Growth Analysis of the Sea Cucumber *Holothuria* (*Halodeima*) *atra* (Holothuroidea Aspidochirotida) in Seagrass and Seaweed Habitats

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ABSTRACT

The sea cucumber *Holothuria atra* is an ecologically and economically important benthic animal. However, biological and ecological data on growth of *H. atra* in Thai waters are non-existent. Therefore, the present study aimed to obtain and compare growth parameters from length-frequency data of *H. atra* collected from two habitats. Specimens were collected above ground on intertidal seagrass and seaweed beds along the Andaman coast of Thailand in Satun Province. Theoretical von Bertalanffy growth parameters were analyzed using the ELEFAN I program in the FiSAT II software package. Asymptotic length was smaller and growth coefficient was higher in the seagrass habitat than in the seaweed habitat (L_∞ = 32 cm; K = 0.65 year^{-1} and L_∞ = 40 cm; K = 0.55 year^{-1}, respectively). It might be that sea cucumbers in the seagrass habitat survived in the less favorable environment by reaching asymptotic length more rapidly. The more complex structure of the seaweed habitat provides protection and shelter from water movement and low tide stresses. These conditions might be more suitable for growth. The theoretical age at length zero was -0.24 year in the seagrass habitat and -0.27 year in the seaweed habitat. In both habitats, length at birth was around 5 cm. Growth was rapid from age 0-2 years, but slow thereafter, until asymptotic length was reached at around 4 years in the seagrass habitat and 5 years in the seaweed habitat. These findings suggest that different habitats influence the growth of *H. atra*.

Keywords: Habitat type, *Halimeda, Halophila, Holothuria*, Length-frequency, von Bertalanffy growth equation

INTRODUCTION

Holothuria (*Halodeima*) *atra* Jaeger, 1833 is the most abundant and widely distributed species of sea cucumber. From shallow waters to deeper zones, it can be found in all habitats including sand, mud, coral, seaweed and seagrass meadows (Lee *et al*., 2008; Dissanayake and Stefansson, 2010). *H. atra* is ecologically important in the benthic community (Toral-Granda *et al*., 2008; Purcell *et al*., 2016). The species plays a major role in bioturbation and removal of organic matter from sediment, consuming an average of 67-80 g dry weight ind^{-1}·day^{-1} (Uthicke, 1999; Mangion *et al*., 2004). *H. atra* was found to significantly increase total ammonia nitrogen concentrations and sediment dissolution rates (Vidal-Ramirez and Dove, 2016). In addition, *H. atra* is a host for commensal symbionts (Mercier and Hamel, 2005; Riaux-Gobin and Witkowski, 2012). The sea cucumber is also economically important in Asia, being considered a gourmet food in Hong Kong and elsewhere (Anderson *et al*., 2010; Purcell, 2014), and has been reported to possess pharmaceutical properties

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Received 25 April 2021 / Accepted 23 October 2021

as an anti-inflammatory, antiviral, anti-microbial, antitumor, and anticancer agent (Dhinakaran, 2014; Dhinakaran and Lipton, 2014; 2015; Satari *et al*., 2017).

Holothuria atra is one of the 84 common sea cucumber species found in the Indo-Pacific region (Uthicke, 2001). It is considered a high-yielding species that is currently overexploited (Li, 2004) even though it is of low commercial value. As stocks of higher value species were depleted, interest shifted to lower value species. Consequently, *H. atra* is now a target for fishermen (Lovatelli *et al*., 2004; Toral-Granda *et al*., 2008; Anderson *et al*., 2010; Hasan, 2019). It has been heavily harvested for subsistence in the west central Pacific Ocean and is exported to Africa, and to China and other parts of Asia as a medicine and food (Choo, 2008; Purcell *et al*., 2012; Purcell, 2014; Xia and Wang, 2015). In Thailand, the density of sea cucumber populations has been declining in recent years (Viyakarn *et al*., 2020).

Holothuria atra is the most well-known fissiparous holothuroid that can also reproduce sexually by developing gonads, although sexual recruits of *H. atra* have rarely been found in natural habitats (Ebert, 1978; Chao *et al*., 1994; Uthicke, 2001; Indriana *et al*., 2018). The scarcity of recruits from sexual reproduction could be a result of low densities of mature individuals (Chao *et al*., 1994). However, newly-settled and early juveniles of *H. atra* have not been observed in natural habitats. In natural environments, *H. atra* populations are maintained and increased asexually by transverse fission (Uthicke, 2001), which can influence population density, size class, and stability (Chao *et al*., 1994; Lee *et al*., 2008).

Despite these findings, little is known about the biology and ecology of the sea cucumber, or the impact on the benthic community of declining sea cucumber densities. Data are urgently needed to help understand population biology, dynamics, and growth of the sea cucumber and to improve fishery management.

Because there is no easy and reliable method of tagging individuals for long-term observation, the estimation of the growth of sea cucumbers is difficult to manage in situ (Lee *et al*., 2008). Tagging is a difficult technique to use in the field since tags are expelled by the sea cucumber's immunological response and rapid regeneration (Rodríguez-Barreras *et al*., 2016; Fujino *et al*., 2017). Additionally, tags can reduce growth, increase burying behavior, and increase mortality among tagged individuals (Purcell *et al*., 2006; Shiell *et al*., 2006; Gianasi *et al*., 2015). Therefore, the growth of sea cucumbers can best be calculated by fitting length-frequency data to growth models such as the von Bertalanffy growth equation (Glockner-Fagetti *et al*., 2016; Siddique and Ayub, 2019).

In Thailand, biological and ecological data of *H. atra* are non-existent where growth is concerned. The present study aims to obtain growth parameters from length-frequency data of *H. atra* collected from seagrass and seaweed habitats.

MATERIALS AND METHODS

Growth of *Holothuria atra* was investigated within the intertidal zone near Lidee Island, Mu Ko Phetra National Park (6°47'09.7"N, 99°45'56.3"E), which is located in the Andaman Sea off Satun Province, Thailand (Figure 1a and 1b). During the study period, the rainy season from May to October was dominated by the southwest monsoon, and the dry season from November to April was dominated by the northeast monsoon. Salinity varied from 28-35 psu. *Holothuria atra* was common and abundant, with a density of 71.88±3.98 ind 100 m^{-2} (personal observation), and was observed in two habitat types, seaweed and seagrass beds. The calcified green alga *Halimeda macroloba* Decaisne was the dominant seaweed species with 47.02±7.57 thalli·m^{-2}, and *Halophila ovalis* (R. Brown) J.D. Hooker was the dominant seagrass species with 46.80±4.00 % cover (Figure 1c and 1d). The two habitats were around 100 m apart and the estimated area of each habitat was around 1 km^2.

To study the growth of *H. atra*, the length of individuals was observed monthly from November 2018 to March 2020 except during March, May, and August 2019, and February 2020 due to rough weather. Within each habitat, three permanent line transects, 50 m long and 10 m apart, were laid perpendicular to the shoreline of Lidee Yai Island. Specimens of *H. atra* were collected along 1-m strips on both sides of the transects and the length of individuals was measured. From these measurements, length-frequency data (grouped in 2-cm intervals) were analyzed using ELEFAN I in FiSAT II software (Gayanilo *et al*., 2005). The estimates of asymptotic length, L_∞ (cm), and growth coefficient, K ($year^{-1}$), extracted from the data analysis were input to the von Bertalanffy growth equation (Ricker, 1975),

$$L_t = L_\infty[1-e^{-K(t-t_0)}]$$

Where L_t is the total length (cm), t is the individual age (year), and t_0 is the theoretical age at length zero (year), which was obtained from the Pauly empirical equation (1979),

$$\log(-t_0) = -0.3952-0.2752\log L_\infty-1.038\log K$$

The length (L_t) obtained from the von Bertalanffy growth equation was plotted against age to obtain the growth curve for each individual.

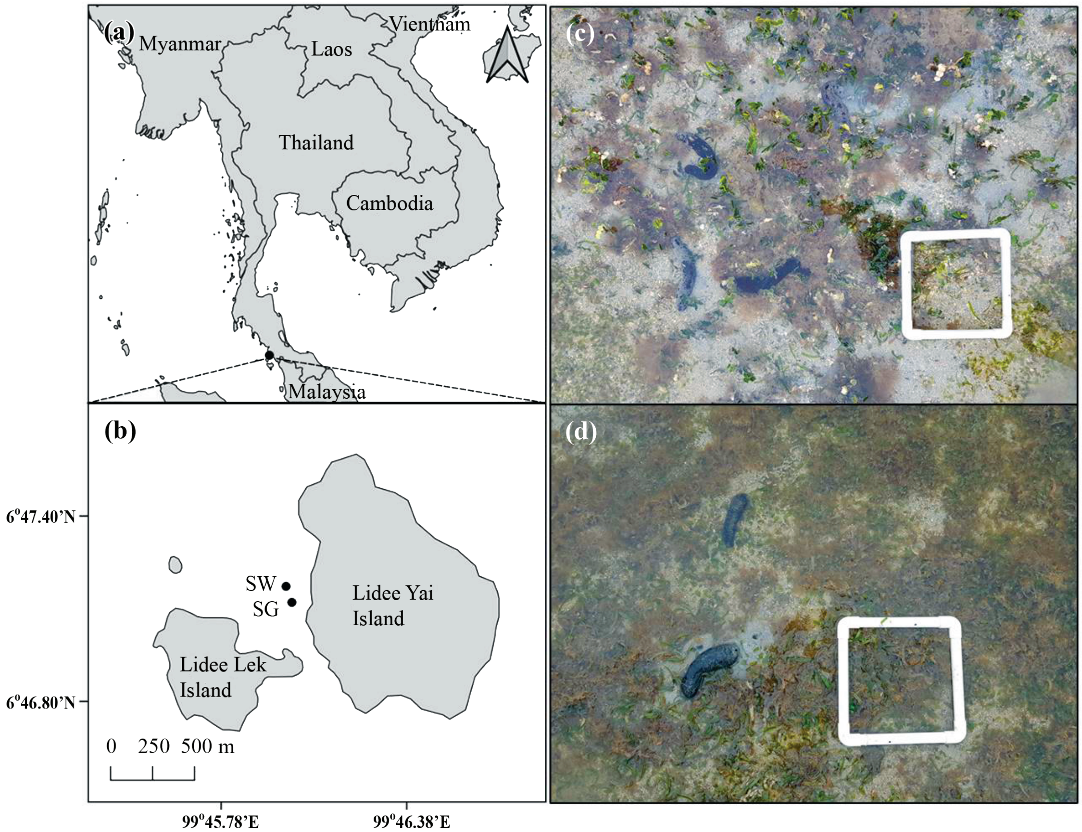

Figure 1. Location of study site in Mo Ko Phetra National Park, in the Andaman Sea, Satun Province, Thailand (a, b). Examples of seaweed habitat (SW, c) and seagrass habitat (SG, d) located between Lidee Yai Island and Lidee Lek Island (b).

RESULTS AND DISCUSSION

The average length of *Holothuria atra* was 12.12±0.10 cm in the seagrass habitat and 13.87±0.09 cm in the seaweed habitat. Asymptotic length was smaller and the growth coefficient was higher in the seagrass habitat than the seaweed habitat (Figure 2). In the former, L_∞ = 32 cm; K = 0.65 year^{-1}; and the score function = 0.243: in the latter, L_∞ = 40 cm; K = 0.55 year^{-1}; and the score function = 0.271 (Figure 2). The structure of *H. macroloba* is more complex than the structure of *H. ovalis*. While *H. ovalis* has very thin leaves and short shoots of 1-2 cm, *H. macroloba* produces highly dimensional branching and a large upright thallus of 5-15 cm, (Panyawai *et al*., 2019). The more complex structure of the seaweed habitat provides a better protection for the sea cucumber and more shelter from water movement and low tide stresses such as sunlight, high temperature, and desiccation, (Seeruttun *et al*., 2008; Dissanayake and Stefansson, 2012; González-Wangüemert *et al*., 2013; Setyastuti, 2014; Günay *et al*., 2015). The sea cucumber might survive in the less favorable seagrass habitat by attaining asymptotic length more rapidly (Sparre and Venema, 1989; Morgan, 2012; Siddique and Ayub, 2019). The growth coefficients in this study were slightly lower than the growth coefficient reported by Ahmed *et al*. (2020) from a study carried out in the northern Arabian Sea. They estimated the growth coefficient, K = 0.75 year^{-1}, using length-frequency distributions as we did. Generally, the growth coefficient varied among populations (Sparre and Venema, 1989). Growth coefficients of *Isostichopus fuscus* and *Holothuria arenicola* have been reported, ranging from 0.18 year^{-1} to 0.35 year^{-1} and 0.37 year^{-1} and 0.74 year^{-1}, respectively (Herrero-Pérezrul *et al*., 1999; Nuño-Hermosillo, 2003; Reyes-Bonilla and Herrero-Pérezrul, 2003; Glockner-Fagetti *et al*., 2016).

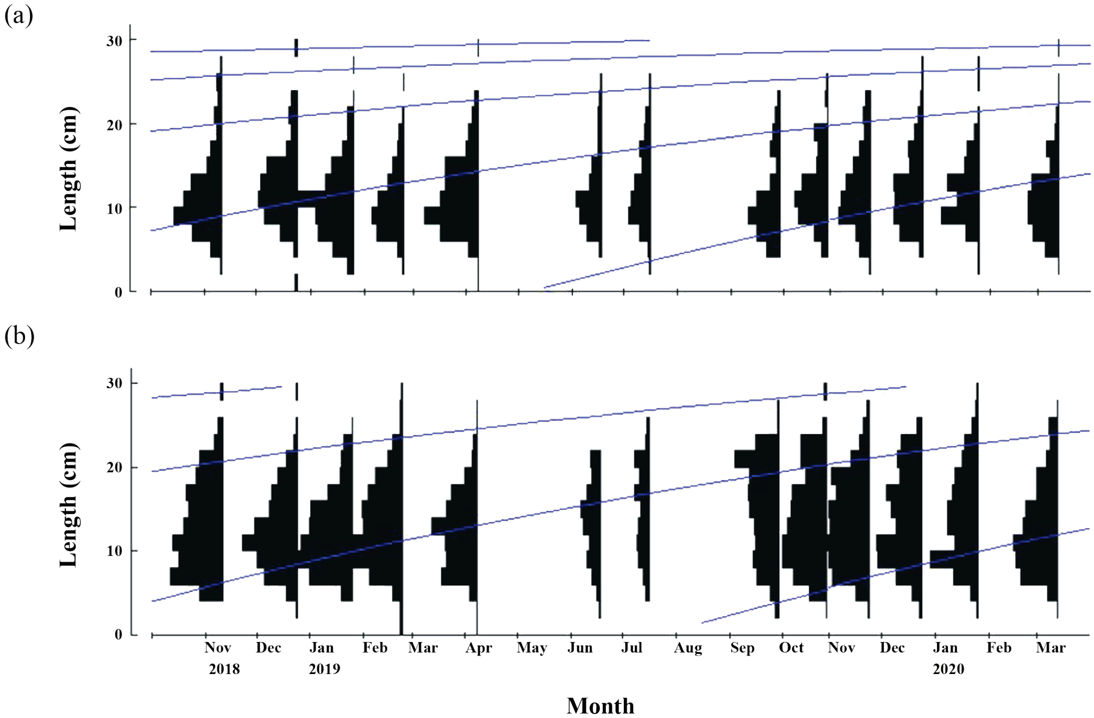

Figure 2. Growth curves (lines) obtained from the von Bertalanffy model using electronic length-frequency analysis (ELEFAN) of length-frequency data of *Holothuria atra* sampled from a seagrass habitat (a) and a seaweed habitat (b).

The theoretical age at length zero was -0.24 year in the seagrass habitat and -0.27 year in the seaweed habitat, but in both habitats, the length at birth of *H. atra* was around 5 cm. This similarity might be a result of asexual reproduction in the shallow, intertidal water since a stressful environment is the triggering factor for asexual reproduction in this species (Ebert, 1978; Harriott, 1985; Chao *et al*., 1993; Conand, 1996; Uthicke, 1997). In this study, *H. atra* grew rapidly from age 0-2 years. After that, growth was slow until the asymptotic length was reached at around age 4 years and 5 years in the seagrass habitat and seaweed habitat, respectively (Figure 3).

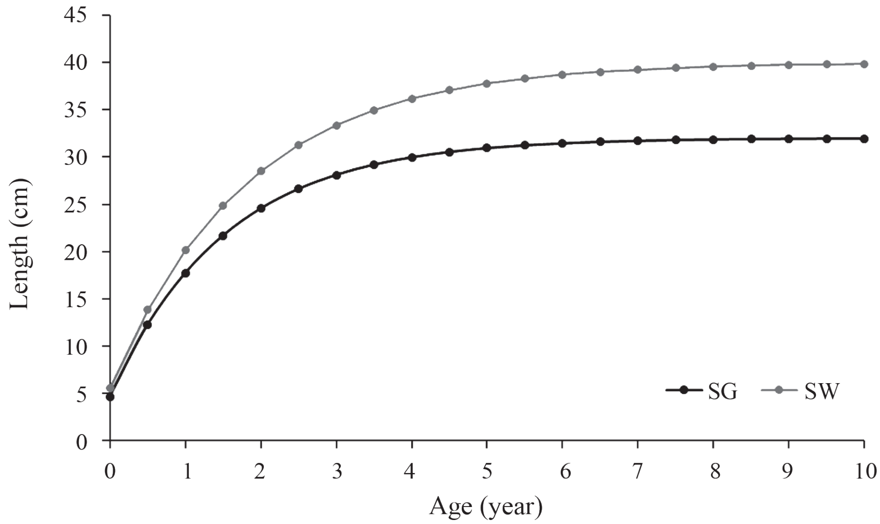

Figure 3. Individual growth curves of *Holothuria atra* in the seagrass habitat (SG) and seaweed habitat (SW).

CONCLUSION

In this study of *Holothuria atra* in a tropical intertidal zone, we demonstrated that asymptotic length was smaller and growth coefficient was higher in a seagrass habitat than a seaweed habitat. It might be that sea cucumbers in the seagrass habitat survived in the less favorable environment by obtaining asymptotic length more rapidly. The more complex structure of the seaweed habitat provides protection and shelter from water movement and low tide stresses. These conditions might be more suitable for growth. These findings suggest that different habitats influence the growth of *H. atra*. Therefore, habitat preservation might be a very important management strategy in maintaining populations of this species.

ACKNOWLEDGEMENTS

This research was supported by the Faculty of Science Research Fund, Prince of Songkla University (PSU) (J.M., Research Grant, 2020, contract no. 163003) and the Faculty of Science Research Fund, Prince of Songkla University (PSU) (V.K., contract no. 1-2562-02-007). We are grateful to Mr. Watana Chaithongkeaw and the Seaweed and Seagrass Research Unit TEAM, Prince of Songkla University, for field assistance. We also thank Mr. Thomas Duncan Coyne for assistance with the English text.

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