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Marine Algae of the Eastern Caraga Region, Philippines, I. Historical Survey and an Annotated List of the Brown Algae (Phaeophyceae)

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ABSTRACT

The marine algal flora of the Philippines is highly diverse owing to its strategic location in the middle of the vast Indo-Pacific biogeographic region. However, the diversity of marine algae in many parts of the country remain unknown due to geographic isolation that limits botanical exploration. The Caraga region in northeastern Mindanao Island is one such poorly known locality. This study was aimed to produce a consolidated list of published records of the brown algae from the region, including a historical survey of the few studies conducted there previously. A total of 23 species, eight genera, three families and three orders of marine brown algae were recorded. Information revealed some economically-important species which could be tapped for livelihood creation in coastal villages there. Baseline information presented in this study will be useful for resource exploitation and policy formulation.

Keywords: botanical inventory, brown algae, Mindanao, phycology.

INTRODUCTION

The political region of Caraga in the Philippines is composed of five provinces located on the northeastern part of the island of Mindanao including several large offshore islands. Its eastern coast faces the vast Pacific Ocean from where the warm equatorial currents bring propagules that contribute to the rich marine biodiversity found there. In addition, several typhoons hit the area often bringing storm surges that cause greater water circulation. Some upwelling from the nearby Philippine Trench could also contribute to the high marine productivity seen there.

Compared to other regions in the Philippines, the Caraga region is poorly known in terms of its biodiversity despite the variety of favorable geographical features found there, i.e., the long Agusan River and the vast Agusan Marsh, the majestic Diwata mountain range, the Lake Mainit basin and the several offshore islands with their numerous lagoons and rugged coastlines. During the American colonial period in the early 20th century which saw the start of biological exploration and collecting mainly in the Christianized parts of the Philippines, the Caraga region was among those largely excluded. Instead, the attention of the colonizers was focused on the development of gold and nickel mining activities in the eastern part of the region which continue to this day at immeasurable environmental and social costs.

Limited biological exploration of the Caraga region started during the early years of the American colonial period. Among the pioneers was Edward H. Taylor who was an American herpetologist at that time who explored the region and published on many species known to science for the first time (Borrell, 2013; Taylor, 1920). Among the earliest accounts of marine fauna there were based on the collections of Francisco Nemenzo, Sr. (formerly of the University of the Philippines Diliman) and Exuperancio A. Montecillo (formerly of the University of San Carlos) who led a team of biologists which found new species of scleractinian corals from the waters of Aras-asan Island in Surigao del Sur in 1977 and published subsequently by Nemenzo and Montecillo (1981).

Ernani G. Meñez, who at that time was a research assistant and graduate student at the University of Hawai'i studying under Maxwell S. Doty appears to be the first to collect seaweed samples from the eastern Caraga region. He first collected from Barangay Mangagoy,

Bislig, Surigao del Sur on 29 June 1958, and stayed in the general vicinity for about one week and collected around Mawes Island in Hinatuan and Sanco Point in Maribojoc in Surigao del Sur. His collections currently deposited at the herbarium of the Bernice P. Bishop Museum in Honolulu were studied and published by Taylor (1964, 1977); Hollenberg (1968, 1968a); Gilbert and Doty (1969); Saito (1969); Xia and Abbott (1987); Liao (1990).

Gregorio T. Velasquez, professor of botany at the University of the Philippines Diliman at that time, collected some species of the marine red algal genus Galaxaura from Loreto in Dinagat Island on May 1965 and which were published by Cordero (1977). Later, visits to various sites in the Surigao provinces by the team from the National Museum in Manila led by Paciente A. Cordero, Jr. in the 1970s and 1980s produced many samples which were published by Cordero (1980, 1980a); Cadano and Trono (1987); Modelo and Umezaki (1995); Liao *et al*. (1997), among others. Based on samples collected by his students from various parts of the Surigao provinces, Trono (1997, 2004, 2017, 2017a, 2018) added to the growing species list of marine algae there. He also published numerous species from various sites in the Caraga region collected during the Pacific Seaboard Expedition from 2000 to 2003 (Trono 2017a, 2018).

More recently, Stefano G.A. Draisma, a research fellow at the University of Malaya in Kuala Lumpur at that time made extensive collections of marine algae around the Philippines. From 10-12 April 2014, he collected samples from Siargao Island. Among those he collected were samples of the new species, *Halymenia malaysiana* P.-L. Tan, P.-E. Lim, S.-M. Lin and S.-M. Phang which was formally described by Tan *et al*. (2015).

Home-grown biologists also contributed to the study of marine algae in subsequent years. Cynthia P. Sajot of the Surigao del Sur State College at that time conducted a comprehensive survey of the marine algal flora of several sites around Lianga Bay in Surigao del Sur (Sajot, 2006). Fajardo *et al*. (2016) at the Caraga State University surveyed the marine algae and seagrasses near the mining site in Barangay Cagdianao, Placer, Surigao del Norte.

This paper attempted to produce a comprehensive unified list of all species of marine brown benthic algae (Phaeophyceae) reported thus far from the eastern Caraga region, namely the provinces of Surigao del Norte, Surigao del Sur and the Dinagat Islands to serve as baseline information for purposes of resource management and exploitation, environmental protection, biodiversity conservation and the formulation and implementation of appropriate policies and legislation thereof. This study also aimed to encourage further studies of the marine algae in the Caraga region, to sample in areas where no data are available, to identify species of economic and ecological importance, among other goals.

MATERIALS AND METHODS

This review is based entirely on a comprehensive survey of the published taxonomic literature of marine algae from the three coastal provinces of eastern Caraga region, comprising of Surigao del Norte, Surigao del Sur and the Dinagat Islands. Sources include online materials, library collections and materials compiled personally by the authors. Records were retrieved from each reference and compiled into the checklist presented in this paper. Actual samples were not examined in this survey, instead critical annotations are provided for species whose identity are either doubtful or questionable on biogeographical and other grounds. Data-mined names and records were listed and arranged following the classification system of Dawes and Mathieson (2008) which was selected arbitrarily for adoption in this study. Validity of each names were verified by consulting the latest taxonomic literature and by referring to AlgaeBase (Guiry and Guiry 2020).

RESULTS AND DISCUSSION

The list of all known published species of marine benthic brown algae from the eastern Caraga region, namely the provinces of Surigao del Norte, Surigao del Sur and the Dinagat Islands revealed a total of 23 species, eight genera, three families and three orders. The list is presented below following the classification scheme of Dawes and Mathieson (2008). Sources of original reports are indicated inside brackets.

HETEROKONTOPHYTA
Class PHAEOPHYCEAE
Order DICTYOTALES
Family DICTYOTACEAE
Canistrocarpus cervicornis (Kützing) De Paula and De Clerck [Trono, 2018]
Dictyopteris jamaicensis Taylor [Fajardo *et al*., 2016]

Remarks: *D. jamaicensis* is a tall species (15 cm or more) first described from the deep waters off Jamaica by Taylor (1960) and is likely confined to the waters of the Caribbean. The name has become of convenient use as applied to larger (>10 cm) plants collected from the Philippines (Silva *et al*., 1987). Obviously Philippine

representatives of this genus are in need of critical study.

Dictyopteris repens (Okamura) Børgesen [Trono, 2018]
Dictyota dichotoma (Hudson) J.V.Lamouroux [Trono, 2018]

Remarks: This record should be treated with caution as this species seems restricted to European waters. Kraft (2009: 164) opined that species lacking structural or habit peculiarities, except perhaps for having evenly dichotomous branching, have been conveniently placed under this species.

Dictyota mertensii (Martius) Kützing [Trono, 2018]
Lobophora variegata (J.V.Lamouroux) Womersley ex E.C.Oliveira [Trono, 2018]

Remarks: This identification should be considered tentative as molecular studies have revealed a bewildering number of cryptic species therein (see Vieira *et al*., 2016).

Padina australis Hauck [Geraldino *et al*., 2005; Sajot, 2006; Trono, 2018]
Padina boryana Thivy [Geraldino et al., 2005]
Padina fernandeziana Skottsberg and Levring [Geraldino *et al*., 2005]

Remarks: The singular report of this apparently endemic Eastern Pacific species needs to be reevaluated in the light of many new species recently described from the Indo-West Pacific (Ni-Ni Win *et al*., 2010, 2011, 2012).
Padina japonica Yamada [Trono, 2018]
Padina minor Yamada [Geraldino *et al*., 2005; Sajot, 2006; Fajardo *et al*., 2016; Trono, 2018]

Remarks: Philippine records of this species need to be treated with caution as there is a tendency among researchers to apply this name indiscriminately to Padina species which are "smaller than usual" disregarding other plant features (Modelo and Umezaki, 1884; Geraldino *et al*., 2005; Tsutsui *et al*., 2005)

Padina moffittiana Abbott and Huisman [Geraldino *et al*., 2005]

Remarks: Originally described from Hawaii, this species has now been reported from southern Japan (Ni-Ni-Win *et al*., 2010) and several sites in the Philippines (Geraldino *et al*., 2005).
Padina sanctae-crucis Børgesen [Geraldino *et al*., 2005]
Padina sp. [Fajardo *et al*., 2016]

Order ECTOCARPALES
Family Scytosiphonaceae
Colpomenia sinuosa (Mertens ex Roth) Derbés and Solier ex Castagne [Trono, 2018; Sajot, 2006, as *Colpomenia* sp.]

Remarks: The record of Sajot (2006) most likely refers to the amorphous and convoluted sac-like species listed above.

Hydroclathrus clathratus (C.Agardh) Howe ex Britton and Millspaugh [Trono, 2018; Sajot, 2006, as *Hydroclathrus* sp.]

Remarks: The identity of the sample of Sajot (2006) cannot be ascertained without a critical examination of voucher specimens. In the Philippines, two reticulate species have been customarily reported: *H. clathratus* which is a cosmopolitan species characterized by branches of irregular diameters (>3 mm), and *H. tenuis* Tseng and Lu, a more fragile species with consistently finer branches (<2 mm) and a more restricted distribution than the former. Kraft and Abbott (2003), Santiañez and Wynne (2019), and Santiañez *et al*. (2017, 2018) have identified superficially similar reticulate species as new species and new genera with the aid of molecular and morphological evidence.

Order FUCALES
Family SARGASSACEAE
Hormophysa cuneiformis (Gmelin) Silva [Liao *et al*., 1997; Trono, 2018: Sajot, 2006 as *Hormophysa* sp.]

Remarks: The triquetrous nature of the thallus is distinctive for this species. In mature specimens, air vesicles are embedded into the thallus. Formerly placed within the Cystoseiraceae, this genus is now classified within the Sargassaceae after Draisma *et al*. (2010) synonymized the two families. The unidentified species reported by Sajot (2006) is almost certainly *H. cuneiformis*.
Sargassum angii L.M.Liao
=*Sargassum yoshidae* Trono [Trono 2018]

Remarks: The current name is a replacement of *S. yoshidae* Trono originally described from Ilocos Norte which is a synonym of *S. yoshidae* Yoshida and T. Konno, a species known to occur only in Japan (see Modelo *et al*., 1998).

Sargassum aquifolium (Turner) J.Agardh
=*Sargassum heterocystum* Montagne [Cordero, 1980; Modelo and Umezaki, 1995]
Sargassum ilicifolium (Turner) C.Agardh
=*Sargassum cristaefolium* C.Agardh [Trono, 1997; Fajardo *et al*., 2016; Trono, 2018]
=*Sargassum duplicatum* J.Agardh [Cordero, 1980, as *Sargassum* sp. 1, 1980a]
Remarks: The duplicated margins consisting of serrated or dentate rows may be seen either disposed entirely on leaf margins or only on the distal half of the leaf.
Sargassum grandulifolium Grunow ex Piccone [Modelo and Umezaki, 1995]

Sargassum oligocystum Montagne [Trono, 1997]
Sargassum paniculatum J.Agardh [Fajardo *et al*., 2016]
Sargassum polycystum C.Agardh [Trono 1997; Fajardo *et al*., 2016]

=*Sargassum myriocystum* J.Agardh [Modelo and Umezaki, 1995]

Remarks: This species is among the easiest to identify with its distinctively 'spiny' main axis which are, in fact, beset with cryptostomata that have expanded ostioles (Chiang *et al*., 1992).

Sargassum samarense Trono [Trono, 2018]
Sargassum siliquosum J.Agardh [Trono, 2018]
Sargassum sullivanii Trono [Trono, 2018]
Sargassum sp. [Sajot, 2006; Fajardo *et al*., 2016]
Sirophysalis trinodis (Forsskål) Kützing

=*Cystoseira trinodis* (Forsskål) C.Agardh [Liao *et al*., 1997]

Remarks: For so many years, this peculiar species was recognized under *Cystoseira* with a distinctively Indo-Pacific distribution quite different from its congeners that are restricted within the Mediterranean basin, its presumed center of distribution. Draisma *et al*. (2010) removed it from *Cystoseira* and transferred it into its own genus and at the same time subsuming the Cystoseiraceae (containing *Cystoseira*, *Hormophysa* and *Sirophysalis*) under the Sargassaceae based on molecular evidence.

Turbinaria condensata Sonder [Taylor, 1964]
Turbinaria conoides (J.Agardh) Kützing = *T. conoides* [Trono, 2018]
Turbinaria conoides f. *laticuspidata* Taylor [Taylor, 1964]
Turbinaria decurrens Bory [Taylor, 1964; Trono, 1997, 2018]

The three-sided obpyramidal shape of the main photosynthetic blade is distinctive. Another morphologically similar species is *T. murrayana* Barton which is delineated from *T. decurrens* by "having short, thick, unbranched stem,…" among other features.

Turbinaria ornata (Turner) J.Agardh [Trono, 2018]

Records of marine benthic algae in the Philippines are largely scattered due to various factors. Geographic distance and isolation of some habitats can be cited for the uneven data thus far available, especially in an archipelagic country like the Philippines where safe access is of vital concern. Weather concerns are also taken into account. In the study area of the eastern Caraga region and throughout the Pacific coasts of the Philippines (Evangelista *et al*., 2015), typhoons pose serious threats to collecting activities. Another important factor to explain the patchy distributional records of marine algae in the Philippines is the lack of coordinated collecting efforts especially in far flung regions like Caraga. For practical reasons, collections have focused on easily accessible areas and those located near research centers in the national capital.

This survey revealed the obvious absence of common tropical marine floral elements. For instance, some unaccounted for in the literature survey were common epiphytic brown algae such as those belonging to uniseriate *Hincksia* and *Feldmannia* (Acinetosporaceae) and multiseriate *Sphacelaria* (Sphacelariaceae). Silva *et al*. (1987) reported 3-4 species of each of these genera from the Philippines where they form dense epiphytic tufts on larger algae, but it is believed the diversity of these microscopic brown species are understated, at least in the Philippines. Another missing element are the crustose brown algae belonging to the Ralfsiales.

Among the most common species listed are members of Sargassum which are an emerging source of alginate (Fawzy *et al*., 2017) in many parts of the world. Alginate extraction residues have also been used to absorb toxic heavy metals (Cardoso *et al*., 2017). Many species are also of biomedical importance for their cytotoxic (Shofia *et al*., 2018) and anti-inflammatory effects (Luo *et al*., 2019). In addition to Sargassum, biomass from species of *Padina* have been used as potential agents for aquatic environmental remediation (Sheng *et al*., 2004).

The marine flora of the eastern Caraga region may be considered moderately rich as evidenced by the number and diversity of species recorded there. The absence of some common tropical species in the literature survey suggested that more surveys need to be conducted in eastern Caraga to account for species that are commonly expected in tropical marine ecosystems. To account for species that may exhibit seasonality, sampling should be done during the dry and wet seasons of the year. Notwithstanding the gaps exposed in this survey, this compilation of past records is an important step towards completing the total phytogeographical picture of the Philippines.Similar compilations of records have helped immensely in consolidating scattered records (Silva *et al*., 1987) and the updating and revision of records have kept up with changes in taxonomy (Liao and Young, 2002; Evangelista *et al*., 2015). Without doubt, the records of the marine flora of the Caraga region will increase with more collections through time. The information in this report will hopefully point out a number of taxonomic gaps. As succinctly stated by Silva *et al*. (1987), works such as species surveys and

listings "are not intended to endure like monoliths," but their "rate of obsolescence [becomes] an index of progress" for the study of marine algae including those to be found in the Caraga region.

CONCLUSION

This inventory of the species of marine algae, specifically of the brown algal species (Phaeophyceae), of the eastern Caraga region represents an attempt to compile information which would otherwise be obscured or lost. The current effort is important considering that whatever widely scattered available information needs verification. This effort is important as there is a general lack of research cooperation and coordination, sporadic publication in the gray literature, scarcity of taxonomic expertise, and low emphasis on the importance of seaweed resources, among other reasons. The current survey is a contribution towards increasing the profile of seaweed resources for resource managers and policy makers especially in an area like the Caraga region whose marine resources are obviously plentiful but only minimally exploited. Annotated checklists like the current work can serve to highlight the biodiversity of marine algae, identify those with potential economic importance which can be tapped for economic improvement for coastal communities. Information herein can also be used to help technology transfer by extension workers for income generation, among many other applications.

DECLARATION OF CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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