotany, the study of interactions between people and plants, offers critical insights into traditional knowledge and resource management. While research on higher plants is well-established, studies on seaweed ethnobotany are less common, particularly in Vietnam. Studies indicate that integrating traditional ecological knowledge into contemporary natural resource management results in enhanced economic, environmental, and social benefits for stakeholders engaged in such practices, such as government, local communities, and industries (Thurstan et al. 2018; Silambarasan et al. 2023).

The exploration of traditional knowledge in local communities has increasingly highlighted the role of socio-economic factors in shaping the depth, distribution, and transmission of such knowledge. Variables such as age, gender, education, and occupation have been shown to significantly influence how traditional knowledge is acquired, retained, and handed down through generations (Beltrán-Rodríguez et al. 2014; de Souza et al. 2021). For instance, older individuals often possess more extensive plant knowledge due to their long-term interaction with the environment and their responsibility in family and community (de Souza et al. 2021; Ndavaro et al. 2024). Gender-specific roles also contribute to differentiated knowledge systems, although significant variations exist across cultures due to differences in division of social roles, beliefs, and psychological factors (de Souza et al. 2021; Ishtiaq et al. 2024). The impact of formal education on ethnobotanical knowledge is nuanced. Several studies demonstrate higher levels of education may lead to a reduced reliance on traditional practices, thereby diminishing local knowledge (Awoke et al. 2024). However, it can also enhance awareness about the importance of biodiversity conservation and sustainable resource management (Ahoyo et al. 2023). In addition, occupation has been also highlighted for its effects on traditional knowledge with both positive and negative aspects due to its common linked to socio-economic status (Beltrán-Rodríguez et al. 2014). For example, individuals whose occupations are directly dependent on the natural environment such as herbalists tend to retain higher levels of traditional ethnobotanical knowledge, whereas those less reliant on local ecosystems (e.g., wage laborers, urban workers) often exhibit a decline in such knowledge (Ishtiaq et al. 2024). Therefore, understanding variations in socioeconomic status is essential for conservation strategies and sustainable resource management (de Souza et al. 2021).

Thai An, a coastal village within Nui Chua

National Park in Ninh Thuan Province, provides an ideal case study for seaweed research. While the region's intertidal zones are known for their biodiversity, little is known about seaweed diversity and traditional utilization in Thai An. In contrast to the neighboring villages such as My Hoa (85 species) and Son Hai (66 species), where seaweed diversity has been documented (Le 2000), Thai An remains largely unexplored despite its distinct tradition of seaweed harvesting that supports both household consumption and small-scale trade. This tradition, though declining in recent years, remains integral to the community's livelihood, alongside agriculture and fishing (Vu 2012). Seaweed-related activities, such as seaweed gathering and trading, primarily carried out by middle-aged women contribute significantly to household and community economies. However, with the younger generations showing less interest in traditional practices, the knowledge of seaweed resources in Thai An is at risk of erosion (Phengmala et al. 2023). This highlights the importance of documenting and preserving both the ecological and cultural dimensions of seaweed use in the community. Guided by this theoretical context, the current study aims to investigate the diversity of seaweed species in Thai An and explore the community's traditional knowledge regarding their utilization. It also examines how socio-economic factors, including gender, education level, occupation and primary activity related to seaweed resource, influence local knowledge and practices concerning seaweed exploitation. The findings are expected to contribute to the understanding of seaweed's ecological and cultural significance, providing insights for sustainable management and broader ethnobotanical studies in Vietnam.

MATERIAL AND METHODS

Study area

Nui Chua National Park, located in Ninh Thuan Province along the Bien Dong coast (East Vietnam Sea), was recognized as a World Biosphere Reserve in 2021 (Le et al. 2024; Truong et al. 2023; Figure 1). Covering 29,865 hectares, the park encompasses a variety of ecosystems, including both terrestrial (22,513 ha) and marine environments (7,352 ha). The region experiences a semi-arid climate, characterized by low annual rainfall (approximately 650 mm) and high evaporation rates, ranging from 1,295.8 to 2,210.1 mm. The average annual temperature is 27°C, with temperatures ranging from 14.40C to 41.70C (Hoang et al. 2021; Truong et al. 2023). Significant seasonal winds and irregular diurnal tides influence wave patterns. Southwest winds (from January to April) generate waves ranging from 1.0 to 1.1 meters, while northeast winds (from October to December) produce waves up to 2.5 meters. Importantly, Nui Chua is situated within the nutrient-rich Ninh Thuan - northern Binh Thuan upwelling zone, which brings essential nutrients to the surface waters of the ocean, supporting one of the most productive marine ecosystems in the region (Hoang et al. 2021; Nguyen 2007).

Thai An Village is one of three villages located within Nui Chua National Park, with 830 households and a population of 2,850. The main source of income comes from agricultural activities, particularly grape cultivation, which is well known, along with fishing. Additionally, local people earn extra income from seaweed collecting and processing, depending on seasonal availability. Many seaweed products are popular among tourists passing through the area, as the neighboring village, Vinh Hy, has a well-developed tourism industry.

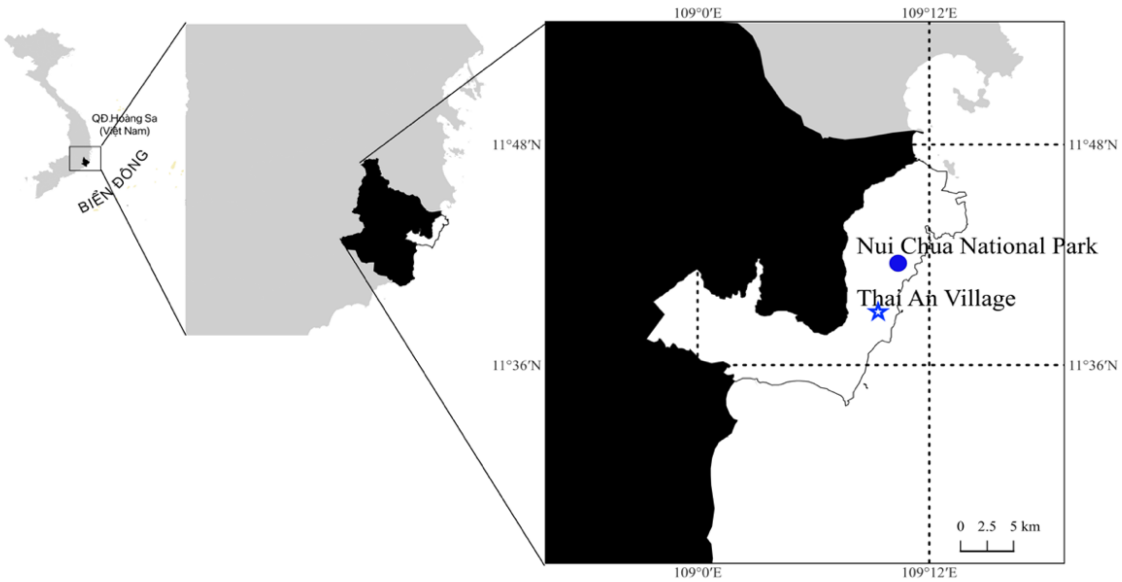
Survey on seaweed diversity

Seaweed samples were collected from the coast of Thai An Village in May, June, August, October 2023 and March 2024. Seaweed was collected around an area within 1 meter distance from the transect line. Samples were removed by hand, while those closely adhering to the substrate were carefully detached using a knife. Both wet and dry samples were prepared for identification. The wet samples were placed in sample bottles and preserved with a 4% formaldehyde solution. The dry samples were spread on Croki paper, excess water was removed, and they were compressed and air-dried to create dry specimens (Pham-Hoang 1969, Roy 2020). Voucher specimens were prepared and deposited at the Pham Hoang Ho Herbarium (PHH Herbarium), University of Science, Vietnam National University-Ho Chi Minh City.

These specimens were identified using identification references (Dawson 1954; Pham-Hoang 1969) and their accepted names were checked and classified through Algaebase web site `http://www.algaebase.org` (Guiry and Guiry 2025). Common names of seaweeds primarily follow the reference "Marine algae of South Vietnam" (Pham-Hoang 1969). In cases where this reference does not provide a common name, alternative sources were consulted and clearly indicated in the relevant sections.

Traditional knowledge of seaweed utilization

The permits for the study were obtained through official documents from both the local government and Nui Chua National Park, allowing researchers to work



Hình 1. Map of study site - Thai An village, Nui Chua National Park, Ninh Thuan Province, Vietnam.

with local people and collect seaweed specimens for interviews and voucher preparation. Additionally, the local government and the National Park authorities also supported the research by facilitating contact with community members, especially key informants who often accompanied research team during fieldwork. Furthermore, when contacting the local people, the researchers explained the aim of the study to the informants in order to obtain their verbal consent for the collection and dissemination, exclusively for educational and research purposes, of traditional knowledge. The informants also permitted the publication of their names and personal information when necessary, or they could withdraw their information at any time.

Seaweeds collected during the diversity phase were presented to informants, and information on their uses was gathered through semi-structured interviews with 33 local representatives. These individuals were categorized into three groups based on their involvement with seaweed resources: consumers, gatherers, and traders. Consumers are individuals who primarily use seaweed purchased from others rather than collecting or exchanging it themselves. Gatherers engage in harvesting seaweed, either for personal use or as a source of income by selling it. Traders purchase seaweed from others to resell or for other commercial purposes.

In practice, survey informants often belong to more than one group. For example, an individual might be both a gatherer and a consumer, as they may not rely solely on the seaweed they harvest and might also purchase additional materials from the market for personal use. To address these overlaps and ensure accurate classification, participants were asked to identify their primary role concerning seaweed resources during the survey. If an informant identified with multiple roles (e.g., both a gatherer and a consumer), they were asked to specify their primary role based on the frequency and significance of each activity. This approach allowed for more precise group classification and better understanding of resource use patterns.

Data analysis

The similarity of seaweed species

The similarity Sorensen's index (SI) was used to calculate the similarity of seaweed species composition between areas. The similarity index SI was determined by the formula: $SI = 2C/(A+B)$ Where C is the number of species occurring in both areas A and B, A is the number of species in area A, and B is the number of species in area B (Wolda 1981).

The Relationship between seaweed knowledge and social factors

Traditional knowledge data were imported into Microsoft Excel 365 and analyzed using R version 4.3 to examine the relationships between seaweed knowledge and gender (Mann-Whitney test), occupation (Chi-square test), and age groups (ANOVA).

Determination of important species using ethnobotanical indices

Use-report: A species mentioned for a particular purpose was considered to be one "use-report".

In cases where the species was cited for several uses within the same use category, such as food, it only received one "use report" (Tardío and Pardo-De-Santayana 2008).

Use value (UV) quantifies the relative importance of species in the survey area, following the formula: $UV = \frac{\sum U_i}{N}$.

Where Ui is the use-reports given by each informant for a particular species, and N is the number of informants interviewed. A higher UV value indicates a greater significance of the plant within the community, reflecting its versatility or prominence in traditional practices. Therefore, UV is often used to determine the most useful species for a specific group, evaluate the value of use based on the potential of the species, and determine the scope of knowledge about that species in the community (Albuquerque et al. 2006; Phillips and Gentry 1993).

Fidelity level (FL) was used to measure the percentage of informants who consistently mentioned the use of a specific plant species for a particular category of use. It was calculated using the following formula: $FL(\%) = \frac{Np}{N} \cdot 100$.

Where Np is the use-report for a species in a specific category of use, N is the total number of use reports for the species across all categories. A high FL value indicates that a species is consistently used for a particular purpose, making it the preferred species for that use category. Whereas, a low FL value suggests that the species is used for diverse purposes (Friedman et al. 1986).

RESULTS

The diversity of seaweed

A total of 71 seaweed species were recorded from Thai An village (Table 1), classified into three divisions: Rhodophyta, Heterokontophyta, and Chlorophyta. Within these divisions, Rhodophyta comprised two classes, Bangiophyceae and Florideophyceae, while Heterokontophyta and Chlorophyta each had one class, Phaeophyceae and Ulvophyceae, respectively. Rhodophyta (red algae) accounted for 28 species (39.4%), Phaeophyceae (brown algae) included 27 species (38.0%), and Ulvophyceae (green algae) comprised 16 species (22.6%). Red algae had the highest number of genera (17), followed by green algae with 9 genera, and brown algae with 7 genera.

Seaweed composition across survey

The composition of seaweed species varied throughout five surveys, showing noticeable trends over time (Figure 2). The highest number of species was recorded in March 2024, with 39 species, while the lowest was in August 2023, with only 9 species. In May and June 2023, the diversity of brown and red algae was most prominent. In May, 32 species were recorded, with brown algae accounting for the highest proportion (15 species), followed by red algae (11 species) and green algae (6 species). Notably, *Sargassum*, a genus of brown algae, was the most species-rich, with 11 species. By June, the total species count dropped slightly to 27, with red algae (12 species) leading, followed by brown algae (10 species) and green algae (5 species). Red algae exhibited the greatest genera diversity, while *Sargassum* continued to dominate with 6 species. In contrast, the composition shifted in March 2024, with green algae becoming the most abundant group, recording 15 species, followed by red algae (14 species) and brown algae (10 species). Despite a decrease in brown algae diversity, *Sargassum* remained the most species-rich genus with 4 species. The lowest species diversity was observed in August 2023, with only 9 species in total: 6 brown algae, 2 red algae, and 1 green algae.

Demographic profile of informants

Thirty-three local people participated in this study, the majority of whom were female (78.8%). Participants ranged in age from 18 to 66 years, with a mean age of 50 years. Regarding education level, most of them were at a primary level (42.4%), following by the group illiterate (24.3%). To explore the diversity of traditional knowledge, an ethnobotanical survey was conducted with informants classified into three categories based on their seaweed-related occupations: consumers (21.2%), gatherers (66.7%), and traders (12.1%). Despite efforts to include more traders, their limited representation reflected the seasonal nature of seaweed availability and its impact on income stability. In addition to their roles related to seaweed, participants reported a variety of primary occupations or sources of income. The majority were farmers (69.7%), followed by laborers and seaweed collectors, each comprising 9.1% of the respondents (Table 2).

Bảng 1. The species composition of seaweed in Thai An.

No.	Species/ Herbarium code	Common namea	Recording time during study periodb
	Rhodophyta (Red algae)		
1	*Acanthophora spicifera* (M.Vahl) Børgesen/ PHH0500001	Rong cú't đài	10,3
2	*Actinotrichia* sp./ PHH0500002		6
3	*Amansia glomerata* C.Agardh/ PHH0500003	Rong hải cúc	10,3
4	*Amphiroa foliacea* J.V.Lamouroux/ PHH0500004	Rong thạch giác	6
5	*Amphiroa fragilissima* (Linnaeus) J.V.Lamouroux/ PHH0500005	Rong thạch giác	5,6
6	*Asparagopsis taxiformis* (Delile) Trevisan/ PHH0500006	Rong hải tùng	5,6
7	*Betaphycus gelatinus* (Esper) Doty ex P.C.Silva/ PHH0500007	Rong hồng vân[1]	5
8	*Centroceras clavulatum* (C.Agardh) Montagne/ PHH0500008	Rong trung giác	3
9	*Ceratodictyon spongiosum* Zanardini/ PHH0500009	Rong võng giác	5,6
10	*Galaxaura* sp.1/ PHH0500010		6,8
11	*Galaxaura* sp.2/ PHH0500011		6
12	*Gelidiella acerosa* (Forsskål) Feldmann & Hamel/ PHH0500012	Rau câu rễ tre	5,6,3
13	*Gracilaria arcuata* Zanardini/ PHH0500013	Rau câu cong[2]	5,6,3
14	*Gracilaria salicornia* (C.Agardh) E.Y.Dawson/ PHH0500014	Rau câu đốt[2]	5,6,8,10,3
15	*Gracilaria* sp.1/ PHH0500015		6
16	*Gracilaria* sp.2/ PHH0500016		3
17	*Hydropuntia eucheumatoides* (Harvey) Gurgel & Fredericq/ PHH0500017	Rau câu chân vịt[2]	5,6,10,3
18	*Hypnea boergesenii* T.Tanaka/ PHH0500018	No data	3
19	*Hypnea* sp./ PHH0500019		10
20	*Laurencia microcladia* Kützing/ PHH0500020*	Rong lỗ năng nhánh nhỏ	3
21	*Laurencia* sp.1/ PHH0500021		5
22	*Laurencia* sp.2/ PHH0500022		5
23	*Laurencia* sp.3/ PHH0500023		3
24	*Laurencia* sp.4/ PHH0500024		5
25	*Liagora* sp./ PHH0500025		3
26	*Palisada intermedia* (Yamada) K.W.Nam/ PHH0500026*	No data	3
27	*Palisada perforata* (Bory) K.W.Nam/ PHH0500027	Rong lỗ năng xoi	10,3
28	*Porphyra* sp./ PHH0500028	Rong mứt	3
	Phaeophyceae (Brown algae)		
29	*Colpomenia sinuosa* (Mertens ex Roth) Derbès & Solier/ PHH0500029	Rong bao tử	3
30	*Dictyota bartayresiana* J.V.Lamouroux/ PHH0500030	No data	3
31	*Dictyota implexa* (Desfontaines) J.V.Lamouroux/ PHH0500031	No data	5
32	*Hydroclathrus clathratus* (C.Agardh) M.Howe/ PHH0500032	Rong ruột heo	3

to be continued...

No.	Species/ Herbarium code	Common namea	Recording time during study periodb
33	*Padina australis* Hauck/ PHH0500033	No data	6,8,10,3
34	*Padina Boryana* Thivy/ PHH0500034	No data	6,1
35	*Pseudochnoospora implexa* (J.Agardh) Santiañez, G.Y.Cho & Kogame/ PHH0500035	Rong mao tử rối	8,10,3
36	*Sargassum aquifolium* (Turner) C.Ag/ PHH0500036	No data	5
37	*Sargassum assimile* Harvey/ PHH0500037	Rong lá mơ trại	5
38	*Sargassum baccularia* (Mertens) C. Agardh/ PHH0500038	Rong lá mơ trải nhỏ	8
39	*Sargassum bicorne* J.Agardh/ PHH0500039	Rong lá mơ hai sừng	5
40	*Sargassum capillare Kützing*/ PHH0500040*	No data	8
41	*Sargassum cinereum* J.Agardh/ PHH0500041*	Mơ tro gai[3]	8
42	*Sargassum feldmannii* Pham-Hoàng/ PHH0500042	Rong lá mơ Feldmann	5,6
43	*Sargassum flavicans* (Mertens) C. Agardh/ PHH0500043	Rong lá mơ vàng vàng	6
44	*Sargassum glaucescens* J.Agardh/ PHH0500044*	Rong lá mơ hơi mốc	5
45	*Sargassum herklotsii* (J. Agardh) J. Agardh/ PHH0500045*	Mơ herklot[3]	3
46	*Sargassum ilicifolium* (Turner) C. Agardh/ PHH0500046	Rong lá mơ ô rô	5,6
47	*Sargassum mcclurei* Setchell/ PHH0500047	Rong lá mơ McClurei	5
48	*Sargassum miyabei* Yendo/ PHH0500048*	No data	5,3
49	*Sargassum natans* (Linnaeus) Gaillon/ PHH0500049*	No data	3
50	*Sargassum polycystum* C. Agardh/ PHH0500050	Rong lá mơ nhiều phao	5,6,10,3
51	*Sargassum vietnamense* A.D.Zinova & Dinh/ PHH0500051*	Mơ Việt Nam[3]	5,6,8
52	*Sargassum virgatum* C. Agardh/ PHH0500052*	Mơ chổi[3]	5
53	*Turbinaria conoides* (J.Agardh) Kützing/ PHH0500053	Rong chùy diệp chùy	5
54	*Turbinaria ornata* (Turner) J.Agardh/PHH0500054	Rong chùy diệp đẹp	5,6,3
55	*Turbinaria ornata* var. *prolifera* P.H.Hô/ PHH0500055	Rong cùi bắp nhánh dài[3]	5,6
	Chlorophyta (Green algae)		
56	*Boergesenia forbesii* (Harvey) Feldmann/ PHH0500056	Rong biệt sinh Forbes	5,3
57	*Boodlea composita* (Harvey) F.Brand/ PHH0500057	Rong búp đều	3
58	*Caulerpa chemnitzia* (Esper) J.V.Lamouroux/ PHH0500058	No data	3
59	*Caulerpa racemosa* (Forsskål) J.Agardh/ PHH0500059	Rong cầu lục chùm	5,6,10,3
60	*Caulerpa sertularioides* (S.G.Gmelin) M.Howe/ PHH0500060	Rong cầu lục lông chim	10,3
61	*Caulerpa taxifolia* (M.Vahl) C.Agardh/ PHH0500061	Rong cầu lục song đính	3
62	*Caulerpa verticillata* J.Agardh/ PHH0500062	Rong cầu lục	3
63	*Chaetomorpha aerea* (Dillwyn) Kützing/ PHH0500063	No data	3
64	*Dictyosphaeria cavernosa* (Forsskål) Børgesen/ PHH0500064	Rong võng cầu bộng	5,6,3
65	*Halimeda cuneata* Hering/ PHH0500065*	Rong hải cốt	5,6
66	*Halimeda opuntia* (Linnaeus) J.V.Lamouroux/ PHH0500066	Rong hải cốt	5,6,10,3
67	*Neomeris annulata* Dickie/ PHH0500067	Rong tân tiết ngắn	5,3

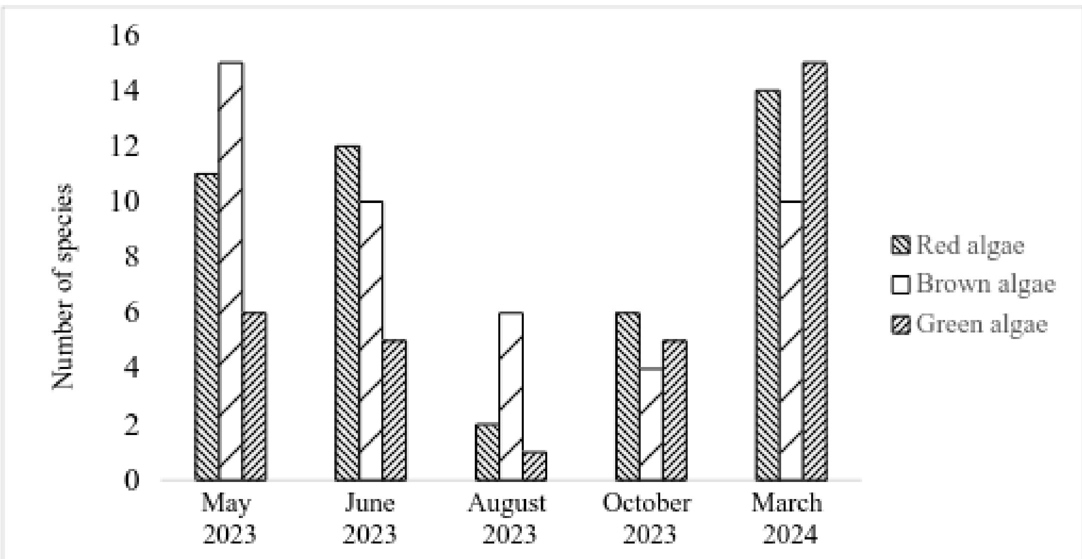
to be continued...

No.	Species/ Herbarium code	Common namea	Recording time during study periodb
68	*Ulva intestinalis* Linnaeus/ PHH0500068	Rong trường tảo	3
69	*Ulva lactuca* Linnaeus/ PHH0500069	Rong xà lách	10,3
70	*Ulva reticulata* Forsskål/ PHH0500070	Rong xà lách lỗ	6,8,10,3
71	*Valonia fastigiata* Harvey ex J.Agardh/ PHH0500071	Rong đại bào bó	3

Legend: a The superscript numbers refer to the source of the common name 1(Nguyen et al. 2009), 2(Le 2012), 3(Nguyen 2007); if not provided, the name follows "Marine algae of South Vietnam" (Pham-Hoang 1969). b Recording time: 5-May 2023, 6- June 2023, 8-August 2023, 10-October 2023, 3-March 2024. * Species recorded for the first time in Ninh Thuan province.

Bảng 2. Demographic of informants

Characteristic		Number of people (Percentage %)
Gender	Female	26 (78.8%)
	Male	7 (21.2%)
Age group (years old)	<45	11 (33.3%)
	46-55	10 (30.3%)
	>55	12 (36.4%)
Educational level	No proper education	4 (12.1%)
	Illiterate	8 (24.3%)
	Primary	14 (42.4%)
	Secondary	6 (18.2%)
	Highschool and above	1 (3.0%)
Main occupation	Farmer	23 (69.7%)
	Labor	3 (9.1%)
	Seaweed collector	3 (9.1%)
	Small business	2 (6.1%)
	Student	1 (3.0%)
	Fishery	1 (3.0%)
Occupation related seaweed*	Consumer	7 (21.2%)
	Gatherer	22 (66.7%)
	Trader	4 (12.1%)



Hình 2. Seaweed composition across surveys.

Bảng 3. List of ethnobotanically seaweeds used by local people in Thai An village, Nui Chua National Park.

Phylum/ Species/ Herbarium code	Category of use	Traditional use	Mode of preparationa	UV	FL (%)	Previous studies
Rhodophyta						
Actinotrichia sp.	Ornament/ Kids' toy	Decorative item	Or	0.06	100.0	
Asparagopsis taxiformis	Food	Salad	Sa	0.03	100.0	Food (Xia and Abbott 1987)
	Food	Soup/ Boiled vegetable	So		100.0	
Betaphycus gelatinus	Beverage	Refreshing drink - *(Nước mát)*	Be	1.55	5.9	Food (Dumilag et al. 2022)
	Food	Jellies - *(Mứt)*	Je		58.8	
	Food	Salad	Sa			
	Economy	Sell to traders as fresh or dried form.	-		31.4	
	Medicine	Eyesight improvement	Be		3.9	
Gelidiella acerosa	Beverage	Refreshing drink - *(Nước mát)*		2.15	29.6	Food (Dumilag et al. 2022; Xia and Abbott 1987)
	Food	Jellies - *(Rau câu)*	Je		42.3	
	Economy	Sell to traders as fresh or dried material				
	Medicine	Cooling the body	Be		5.6	
Gracilaria arcuata	Animal feed	Feed pigs	An	1.00	35.5	Food (Anggadiredja 2009; Dumilag et al. 2022; Xia and Abbott 1987), medicine (Anggadiredja 2009)
	Food	Salad	Sa		65.2	
	Food	Jellies - *(Rau câu)*	Je			
	Economy	Sell to traders as fresh or dried material	-		30.4	
Gracilaria salicornia	Animal feed	Feed pigs	An	1.36	9.3	
	Beverage	Refreshing drink - *(Nước mát)*	Be		11.6	
	Food	Jellies - *(Rau câu)*	Je		34.9	
	Food	Salad Boiled vegetable	Sa			
	Economy	Sell to traders as fresh or dried material	-		41.9	
	Medicine	Cooling the body	Be		2.3	

to be continued...

Phylum/ Species/ Herbarium code	**Category of use**	**Traditional use**	**Mode of preparationa**	**UV**	**FL (%)**	**Previous studies**
Gracilaria sp1.	Ornament/ Kids' toy	Decorative item		0.03	100.0	
Hydropuntia eucheumoides	Beverage	Refreshing drink - *(Nước mát)*	Be	2.12	13.4	(Dumilag et al. 2022)
	Food	Salad	Sa		47.8	
	Food	Jellies - *(Chè)*	Je			
	Economy	Sell to traders as fresh or dried form	-		19.4	
	Medicine	Goitre Eyesight improvement Cooling the liver	Be		19.4	
Porphyra sp.	Food	Soup	So	1.21	76.9	Food (Anggadiredja 2009; Xia and Abbott 1987)
	Food	Snack	Sn			
	Economy	Sell to traders as dried material	-		5.1	
	Medicine	Cooling the body	Used as an ingredient in daily meals, such as in soups, salads, or stir-fried dishes.		7.9	
Laurencia sp.2	Food	Salad Boiled vegetable	Sa	0.06	100.0	
Laurencia sp.4	Food	Salad	Sa	0.06	100.0	
Phaeophyceae						
Padina sp.	Fertilizer	Fertilizer	Fe	0.06	100.0	*P. austrlis, P. japonica* Food (Anggadiredja 2009)
Sargassum spp.	Beverage	Tea *(Trà)*	Be	1.67	61.1	Food (Anggadiredja 2009; Xia & Abbott 1987), medicine (Anggadiredja 2009), transport cover (Dumilag et al. 2022)
	Economy	Sell to traders as fresh or dried material	-		18.5	
	Medicine	Goitre Eyesight improvement Detoxify the liver Cooling the body	Be		18.5	

to be continued...

Phylum/ Species/ Herbarium code	Category of use	Traditional use	Mode of preparation[a]	UV	FL (%)	Previous studies
Turbinaria spp.	Beverage	Tea *(Trà)*	Be	0.36	66.7	Food (Anggadiredja 2009), medicine (Anggadiredja 2009), transport cover (Dumilag et al. 2022)
	Economy	Sell to traders as fresh or dried material	-		8.3	
	Fertilizer	Fertilizer Goitre	Fe		8.3	
	Medicine	Eyesight improvement Cooling the body	Be		16.7	
Chlorophyta						
Caulerpa racemosa	Beverage	Refreshing drink	Be	0.09	66.7	Food (Anggadiredja 2009; Ostraff 2006; Tiitii et al. 2022; Xia and Abbott 1987), medicine (Ostraff 2006), cultural value (Tiitii et al. 2022)
	Ornament/ Kids' toy	Kids' toy	Crush the grape-like structures to produce a "bip-bip" sound, which is pleasant to hear		33.3	
Ulva reticulata	Animal feed	Feed pigs	An	1.06	8.8	*U. lactuca* Food (Anggadiredja 2009; Xia and Abbott 1987), medicine (Anggadiredja 2009)
	Beverage	Refreshing drink	Be		20.6	
	Economy	Sell to traders as fresh or dried material	-		41.2	
	Fertilizer	Fertilizer	Fe		2.9	
	Food	Snack	Sn		26.5	

Legend: a Mode of seaweed preparation with relevant traditional uses: An - Animal feed, Be - Beverage, Fe - Fertilizer, Je - Jellies, Sa - Salad, Sn - Snacks, So - Soup.

Traditional knowledge of seaweed utilization

A total of sixteen seaweed species, belonging to three groups (Rhodophyta, Phaeophyceae, and Chlorophyta), were reported to be traditionally used by the informants across seven categories: animal feed, beverages, economy, fertilizers, food, medicine, and ornament/ kids' toys (Table 3). Most species were used for food (10 out of 16 species), followed by beverage (8 species) while the "ornament/ kids' toy" category had the fewest species reported (3 species). In general, seaweeds tend to have multiple uses. For example, *G. acerosa* was the most versatile species, reported for use in 5 out of 7 categories.

There were no statistically significant differences in the number of seaweed species used based on gender, education level, occupation, or whether individuals were involved in seaweed resource exploitation or specific seaweed-related activities. In addition, the overall analysis did not reveal significant differences in the number of seaweed species used across age groups. However, post-hoc results indicated that individuals in the <45 age group used significantly fewer seaweed species than those in the 46-55 and >55 age groups, while no significant differences were observed between the 46-55 and >55 age groups.

Mode of preparation of seaweed

Seaweed is prepared using various methods, as summarized in Table 4. A distinctive aspect of its local utilization is its transformation into jellies, a popular dessert in Asia. At first glance, these products appear quite similar, often taking the form of translucent or opaque white jellies. However, they differ significantly in flavor and usage, leading locals to give them distinct names such as *xu xoa/ rau câu*, *chè*, and *mú't*(Figure 3). These variations depend on the specific seaweed species used and the corresponding preparation techniques. For example, *G. acerosa* is used to prepare *xu xoa*, *H. eucheumoides* for *chè*, and *B. gelatinus* for *mú't* (Table 3).

In general, the traditional method of making jellies from seaweed involves the following main steps: i/ Rinsing: Rinse fresh or dried seaweed thoroughly in freshwater, drain, and repeat the rinsing process until the seaweed loses its natural color; ii/ Boiling: Gently boil the seaweed in water, adjusting the ratio depending on the type of jelly being made. Add acidic ingredients, such as lemon juice or tamarind extract, and continue boiling until the liquid thickens and becomes opaque; iii/ Filtering and molding: Filter the mixture through a cloth to retain the undissolved seaweed, pour the liquid into molds, and allow it to solidify. Similar findings on traditional seaweed preparation methods have been reported in previous studies, supporting the consistency of these practices across different local contexts (Dumilag et al. 2022; Xia and Abbott 1987).

Ethnobotanical indices of seaweeds: Important species for the local community

The ethnobotanical indices of sixteen traditional seaweed species are presented in Table 3. Concerning UV, the values ranged from 0.03 to 2.15. Among the species, G. acerosa exhibited the highest value (2.15), followed by *H. eucheumoides* (2.12), indicating that these species were predominant seaweed taxa used by the locals (Figure 4). In contrast, *Actinotrichia* sp., *A. taxiformis*, *Gracilaria* sp1., and *Laurencia* sp2. showed the lowest values, suggesting that these species were less frequently used. The FL values varied significantly among species and across categories of use within a species, ranging from 2.3 to 100.0. In the case of versatile species, the categories of "food" and "beverage" generally received higher values than others. For example, *Sargassum* spp. was reported in four categories of use, with FL values ranked in descending order as follows: beverage (61.1), economy (18.5), medicine (18.5) and fertilizer (1.9) (Figure 4).

DISCUSSION

Field surveys demonstrated that locals in Thai An village continue to utilize seaweeds for various purposes, with food and beverage uses being the most common. This aligns with current consumer trends toward natural, organic, and plant-based products, partly driven by health and environmental awareness (de Villiers et al. 2024), and seaweeds are also recognized for enhancing nutrient bioavailability and possessing medicinal properties (Peñalver et al. 2020). As a result, global seaweed demand has tripled over the past two decades, reaching USD 17 billion in 2021 (United Nations Conference on Trade and Development 2024). Although the use of several seaweed species is widespread and does not significantly differ across socioeconomic groups, which likely due to the economic benefits, some species receive less attention, as indicated by low UV value. Moreover, seaweed harvesting relies entirely on wild collection, with little consideration for sustainable practices. This is evident as certain species become scarce or disappear completely from nature, leading to the gradual fading of related traditional knowledge (Parween and Marchant 2022). This raises concerns about the retention and transmission of traditional knowledge to future generations. Therefore,

Bảng 4. Methods of preparing seaweed locally.

Traditional uses	Preparation of seaweed
Animal feed	Wash, cook it with water until the seaweed dissolves, then mix it with bran in the desired ratio and feed it to pig.
Beverage	***- Nước mát* (Refresing drink)**: The undissolved seaweed retained during filtering is cooked again with plenty of water, pandan leaves, ginger, and sugar to produce a refreshing, lightly sweetened drink with chewy bits.
	- Trà (Tea): Wash and boil with water to make a brown liquid, then drink it like tea. More water can be added and boiled to make another serving. This process can be repeated until the flavor diminishes. Additional ingredients like ginger or monk fruit can be added to enhance the flavor.
Fertilizer	Wash multiple times with fresh water or spread it out in a thin layer to let rainwater rinse off some of the salt. Occasionally spray water to help the seaweed decompose faster, then gather it and compost it for 3-4 months. It can be used directly as fertilizer or mixed with other types of fertilizer.
Ornament	Dry until only the hard skeleton remains, then use it to decorate the wall or leave it in a corner of the garden.
Jellies	Wash, boil with acidic ingredients until thick, filter, pour into molds, and let solidify. Slight variations occur among local jelly preparations:
	- Xu xoa: The filtered liquid is poured into molds to solidify, then cut into bite-sized cubes (can be stored in an ice bowl for a crunchier texture). Serve with sugar syrup made from rocky sugar, ginger, and pineapple.
	- Chè: The seaweed must be blended with a small amount of water before cooking, as this type dissolves less easily. The filtered liquid is poured into small molds, usually 7 cm-wide bowls, and refrigerated for later consumption without syrup.
	- Mứt (Sweet jellies): The filtered liquid is poured into large molds, allowed to solidify, then cut into small cubes. These are coated with a thin layer of sugar and sun-dried.
Salad	Wash, then use directly or mix with the desired amount of vinegar or lemon juice. Other ingredients, such as cooking oil and boiled eggs, can also be added.
Snack	Dry, then mix with garlic oil, garlic, toasted sesame seeds, and a pinch of dry seasonings (salt, sugar, chili). Serve with rice, noodles, or eat on its own as a snack.
Soup/ Boiled vegetables	Wash, then cook with water. The difference between soup and boiled vegetables lies in the preparation style. In soup, other ingredients are added, including a protein source (usually meat, fish, shrimp, or whatever the locals have), along with seasonings such as salt, fish sauce, or seasoning powder. In contrast, nothing is added in the boiled style.

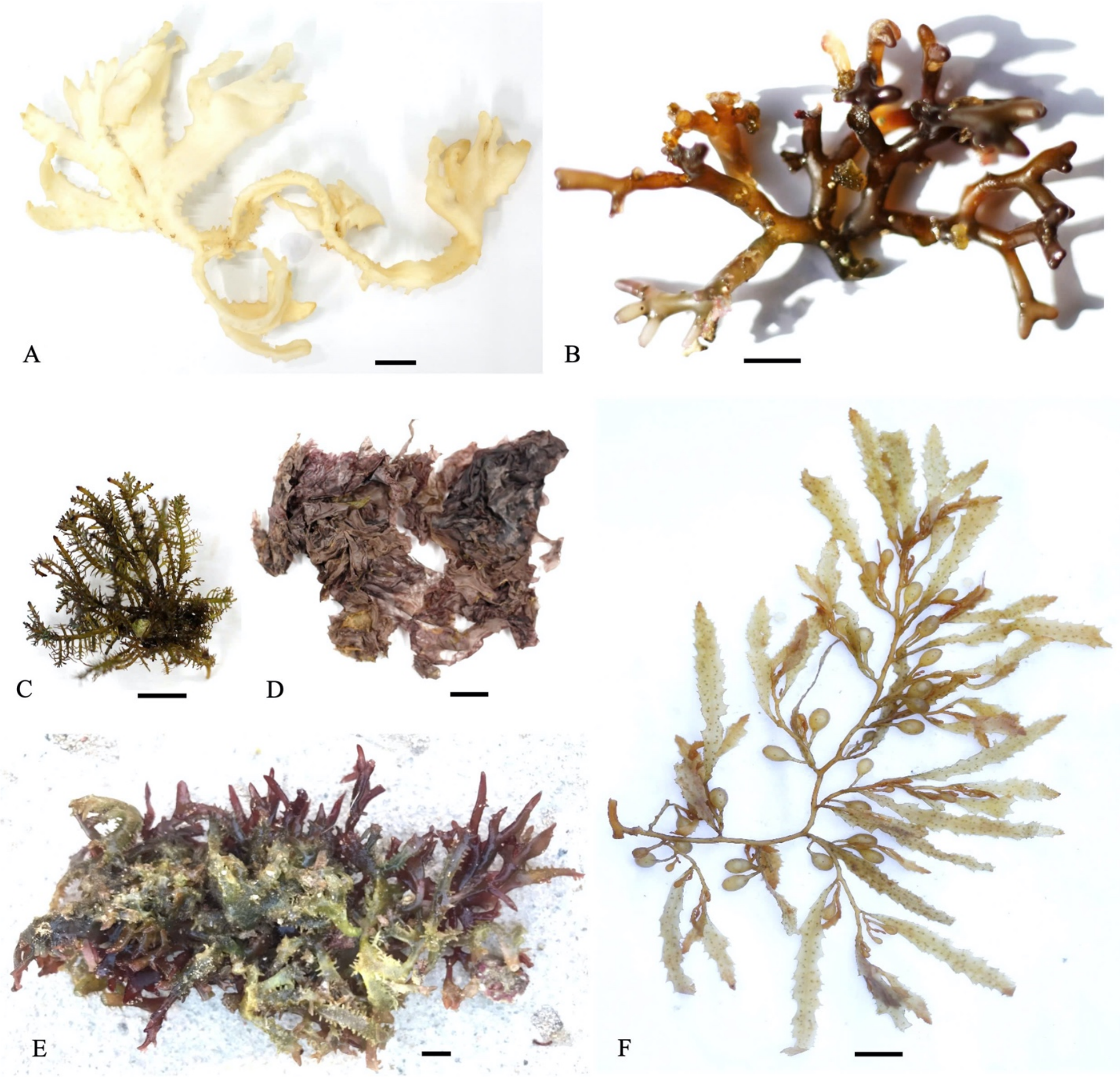
it is crucial to promote seaweed farming programs involving local participation to support sustainable development while preserving traditional knowledge and biodiversity.

Seaweed diversity in Ninh Thuan province has been previously reported by Le (2000) and Dam (2016). In the present study, a total of 71 seaweed species were recorded, which is lower than the diversity observed in the neighboring area - My Hoa (approximately 7 km), but higher than in other locations, including Son Hai, Ca Na, and Nai Lagoon. The species composition in Thai An shows a nearly equal ratio of red and brown algae species (39.4% and 38.0%, respectively), with the proportion of green algae being the lowest at 23.6% (Table 5). This low proportion of green algae in Thai An is consistent with observations in My Hoa, Son

Hình 3. Local products from seaweeds. **A-**Dried seaweeds packaged for sale to tourists, including *B. gelatinus*, *G. acerosa*, *H. eucheumoides*, and *Sargassum* spp. (from left to right). **B-**Mứt hồng vân made from *B. gelatinus*. **C-**Sheets dried of *Porphyra* sp.. **D, E-**Popular beverages from *G. acerosa* (light green bottle) and *Sargassum* spp. (dark brown bottle). **F-**Decorative items in the courtyard made from seashells and seaweed skeletons. **G-J-**Seaweed harvesting, drying, and storage. **K-**Tools used for seaweed gathering.

Hai, and Ca Na. However, it differs from the seaweed composition in Nai Lagoon, where the proportion of green algae exceeds that of both brown and red algae (Dam 2016). In terms of species composition, Thai An is more similar to its neighboring areas, My Hoa and Son Hai, than to Ca Na and Nai Lagoon. The Sorensen similarity coefficient between Thai An and My Hoa is 38.5%, and between Thai An and Son Hai, it is 38.0%. In contrast, the similarity with Ca Na is 24.3%, and with Nai Lagoon, it is 14.2%.

The seaweed species recorded in Thai An have been included in Nguyen's checklist (Nguyen et al. 2023). However, there are 11 species recorded for the first time in Ninh Thuan, most of which belongs to the genus *Sargassum*. These include *Laurencia microcladia*, *Palisada intermedia*, *Sargassum capillare*, *Sargassum cinereum*, *Sargassum glaucescens*, *Sargassum herklotsii*, *Sargassum miyabei*, *Sargassum natans*, *Sargassum vietnamense*, *Sargassum virgatum*, and *Halimeda cuneata*.



Hình 4. Six seaweed species with the highest UV value. **A-***G. acerosa,* bushy thallus with a short, curved cylindrical axis and branches, yellow to brownish-red. **B-***H. eucheumatoides,* thallus was cartilaginous, flattened, hard with small spines or teeth at the margin, attached by a small discoid holdfast. **C-***G. salicornia,* branching irregularly or dichotomous, cylindrical branches consisted of many constricted segments, color ranging from yellow to red. **D-***Porphyra* sp., the thallus had irregular shapes, formed blades with margins smooth or ruffled, and reached 5-10 cm in length and 1-2 cm in width. **E-***B. gelatinus,* thallus cartilaginous, flattened and knitted, margin may be smooth or dentate, attached by a discoid holdfast, green to dark purple. **F-***S. flavicans*, the thallus was similar to the vascular plant, composed of a holdfast, a primary axis with many secondary axes on which leaf-like, vesicles, and receptacles arise.

Ninh Thuan has two distinct seasons: the dry season from February to August, and the rainy season from September to January of the following year, with June being the hottest month (32° C) and January the coldest (25.5° C) (Le 2000, Nguyen et al. 2016, Tu et al. 2018). The northeast monsoon occurs from October to February, while the southwest monsoon dominates from March to September, peaking in strength between June and August (Le 2000). During the northeast monsoon period, the study area is influenced by terrestrial runoff and rainfall (Nguyen et al. 2016).

The distribution of macroalgae species is neither spatially or temporally uniform but rather dynamic (Lobban & Harrison 1994), shaped by complex ecological processes such as species-species recruitment, growth and mortality rates (Cervin et al. 2005; Foster et al. 2003). For example, *B. gelatinum* and *H. eucheumoides* persist throughout the year, with peak growth between March and

Bảng 5. Comparison of the number of seaweed species.

No.	Number of species (%)				Locations (References)
	Red algae	**Brown algae**	**Green algae**	**Total**	
1	28 (39.4%)	27 (38.0%)	16 (23.6%)	71	Thai An (This study)
2	29 (34.1%)	39 (45.9%)	17 (20.0%)	85	My Hoa, 7 km from Thai An (Le 2000)
3	21 (31.8%)	26 (39.4%)	19 (28.8%)	66	Son Hai, 45 km from Thai An (Le 2000)
4	14 (31.8%)	20 (45.5%)	10 (22.7%)	44	Ca Na, 62 km to the south (Le 2000)
5	15 (35.7%)	5 (11.9%)	22 (52.4%)	42	Nai Lagoon, 25 km to the northeast (Dam 2016)

May. In contrast, *Sargassum* spp. and *Turbinaria* spp. exhibit seasonal abundance from April to May (Le 2000; Nguyen et al. 2009). In this study, the highest number of *Sargassum* species (11 species) was recorded in May, consistent with their known seasonal peak. Additionally, environmental factors such as temperature, salinity, irradiance, and nutrients also influence the growth and development of seaweed (Harley et al. 2012; Ngo et al. 2011; Nguyen et al. 2013; Ralow et al. 2012; Soufi et al. 2024; Yu et al. 2013). However, the extent to which each factor affects the distribution of individual macroalgal species varies depending on spatial and temporal scales (Pereira and Neto 2014). For example, elevated temperatures can increase respiration rates and reduce photosynthetic efficiency, ultimately leading to decreased growth and even mortality in seaweed (Lowthion et al. 1985). Increased turbidity, particularly from suspended solids, can led to a reduction of light in the water column, limiting algal productivity (Lowthion et al. 1985; Martins et al. 1999). Likewise, lower salinity has been shown to reduce seaweed growth (Martins et al. 1999), and to cause a steady decline in seaweed species diversity (Schubert et al. 2011).

During the northeast monsoon, many seaweed species experience dieback. Toward the end of this period, seaweed begins to grow again, and by March and April, species richness reaches its peak. Rainfall typically begins in June (from 55-115mm) and gradually increased until November (119-300 mm) (Tu et al. 2018), leading to higher Total Suspended Solids in August compared to April (Nguyen et al. 2016). This increase in turbidity explains the lower seaweed diversity observed in August, as many species were absent during this period. Our findings align with previous reports by Le (2000), who documented the highest seaweed diversity between February and April. This pattern is probably driven by conditions favorable for seaweed growth such as higher irradiance and less intense wave action (Le 2000). From June to September, seaweed populations begin to decline, and from July to October, most seaweed has died back, leaving only a few perennial species, such as *G. acerosa, H. eucheumoides*, and *B. gelatinum* (Le 2000).

Among the seaweeds, red algea are particularly favored by the locals due to their contribution to the production of agars (*G. acerosa*, *Gracilaria* spp.) and carrageenans (*B. gelatinus*), which are widely utilized in food and beverages. Notably, 10 out of the 16 species traditionally used belong to this phylum. The study by Anggadiredja (2009) also reported that locals on Sumba Island favored red algae for both food and medicinal purposes, although brown algae were used more widely in medicinal applications.

A prime example of the cultural and economic significance of red seaweed is the traditional sweet jelly *Mứt hồng vân*, made from *B. gelatinus* (Figure 3). This delicacy, a specialty of Ninh Thuan Province, especially in Thai An village, is highly popular among tourists and is sold in many neighboring areas, providing a crucial source of income for the local community. In addition to its culinary applications, *B. gelatinus* is a valuable source of high-quality carrageenan, extensively used in the food, cosmetic, and pharmaceutical industries (Usov 2011). However, recent observations reveal that the natural harvest yield of this seaweed has been inconsistent and is showing a declining trend, corroborating previous research findings (Huynh et al. 2024). To address these challenges, several cultivation projects have been launched, including initiatives in the study area. These efforts aim to enhance the sustainable development of this economically significant seaweed while alleviating pressure on natural harvesting. Promising results include successful cultivation in natural environments, with a growth rate of 2.02% per day and carrageenan content reaching 59.9% during the optimal growth period (June). *B. gelatinus* is predominantly distributed along Vietnam's coastal regions from Quang Ngai to Ninh Thuan provinces, thriving in reef habitats exposed to strong wave activity (Huynh et al., 2024). Beyond Vietnam, *B. gelatinus* also holds cultural and economic importance in the Philippines, as noted by Dumilag et al. (2022), where it contributes to the regional identity of eastern Sorsogon.

When comparing the number of seaweed species utilized, the present study reports a higher count (16 species) compared to previous findings: 8 species (Ostraff 2006), 12 species (Dumilag et al. 2022), but fewer than the 54 species reported by Anggadiredja (2009). Some species show similarities in their uses, especially those used as food such as *C. racemosa, G. acerosa,* or *G. arcuata* (Table 3). This indicates that such uses are widely accepted across various communities (Kazancı et al. 2020) and underscores the importance of preserving and promoting indigenous knowledge as a core cultural component.

The harvesting of seaweed at the study site occurs seasonally, with yields varying annually. Although a significant amount of seaweed is traded in the local market, the exact quantity remains unknown or is reported inconsistently. Similar findings have been documented in studies conducted in China, Japan, and the Philippines (Abbott and Williamson 1974). Furthermore, during the research period, no conservation activities related to seaweed were observed in the area. The collection of seaweed by local people is not regulated in terms of harvesting seasons or quantities. This raises concerns about the sustainable use of this natural resource, which plays a vital role in both the marine ecosystem and the local economy.

Seaweed cultivation has been widely discussed due to its numerous benefits, including improved water quality, climate change mitigation, support for biodiversity, ecosystem restoration, and reduced pressure on wild harvesting (Pereira and Cotas 2024). Several cultivation methods hold potential for large-scale and sustainable production. These include offshore cultivation, which grows seaweed in open waters using floating structures, and integrated multi-trophic aquaculture (IMTA), a system that combines the farming of multiple species in a symbiotic relationship. In IMTA, seaweed plays a vital role by absorbing excess nutrients released from aquaculture farming, thereby reducing environmental impacts and promoting sustainability. Land-based systems allow for year-round seaweed cultivation under controlled conditions (Pereira and Cotas 2024). However, successful seaweed farming requires the involvement of multiple stakeholders, particularly local communities, through participatory and sustainable management approaches. For example, Forestin et al. (2024) applied a RAPFISH analysis to evaluate the sustainability of brown seaweed (*Sargassum* sp.) management in the Ujung Kulon Conservation Area (Indonesia). Their study revealed that while the economic and ecological dimensions were found to be sustainable or moderately sustainable, the social and institutional aspects still require significant improvement.

Seaweed gathering in the study area is primarily carried out by women, a trend also reported in Tonga (Ostraff 2006). Although this activity only takes place during specific times of the year, depending on the seasonal growth of seaweed - for example, *Sargassum* spp. in June and *Porphyra* sp. in December-January - it significantly contributes to household income. Women prefer this work as it allows them to earn money for their families in addition to their daily tasks, which they can manage flexibly. In contrast, men typically engage in stable-income activities such as fishing or grape farming. Interestingly, the number of seaweed species reported by women and men does not differ significantly. Similarly, traditional knowledge about seaweed does not vary notably among groups classified by socioeconomic factors, such as primary occupation and seaweed-related activities. This finding differs from Kodirekkala's observation (2017), which suggested that individuals specializing in trading and resource management tend to acquire deeper and more comprehensive knowledge about those resources.

The similarity in traditional seaweed knowledge among the locals could be attributed to the widespread use of certain species within the community. These species are commonly used for edible products, which are easily prepared at home or widely available in local markets, which facilitates knowledge sharing through everyday practices. When informants were asked about the sources of their seaweed knowledge, most identified neighbors and other community members as key transmitters, along with parents and relatives. This contrasts with the findings of Dumilag et al. (2022), where one-fifth of informants reported not transmitting their seaweed knowledge to others. Although market integration can contribute to the erosion of traditional knowledge due to its association with modernization and cultural assimilation (Kodirekkala 2017; Reyes-García et al. 2007), its roles is particularly relevant in this study because commercial activities, both local and external, appear to promote the preservation and transmission of traditional knowledge, especially regarding economically valuable seaweeds. This influence is evident in the higher UV values of six commercially important species such as G. acerosa (2.15), *H. eucheumoides* (2.12), and *Sargassum* spp. (1.67) compared to less commercially important species like *A. taxiformis* (0.03) and *Gracilaria* sp1.

(0.03) (Table 3). Moreover, it appears to be a general rule that the more versatile a plant, the more widespread its usefulness (Tardío and Pardo-De-Santayana 2008), also contributes to the preferential selection of these species.

Despite most of the seaweed used by local people being consumed as food, several species are also utilized for other purposes, especially for their health benefits. For example, *H. eucheumoides* has been reported to enhance eyesight and cool the liver, reflecting the growing recognition of the value of indigenous foods in other parts of the world (Tiitii et al. 2022). A similar observation was made for *G. acerosa,* which was reported to serve multiple functions across four of the seven use categories, including beverage, food, economic and medicinal purposes. As a result, these two species recorded the highest UV value: 2.15 for G. acerosa and 2.12 for *H. eucheumoides* (Table 3). According to Albuquerque et al. (2006), a plant's versatility and usefulness significantly contribute to its UV. Another important factor is Relative Frequency of Citation (RFC), which reflects how often a species is mentioned by informants (Zenderland et al. 2019). In this study, both hypotheses hold true for G. acerosa and H. *eucheumoides,* as they were used for diverse purposes and frequently cited.

Ultimately, the results of this study underscore the broader contributions of ethnobotanical research to resource sustainable management and food security. By documenting the diversity of seaweed species and their utilization in Thai An, this study reveals the critical role of traditional knowledge in maintaining resilient food systems. Notably, two-thirds of the recorded seaweed species are used as food in the area (Table 3). This finding aligns with the observations of Quave and Pieroni (2015), who described traditional ethnobotanical knowledge as a "reservoir of resilience" among the Gorani and Albanians living in one of the most economically disadvantaged districts in Albania. In that context, local communities relied heavily on wild plants for both daily nutrition and health benefits. Furthermore, the study emphasized that a robust set of ethnobotanical knowledge about wild edible resources can enhance a community's capacity to cope with environmental and economic instability. Additionally, the preservation of traditional food processing and preparation techniques, often enhancing nutritional value, storability and palatability, also supports the culturally appropriate use of local plant resources (Shewayrga and Sopade 2011). This is exemplified in Thai An by traditional seaweed-based products that have gained popularity among tourists and neighboring areas, such as *Mứt hồng vân* made from *B. gelatinus.* Currently, seaweed-related activities in the community are closely linked to women, who play key roles in gathering, processing and trading. Therefore, it is essential to develop programs that generate added and uplifts coastal communities by recognizing and enhancing the significant contributions of women. This approach to women's empowerment is also demonstrated in successful initiatives in Tanzania and Kenya (United Nations Conference on Trade and Development 2024).

CONCLUSION

Seaweeds continue to be an essential resource for coastal communities, contributing significantly to various sectors such as the nutrient, economy, ecology, culture, and society. The present study recorded a high diversity of seaweeds and their widespread utilization by locals in Thai An village, a community with a long-standing tradition of seaweed harvesting. Recognizing the seasonal availability of seaweed groups is crucial for developing strategies to conserve seaweed diversity and advising government and communities on effective, sustainable resource use. The ethnobotanical survey revealed diverse traditional uses of seaweed, with several species playing vital roles in local livelihoods. The use value index serves as a valuable baseline for identifying priority species for management, supporting conservation through local knowledge, and informing policy and resource planning. Notably, species such as *G. acerosa*, *H. eucheumoides*, and *B. gelatinus* are recommended for future sustainable development studies involving active community participation, particularly women, who are closely engaged in the harvesting and utilization of seaweed resources. This approach not only contributes to promoting women's economic empowerment but also supports the broader goal of preserving and revitalizing traditional knowledge and practices in coastal communities. By recovering and strengthening this knowledge base, new opportunities may arise for sustaining customary practices and fostering community-led innovations, especially in food production and cultural tourism.

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DATA AVAILABILITY

The data used to support the findings of this study are available from the corresponding author upon reasonable request.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

CONTRIBUTION STATEMENT

Conceived of the presented idea: TTNL, XMAN
Diversity of seaweed: TTNL and BTTL
Ethnobotanical interviews: XMAN and TMAN
Data analysis: TTNL, XMAN, BTTL, TMAN
Supervision and coordination of the study: TTNL, XMAN
Review and final write of the manuscript: TTNL, XMAN, BTTL

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