

## Discovery of large mangrove-dwelling *Elysia* species in the newly-grown mangrove habitats, Pattani, Thailand

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### Abstract

The first report on the occurrence of the remarkable and highly ephemeral sap-sucking sea slugs *Elysia bangtawaensis* and *E. leucolegnote* from the newly grown mangrove forest in the Prince of Songkla University, Pattani, Thailand. *Elysia* was surveyed by exploring from the inner part to the floor front zone of the mangrove area. The various sizes and numbers of *E. bangtawaensis* were clumped distribution in some microhabitats throughout the area, while *E. leucolegnote* was distributed in the floor front zone of the area. Both species have similar external morphological characters with conspecifics previously reported in Pattani Bay, Gulf of Thailand, Andaman Sea, and elsewhere. *E. bangtawaensis* showed a surprisingly larger size than previously reported. This discovery is important in identifying the changes in ecosystems within the area to support the diversity of organisms that will come to use the area in the future.

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### 1. INTRODUCTION

Mangrove areas are recognized as an important junction between land and sea. This coastal ecosystem not only protects from coastal erosion and disasters but also harbors rich biodiversity that provides food, shelter and energy for animals, and humans (Hajisamae and Yeesin, 2014). Tropical mangroves are highly productive and are important contributors to the food chain and food web (Bouillon and Connolly, 2009). They provide habitat for nesting and breeding and provide food for myriad crustaceans, fish, marine animals, and wild birds. Pattani Bay is known as an extraordinary biological system, which two major rivers, the Pattani River and the Yaring River,

parapodia bordering the posterior part of the foot, which it imparts with Plakobranchus and Thuridilla. The species have neither a shell nor oral tentacles. Most species of *Elysia* are smaller than 20 mm, but a few are larger, measuring between 25-50 mm. Several large species living in turbid water in mangrove forests have just been found in most recent 20 years. The first large mangrove, *E. leucolegnote*, described by Jensen in 1990, was found in Hong Kong. Then, Swennen (2011) discovered *E. bangtawaensis* Swennen, 1998, from the Gulf of Thailand. *Elysia* dwell in the mangrove forest. They play an important ecological role in food webs. *Elysia* feed on algae, and they also provide food for other organisms in the trophic levels. In the future, information on *Elysia* and their

flow directly to Pattani bay (Hajisamae and Yeesin, 2014). The rapid sedimentation process in Pattani Bay has resulted in the natural formation of new shallow mudflats along the 2-mile-long shoreline of the mouth of the Pattani River, which has not yet been colonized by any plant species (Yeesin *et al.*, 2017).

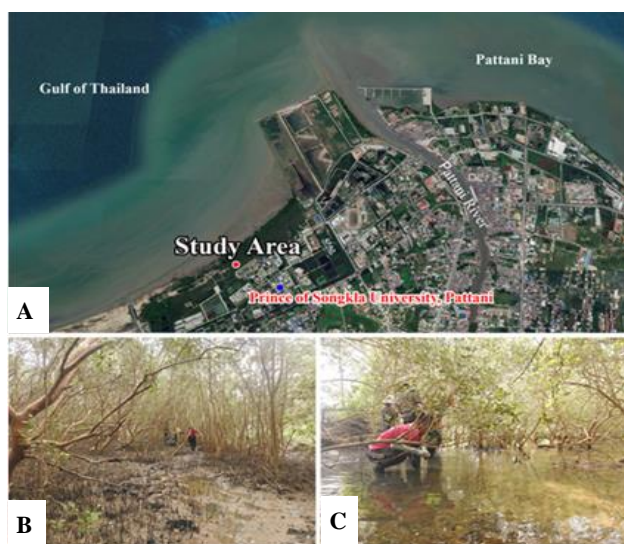
Sacoglossian opisthobranchs have no jaws, and their radula comprises of a single, longitudinal row of teeth, the older teeth being held in an ascus during their life (Pruvot-Fol, 1954). The classification of Sacoglossa was last investigated by Jensen (1996). *Elysia* was put in order Sacoglossa, family Plakobranchidae (formerly Elysiidae), the largest family. *Elysia* being the most speciose genus. The clearest feature of *Elysia* is the presence of wing-like relation to environmental factors can be used as an indicator of environmental quality.

*Elysia bangtawaensis* and *E. leucolegnote* can retain their chloroplasts for months; *E. bengalensis* and *E. singaporensis* could not be tested. Long-term functional chloroplast retention has only been found in the Plakobranchioidea, but several large *Elysia* species do not have this property (Händeler *et al.*, 2009). In Thailand, the occurrence of *Elysia* spp. in newly-grown mangrove habitats has never been reported. Prior to this first report only the family Onchidiidae in the PSU mangrove area by Yeesin *et al.* (2017). This study was to report the presence of Large *Elysia* species and their associated ecology in newly grown mangrove areas.

## 2. MATERIALS AND METHODS

### 2.1. Study area

The study area located in the northern part of Prince of Songkla University, Pattani campus, in southern Thailand (6°52'59.33"N, 101°13'59.67"E), is connected to Pattani Bay and South China Sea (Figure 1). The mangrove forest has a size of about 53.56 hectares (0.54 km<sup>2</sup>). *Avicennia marina* (Forssk.) Vierh., planted in 1987 is the dominant species. The mangrove areas are a continuous coastal ecosystem on the west side of Pattani bay, Pattani province. The site was surveyed on 20 January 2021, after the rainy season when low tide. From the survey, *Elysia* was found in a swampy patch inside the mangrove forest, with a water depth of about 5-30 cm, approximately 10 m<sup>2</sup> in area. The light can penetrate the ground. The sea slugs were found clumped.



**Figure 1:** Study area. A, B, C: The newly grown mangrove forest in the north of Prince of Songkla University, Pattani province, Thailand, *Avicennia marina* (Forssk.) Vierh. is a dominant species. B: Dry habitat when low tide; C: Swamp mangrove forest out intertidal zone.

### 2.2. Sampling method

Large Mangrove-Dwelling *Elysia* was surveyed by exploring the mangrove forest from the innermost part of the forest to the mud flat, the floor front zone of the area. In the field, specimens of the large mangrove-dwelling *Elysia* species were observed in morphology and coloration appearance. *Elysia* species were identified based on Swennen (2011). Fifty individuals of *E. bangtawaensis* were randomly sampled for measuring body length and width using vernier calipers, and weight with a portable digital weighing scale. And follow the same measurement step for only one individual from the field survey of *E. leucolegnote*.

### 2.3. Environmental factors

This study of environmental factors provides preliminary data to explain factors affecting the presence

of 2 species of sea slugs in the area. Water temperature and dissolved oxygen (DO) were measured by using a multiparameter checker, YSI model 550A. Salinity, pH, total dissolved solids (TDS), and conductivity were measured by using a multiparameter checker, YSI model Pro 1030. Illuminance was measured by using Digital Lux Meter TES-1332A. Air temperature and humidity were measured by using SK-110 TRHII Type 5 Brand SATO. Transparency depths were measured by using a Secchi disc. Sediment organic matter was measured in the laboratory by a method of Dichromate Oxidation and FAS Titration method (Walkley and Black, 1947).

## 3. RESULT AND DISCUSSION

### 3.1. Species account

From the researcher's previous survey, 2 species of *Elysia* were found. First recorded in 2018 began to explore a few medium sizes of *E. bangtawaensis*, and in 2020 began to see a few small sizes of *E. leucolegnote*.

*Elysia leucolegnote* K. R. Jensen, 1990 (Figure 2)

Live colorations. – Narrow white line along parapodial borders, frequently privately enlarged. Some have not many white spots on reno pericardial conspicuousness, and occasionally with a few white spots on dorsal sides of parapodia. White triangle on head associated with a white line over dorsal sides of rhinophores. Tips of rhinophores and regularly likewise posterior side of renocardial prominence lack tubules of the digestive gland (Swennen, 2011)

Remarks. – Only 2 small *E. leucolegnote* are in a small pool under the shade of the *Avicennia marina* (Forssk.) Vierh. tree, between the bare mudflat area, the outer side of the forest, and the mangrove forest (5 m tree height). Body size measured from a single complete one, showing size with length 10 mm width 5 mm, similar in size to those surveyed from other areas.

*Elysia bangtawaensis* Swennen, 1998 (Figure 3)

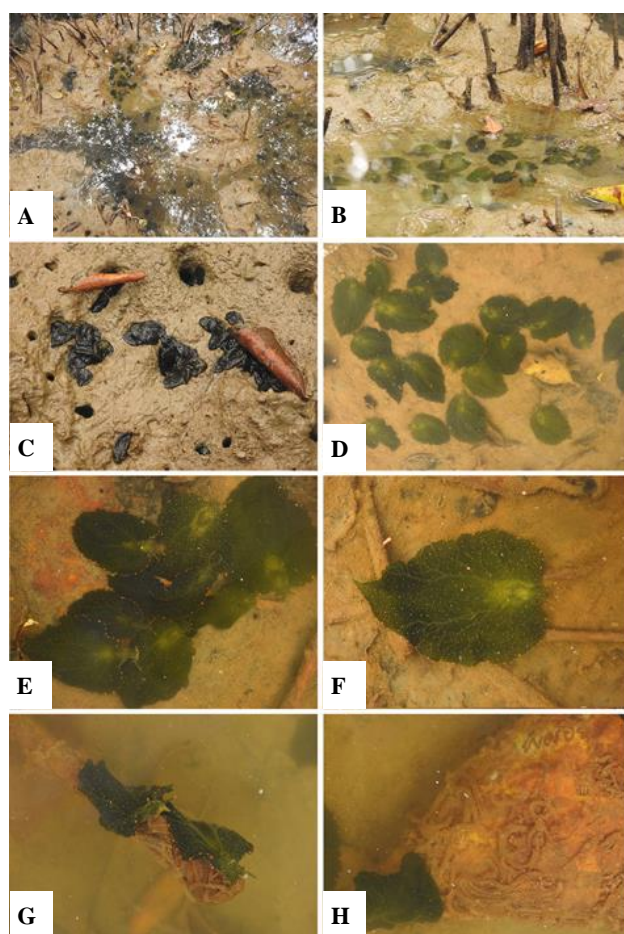
Live colorations. – marked rosy/bright red to orange, glandular spots along parapodia borders. White spots of various sizes and fine rosy bits/dots scattered on the dorsal and ventral parts, together with the foot base. Green ductules of the digestive gland organ cover up the renal part in many specimens; they don't arrive at the tips of rhinophores. Tips are pale or shaded by white and orange spots (Swennen, 1998; Swennen, 2011)

Remarks. – Fifty individual slugs of various sizes, lengths ranging between 15.1-54.1 mm, width 9.05-35.05 mm, and weight 0.075-1.240 g, were measured in 2 sites where a great number of *E. bangtawaensis* of more than 500 individuals were distributed in brackish water depth <5 cm. The first site was approximately 10 x 18 m<sup>2</sup> in area, and the second site was approximately 1.5 x 20 m<sup>2</sup>. They were distributed in some microhabitats such as a small discontinuous channel, small tide pool, mangrove crab borrows, and footprints (8-100 individuals per colony)

(Figure 3A-E). All sites were covered by *Avicennia marina* (Forssk.) Vierh. (3-6 m tree height). Several *E. bangtawaensis* were observed laying eggs string together on a wood stick and plastic bag (Figure 3G-H).



**Figure 2:** *Elysia leucolegnote*. Specimens photographed in the field in a footprint and small one showed some damage to the posterior part presumably by a predator.



**Figure 3:** *Elysia bangtawaensis*. Specimens were photographed in the field. A, B, D, E, F: An individual with partially relaxed parapodia displaying characteristic leaf-shaped bodies in brackish water; C: Slugs exposed on mud surface at low tide; G: Egg string laying on a wood stick; H: Egg strings, with a laying slug, on a plastic bag.

### 3.2 Environmental factors

Environmental factors in the newly grown mangrove after rain season on January 23, 2021, the factors in this study indicate the condition of the area in which the presence of slugs (Table 1).

**Table 1:** Environmental factors in PSU mangrove forest (newly grown mangrove), Pattani province, Thailand (January 23, 2021: 10.00-11.30 am)

Factors	Volume Data
<b>Soil</b>	
Organic matter (%)	2.33-4.73
<b>Water</b>	
Temperature (°C)	25.2-27.5
pH	7.33-7.61
Dissolved Oxygen (mg/L)	2.07-3.11
Total Dissolved Solid (mg/L)	14,610-17,287
Conductivity (mS/cm)	23.11-27.67
Salinity (ppt)	13.5-16.5
Dept (cm)	3-7
Transparency (cm)	The light hits the ground
<b>Air</b>	
Humidity (%)	45-69.8
Temperature (°C)	28.6-33.0
Illuminance (Lux)	44,000-182,000
<b>Mud thickness</b>	
	soft mud and thickness of about 1-10 cm
<b>Dominant plant</b>	
	<i>Avicennia marina</i> (Forssk) Vierh Height: mostly less than 3-4 m (girth at breast height less than <21 cm) and 5-6 m (girth at breast height less than 30-48 cm) are the minority.

This study site is a huge sedimented land that has been claimed de facto as the territory of Prince of Songkla University of Pattani. In 1987, the university initiated a plan to crop mangroves flora along the shoreline of Pattani bay. Previously, the intertidal mudflat zone which sediment kept is now an approximated 40-hectare living space of established mangroves. It has been well-managed as a mangrove study center and the habitat provides a feeding site and sheltered protected area for many organisms. The previous studies in this area have reported only shrimps, crabs, and gastropods (Yeesin *et al.*, 2017).

*Elysia leucolegnote*, in Thailand, length up to 41 mm, alive specimen (Swennen, 2011), length of 6-18 mm Indonesia had a total length more than in this study (Mardiansyah and Wardiatno, 2020). *E. bangtawaensis* in this study seem larger than those previously reported from other sites. Swennen (1998, 2011) reported lengths of 35–52 mm, and widths less than twice their length. In India, Mandovi estuary, Goa (central west coast) recorded lengths of 35–40 mm and 10–15 mm widths (Jagtap *et al.*, 2009). Moreover, on Capao Island, their population was found to be high density (50 – 400 individuals/m<sup>2</sup>) with lengths of 30-40 mm and 25-30 mm width (Shenai-Tirodkar *et al.*, 2012).

In this study, *Elysia bangtawaensis* were widely distributed in microhabitats such as a small discontinuous channel, small tide pool, crab borrow, footprints, etc., while *E. leucolegnote* exhibits limited distribution, only found in a small pool under the shade of the tree, between a bare mudflat area and mangrove forest.

*Elysia leucolegnote* was first reported outside Hong Kong by Swennen (2011). In Thailand, this species is widely distributed in the Gulf of Thailand (Chumphon, Surat Thani, Nakornsrihammarat, and Pattani), and the Andaman Sea (Ko Libong in mangrove and mangrove east of Krabi (Swennen, 2011). It was subsequently reported from Darwin Harbour, Northern Territory, Australia (Bourke, 2016), the Verde Island Passage, Philippines (Sanchez-Escalona, 2019), and Biak Numfor, Papua, Indonesia (Mardiansyah and Wardiatno, 2020).

*Elysia bangtawaensis* is now known to be widely distributed in turbid intertidal and mangrove habitats (Swennen, 1998). Other than the original mangrove forest, our team also found them in the newly planted mangrove areas, and in the fishing boat moorage at Rusamilae village, salt pond canal and salt pond around Pattani bay. This species is also distributed in other coastal areas of Thailand both in the Andaman Sea and the Gulf of Thailand (Swennen, 2011). It has also been reported in Straits of Malacca and Johor State, Malaysia, South Pacific Ocean, Australia, and Queensland (Swennen, 2011), Darwin Harbor, Northern Territory, Australia (Bourke, 2016), and from Mondovi estuary, Goa, west coast of India (Shenai-Tirodkar et al., 2012). Last, in the wild, the biogeographic extent distribution of *E. bangtawaensis* and *E. leucolegnote* is found in Indo-Malay and Australasia regions. (Olson et al., 2001; Jensen, 2007; Yonow, 2008).

The ecological parameters in the habitat of *Elysia bangtawaensis* in Mondovi estuary, Goa, west coast of India, reported by Shenai-Tirodkar et al (2012), from Nov. 2007 - Oct. 2008, are 26.1-34 °C air temperature, 25-30 °C water temperature, 6-7.59 pH, and 0.08- 29.57 ppt. While in this study are 28.6-33 °C air temperature, 25.2-27.5 °C water temperature, 7.33-7.61 pH, and 13.5-16.5 ppt. The environmental conditions from Mondovi estuary, Goa, west coast of India do not greatly differ from this study. The continuous study of *Elysia* and their related environmental parameter will provide clearer information on factors affecting *Elysia* species. These can be used as essential information for further studies.

In Thailand, the primary food of *Elysia leucolegnote* and *E. bangtawaensis* appears to be *Boodleopsis cf. pusilla* which grows in high mud between mangrove roots (Swennen, 2011). In Hongkong, Jensen (2003) reported that they feed on *Boodleopsis pusilla*, *Cladophora*, *Cladophoropsis*, and *Enteromorpha* in the laboratory. During the survey, we saw these algae growing and expanding in the area.

However, the presence of both sea slug species in this area must be monitored in parallel with the ongoing reporting of environmental factors in all topics according to the methodology of this study. As well as may need to study more about soil composition, minerals, and various organic matter. These factors are directly related to the growth of algae, which are the food of the sea slugs. In

addition, the area where the presence of these two species of sea slugs is found in Pattani bay, as reported by a previous study, should be selected for a comparative study will allow for a better understanding of the biology and ecology of these two species. Furthermore, sea slugs and other related organisms should be surveyed throughout the mangrove forests and mudflats, which may be spread from nearby areas or be carried by sea currents during the monsoon season. Because this mangrove forest is quite an environment, suitable for living organisms. Which new species of sea slugs including other living things found in the area, will increase the biodiversity that makes this area important to the extent that it must be maintained, protected, and managed as an important natural learning center for everyone in the future. The studies on egg string laying patterns, development of the egg, and the life cycle of a sea slug in the related environmental factors is another interesting subject, adding more information about sea slugs in this district.

#### 4. CONCLUSION

This discovery of *Elysia leucolegnote* and *E. bangtawaensis*, 2 large mangrove dwelling *Elysia* in the newly grown mangrove, previously reported only one species in the family Onchidiidae. It's an important indication that this newly grown mangrove in Prince of Songkla University has changed its ecological characteristics; soil, water, air, mud thickness, and plant until it is suitable for living and capable of supporting wildlife or biodiversity that will appear more in the future. Therefore, it is imperative to plan the management, track, and study more on in various fields.

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