ABSTRACT

Red algae are known for its ecological role in coral reefs, a primary producer in a variety of habitats and source of carrageenan, agar, human food and bioactive metabolites. However, due to increasing anthropogenic pressure, benthic richness has decreased, and coastal communities including the algae, are threatened. As one of the most visited tourist destinations in the Philippines, the island of Siquijor experiences influx of tourists, massive development of beach resorts and pollution which could result in the decrease in the algal abundance, cover, and species richness. Thus, this study was conducted to assess the species composition of red algae in the intertidal areas of Siquijor in relation to anthropogenic activities. Red algae were collected from Tambisan, Cang-alwang, and Solangon using transect line and quadrant sampling method. A total of 26 species of red algae belonging to six orders and ten families were identified based on morphological and anatomical features. Tambisan has the highest number of species identified while Solangon has the least number of species which could be attributed to the anthropogenic activities. The result of the biotic similarity tests (Jaccard and Sørensen indices) revealed that there is high similarity of species found in Cang-alwang and Solangon where anthropogenic activities are observed.

Keywords: red algae, species composition, anthropogenic activities, biotic similarity, Siquijor.

INTRODUCTION

Red algae are considered to be important ecological and economic components of the marine ecosystems around the world. They are one of the primary producers of organisms in a variety of habitats. Encrusting calcified corallines play a significant ecological role in coral reefs by constructing and cementing reefs, facilitating the establishment of coral, stabilizing wave impacted crests and providing habitat for the benthic communities (McCook, 1999; Sahayaraj et al., 2014). Red algae are also best known for their economic importance as a source of agar, carrageenan, human food and bioactive compounds that exhibit a wide range of bioactive properties.

Despite the ecological and economic contributions of marine red algae, the coastal communities are threatened by the anthropogenic activities in many areas of the world. It was observed in the tropical South Atlantic coast by Portugal et al. (2016) that increasing anthropogenic pressure has decreased benthic richness. Coastal development, including the conversion of coastal areas into industrial
zones and human settlement, result to the total loss of the coastal habitats that limit their ability to provide valuable ecological services (Addessi, 1994). In the Philippines, coastal development has increased significantly with about 62% of the population settled into the coastal areas during the past decades (Padilla, 2008). Furthermore, tourist related activities such as trampling, damage caused by vessels and sediment resuspension resulted in ecological imbalance favoring the annual seaweeds with short life cycle and opportunistic algae like Caulerpa racemosa (Silva et al., 2012). Human trampling was found to cause loss of a particular percentage of the biomass of algae, leading to decrease in the algal cover, both turfing and encrusting coralline algae (Huff, 2011).

Siquijor, Philippines is one of the most visited tourist destinations with around 13,643 tourist arrivals recorded by the Department of Tourism Region 7 in 2014 and 35% of this was revealed to enjoy the island’s marine attractions (www.tourism.gov.ph). The proliferation of industries and other anthropogenic activities brought by the influx of tourists could result to the change in water quality and increase in pollutants to nearby coastal zones. Moreover, the expanded coastal settlements and activities also resulted in the persistence of pollution in the particular area which decreases the algal abundance, cover and species richness (Borowitzka, 1972). Thus, reassessment of the marine red algal community in Siquijor is deemed necessary since the last report on its species composition was last reported in 1978 by Reyes. The results of this study will not only provide updated information on the species composition and diversity of red algae in Siquijor but will also serve as a guide for further exploration of the potential of locally-available red algae, as well as a basis for formulating and implementing guidelines for coastal resources management.

MATERIALS AND METHODS

Collection, identification and preservation of samples

Red algae found in the intertidal areas of Cang-alwang (09° 13.135’N; 123° 27.875’E), Tambisan (09° 11.363’ N, 123° 27.209’ E) and Solangon (09° 17.236’ N, 123° 47.219’ E), Siquijor were collected using transect line method. These areas were previously surveyed by Reyes (1980). The area in Cang-alwang, with a human coastal settlement, is dominated by seagrasses and green algae, whereas, the sampling station in Tambisan has a mangrove area which is located approximately 1km from the sampling station. The Solangon sampling station is located near several resort establishments and is dominated by seagrass beds with deep muddy-sandy substrate type.

Three 100-m calibrated transect line was spread per study site (with a distance of approximately 50 m from each other) perpendicularly to the shore. Twenty 3x3 m quadrants were randomly placed along the transect line. Sampling was done during low tides from August to February. Procedure on the collection of fleshy samples followed that of Huisman et al. (2005) in which the entire plant thallus, including the holdfast of fleshy specimens, are collected. Meanwhile, the collection of coralline red algae followed the procedure suggested by Farr et al. (2009). Here, pieces of coralline red algae, usually 4-10 mm in size, with intact conceptacles, were picked up or scraped using a small chisel. The samples were placed in plastic bag containers with sufficient seawater to keep them from drying. At least two specimens (duplicates) per sample specimen were collected. The algae were rinsed with tap water to remove any clinging debris and then fixed with 4% formalin-seawater solution (Bean, 2013).
Morphological and anatomical examinations were done for the identification of the collected red algae samples. Fixed specimens were sectioned following the method suggested by Doty (1947). The specimen was placed in the water towards one end of a clean slide on the microscope stage. A second slide was placed lengthwise over the first with one end overlapping the specimen. The slides were held firmly with finger pressure. The specimen was cut thinly using a razor blade; by progressively altering the angle of the razor blade to the vertical, a series of thin, slightly wedge-shaped sections were cut. For anatomical examinations, coralline samples were decalcified in 1% HCl solution (Farr et al., 2009) and sectioned by hand following the method mentioned above. Sectioned materials were then mounted and examined under the compound microscope. Photomicrographs were taken with a CMEX-3 DC 3000C digital camera mounted on the microscope.

Species identification was done using available catalogs and references which included “The seaweeds of Panay” by Hurtado et al. (1992); “Catalog of the Benthic Marine Algae of the Philippines” by Silva et al. (1987); “New records of red algae (rhodophyta) for Cabezo Reef, National Park Sistema Arrecifal Veracruzano, Gulf of Mexico” by Galicia-Garcia, Robinson and Okolodkov (2013); “ Morphology and molecular phylgeny of Hypnea flexicaulis (Gigartinales, Rhodophyta) from Korea” by Geraldino, Yang and Bu, (2006); “A taxonomic study of seaweeds of North Sulawesi, Indonesia” by Thenu, (1997); “The marine benthic algae of Siasi Island and Vicinity III” by Trono (1974); and “New records of marine algae from the Philippines” by West and Calumpong (1990).

Computation of Biotic Similarity

The Jaccard and Sørensen indices were used in determining the biotic similarity in terms of species composition between the sampling sites. The Jaccard index compares the number of shared species to the total number of species in the combined assemblages, thus a comparison based on total diversity. The Sørensen index compares the number of shared species to the mean number of species in a single assemblage; thus, a comparison based on local diversity. The classic Jaccard and Sørensen indices for incidence counts follows:

\[
J_{\text{clas}} = \frac{A}{A+B+C} \quad \text{and} \quad S_{\text{clas}} = \frac{2A}{2A+B+C}
\]

where:
- A refers to the number of shared species in both assemblages
- B refers to the number of species unique in Assemblage 1
- C refers to the number of species unique in Assemblage 2

RESULTS

A total of 26 species of red algae were identified in this study (Table 1). Nine species were from the Order Ceramiiales with four Families: Ceramiaceae, Dasyaceae, Delesseriaceae, and Rhodomelaceae. Seven species were under Order Gigartinales with two Families: Hypneaceae and Solieriaceae. On the other hand, three species under one family were identified for Nemaliales, Corallinales, and Gracilariales while only one species, one family was under Gelidiales.

Out of 26 species of red algae, nine (9) species were common in Tambisan, Cang-alwang, and Solangon. These are Acanthophora spicifera, Actinotrichia fragilis, Gracilaria edulis, G. salicornia, Hypnea spinella, H. tenuis, Jania adhaerens, Laurencia papillosa (Syn. Palisada perforata), and Lithothamnion indicum. However, eleven (11) species were found only
in Tambisan and five species in Cang-alwang. No species were specific in Solangon. For Tambisan, these species include *Amansia glomerata*, *Dasya villosa*, *Galaxaura fasciculata*, *Galaxaura rugosa*, *Gelidiella acerosa*, *Hypnea flexicaulis*, *H. nidulans*, *H. pannosa*, *Mastophora rosea*, *Martensia fragilis* and *Ceramium* sp 1, *Ceramium* sp 2, *Chondrophycus* sp., *Eucheuma denticulatum*, *Gracilaria caudata*, *Sypyridia filamentososa*, on the other hand, were found specific in Cang-alwang.

Table 1. Species composition and distribution of marine red algae (Rhodophyta) in Tambisan, Cang-alwang and Solangon, Siquijor, Philippines.

<table>
<thead>
<tr>
<th>Order</th>
<th>Family</th>
<th>Genera</th>
<th>Species</th>
<th>Sampling Stations</th>
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<td>Ceramium (Roth)</td>
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<td>fragilis</td>
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<td>Jania (Lamouroux)</td>
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<td>Actinotrichia (Decaisne)</td>
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<td>Galaxauraceae</td>
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<td>oblongata</td>
</tr>
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</table>
Below shows the key morphological and anatomical features of the Red Algae observed in this study.

**Order Ceramiales**  
**Family Ceramiaceae**  
**Ceramium (Roth)**

*Plate 1A. Ceramium sp 1.* A. Fresh specimen showing clustered thalli. B. Extremities of branches with apices showing slightly in-curved (CT) (LPO). C. Vegetative branch showing corticating bands (CB) with four cells (HPO).

**Plate 1B. Ceramium sp 2.** A. Fresh specimen showing wide main axes of thallus towards base and ultimate branchlets (UB) with in-rolled tips. B. Zonately divided tetrasporangia (arrowed) located on the base of the ultimate branchlets (HPO, Vegetative branch showing corticating bands).

**Family Dasyaceae**  
**Dasya (C. Agardh)**

*Plate 2. Dasya villosa.* A. Fresh specimen showing clustered thallus supported by slender rhizoid (RS). B. General view of pyramidal branches (PB) C. Microscopic view of distal part of branches showing round terminal cells (TC) (LPO). D. Magnified view of tips of branch showing cylindrical cortical cells (CC) (HPO).

**Family Delesseriaceae**  
**Martensia (Hering)**

*Plate 3. Martensia fragilis.* A. Fresh specimen showing thallus with membranous blades forming mats. B. General view of branches revealing latticework organization of veins and thickened lamellae (LL) (LPO) C. Globose cystocarp (arrowed) found lateral on the lamellae (HPO).
Family Rhodomelaceae

Plate 4. Acantbophora spicifera. A. Fresh specimen; thallus exhibit subdichotomous to alternate branching pattern. B. Extremities of tapering branches (AB) with acute tips and spirally arranged spikelets (SS). C. Magnified spikelet of terminal branch (LPO). D-E. Magnified axillary part of branch showing newly developed branchlet (NB) (HPO). F. Cross-section of vegetative branch showing semi-compact, irregularly shaped medullary cells (MC) (HPO).

Plate 5. Amansia glomerata. A. Fresh specimen showing foliaceous thallus with rosette arrangement of blades. B. Surface view of unrolled blade showing irregular serrate margins. C. Magnified view of unrolled blade showing apical cells at the distal portion of the involute tips (IT) (LPO). D. Surface view of elongated cells of blade (BC) (HPO). E. Cross-section of axis showing distinct rows of algal cells (AC) (HPO).


Plate 7. Chondrophycus sp. A. Fresh specimen; thallus with distichous and irregularly subopposite branches. B. General view of short and terete ultimate branchlets (UB) (LPO). C. Tetrasporophytic branchlet (TB) located at the axial part of the main axes (arrowed) (HPO). D. Surface view of epidermal cells (EC) that never show a palisade-like arrangement (HPO). E. Cross-section of thallus showing thickened medullary cell walls (MC) (HPO).

Order Corallinales
Family Corallinaceae


Plate 10. *Lithothamnion indicum*. Fresh specimen; growing as rhodolith with warty or fruticose protuberances (PB). B. Magnified view of calcified rounded to spherical epithalial cells (LPO). C. Adjacent cortical cells (CC) with no secondary pit-connections (HPO).

Plate 11. *Mastophora rosea*. Fresh specimen showing thalli with clustered apices. B. Microscopic view of fan-shaped apices and margins curled inward (LPO). C. Magnified view of the apex showing dome-shaped carpogonial conceptacle (arrowed) (HPO).

Order Gracilariales
Family Gracilariaceae

Plate 12. *Gracilaria caudata*. A. Fresh specimen showing thalli with curved branches. B. Extremities of branches; acute apical branches studded with cystocarps (CP). C. Cross-section of thallus showing compressed cortical cells (CC) (HPO).

Plate 14. *Gracilaria salicornia*. A. Fresh specimen; segmented thallus with irregular branching. B. Inconspicuous discoid holdfast (DH). C. Magnified view of inflated tips (IN) and constricted base (CB). D. Cross-section of thallus showing thickened cell walls (CW) (LPO).

Order Gelidiales
Family Gelidiaceae


Order Gigartinales
Family Hypneaceae

Plate 16. *Hypnea charoides*. A. Fresh specimen; thallus with creeping branches covered with branchlets. B. Magnified view of apical branch (AP) showing spiky branchlets (SB) (LPO). C. Microscopic view of apical part of branch showing elliptical apical cells (PC) (HPO). D. Lateral tetrasporangia found adjacent to branchlet (arrowed) (LPO). E. Transverse section of tetrasporangia (HPO).

Plate 17. *Hypnea flexicaulis*. A. Fresh specimen; thallus is creeping with flexuous branches. B. Surface view of pseudo-dichotomous apical branch (LPO).

Plate 19. *Hypnea spinella*. A. Fresh specimen; thallus densely covered with spines. B. Extremities of main branch showing pointed spine-like branchlets (SB) (LPO). C. Detail of a branchlet showing round cortical cells (CC) (HPO).


Plate 21. *Eucheuma denticulatum*. A. Fresh specimen showing thallus with thick irregular branches. B. Extremities of main branch showing acute tips (AT). C. Main axis covered with spinose or pointed proliferations (SP). D. Cross-section of main axis showing large medullary cells (HPO).

Order Nemaliales
Family Galaxauraceae


Plate 24. *Galaxaura oblongata*. A. Fresh specimen; bushy moderately calcified thalli. Discoid holdfast (DH) (red circle). B. Smooth, dichotomous branches with perforated tips (arrows). C. Magnified view of uniporate conceptacle (CN) at the terminal portion of the calcified segment (HPO).

Both the Jaccard and Sørensen indices showed highest biotic similarity in the Cang-alwang and Solangon stations, followed by the Tambisan and Solangon stations. Least biotic similarity was found in the Tambisan and Cang-alwang stations (Table 3).

**Table 3.** Biotic similarity in terms of species composition between the sampling sites.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Stations compared</th>
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<tr>
<td></td>
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<td>Sørensen index</td>
<td>Solangon</td>
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<td>Solangon</td>
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<td>Cang-alwang and</td>
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<td>Jaccard index</td>
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<td>Sørensen index</td>
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</table>

**DISCUSSION**

The Ceramiales was shown to be the order with the highest number of species identified with approximately half of the genera and one-third of all the species from the Rhodophyta. This order is characterized by having a well-resolved phylogeny and rapid completion of life history which may contribute to its diversity and richness (Maggs et al., 2011). This may explain the highest number of genera and species of red algae under Order Ceramiales as observed in this study and as supported by other compilation studies from several authors including Cordero (1977), Reyes (1980) as cited by Silva et al. (1987) and Evangelista et al., (2015).

The least number of species of red algae found in Solangon can be attributed to the high anthropogenic disturbances present in the area. Solangon is surrounded by some resort establishments and is subjected to varying anthropogenic activities including regular human visitation, fishing activities and docking of boats that could increase the impact on the algal community in the area. Human trampling was found to cause the reduction in the density and diversity of rocky shore organisms, in particular, both the fleshy and calcified forms of turf-forming species (Huff, 2011). The increased coastal settlements and activities also resulted in the persistence of pollution in the area. According to Borowitzka (1972), pollution primarily reduces the number of species of algae, specifically, the red and brown al-
gae. This reduction and variability in the number of species could be attributed to the toxic effects of the sewage components as these species are known to be sensitive to changes in the water quality. The addition of pollutants into the waters results in the degradation of perennial canopy often leading to the dominance of species which have high tolerance to pollution such as green algae Enteromorpha spp. like the ones seen at the Cang-alwang station. Like Solangon, Cang-alwang is also exposed to different anthropogenic activities including sewage products and run-off from the nearby coastal settlements which could also contribute a smaller number of red algae species. The high biotic similarity of red algae noted in Cang-alwang and Solangon may further support the effects of anthropogenic disturbances to the species composition of red algae.

CONCLUSION

A total of 26 species were identified, including some of the economically important species, such as Gracilaria spp. and Eucheuma spp. Most of the collected species belong to the Order Ceramiales with five Families and nine species. The area in Solangon, Siquijor, which is observed to have resort establishments, had the least number of species.

RECOMMENDATIONS

The authors recommend that this study will be used as a baseline for future monitoring of changes in macroalgal species composition. Species abundance should be included in the monitoring as the abundance of species can change in response to anthropogenic impacts.

ACKNOWLEDGMENT

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