Effect of habitat attributes on the abundance of Sargassum's epifauna and the feeding habit of an amphipod epifauna from the coast of Western India

T Imchen* & W Ezaz

CSIR-National Institute of Oceanography, Dona Paula, Goa – 403 004, India
*[E-mail: temjen.imchen@gmail.com; timchen@nio.org]

Received 06 February 2023; revised 09 September 2023

The Sargassum bed along the rocky intertidal region is highly productive and serves as a habitat for numerous associated species. In this study, the effect of habitat attributes (algal morphology) on the abundance and diversity of epifauna in Sargassum tenerrimum was investigated. Qualitative and quantitative analysis showed that the overall species diversity was high, and Hyalena nuda, Gammaropsis sp. and Modiolus adriaticus were the most abundant epifaunal species observed. The abundance of epifauna varied significantly with time. Compared to pre-monsoon months (February to May), post-monsoon (October to January) had a greater diversity of S. tenerrimum associated epifauna. The diversity was particularly high in the month of November. Epifauna showed a positive correlation with the characteristic of algal morphology, indicating its influence on abundance and diversity. Hyalena nuda being the most ubiquitous and abundant epifauna observed, the biotic interaction between S. tenerrimum and H. nuda was studied further. Close examination of the gut contents of H. nuda revealed that they graze and consume the epiphytic microalgae of S. tenerrimum, instead of the macroalgal fronds. This suggests that through this relationship, epibiosis in Sargassum may remain in control, while the amphipod derives food, shelter and protection from the predators.

[Keywords: Abundance, Community structure, Diversity, Epiphytic macrofauna, Epiphytic microalgae, Hyalena nuda, Seasonal variations]

Introduction

The intertidal rocky shore is an important marine ecosystem. In the rocky intertidal zone, including the subtidal zone, seaweeds are one of the major producers forming base of the trophic structure. They also function as a habitat former, space occupier, source of food, shelter and protection for a variety of associated organisms, and provide space for settlement\(^1\text{--}^4\). Intertidal ecosystems especially rocky shores, experience extreme physical stresses such as desiccation and wave impact. The canopy of seaweeds offers protection from such physical stresses to the associated epifauna, defends against predators, and aids in the settlement of other benthic species\(^5\text{--}^6\). Fishes, molluscs, crustaceans, and other epifauna that live on the macroalgal bed are quite diverse and occupy various trophic levels\(^7\text{--}^{10}\).

Various studies showed that the host macroalgal morphological characteristics can affect species diversity because epifauna often chooses algae with more morphological complexity\(^11\text{--}^{15}\). Seaweeds with higher morphological complexity are usually preferred by associated organisms because they provide a greater surface area to inhabit\(^11\text{--}^{14}\). According to Le Hir & Hily\(^14\), the complexity of structural habitat is also influenced by seasonal variation in the growth of seaweeds, which may eventually have an impact on associated epifaunal abundance.

Sargassum is an important seaweed inhabiting rocky intertidal ecosystems, and their thalli are structurally intricate\(^16\). It has long, branched thalli with fronds that resemble leaves and air-filled floats (pneumatocysts). These highly branched thalli also give a canopy effect and greater surface area to the associated organisms to inhabit. As a result, seaweeds, particularly Sargassum species, play a significant role in the functioning of the intertidal rocky shore ecosystems. A variety of fishes, molluscs, crustaceans, and many other types of species find shelter and refuge in association with Sargassum beds. According to previous studies, the epifauna of Sargassum spp. is extremely diversified, including filter feeders or detrivores, or carnivores. However, majority of them are herbivores that graze on the host or epiphytic microalgae\(^7\text{,}^{17\text{--}^{19}}\).

Considering these characteristics of the seaweeds and their role in the rocky shore intertidal ecosystem, the effect of habitat attributes (macroalgal
morphology) on the seasonal distribution of *Sargassum tenerrimum* associated epifauna was investigated in this study. The abundance of epifauna was analysed from the monthly collected macroalgal samples from the rocky intertidal shore of Anjuna, west coast of India. The mature thalli of *S. tenerrimum* break off due to strong wave action and currents during monsoon months (June to September; author's personal observation); hence, samples from those months were not investigated. Throughout the study, *Hyale nuda*, an amphipod epifauna, frequently appeared. The nature of the interaction was thus of interest. So, in this study, the effect of thalli attributes on the temporal abundance and diversity of epifauna, as well as the biotic interaction between *S. tenerrimum* and *H. nuda* was examined. It is hypothesized that due to the frequent occurrence and abundance of *H. nuda*, this species might be feeding on the fronds of *S. tenerrimum*. The subsequent observations and results have been described in detail in the article.

### Materials and Methods

#### Study area

Sampling was done over the course of a year from October 2013 to May 2014 from the rocky intertidal shore of Anjuna, Goa, India, located between 15°34'04" N and 73°44'27" E (Fig. 1). The study area is an exposed and sea-facing rocky intertidal shore with a rich diversity of seaweeds. The substrata is of flat rock and boulders with very little deposition of sand. The samples of *S. tenerrimum*, a brown seaweed, were collected every month during low tide, except for the monsoon months. The seaweed samples of ~ 7 inches long were selected and cut off with a scissor. The samples were kept in a poly bag to prevent the loss of epifauna and brought to the laboratory in an icebox for further investigation. In total, eight months of samples in triplicate were collected for the present study.

#### Sample processing and analysis

In the laboratory, the samples were fixed in a buffered Rose-Bengal formalin solution (5 %). The epifauna were removed by repeated washing under running tap water through a 500 µm mesh. After sorting, the epifaunal samples were then preserved in 10 % buffered formalin solution and kept for later identification.

Epifaunal abundance was quantified and analysed under a light microscope (Olympus). In the current study, epifauna like hydroids, bryozoans, etc., were not considered as they were not associated directly with *Sargassum* thalli. In the case of fragmented specimens, such as polychaete, only the heads were counted. The epifauna were identified to the lowest possible taxonomic level and to the species level, whenever possible. Epifaunal total abundance was calculated and expressed as the number of individuals per 100 g algal wet weight.

#### Effect of habitat attributes

To study the effect of habitat attributes, the algal thalli were dried by blotting with tissue paper, and thereafter the total length of the thallus (LT), the number of thalli (NT), and the fresh weight (FW) of the algal thalli were recorded.

#### Analysis of gut content of *H. nuda*

The gut content of *H. nuda* was analysed to examine the nature of interrelationship and interactions with *S. tenerrimum*. The samples of *H. nuda* were preserved with Lugol’s solution. In another set, samples of epiphytic microalgae of *S. tenerrimum* were collected by scraping and stored in Lugol’s
solution. For the examination of gut contents, this epiphytic microalgae data was used as a reference. Under an inverted microscope, the gut content of preserved *H. nuda* samples was dissected and analysed. The following equation was used to determine the relative abundance ($A$) and the frequency of occurrence ($F$) of microalgae in the gut content\[^{20}\]:

\[
\%
A = \left( \frac{\sum S_i}{\sum S_t} \right) \times 100
\]

\[
\%
F = \left( \frac{n_i}{N} \right) \times 100
\]

Where, $n_i$ is the number of microalgae within the gut content, $N$ is the total number of microalgae in the gut, $S_i$ is the number of microalgae found on the thalli of *S. tenerrimum*, and $S_t$ is the total number of microalgae on *S. tenerrimum* thalli. The epiphytic microalgae from algal thalli and gut contents were identified to the lowest possible taxonomic level using available taxonomic keys\[^{21-22}\].

### Data analysis

One-way ANOVA was used to evaluate epifaunal temporal abundance and species richness. The correlation between the epifaunal abundance and algal morphological characteristics (habitat attributes) was analysed using Pearson rank correlation. Stat Soft Statistica 8 was used for all the analysis. Bray-Curtis Index and similarity percentage (SIMPER) in PRIMER v.5 (Plymouth Marine Laboratory, Plymouth, UK) was used to analyse the similarity in seasonal distribution of epifauna. Plotting of the similarity results was done using Multidimensional Scaling (MDS). Species diversity was calculated using Shannon-Wiener formula\[^{23}\].

\[
H' = -\sum_{i=1}^{s} p_i \times \ln p_i
\]

Where, $p_i$ is the proportion of the entire community made up of individuals of species, $\ln$ is the natural logarithm, $s$ is the species richness, and $H'$ - the species diversity.

### Results

In this study, a total of 31,962 individual epifauna per 100 g algal wet weight was recorded. They belonged to 25 species representing 8 major taxonomic groups (Table 1). The two groups with the greatest diversity were amphipoda (8 species) and

<table>
<thead>
<tr>
<th>Species</th>
<th>OCT</th>
<th>NOV</th>
<th>DEC</th>
<th>JAN</th>
<th>FEB</th>
<th>MAR</th>
<th>APR</th>
<th>MAY</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Hyale nuda</em></td>
<td>109</td>
<td>547</td>
<td>656</td>
<td>5255</td>
<td>2773</td>
<td>4160</td>
<td>4160</td>
<td>3430</td>
<td>21090</td>
</tr>
<tr>
<td><em>Gammarus locusta</em></td>
<td>36</td>
<td>36</td>
<td>0</td>
<td>182</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>72</td>
</tr>
<tr>
<td><em>Gammarus sp.</em></td>
<td>36</td>
<td>145</td>
<td>291</td>
<td>182</td>
<td>0</td>
<td>474</td>
<td>0</td>
<td>182</td>
<td>1310</td>
</tr>
<tr>
<td><em>Maera serratipalma</em></td>
<td>72</td>
<td>145</td>
<td>0</td>
<td>328</td>
<td>182</td>
<td>0</td>
<td>255</td>
<td>0</td>
<td>982</td>
</tr>
<tr>
<td><em>Gammaropsis sp.</em></td>
<td>0</td>
<td>109</td>
<td>364</td>
<td>547</td>
<td>255</td>
<td>72</td>
<td>948</td>
<td>255</td>
<td>2550</td>
</tr>
<tr>
<td><em>Gammaridae sp.</em></td>
<td>109</td>
<td>182</td>
<td>182</td>
<td>145</td>
<td>109</td>
<td>109</td>
<td>0</td>
<td>0</td>
<td>836</td>
</tr>
<tr>
<td><em>Amphiose sp.</em></td>
<td>0</td>
<td>0</td>
<td>36</td>
<td>36</td>
<td>182</td>
<td>437</td>
<td>0</td>
<td>291</td>
<td>982</td>
</tr>
<tr>
<td><em>Melita sp.</em></td>
<td>0</td>
<td>0</td>
<td>145</td>
<td>0</td>
<td>72</td>
<td>36</td>
<td>36</td>
<td>0</td>
<td>289</td>
</tr>
<tr>
<td><em>Platynereis sp.</em></td>
<td>72</td>
<td>218</td>
<td>72</td>
<td>0</td>
<td>0</td>
<td>72</td>
<td>36</td>
<td>36</td>
<td>506</td>
</tr>
<tr>
<td><em>Nereis aibuhitensis</em></td>
<td>145</td>
<td>218</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>36</td>
<td>36</td>
<td>399</td>
</tr>
<tr>
<td><em>Syllis syllis</em></td>
<td>145</td>
<td>109</td>
<td>36</td>
<td>0</td>
<td>36</td>
<td>72</td>
<td>36</td>
<td>434</td>
<td></td>
</tr>
<tr>
<td><em>Myrianida edwardsi</em></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>36</td>
<td>0</td>
<td>0</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td><em>Lumbrineris sp.</em></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>36</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td><em>Pectinaria papillosa</em></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>36</td>
<td>0</td>
<td>0</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td><em>Ovenia fusiformis</em></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>36</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td><em>Dinamene bidentata</em></td>
<td>0</td>
<td>36</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>36</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td><em>Pentidotea sp.</em></td>
<td>0</td>
<td>328</td>
<td>160</td>
<td>0</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>596</td>
</tr>
<tr>
<td><em>Mitrella vatovi</em></td>
<td>36</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td><em>Epitonium sp.</em></td>
<td>0</td>
<td>145</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>145</td>
</tr>
<tr>
<td><em>Diodora gibberula</em></td>
<td>0</td>
<td>72</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>72</td>
</tr>
<tr>
<td><em>Brachiodontes variabilis</em></td>
<td>0</td>
<td>36</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>36</td>
</tr>
<tr>
<td><em>Modiolus adriaticus</em></td>
<td>36</td>
<td>583</td>
<td>72</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>871</td>
</tr>
<tr>
<td><em>Acanthonyx eryseroche</em></td>
<td>0</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>0</td>
<td>0</td>
<td>72</td>
<td>180</td>
<td></td>
</tr>
<tr>
<td><em>Ophiactis resiliens</em></td>
<td>0</td>
<td>72</td>
<td>36</td>
<td>36</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>180</td>
<td></td>
</tr>
<tr>
<td><em>Apseudes chilkensis</em></td>
<td>0</td>
<td>36</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Total abundance</td>
<td>796</td>
<td>3053</td>
<td>1926</td>
<td>6761</td>
<td>3645</td>
<td>5540</td>
<td>5579</td>
<td>4482</td>
<td>31782</td>
</tr>
</tbody>
</table>
polychaeta (7 species) followed by gastropoda (3 spp.), bivalvia (3 spp.), isopoda (2 spp.), and decapoda (1 sp.). The species of echinoderms and tanaids were also recorded.

The epifaunal diversity and abundance exhibited a significant temporal effect, with diversity being higher in the post-monsoon months of October to December and gradually declining thereafter. From the months of October through December, seen a decline in epifaunal abundance. Amphipoda, polychaeta, and bivalvia were the most common and numerous groups. Among all the groups identified, amphipoda was the most abundant faunal group (Fig. 2). The species diversity as per the Shannon and Wiener index showed that the month of November, with 18 species, had the highest diversity, and the lowest was in the month of April (Fig. 3). However, the species were more evenly distributed in the month of October than in November.

Several amphipod and bivalve species were observed during the course of the study. However, *Hyale nuda* (amphipoda) was the most common and dominant species in the subsequent months, while, *Modiolus adriaticus* (bivalvia) was the dominant species in November (Table 2). January had the highest abundance of amphipods (~5255) (Table 1). Epifaunal diversity ($F = 5.16, P = 0.003$) and seasonal abundance ($F = 9.84, P = 0.000$) varied significantly.

Two separate clusters were revealed by the similarity analysis of the epifaunal distribution (Fig. 4). October and November formed one group, and the other months, December to May, comprised the other. Furthermore, the similarity percentage (SIMPER) showed that the epifauna recorded from December to May had a significant species similarity (67.15 %), while it was 60.61 % in those found between October and November. The dissimilarity between the groups was 58.55 %. Species like *Hyale nuda* (17.71 %), and *Platynereis* sp. (12.79 %) contributed majorly to the similarity in group 1, whereas *Hyale nuda* (51.4 %), *Gammaropsis* sp. (14.42 %) and *Ampithoe* sp. (5.97 %) were responsible for the major contribution in group 2 similarity. The dissimilarity between the groups was mainly contributed by *Hyale nuda* (13.02 %) and *Nereis* sp. (10.14 %). The analysis showed that algal thalli size and branching had an influence on the abundance and species richness of epifauna. There was a positive correlation between the habitat attributes of the macroalga and overall abundance ($R^2 = 0.459, P < 0.024$).

---

**Table 2 — Temporal dominance of *Sargassum tenerrimum’s* major epifauna**

<table>
<thead>
<tr>
<th>Time (M)</th>
<th>No. of species</th>
<th>Dominant sp.</th>
<th>Dominance (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>October</td>
<td>10</td>
<td>Polychaeta spp.</td>
<td>18.2</td>
</tr>
<tr>
<td>November</td>
<td>18</td>
<td><em>Modiolus adriaticus</em></td>
<td>19</td>
</tr>
<tr>
<td>December</td>
<td>11</td>
<td><em>Hyale nuda</em></td>
<td>33.5</td>
</tr>
<tr>
<td>January</td>
<td>10</td>
<td><em>Hyale nuda</em></td>
<td>77.72</td>
</tr>
<tr>
<td>February</td>
<td>8</td>
<td><em>Hyale nuda</em></td>
<td>76</td>
</tr>
<tr>
<td>March</td>
<td>12</td>
<td><em>Hyale nuda</em></td>
<td>75</td>
</tr>
<tr>
<td>April</td>
<td>8</td>
<td><em>Hyale nuda</em></td>
<td>74.5</td>
</tr>
<tr>
<td>May</td>
<td>12</td>
<td><em>Hyale nuda</em></td>
<td>76.5</td>
</tr>
</tbody>
</table>
The gut content of *H. nuda* exhibited a variety of microalgae. The microalgae recorded in the gut content matched to those found on the thalli of *S. tenerrimum*, which are epiphytic microalgae (Table 3). The two most common epiphytic microalgae on macroalgal thalli were *Diatoma* sp. (N = 1455) and *Navicula oblonga* (N = 1151). *Pinnularia viridis* (~ 63) and *Navicula oblonga* (~ 190) were the most consumed microalgae according to the analysis of gut contents (Table 3).

The gut content did not contain any bits of invertebrates or macroalgal thalli/fronds.

**Discussion**

Studies showed that several factors, such as environmental factors, macroalgal habit, food availability, and seasons, may impact the abundance and diversity of algae-associated epifauna. The present study showed significant temporal variation in the abundance and diversity of *S. tenerrimum* epifauna. The community characteristics were more diverse in the month of November. During this time, the population of amphipoda was comparatively low and the population density of *Modiolus adriaticus* was higher. However, the population of amphipods grew steadily over time and became more abundant. The most diverse and abundant groups in this study were amphipoda, followed by polychaeta, and bivalvia.

The results showed that when there was an increase in the amphipoda population, the characteristics of epifaunal community changed due to a decline in the abundance and diversity of other associated epifauna. This variation could be attributed to a temporally influenced factors as well as interspecific competition. In agreement with this, a study by Gabr *et al.* showed that such variations in diversity and abundance are due to seasonal effects. Although amphipod predation on associated organisms was not investigated in the present study, some studies showed that amphipods have an impact on the abundance of epifauna, such as bivalves, due to predation. Conversely, Wakabara *et al.* showed that the morphological adaptation of the species, such as their mobility and ability to attach to the algae, is what causes macroalgal epifauna like amphipods, to dominate.

The most abundant epifauna in the present study were amphipods. *Hyale nuda* was the most common species among them, with a density of about 85 % in January. It was observed that low populations of bivalve and other amphipod species coincided with high abundance of *H. nuda*. This was most probably due to interspecies competition. However, Valério-Berardo & Flynn claimed that the temporary change in community structure is driven by the population dynamics of the dominant species, including predation stress, whereas Ba-Akdah *et al.* reported that the seasonal variation in environmental factors controls the abundance of epifauna and other benthic organisms. In a similar study by Duffy & Hay...
showed how a particular species dominance influences a community structure. Resource competition was cited as another reason why the community structure changes. They also observed that grazing amphipods have such a significant effect on the community structure of epifauna that they play an important role in determining the characteristics of the community36. A seasonal study on epifauna showed that amphipod population dominance varied over time, and they were more abundant in the winter35. In addition, numerous studies showed that tropical amphipod species typically exhibit seasonal abundance35,37-40.

According to previous studies, the complex algal morphology has been linked to increased species richness and epifaunal habitat preferences26,41-42. In agreement with these studies, a positive correlation ($R^2 = 0.459, P = 0.024$) was found between the abundance of epifauna and the highly branched macroalgal thalli. The highly branched thalli increase the space and food availability, which can contribute to greater diversity and abundance. Given that the community structure of epifauna is significantly influenced by the surrounding landscape, the temporal increase in the abundance of epifauna, particularly amphipods, may also be linked to the growth and increased branching of the algae43. Additionally, Tavares et al.44 also showed that the choice of marine macrophyte by epifauna is complicated and determined by a variety of factors, including the nutritional value of macroalgae, palatability, value of habitat, availability of microalgae in the environment and protection from the predators.

Amphipods exhibit a variety of feeding strategies, including suspensivory, detritivory, predatory, herbivory, and sometimes omnivory45, and these strategies can vary between habitats and seasons within the same species21,46,47. In the present study, it was hypothesised that $H. nuda$ consumes $S. tenerrimum$ fronds or thalli. However, the gut content study showed that they did not consume macroalgal fronds. The results revealed a variety of epiphytic microalgae rather than frond fragments in the gut content. This suggested that they consume the algal epiphytes when grazing. The two main epiphytes found in the gut contents were $Pinnularia viridis$ and $Navicula oblonga$. They accounted between 70 and 89 % of the relative abundance and between 85 – 100 % of the frequency of occurrence of the consumed microalgae. $Navicula oblonga$ appeared to be a relatively common species in the gut content, which could suggest that it is a preferred food source. In a related study, Aiken & Kikuchi48 demonstrated that amphipods graze and consume diatoms.

Although there can be differences in the feeding habits and food sources between species and groups, studies showed that a controlled epibiosis caused by selective epiphyte grazing benefits the host because it improves photosynthesis6,49. Buschmann50 also demonstrated that mobile invertebrates that live on the intertidal macroalgae can use the algae both as food and a place of refuge because they can distinguish between the two in terms of time and space.

**Conclusion**

The present study showed that the abundance and diversity of epifauna on $S. tenerrimum$ is temporally affected along with the habitat attributes, such as the characteristic of algal morphology. As a result, the diversity was higher in the post-monsoon months, especially in the month of November, than in the pre-monsoon months (February to May). The change in community characteristics of epifauna with increase in the population of amphipoda could be due to interspecific competition as well as temporal factors. The analysis of gut content employed to study the biotic interaction between $S. tenerrimum$ and $H. nuda$ revealed that $H. nuda$ consume epiphytic microalgae of $S. tenerrimum$, and not the fronds of macroalga. This indicated that grazing by $H. nuda$ may control the extent of epiphytism on $S. tenerrimum$, while amphipods derive benefits in the form of food, shelter and protection from the predators. However, to understand the trophic dynamics and its consequent impacts on the diversity of macroalgal epifauna, more extensive research on the feeding behaviour of macroalgal epifauna is necessary.

**Acknowledgements**

The authors are grateful to the Director, CSIR-National Institute of Oceanography, for his support and encouragement. This is NIO contribution no: 7214.

**Conflict of Interest**

There is no conflict of interest.

**Author Contributions**

Both the authors have contributed equally.
References


IMCHEN & EZAZ: EPIFAUNA OF SARGASSUM SEAWEED


