

ВОДНА ФЛОРА І ФАУНА

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К. САДУХАН,

Національний центр прибережних досліджень, Міністерство наук про Землю,
Центр польових досліджень, Мандапам, Індія
e-mail: sadhukhan.1985@gmail.com

С. ЛАККАКУЛА,

Відділ прикладної фікології та біотехнології,
Станція досліджень морських водоростей,
Центральний науково-дослідний інститут солі та морських хімікатів,
Мандапам 623519, Таміл Наду, Індія

Т. ШУНМУГАРАЙ,

Національний центр прибережних досліджень, Міністерство наук про Землю,
Ченнаї 600100, Індія

М.В. РАМАНА МУРТІ,

Національний центр прибережних досліджень, Міністерство наук про Землю,
Ченнаї 600100, Індія

ПЕРШЕ ПОВІДОМЛЕННЯ ПРО ОБРОСТАННЯ ЧЕРВОНОЮ ВОДОРІСТЮ *HALYMENIA* SP. КАМ'ЯНИСТИХ КОРАЛІВ НА МІЛКОВОДНИХ КОРАЛОВИХ РИФАХ УЗБЕРЕЖЖЯ ЗАТОКИ ПАЛК, ІНДІЯ¹

Масовий розвиток червоної водорості роду *Halymenia* С. Agardh на кам'янистих коралах на мілководних коралових рифах узбережжя затоки Палк (Індія) спостерігали у березні 2024 р. Це створювало загрозу для виживання коралів, які утворюють рифи, а також для асоційованої з ними біоти. Ця знахідка вважається першим повідомленням про масовий розвиток *Halymenia* sp. на коралових рифах затоки Палк в районі Таміл Наду. Дослідження проводили на рифі Ведхалай у затоці Палк, який добре відомий наявністю живих коралів. Під час дослідження площа покриття, що формується живими коралами, в середньому становила $34,5 \pm 15,6$ %. При цьому частота трапляння обростання *Halymenia* sp. на живих і мертвих формах бентосних угруповань становила 80,19 % ($n = 313$). Ця макроводорість заселяла живі колонії чотирьох видів коралів, а також мертві корали. Після ретельного дослідження 313

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колоній було виявлено, що *Halymenia* sp. вразила 38,65 % живих і 61,35 % мертвих колоній коралів. Встановлено, що такі види коралів як *Porites* (60,94 %), *Favites* (66,67 %), і *Dipsastraea* (71,43 %) значно постраждали від цієї червоної водорості. Домінування макроводоростей на живих рифах завдає серйозної шкоди кам'янистим коралам. Це зменшує здатність коралів до відновлення через надмірне заростання субстрату та сприяє розвитку мікробної інфекції на рифах, про що свідчать попередні дослідження.

Ключові слова: *Halymenia* sp., макроводорості, обростання, коралові рифи, затока Палк.

Introduction

Coral reefs are the most complex and diverse ecosystems on earth, which provides several benefits to the coastal population in terms of shoreline protection, livelihood (fisheries and tourism), and cultural services. However, over the few decades coral reefs have been threatened by climate change impacts (coral bleaching and ocean acidification) and several anthropogenic disturbances (overexploitation of reef resources, marine pollution, and destructive fishing practices) [5, 6, 9, 14, 20]. Macroalgal overgrowth can have a direct or indirect impact on important coral reef ecosystems through microbial promotion, allelopathy, abrasion and shading [3]. Phase shifts from coral-dominated to coral depleted or algal-dominated reefs have occurred on many reefs due to the development of fleshy macroalgae [16, 22, 27, 32]. The red macroalgae, which overgrow coral species are *Kappaphycus* sp. [1, 10], *Chondria* sp. [33], and *Ramicrosta* sp. [7, 8]. However, so far, there is no report of *Halymenia* sp. to overgrow or form blooms in Indian coastal waters. This can be considered as the first observation of *Halymenia* sp. overgrowth of corals in the natural ecosystem. Earlier [23] it was reported the use of *Halymenia* sp. on corals under the experimental trails within an aqua tank to determine the effect of nutrient enrichments on competitive interactions between a hard coral, macroalgae and a sea anemone at Nanwan Bay, Southern Taiwan. *Halymenia* C. Agardh, a marine red algal genus of the family Halymeniaceae, is one of several species-rich red algal genera with 80 known species [12]. This red alga has long been a subject of attention due to its many applications, including food additive, skincare ingredient, nutritional supplement, and cosmetic agent [13, 31]. But excessive growth of the seaweed *Halymenia* sp. in a coral reef substrate has not been reported earlier from the reef system.

In this regard, the purpose of this study was to assess the extent of *Halymenia* sp. development on the colonies of live and dead corals in Palk Bay coastal waters, as well as to assess possible potential risks, which could have long-term implications for the entire marine ecosystem.

Material and Methods

Palk Bay coast has a diversified habitat and productive ecosystem that is comprised of estuaries, salt marshes, mudflats, mangroves, sea grass, seaweeds, and coral reefs. Palk Bay water is rich in marine resources, which include 16 species of mangroves, 302 species of seaweeds, 580 species of fishes (55 economically important fish species), 186 species of birds, and more than 344 species

of other marine faunal taxa [4, 21]. Palk Bay reef is a shallow water patch reef within the depth range of 2–7 meters and has an average live coral cover of only 30.8 %, which is quite lower than other reefs of India [28]. Palk Bay has five coral reef sites: the Vedhalai Reef, Munaikadu Reef, Mandapam Reef, Vadakkad Reef, and Olaukuda Reef, of which the Vedhalai has the maximum live coral coverage compared to other reef sites of Palk Bay [24, 28]. It cannot be overstated how vital the region's marine resources are in providing sustainable livelihoods. From fisheries production to seaweed cultivation, these resources are valuable assets that must be protected and nurtured for future generations. The coastal communities in Palk Bay also depend on coral-associated fisheries resources for their daily livelihoods, which encourage them to exploit reef resources unsustainably by inshore fishing practices [26].

During the routine health monitoring studies of coral reefs on the 16th March of 2024 and 4th April of 2024, plenty of fleshy and floppy red seaweeds were found to have overgrown the benthic community structure of the Vedhalai reef of Palk Bay (Site coordinates: N09°17.687'; E79°06.946' and N09°17.680'; E79°07.016') (Figure 1). Specimens were collected and preserved in wet (70 % alcohol) and dry conditions and kept in NCCR Mandapam Field office for future reference (Registration N NCCR/MFRC/058). The identification was confirmed from the earlier literature of [18] and algal database [12]. A 20 meter long line intercept transect (LIT) was employed at five numbers in affected sites of the Vedhalai reef to estimate the benthic cover, which was categorized into live cover, dead cover with algae, and other dead forms (sand, rubbles, and silt). A total of 30 numbers of Quadrat (1 m²) was employed randomly on the reef to estimate the percentage of occurrence of *Halymenia* sp. on live and dead corals, and also to measure the rate of *Halymenia* sp. overgrowth based on coral species. The present study mainly documents the first report of *Halymenia* sp. overgrowth in Indian reefs. Therefore, rapid observational data have been provided here and continuous monitoring is underway to provide comprehensive data on the impact of *Halymenia* sp. overgrowth on the shallow water coral reefs of Palk Bay. The photographs of LIT, Quadrat studies and videos were also documented by using GoPro HERO11 handheld action camera (Figure 2). The coral species photographed during the study were identified up to the genus level from the earlier literature [36, 37].

Results and Discussion

The study revealed that the red seaweed, *Halymenia* sp., proliferated on the benthic substrate of Palk Bay reef at an alarming rate, and also grow on live corals, dead corals, and rocks (Figure 3). This rapid growth has led to a significant reduction in the live coral cover, which indicates a severe negative impact on the coral reef ecosystem. The findings of this study suggest that *Halymenia* seaweed species has the potential to cause considerable damage to the coral reef, which could have long-term implications for the entire marine ecosystem. An estimation of benthic community structure revealed average live benthic cover in the Vedhalai reef as 34.5±15.6 %, dead coral with algae 52.1±15.4 %, and other dead cover as 13.4±7.0 % (Table 1). A total of 313 live and dead colonies

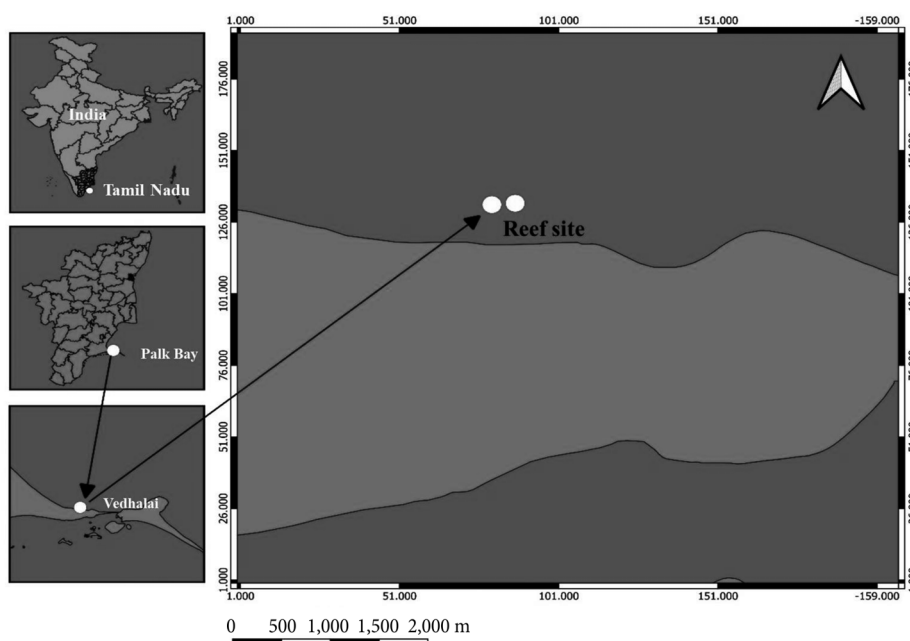


Fig. 1. Study area map with two GPS locations showing the transect and Quadrat area covered in between these two sites

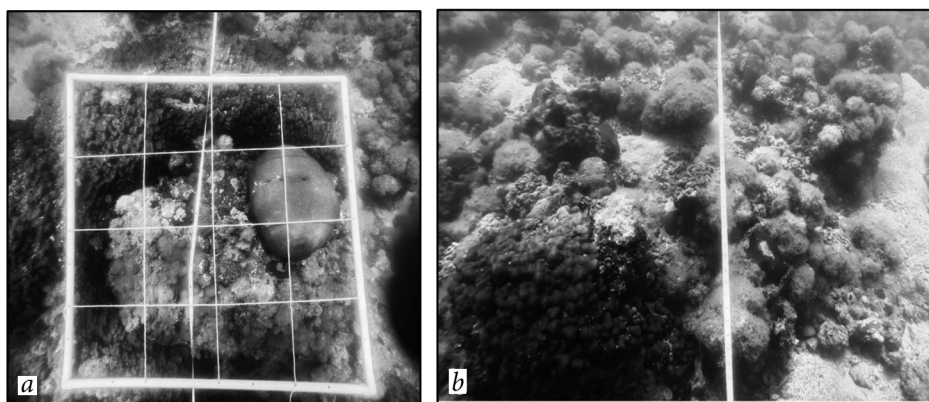


Fig. 2. Methods used for sampling: *a* — Quadrat method; *b* — LIT method

were assessed, of which 251 colonies were affected by the *Halymenia* seaweeds that estimated percentage of overgrowth by this alga as 80.19 %. Among the 251 colonies, 97 live colonies were overgrown by the seaweeds, which constitutes 38.65 % of prevalence of overgrowth on the live corals, whereas 61.35 % of dead corals were overgrown by *Halymenia* sp. (Figure 4). Among the coral genera, *Porites* (60.94 %), *Favites* (66.67 %) and *Dipsastraea* (71.43 %) were highly affected in the study sites (Table 2). Macroalgae severely threaten coral tissue, directly impacting it through overgrowth, chemical effects, abrasion, and shado-

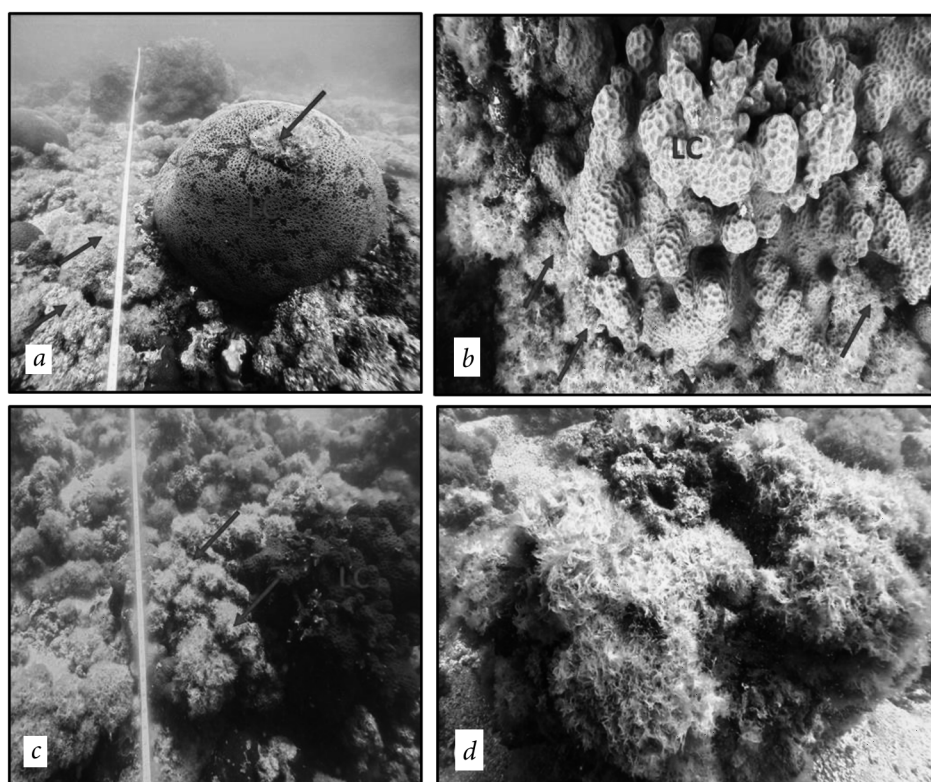


Fig. 3. Proliferation of *Halymenia* sp. on live (LC) and dead corals: a — *Dipsastraea* sp.; b — *Porites* sp.; c — *Favites* sp.; d — dead corals

wing [34]. It is essential to take action and address this issue to protect the health and longevity of coral reefs. They also increase coral microbial activity, serve as a vector for possible infections, and hinder the regeneration of coral tissue [2]. Coral community dynamics monitored continuously and several seasonal

Table 1

Details of benthic cover (mean \pm SD) using LIT method at study sites

T	LC	DCA	Other dead
T1	26.4	65.6	8.0
T2	47.8	34.7	17.5
T3	52.7	42.4	4.9
T4	14.9	70.6	14.5
T5	30.7	47.1	22.2
Mean	34.5	52.1	13.4
SD (\pm)	15.6	15.4	7.0

Note. T — transect; LC — live coral cover, DCA — dead corals with algae; Other dead — rubbles, sand, rock; SD — standard deviation

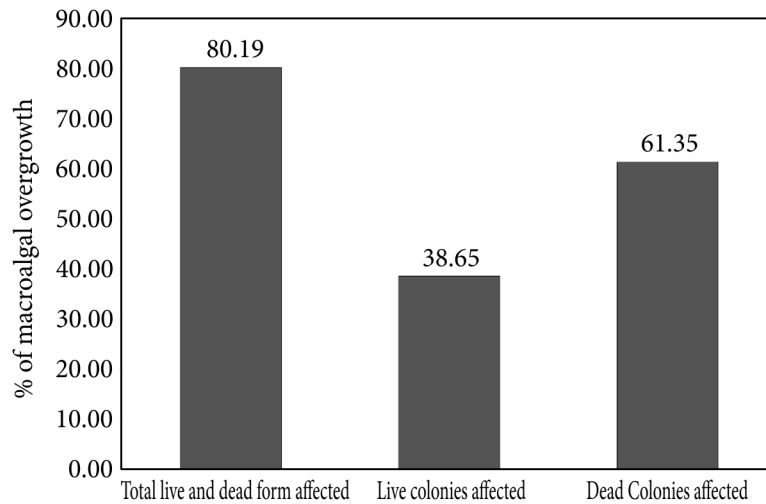


Fig. 4. Frequency of occurrence of *Halymenia* sp. overgrowth on benthic substrate

macroalgal blooms by *Caulerpa* sp., *Turbinaria* sp., *Lyngbya* sp. and *Kappaphycus alvarezii* were earlier documented from the Gulf of Mannar and Palk Bay reefs [1, 25, 29, 30]. The present investigation has provided evidence that the red alga *Halymenia* sp. is overgrowing coral colonies in Indian coral reefs, marking the first recorded instance of this phenomenon. Since the Palk Bay reef is connected to the Gulf of Mannar Marine National Park, this algal overgrowth could be extended to the Gulf of Mannar reefs. This finding has significant implications for the region's coral reef health and conservation efforts. The potential expansion of this algal overgrowth threatens the already stressed coral colonies in the area. Although *Halymenia* sp. is reported from Indian coastal waters, there are neither reports of bloom generation from these waters, nor from any other reefs worldwide. *Halymenia* sp., a marine red alga genus of the family Halymeniaceae, is popularly known for its traditional food and medicinal values from countries across Asia and Europe. Further research is necessary to understand the underlying causes of this incidence and develop effective manage-

Table 2

Species-specific estimate of overgrowth by *Halymenia* sp.

Coral species	Total colonies surveyed	Affected colonies	Percentage of colonies being affected
<i>Acropora</i> sp.	16	9	56.3
<i>Dipsastraea</i> sp.	49	35	71.4
<i>Porites</i> sp.	64	39	60.9
<i>Favites</i> sp.	21	14	66.7
Dead corals	163	151	94.5

ment strategies to mitigate the spread of *Halymenia* sp. and its impact on coral reef ecosystems.

Few species of this red alga genus have different biological activities such as anti-coagulant, antitumor, antibacterial, hypocholesterolemic, and antiaging properties. In a recent research [17], it has been found that *Halymenia dilatata* collected from Palk Bay region of the Rameswaram Island has the larvicidal activity of its crude methanolic extracts, which were actively screened for their biocontrol potential against major insect pests *Aedes aegypti*. The red seaweed genus *Halymenia* is a species rich taxon, which comprised of 80 known species [12]. The morphological characteristics of the *Halymenia* sp. investigated are as follows: the thallus is solitary, fleshy, foliose, gelatinous brownish to dark red in appearance (Figure 5 *a, b*). Young blades of the thallus are irregular in outline and a bright brown stripe is present on the surface of the blade. The outer cortex of the thallus is thick and polygonal cortical cells with reticulated plastids were observed under the microscope (Figure 5 *c, d*). Cell layers in between outer and inner cortical cells are arranged in anticlinal rows. Macroalgal overg-

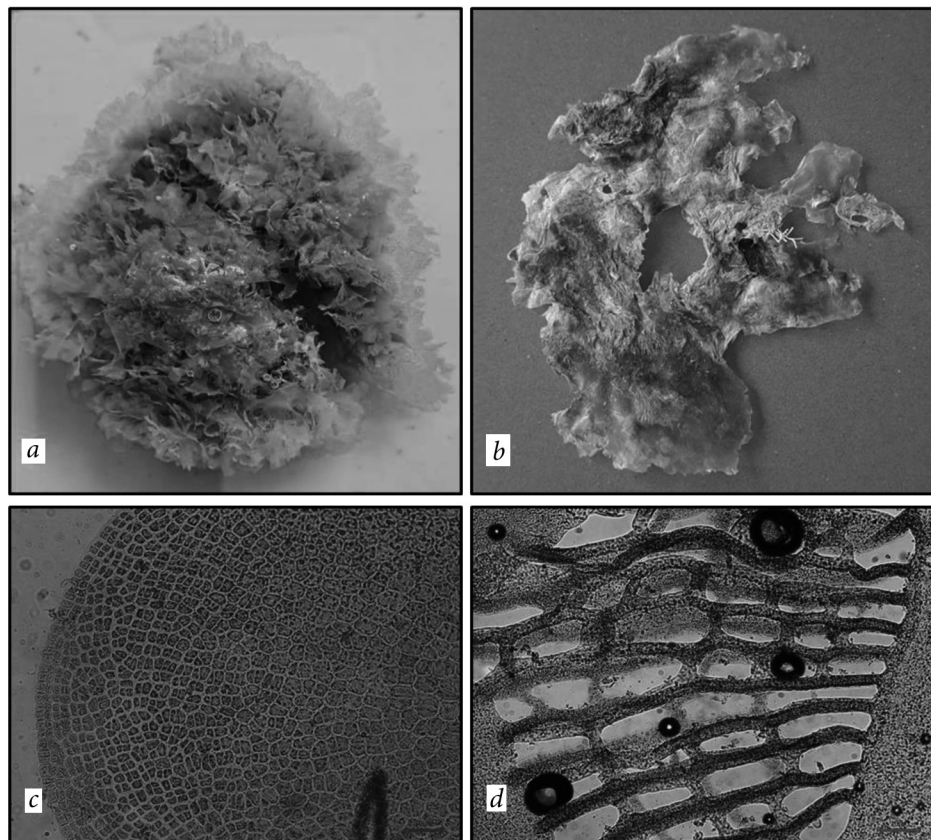


Fig. 5. *Halymenia* sp.: *a* — field photograph of the seaweed *Halymenia* sp.; *b* — specimen preserved in dry conditions at the NCCR Mandapam office; *c* — outer cortical cells of the thallus with reticulated plastids; *d* — cross sectional view of young blade showing the cell layers arranged in anticlinal rows

rowth depends on several factors such as nutrient enrichment in the water, competition of algae with live corals in degraded reefs and overfishing of herbivore fishes from the reef ecosystem [11, 15, 16]. The Palk Bay region is unprotected by law, which encourages fishermen to practice inshore fishing and exploit the reef resources, which could be a reason for the herbivore density depletion in Palk Bay reefs. The annual occurrence of coral bleaching in the Gulf of Mannar and Palk Bay [19, 20] limits the possibility for coral species to recover and provides a favorable substrate for macroalgae to overgrow stony corals. Present study also revealed that dead coral substrate is highly overspaced by algae followed by the live colonies of *Favites* sp., *Dipsastraea* sp., and *Porites* sp. (Figure 3). The macroalgal bloom by *Caulerpa taxifolia* in the Gulf of Mannar and Palk Bay reefs causes an annual reduction of live coral cover at a rate of 4 % during 2013 and 2014 [25]. Bioinvasive red algal species *Kappaphycus alvarezii* also invades the Gulf of Mannar reef and causes the reduction of live coral cover at a rate of 9.1 % in Valai Island and 3.9 % in Thalairi Island [1]. Present study also revealed a high rate of *Halymenia* sp. overspace on live and dead reefs; however the death of coral species was not recorded during this time. Therefore, continuous coral reef health monitoring is underway to understand the cause of the *Halymenia* sp. overgrowth and the rate of progression and damage to the reef sites of Palk Bay.

Despite of having pristine reef ecosystem and rich marine biodiversity, Palk Bay reef is not protected by law and therefore, Palk Bay reef is highly vulnerable to degradation due to local anthropogenic threats as well as natural threats over the few decades which results in reduction of stony coral species diversity from 63 to 26 [10, 28, 35]. The reef also faces a serious issue regarding the depletion of herbivores due to the overexploitation of marine resources from Palk Bay reefs [26]. In addition, *Halymenia* sp. proliferation in Palk Bay reef has the potential chance of overspacing the benthic substrate, altering coral species composition, and reducing the reef resilience in the future. As reefs undergo shifts from coral to algae alternate states, knowledge of algal-coral competitive interactions is necessary to understand current reef dynamics and predict future trends.

Conclusion

The present study provides an overview of the *Halymenia* sp. overgrowth on reef substrate from Palk Bay reefs, which could lead to change macroalgal dominated reef if the ecological process favor the macroalgae to grow rapidly. However, till date direct macroalgal management options are very limited. Furthermore, macroalgal removal through manual or mechanical 'weeding' on small local scales and/or the targeted release of large herbivorous invertebrates is now increasingly being discussed or trialed. In Palk Bay, wild harvesting of *Sargassum* sp. is encouraged for industrial applications by local people. As *Halymenia* sp. also has biological and chemical potential in pharmaceutical and food industries, we suggest this species may also be harvested and utilized for further industrial applications. This approach would help to reduce the risks prone to coral settlement and to substantially control the proliferation of this

species. Along with physical removal of macroalgal species, reef restoration of resistant coral species in shallow water reefs could be feasible choice to restore the degraded reefs. The present study also concludes that as the *Halymenia* sp. bloom is first time observed in the coastal waters of Gulf of Mannar and Palk Bay, detail monitoring on the cause of algal overgrowth and coral health is required in future.

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K. Sadhukhan,

National Centre for Coastal Research (NCCR), Ministry of Earth Sciences (MoES),
Mandapam Field Research Centre,
Mandapam Camp, Ramnathapuram District, India
e-mail: sadhukhan.1985@gmail.com

S. Lakkakula,

Applied Phycology and Biotechnology Division, Marine Algal Research Station,
Central Salt and Marine Chemicals Research Institute,
Mandapam 623519, Tamil Nadu, India

T. Shunmugaraj,

National Centre for Coastal Research (NCCR), Ministry of Earth Sciences (MoES),
Velachery Tambaram Road, Chennai 600100, India

M.V. Ramana Murthy,

National Centre for Coastal Research (NCCR), Ministry of Earth Sciences (MoES),
Velachery Tambaram Road, Chennai 600100, India

FIRST REPORT OF RED ALGA *HALYMENIA* SP. OVERGROWTH OF STONY
CORALS AT SHALLOW WATER CORAL REEFS OF PALK BAY COAST, INDIA

A fleshy red alga of the genus *Halymenia* C. Agardh rapidly attained alarming levels of benthic coverage, including stony corals, in shallow water reefs of Palk Bay, during March 2024 and posed a serious threat to the survival of reef-building corals and their associated marine biota. This finding is considered as the first report of *Halymenia* sp. blooms in the coral reefs of Palk Bay regions of Tamil Nadu. The study was conducted at the Vedhalai reef of Palk Bay, which is well known for its live coral cover. During the study, average live coral cover was recorded as 34.5 ± 15.6 %. In this case, the frequency of occurrence of *Halymenia* sp. cover on live and dead forms of benthic communities accounted for 80.19 % ($n = 313$). This macroalga invaded live colonies of four coral genera and dead corals. After a thorough investigation of 313 colonies, it was found that *Halymenia* sp. affected 38.65 % of live colonies and 61.35 % of dead corals. Among the coral species, *Porites* (60.94 %), *Favites* (66.67 %), and *Dipsastraea* (71.43 %) were highly affected by this foliose gelatinous red alga. Macroalgal dominance in live reefs causes severe harm to stony corals. It reduces the coral species' recovery capability due to overgrowing benthic substratum, prevents fresh recruitment to the reefs, and promotes their microbial infection, as evidenced by previous studies.

Keywords: *Halymenia* sp., macroalgae, overgrowth, coral reefs, Palk Bay.