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Leaf reddening in seagrasses of Andaman and Nicobar Islands

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Abstract: Leaf reddening is well documented in terrestrial angiosperms, but has rarely been reported in seagrasses. So far leaf reddening of seagrasses has been documented in 15 seagrass species. For the first time here we recorded the reddening of two seagrass species (*Halophila ovalis* and *Thalassia hemprichii*) from Andaman and Nicobar Islands. Leaf reddening patterns varied from small-patched to band-like on the centre of the leaves. Similar to terrestrial angiosperms, leaf reddening in seagrasses may relate to enhanced production of anthocyanins after exposure to one or more stressors.

Resumen: El enrojecimiento foliar está bien documentado en las angiospermas terrestres, pero raramente ha sido reportado en pastos marinos. Hasta ahora el enrojecimiento foliar ha sido documentado en 15 especies de pastos marinos. Por primera vez aquí registramos el enrojecimiento en dos especies de pasto marino (*Halophila ovalis* y *Thalassia hemprichii*) de las Islas Andamán y Nicobar. Los patrones de enrojecimiento foliar variaron desde manchas pequeñas a un tipo de bandas en el centro de las hojas. Al igual que en las angiospermas terrestres, el enrojecimiento foliar en los pastos marinos puede estar relacionado con un aumento en la producción de antocianinas después de la exposición a uno o más agentes estresantes.

Resumo: O avermelhamento foliar é bem documentada em angiospermas terrestres, mas raramente tem sido relatado nas ervas marinhas. Até agora, o avermelhamento foliar de gramíneas marinhas tem sido documentada em 15 espécies de ervas marinhas. Pela primeira vez, aqui registamos o avermelhamento de duas espécies de gramíneas marinhas (*Halophila ovalis* e *Thalassia hemprichii*) das ilhas Andaman e Nicobar. Os padrões de avermelhamento da folha variaram detectando-se desde as pequenas manchas para as bandas no centro das folhas. Da mesma forma que para as angiospérmicas terrestres, o avermelhamento da folha nas gramíneas marinhas pode estar relacionado com o aumento da produção de antocianinas após a exposição a um ou mais factores de stress.

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Leaf reddening is the expression of red or purple coloration in otherwise green leaves (Novak & Short 2010). In terrestrial plants this phenomenon is caused by the accumulation of anthocyanins and is quite common and well documented (Lee & Gould 2002). Although the phenomenon of leaf reddening has received more attention among terrestrial angiosperms it is considerably less understood in seagrasses. In seagrasses this phenomenon was first observed in Australia and described in various ways. For instance, McMillan (1983) reported this phenomenon as occurrence of "small, purplish or reddish-brown leaves" in *Halodule uninervis* and *Halophila ovalis*. Abal *et al*. (1994) reported "pink coloration" in *Halophila ovalis* and *Zostera capricorni*. Fyfe (2003, 2004) described it as "red immature leaves and dark bronze adult leaves" of *Zostera capricorni.* Initially leaf reddening in seagrasses was considered a localized phenomenon in Australia, but recently Novak & Short (2010) concluded that the phenomenon is wide-spread, occurring in 15 species from the intertidal and shallow subtidal waters of the Tropical Atlantic, Tropical Indo-Pacific, and Temperate Southern Oceans bioregions. Anthocyanins have been considered the responsible molecules for the red coloration in seagrass species (Fyfe 2004; McMillan 1983) and it has been suggested that the functional role of reddening in seagrasses is an adaptation to high ultraviolet (UV) levels (Abal *et al*. 1994) and protection of leaves from excess visible radiation (Fyfe 2004). The functional role of anthocyanins in leaves is still uncertain and researchers have suggested that anthocyanins may be multifunctional (Novak & Short 2010).

As seagrasses generally occur in intertidal and shallow waters they are exposed to stressors like enhanced visible and/or UV light exposure, water temperature extremes, and/or exposure to air at low tide (Novak & Short 2010). Though the exact cause of leaf reddening in seagrasses is still unknown, Trocine *et al*. (1981) suggested that there is a link between enhanced UV radiation and reddening of seagrass leaves based on his observation of reddish methanol-water fractions after exposing *Halophila engelmannii* to increased levels of UV-B in the laboratory. Recently, Novak & Short (2011a) reported that leaf reddening in *Thalassia testudinum* is caused by high concentrations of anthocyanins, is associated with physiological and morphological attributes, and acts as a sunscreen since red leaves were able to maintain high effective quantum yields at high light intensities. Novak & Short (2011b) experimentally demonstrated that exposure to UV-B induces anthocyanin accumulation and red coloration in green-leafed shoots and contributes to the maintenance of high levels of photosynthesis in red-leafed shoots of *Thalassia testudinum*. But in India the phenomenon of leaf reddening in seagrasses has not been recorded. Moreover, seagrass beds are poorly understood in India compared to other similar ecosystems, such as mangroves and seaweedbeds (Jagtap *et al*. 2003).

Situated between 6° N to 14° N and 92° E to 94° E, the Andaman and Nicobar Islands (ANI) are bestowed with varied sheltered coastal habitats suitable for seagrass growth. Of the 14 seagrass species reported from India, 9 species of seagrass are reported from Andaman and Nicobar Islands. To date, only a few studies have been carried out in seagrasses of ANI and India (Ansari 1984; Ansari *et al.* 1991; Das 1996; Jagtap 1987, 1991, 1992, 1996, 1998; Jagtap *et al.* 2003; Jagtap & Untawale 1981; Ramamurthy *et al.* 1992; Sathe & Raghukumar 1991; Thangaradjou *et al.* 2010; Untawale & Jagtap 1989). However, previous researchers have not mentioned leaf reddening in seagrasses. For the first time here we report the leaf reddening of two seagrass species in South Andaman.

Swimming surveys were conducted at low water at five sites to investigate leaf reddening of seagrasses in ANI during May - July 2010. Of the five sites, four sites were located in and around Port Blair, South Andaman (Marina Park, Haddo seashore, Chidiya Tapu and Wandoor) and one site was located in Nancowry Island (Kamorta jetty). In this survey we identified eight seagrass species belonging to six genera. Among the eight seagrass species, we observed leaf reddening in two seagrass species *Halophila ovalis* (at three sites) and *Thalassia hemprichii* (at one site). Leaf reddening patterns varied from small patches to band like on centre of the leaves.

Halophila ovalis exhibited three kinds of leaf reddening pattern (Fig. 1) (Band like, small patches and reddening in petiole) which is quite different from the previously reported leaf redde-

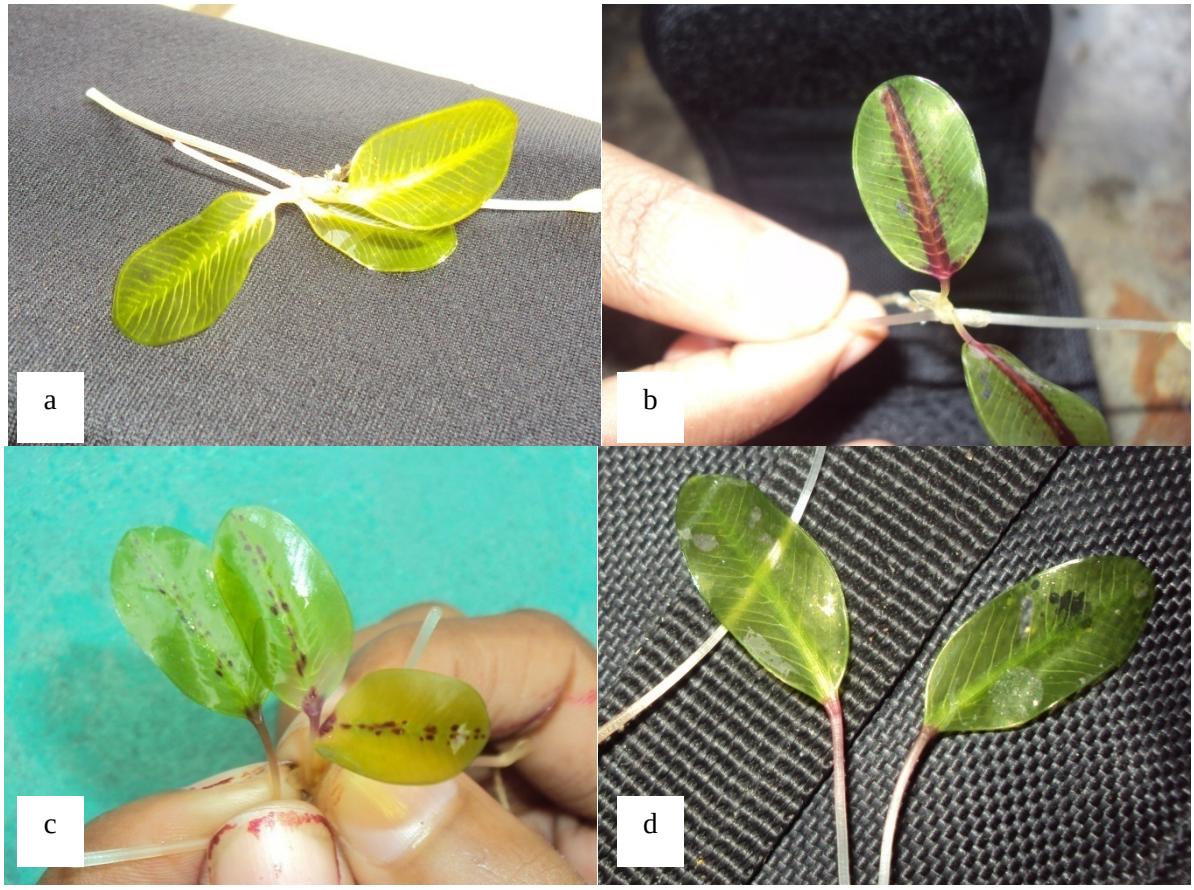

Fig. 1. Leaf reddening in *Halophila ovalis* (a) normal leaves, (b) leaves with band like reddening, (c) leaves with small patches of reddening, (d) leaves with reddening in petiole.

Table 1. Documented leaf reddening in *Halophila ovalis* and *Thalassia hemprichii* from Novak & Short (2010).

Species	Location	Comments
Halophila ovalis	Green Is., Queensland, Australia; Moreton Bay, Australia; Shark Bay Australia; Zhulin, Bei Hai, and Xincun Bay, Hainan, China; Wadi Gemal, Egypt; Andavadoaka and Ifaty, Madagascar; Inhaca Island, Mozambique; Pulau Bada, Myanmar; Ngchesar, Babelthraup, Palau; Bantangas and Guimaras, Philippines; Haad Chao Mai Marine Park, Trang and Panwa Bay, Phuket, Thailand; Ha Long Bay, Vietnam	Intertidal sand and mud flat: uniformly purple leaves, purplish spots, purple between cross veins, striations, purple petiole, or central vein pigmentation in parts of the meadow
Thalassia hemprichii	Inhaca Island, Mozambique; Green Is., Queensland, Australia	Intertidal and sand flat: purple longitudinal stripes or purple spots in parts of the meadow

Table 2. Observed leaf reddening of *Halophila ovalis* and *Thalassia hemprichii* in Andaman and Nicobar Islands.

Species	Location	Comments
Halophila ovalis	Port Blair, South Andaman: Haddo seashore, Wandoor, and ChidiyaTapu	Intertidal sand and mud flat: red band on the centre of leaves, purplish spots on both sides of central vein, pigmentation in petiole.
Thalassia hemprichii	Port Blair, South Andaman: Marina Park	Intertidal and sand flat: complete reddening of leaf

Fig. 2. Leaf reddening in *Thalassia hemprichii* (a) normal plant (b) leaves with complete reddening, (c) & (d) comparison of normal leaf and leaf with reddening.

ning in *H. ovalis* (Tables 1 & 2). *Thalassia hemprichii* exhibited complete leaf reddening (Fig. 2); this is also different from the previously reported leaf reddening pattern in *T. hemprichii* (Tables 1 & 2). This observation supported the findings of Novak & Short (2010) - "leaf reddening is not isolated to Australian sea-grasses in the temperate Southern Oceans bioregion, but is also found in numerous seagrass species growing in shallow subtidal and intertidal areas of the tropical Atlantic and tropical Indo-Pacific bioregions". Most interestingly we observed the leaf reddening of seagrasses in all the sites around Port Blair, where the anthropogenic stresses are high (Chidiya Tapu, Marina Park and Wandoor are important tourist locations and Haddo seashore is near the Harbour and most of the town's sewage is discharged in this area). In the above mentioned sites tourism activities like boating, snorkeling and diving take place throughout the year. They are also characterized by the presence of coastal stabilization measures such as bulkheads, sea-walls, revetments, sand-bags and groynes. These activities are significant sources of sediment loading and can cause eutrophication, two important human impacts on sea-grasses world-wide (Bjork *et al.* 2008). Nancowry is the southern part of ANI and it is comparatively free from anthropogenic stresses. As the factors responsible for the induction of leaf reddening in seagrasses are poorly understood (Novak & Short 2011a) and leaf reddening is considered an adaptive mechanism (Fyfe 2004; McMillan 1983), it is suspected that along with UV and high intensity visible light, anthropogenic stress might be the cause for the leaf reddening in seagrasses. However, additional systemic studies are needed to increase our under-standing of the occurrence and distribution of leaf reddening in seagrasses, as well as to determine its causes, costs, and protective functions.

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