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Original Article

Spatial variations in biological aspects of *Hippocampus* spp. in the Gulf of Thailand

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Abstract

The incidental capture of seahorses by fishing trawlers along three different coastlines in the Gulf of Thailand was investigated from July to November, 2014. Two seahorse species, *Hippocampus spinosissimus* and *H. trimaculatus*, were commonly found during the surveys. Higher proportions of *H. spinosissimus* than *H. trimaculatus* were found in both the eastern and southern coasts, whereas *H. trimaculatus* were found in a higher proportion in the central coast. Biological parameters for both species, including their size, dry weight, and reproductive state were significantly different spatially, but the sex ratio was not different as a whole. The most prevalent size classes *H. spinosissimus* in the southern coast were larger than those in the eastern and central coasts. For *H. trimaculatus*, the most prevalent size classes in the central coast were the largest. The findings of this study provide the basic information for future fishery management in the Gulf of Thailand.

Keywords: Gulf of Thailand, *Hippocampus*, spatial variation, size, reproductive state

1. Introduction

The impact of non-selective fishing gears are of international concern for many vulnerable groups of marine animals (Alverson, Freeberg, Murawski & Pope, 1994; Stobutzki, Miller, Heales & Brewer, 2002; Vincent, 1996). Wild seahorse populations are in decline due to their overexploitation by non-selective fishing methods (trawling), degradation of habitats, and environmental changes. *Hippocampus* spp. are listed in Appendix II of the *Convention on the International Trade of Endangered Species* (CITES) in 2002, with implementation in 2004 (Vincent, Foster, & Koldewey, 2011). In addition, 14 seahorse species are listed as threatened on the International Union for Conservation of Nature (IUCN) Red list (IUCN, 2020).

Monitoring of seahorse life history, size composition, sex ratios and reproductive state is critical information for evaluating their population abundance changes and overfishing status, which is needed for management advice for each particular species. Such information has previously been reported for seahorse species in other areas. An assessment of *H. erectus* in the Gulf of Mexico detailed the mean standard length (SL), sex and stage ratio, and reproductive state during 1998 and 1999 (Baum, Meeuwig & Vincent, 2003). In West Africa, the life history of *H. algiricus* and *H. hippocampus* were surveyed during 2012 and 2013 (Cisneros-Montemayor, West, Boiro & Vincent, 2016). A study conducted in the Gulf of Mannar, along the southeast coast of India, during 2001, detailed the mean SL of male, female, and juvenile members of *H. trimaculatus*, *H. spinosissimus*, *H. kuda*, and *H. fucus* (Murugan, Dhanya, Sarcar, Naganathan, Rajagopal, & Balasubramanian, 2011; Salin, Yohannan, & Mohanakumaran Nair, 2005). Likewise, the size distribution of seahorse species in the Central Philippines during 1996–1998, 2002–2004, and 2005–2010 has also been reported (Yasué, Nellas, Panes, & Vincent, 2015). In Vietnam, seahorse studies were conducted during 1995, 1997, and 1999 and reported the mean SL and weight of the species encountered (Giles, Ky, Do Hoang, & Vincent, 2006; Meeuwig, Hoang, Ky, Job, & Vincent, 2006). The mean SL of *H. trimaculatus*, *H. spinosissimus*, and *H. kuda* was reported for seahorses along Peninsular Malaysia following a survey conducted during 2001 (Choo & Liew, 2003). The life cycle of *H. kelloggi*, *H. spinosissimus*, and *H. trimaculatus* was studied in 2015, reporting the size, mean height, sex ratio, and frequency of mature male and female seahorses (Lawson, Foster, Lim, Chong, & Vincent, 2015).

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Unfortunately, there is limited information on the life history and biology of seahorse species in Thailand. There have been basically three categories of recent seahorse researches in Thailand (2010–2019): (1) seahorse population genetics of *H. kuda* (Panithanarak, Karuwancharoen, Na-Nakorn & Nguyen, 2010), *H. spinosissimus* (Wilaisorn, Boonyong, & Swatdipong, 2018), and *H. mohnikei* (Panithanrak and Karuwonjaroen, 2019); (2) distribution, range, habitat and threats of *H. mohnikei* in Southeast Asia (Aylesworth, Lawson, Laksanawimol, Ferber, & Loh. 2016), and (3) seahorse trading has been examined for a long period of time because Thailand has been reported as being a large supplier in the global seahorse trade (Foster, Wiswedel, & Vincent, 2016; Vincent, 1996). In those latter studies, the data was recorded from both interviews and underwater observational surveys to examine the species, volumes value and structure, and fishery pressure (Aylesworth, Phoonsawat, & Vincent, 2018; Kuo, Laksanawimol, Alyesworth, Foster, &Vincent, 2018; Laksanawimol, Petpiroon, & Damrongphol, 2013; Loh, Tewfik, Aylesworth, & Phoonsawat, 2016; Perry, Lunn, & Vincent, 2010). However, no studies have examined dried seahorse specimens, which are the important materials in the trade routes, to derive data on the life history and biology of the seahorse species in Thailand.

The coastal waters of Thailand are comprised of two seas, the Andaman Sea of the Indian Ocean located along the west side of Thailand and the Gulf of Thailand of the Pacific Ocean located to the east. The Gulf of Thailand has shallow water depths of 30–85 m, with an average depth of 58 m, and covers an area of approximately 300,860 km^2 with 1,840 km of coastline, which can be divided into the three areas of (i) the eastern coast (Chachoengsao, Chonburi, Rayong, Chanthaburi, and Trat provinces), (ii) the central coast (Samut Prakan, Bangkok, Samut Sakhon, Samut Songkhram, Phetchaburi, and Prachuap Khirin Khan provinces) and (iii) the southern coast (Chumporn, Surat Thani, Nakhon Si Thammarat, Phatthalung, and Songkhla provinces).

In total seven seahorse species have been recorded all year round in Thai waters (Lourie, Foster, Cooper, & Vincent, 2004; Perry *et al.*, 2010), where *H. kelloggi*, *H. comes*, and *H. histrix* are only found in the Andaman Sea waters, whereas *H. kuda, H. spinosissimus*, *H. trimaculatus*, and *H. monikei* are found in both the Andaman Sea and the Gulf of Thailand. For *H. mohnikei*, it has been occasionally observed in the eastern coast waters along Chonburi province during September to November and in Phang-nga and Trang provinces (Andaman Sea) during February to April (Aylesworth, Lawson, Laksanawimol, Ferber, & Loh, 2016). Whereas *H. kuda*, *H. spinosissimus*, and *H. trimaculatus* are distributed along the coastlines of Chonburi, Rayong, Chanthaburi, and Trat provinces in the eastern coast of Gulf of Thailand (Laksanawimol *et al.*, 2013). During a scuba diving survey, *H. kuda* was found off Kho Tao (Chumporn province), a southern island in the Gulf of Thailand (Loh *et al.*, 2016).

However, there is still poor information on the biology and ecology of seahorse species along the central and the southern Gulf of Thailand coasts. The basic details about the life cycle and biology of these *Hippocampus* spp. are still limited. The aim of this study was to study the variations in biological parameters of *Hippocampus* spp. in the Gulf of Thailand.

2. Materials and Methods

2.1 Study sites

Fishing areas inside the Thai water area in the region of the Gulf of Thailand were composed of five sub-areas (Figure 1) of which three were selected as the study sites in this study as they contained the main docks that trawled different areas of the Gulf of Thailand. Dried seahorse samples were collected from these three main docks in the Gulf of Thailand where most of fishing trawlers usually land. Most trawlers were small-sized commercial fishing vessels (less than 20 gross tonnages) and had a 150–250 km fishing range from their departure docks. Thus, the seahorse samples were collected from each region independently.

The three docks used as collection (study) sites in this study (Figure 1) were the Samae San Dock (Chonburi province) on the eastern coast, the Prachuap Khiri Khan Dock (Prachuap Khiri Khan province) on the central coast, and the Songkhla Dock (Songkhla province) on the southern coast. The study areas have a dry (December to May) and a wet (June to November) season, but the samples were conducted in the wet season (July to November) of 2014.

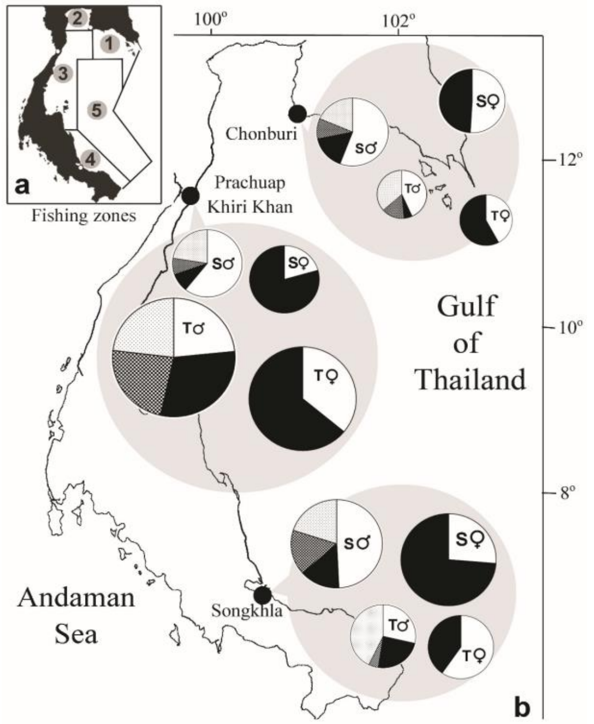

Figure 1. (a) Fishing zone in the Gulf of Thailand and seahorse sampling locations and (b) the proportion of each reproductive state in *H. spinosissimus* (S) and *H. trimaculatus* (T) males and females along the eastern, central, and southern coasts of the Gulf of Thailand. Reproductive states in males consisted of non-brooding ( ), brooding with eggs ( ), brooding with embryos ( ), and embryo-released ( ) states. The states in females were body with ( ) and without ( ) eggs.

2.2 Sampling and data collection

The dried seahorse specimens were sorted and collected by fishing labor on the trawler, ready to sell to local seahorse traders at each dock in each fishing trip. The data of the study were received from six traders (two traders from each dock) who were locally well known and had more than five years of experience in the seahorse trade.

All dried seahorse samples were identified and measured for their SL, which was the sum of the head length (the length from the tip of the snout to the midpoint of the cleithral ring), trunk length, and tail length (the length from the midpoint of the cleithral ring down to the tip of the stretched out tail), as reported by Lourie *et al.* (2004). Their dried weight, sex, and reproductive state were also recorded. The reproductive state of male seahorses was divided into the four categories of (i) non-brooding (empty and taut pouch), (ii) brooding with eggs (pouch full of eggs), (iii) brooding with embryos (pouch full of embryos), and (iv) embryo-released state (empty but distended and wrinkled pouch). The reproductive states of female seahorses were divided into the two categories of body with (i) and (ii) without eggs. In the dried specimens, the eggs in the female body could be obviously observed from the yellow ovaries at the anus.

2.3 Data and statistical analyses

Nine classes of the SL size were defined: ≤ 50, 51–70, 71–90, 91–110, 111–130, 131–150, 151–170, 171–190, and ≥191 mm and the frequency of each class was determined. The minimum, maximum, and mean of the SL and the dry weight of all samples in each area were recorded. Comparison of the mean SL and the mean weight between sexes was performed using the Mann-Whitney test when the samples were not normally distributed and using the Shapiro-Wilk test when the samples were normally distributed. Spatial variations in the *Hippocampus* spp., and their mean SL and weight were analyzed using Analysis of Variance (ANOVA) when the samples were normally distributed and using K-independent tests when the samples were not normally distributed. The sex ratios of *Hippocampus* spp. between the coasts were analyzed using Chi-squared analysis (crosstab statistics). Significance was accepted when P values were <0.05.

3. Results

Table 1 summarizes the values of biological parameters obtained from the study. A total of 3,003 seahorses were collected from the three docks along Gulf of Thailand comprised of two species: *H. spinosissimus* (1,184 seahorses) and *H. trimaculatus* (1,819 seahorses). The proportions of the two seahorse species were different in each area. In the eastern and southern coast, *H. spinosissimus* was more frequent with proportions of 71.5% and 71.1%, respectively, whereas *H. trimaculatus* was more frequent in the central coast at a proportion of 86.3%. In addition, the male:female ratio for both seahorse species along all three coasts was close to 1:1 with no significant variance being recorded (for *H. spinosissimus* χ^2 = 2.319, df = 2, P = 0.314; for *H. trimaculatus* χ^2 = 2.228, df = 2, P = 0.199). Furthermore, the proportions of immature individuals varied across the three areas studied.

Spatial variations in the mean SL of each sex of both seahorse species (*H. trimaculatus* and *H. spinosissimus*) were found during the study. The mean SL in both *H. spinosissimus* males and females along the southern coast were significantly higher than in the other two coasts (F = 21.038, df = 2, P < 0.0001 for males; F = 45.975, df = 2, P < 0.0001 for females). Whereas the mean SL of *H. trimaculatus* in both males and females along the central coast was significantly higher than in the two other coasts (F = 24.943, df = 2, P < 0.0001 for males; F = 39.003, df = 2, P < 0.0001 for females). Furthermore, the size between the sexes in each seahorse species varied in the different areas. The mean SL of *H. spinosissimus* males in the eastern (t = 3.865, df = 348, P < 0.0001), central (t = -6.243, df = 173.263, P < 0.0001) and southern (t = 2.416, df = 575.437, P = 0.016) coasts were significantly higher than females. Whereas, the mean SL of *H. trimaculatus* females along the central coast was significantly higher than in the males (t = 5.823, df = 1397.650, P < 0.0001), but the mean SL between males and females along the eastern (t = 0.171, df = 141, P = 0.865) and southern (t = 0.555, df = 232, P = 0.579), coasts were not significantly different. Moreover, the smallest individuals that were sex distinguishable also varied in each area. For *H. spinosissimus*, the smallest males with a SL of 94.9 mm were found along the southern coast, but the smallest females were 77.1 mm, found at the eastern coast. For *H. trimaculatus*, the smallest males and females were found along the central coast with a SL of 90.5 and 100.1 mm, respectively.

Spatial variations in the mean weight of each sex were found for both seahorse species. The mean weights of *H. spinosissimus* males and females along the southern coast were significantly higher than in the other two coasts (F = 66.263, df = 2, P < 0.0001 for males; F = 50.211, df = 2, P < 0.0001 for females). For *H. trimaculatus*, the mean weight of the males along the southern coast was significantly higher than in the other two coasts (F = 10.969, df = 2, P < 0.0001), whereas the mean weight of the females along the central coast was significantly higher than at the eastern coast with no significant difference along the southern coast (F = 5.911, df = 2, P = 0.003).

Moreover, the mean weight between the sexes of each seahorse species varied in some areas. For *H. spinosissimus*, the mean weight of males along the eastern (t = -4.176, df = 363.628, P < 0.0001) and southern (t = -2.094, df = 576, P = 0.037) coasts were significantly higher than females, but was not different along the central coast (t = 1.645, df = 225.849, P = 0.101). For *H. trimaculatus*, the mean weight of females along the central coast was significantly higher than males (t = 5.294, df = 1390.950, P < 0.0001), whereas the mean weight of males along the southern coast was significantly higher than females (t = -2.025, df = 230.577, P = 0.044), but was not significantly different along the eastern coast (t = 1.052, df = 130.526, P = 0.295).

Figure 1 illustrates the proportion of each reproductive state in the males and females for both seahorse species in each area. The proportion of non-brooding *H. spinosissimus* males were found in relatively similar ratios in all studied regions. Non-brooding *H. spinosissimus* males comprised a high proportion of all males at 56%, 61%, and

Table 1. Species compositions mean SL and mean weight of *H. spinosissimus* and *H. trimaculatus* from trawl landing in the eastern, central, and southern coasts of the Gulf of Thailand

Seahorse species	Coast	Sex	N	Percent of each species in each area	Percent occurrence of immature seahorse in each area	Male: female ratio	Mean standard length (mm) (range)	Mean weight (g) (range)
H. spinosissimus	Eastern	Male	156				134.99 ± 15.86^{*B} (102.02–187.97)	2.74 ± 0.88^{*B} (1.34–6.24)
		Female	212				124.59 ± 20.45^{b} (77.11–175.17)	2.31 ± 1.10^{b} (0.18–5.79)
		Immature	8				70.49 ± 2.80 (65.91–74.24)	0.76 ± 1.11 (0.11–0.45)
		Total	376	71.5	2.13	1:1.36	127.75 ± 20.90 (65.91–187.97)	2.45 ± 1.06 (0.11–6.24)
	Central	Male	102				146.69 ± 17.26^{*A} (104.51–192.95)	2.96 ± 0.93^{B} (1.51–5.52)
		Female	126				134.59 ± 1.93^{b} (103.67–174.98)	3.15 ± 0.93^{b} (1.40–5.90)
		Immature	0				n/a	n/a
		Total	228	13.7	n/a	1: 1.24	140.00 ± 15.73 (103.67–192.95)	3.17 ± 1.84 (1.40–5.90)
	Southern	Male	274				146.68 ± 20.26^{*A} (94.86–223.55)	3.87 ± 1.48^{*A} (1.39–8.29)
		Female	304				142.00 ± 23.20^{a} (84.92–197.02)	3.61 ± 1.48^{a} (0.66–7.75)
		Immature	2				82.32 ± 2.58 (80.50–84.14)	0.78 ± 0.08 (0.72–0.84)
		Total	580	71.1	0.35	1: 1.11	144.16 ± 22.22 (80.50–223.55)	3.78 ± 2.21 (0.66–8.29)
	Overall		1,184					
H. trimaculatus	Eastern	Male	74				146.48 ± 19.61^{B} (103.03–188.54)	3.07 ± 1.48^{B} (1.23–6.80)
		Female	69				147.08 ± 22.40^{b} (103.64–195.85)	3.37 ± 1.84^{b} (0.89–6.95)
		Immature	7				98.59 ± 3.31 (93.97–102.89)	0.73 ± 0.18 (0.40–0.99)
		Total	150	28.5	4.67	1:0.93	144.52 ± 22.85 (93.97–195.85)	3.13 ± 1.70 (0.40–6.95)
	Central	Male	731				155.91 ± 12.66^{A} (90.49–210.53)	3.46 ± 0.84^{B} (0.78–6.24)
		Female	700				160.03 ± 14.10^{*a} (100.12–192.77)	3.71 ± 0.95^{*a} (0.83–6.90)
		Immature	2				80.61 ± 0.95 (79.94–81.28)	1.25 ± 0.59 (0.83–1.67)
		Total	1,433	86.3	0.14	1:0.96	157.82 ± 13.83 (79.94–210.53)	3.58 ± 0.91 (0.78–6.90)
	Southern	Male	105				148.69 ± 17.35^{B} (106.5–202.66)	3.75 ± 1.07^{*A} (1.49–6.46)
		Female	129				150.03 ± 19.15^{b} (100.95–186.83)	3.42 ± 1.39^{b} (0.35–7.72)
		Immature	2				97.92 ± 0.47 (97.59–98.25)	0.66 ± 0.06 (0.62–0.70)
		Total	236	28.9	0.85	1:1.23	149.00 ± 18.86 (97.59–202.66)	3.54 ± 1.28 (0.35–7.72)
	Overall		1,819					

* = Significantly different between sexes (P <0.05); A, B, a, and b = significantly different between areas (P < 0.05).

49% along the eastern, central, and southern coasts, respectively. The brooding males carrying eggs or embryos were highest in proportion along the southern coast (31%) compared to the eastern (26%) and central (17%) coasts. The proportion of embryo-released males was quite similar at each coast, i.e., 19%, 23%, and 20 % at the eastern, central, and southern coasts, respectively.

For *H. trimaculatus*, the males showed a different proportion of each reproductive state from *H. spinosissimus*, with a larger proportion of brooding males, which were more prevalent at the central coast (53%) compared to the eastern (20%) and southern (29%) coasts. Furthermore, a larger proportion of embryo-released *H. trimaculatus* males were found than those observed in *H. spinosissimus* at the eastern (37%), central (23%), and southern (43%) coasts, respectively. For females, high proportions of *H. spinosissimus* females along the central (79%) and southern (74%) coasts were reproductively active (body with eggs), whereas this was 49% along the eastern coast. For *H. trimaculatus* females, 58%, 64%, and 40% along the eastern, central and southern coasts, respectively, were reproductively active.

Each population of both seahorse species displayed a unimodal size distribution. Distribution of the SL size classes of *H. spinosissimus* recorded in the different areas are shown in Figure 2. The most prevalent populations of *H. spinosissimus* males and females in the southern coast were larger (151–170 mm) than in the eastern (111–150 mm) and central (131–150 mm) coasts. However, for *H. trimaculatus*, the largest common size class was found in the central coast (151–170) compared to 131–150 mm in the eastern and southern coast populations (Figure 3).

4. Discussion

There were two seahorse species, *H. trimaculatus* and *H. spinosissimus*, distributed along the eastern, central, and southern coasts of Gulf of Thailand (the west Pacific Ocean) (Lourie *et al.*, 2004). The species composition of *Hippocampus* spp. surveyed from trawler-caught specimens

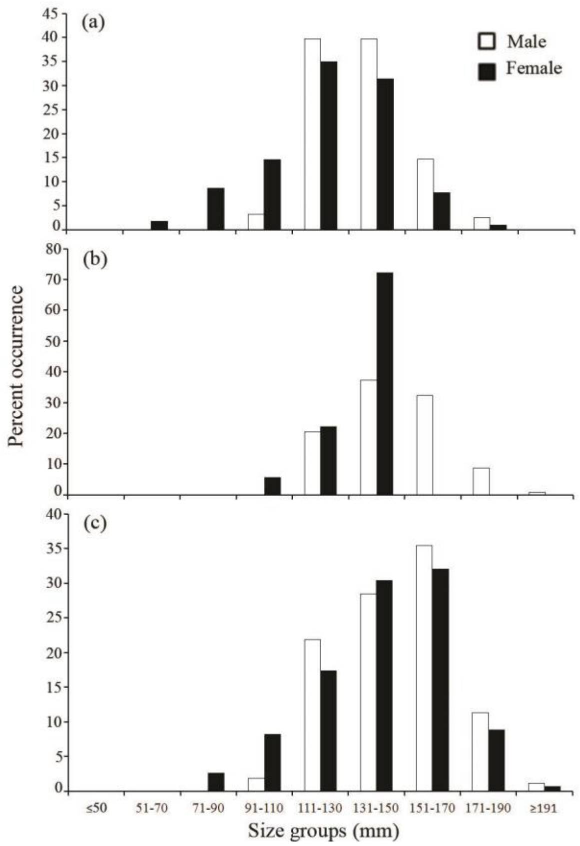

Figure 2. Percent occurrence of each SL size class of *H. spinosissimus* in the (a) eastern, (b) central, and (c) southern coasts of the Gulf of Thailand

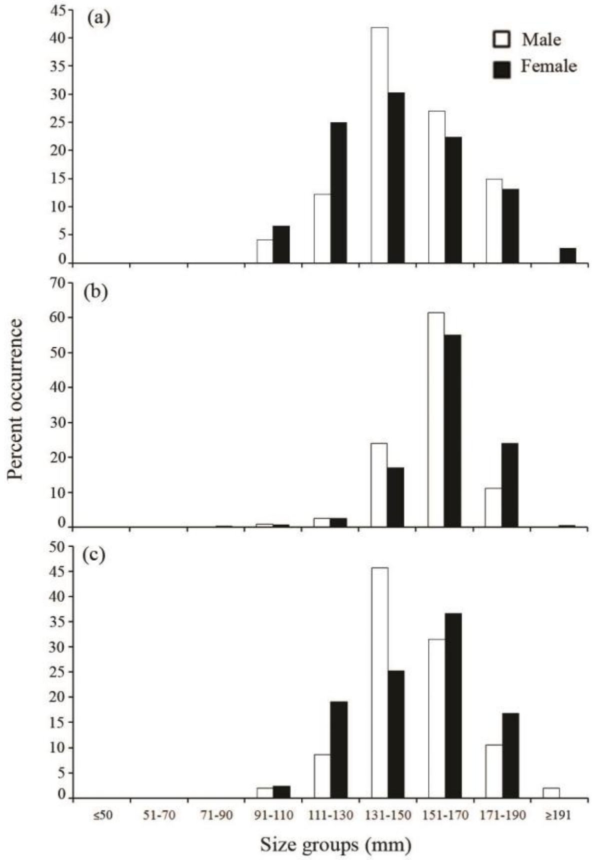

Figure 3. Percent occurrence of each SL size class of *H. trimaculatus* in the (a) eastern, (b) central, and (c) southern coast of the Gulf of Thailand

varied spatially and temporally. Most surveys found that *H. trimaculatus* was likely to be more common than *H. spinosissimus*, with a catch proportion in the range of 62% in Vietnam (Meeuwig *et al.*, 2006) and 33.5–74.1% in Peninsular Malaysia (Choo & Liew, 2003), which are similar to this study in the central coast of Thailand (86.3%). In contrast, the eastern and southern coasts of Gulf of Thailand displayed a different trend where *H. spinosissimus* was the dominant species in the catches at approximately 70%. Temporal changes of the seahorse population were defined in Vietnam and showed that *H. spinosissimus* were more commonly found during the first six months of the year and reversed in the last six months of the year to *H. trimaculatus* (Meeuwig *et al.*, 2006). In the present study, samples were only evaluated in trawler catches from the second half of one year only (July to November, 2014), and so it remains to be established if this temporal (seasonal) change also occurs in the Gulf of Thailand.

Biological parameters of *Hippocampus* spp. varied in both spatial and temporal (but this was not examined in this study) patterns. The mean SL and weight of *Hippocampus* spp. also varied between the sexes. Most *H. trimaculatus* and *H. spinosissimus* males were larger than females, in accord with previous studies, for example *H. spinosissimus* along the west coast of the Peninsular Malaysia and the central coast of the Gulf of Thailand and *H. trimaculatus* along the three coastlines of the Gulf of Thailand. In addition, the mean weight of *H. trimaculatus* and *H. spinosissimus* males was generally greater than that for females in the Gulf of Mannar region, India and the coasts at Peninsular Malaysia (Choo & Liew, 2003; Murugan *et al.*, 2011), as well as along the three coastlines of the Gulf of Thailand (this study). These are probably the effect of male-male competition, where male seahorses compete for a female to mate and larger-sized males have a higher probability of mating success (Vincent, 1994). However, larger females were observed in the eastern and central coasts of the Gulf of Thailand. We found that adult female samples in the areas carried eggs in their body.

Sex ratio variation has been examined in seahorse populations. Female-biased sex ratios of seahorses have also been reported in some areas, such as for *H. erectus* in Chesapeake Bay, Virginia (Teixeira & Musick, 2001) and for *H. trimaculatus* along the south-west coast of the Peninsular Malaysia and the Gulf of Mannar of India (Lawson *et al.*, 2015; Murugan *et al.*, 2011). In the present study, the sex ratio along the three different coastlines of the Gulf of Thailand were essentially equal, similar to previous studies of *H. trimaculatus* in Vietnam, *H. erectus* in the Gulf of Mexico, and *H. brevicep* and *H. whitei* in Australia (Baum *et al.*, 2003; Meeuwig *et al.*, 2006; Moreaua & Vincent, 2004). However, it should be noted that data collection from incidental capture by trawlers is probably affected by a sex-biased catchability, such as for *H. erectus* where males had a higher probability of being caught because they preferred to spend more time in the trawled area (Baum *et al.*, 2003).

Spatial variations in the reproductive state of *Hippocampus* spp. have been recorded. For example, 50% of *H. trimaculatus* and *H. spinosissimus* males in Central Vietnam during 1996–2000 were of a reproductive state, similar to in the Gulf of Mannar, on the southeast coast of India. On the other hand, only about 25% of *H. erectus* males in the Gulf of Mexico were found to be pregnant. The proportions of active reproductive males varied based on the area and time of the year (Baum *et al.*, 2003; Meeuwig *et al.*, 2006; Murugan *et al.*, 2011). In the present research, the proportion of pregnant males varied between the two species and the three coastlines of the Gulf of Thailand that probably depended on the habitat characteristics and food abundance.

Along these three coastlines of the Gulf of Thailand, approximately 20−53% of *H. trimaculatus* males and 17−31% *H. spinosissimus* males were pregnant. In each location, the number of females found with eggs in their bodies of both species was higher than the number of non-brooding males. This could reflect a low male-male competition of the species and high reproductive output. The high ratio of non-brooding male: female with eggs occurred on the southern coast for *H. spinosissimus* (1: 1.7) and on central coast for *H. trimaculatus* (1:2.6). Masonjones & Lewis (2000) reported that female *H. zosterae* needed a longer time to remate, while males spent only 4 hrs to recover themselves. Thus, the high proportion of reproductive females indicated the high potential reproductive rates of the population. Our results clearly indicate that there were high populations of the two seahorse species in these three particular fishing zones (71% of *H. spinosissimus* in the southern coast, 86% of *H. trimaculatus* in the central coast). This information could form the management advice for the species conservation.

In the present study, the proportions of immature or juvenile *H. trimaculatus* and *H. spinosissimus* were not significantly different between all three coasts of the Gulf of Thailand. There were low numbers of juvenile seahorses of both species in the three coastlines, but this was probably because the fishing areas used by the trawlers were not in the habitats used by the juveniles. Aylesworth *et al.* (2018) indicated that the high proportions of juveniles were incidentally captured by small fishing gear (gillnets) that were used by local fishermen in shallow-water. On the other hands the caught juvenile seahorses were used as part of the trash fish (for animal feed industries) and so the sampling is biased against smaller seahorses, including juveniles. Baum *et al.* (2003) stated that the proportions of *H. erectus* juveniles in the Gulf of Mexico were affected by the fishing area and lunar phase. In previous studies, the population structure of *H. trimaculatus* males and females in the Gulf of Mannar were found to consist of three size classes during the year of monitoring, similar to the reports on *H. erectus* in the Gulf of Mexico (Baum *et al.*, 2003; Murugan *et al.*, 2011). In the present study, *H. trimaculatus* and *H. spinosissimus* had a unimodal size distribution that was similar in all three coasts of the Gulf of Thailand, but this likely reflects the limitation of the short-term monitoring in this study. The sampled population structures consisted of 5–7 size classes and their lengths commonly ranged from 111–170 mm, subject to the additional caveat of the likely sampling bias against smaller specimens, especially juveniles, as discussed above.

4. Conclusions

Two major *Hippocampus* spp. were found in the Gulf of Thailand during the wet season of 2014. *Hippocampus spinosissimus* was dominant in both the eastern and southern coasts of the Gulf of Thailand, whereas *H. trimaculatus* was more dominant in the central coast. Thus, different dominant seahorse species in different coasts of Gulf of Thailand were indicated in this study. Spatial variations in the biological aspects (size, dry weight, and reproductive state) of both seahorse species were observed, but their sex ratios were close to 1:1 in all three different coasts studied. The results indicated that the populations of *H. spinosissimus* in southern coast and *H. trimaculatus* in the central coast have a high reproductive potential and potential for sustainable population growth. This information may be applied to be used to support the populations that have a high risk of wild population decline or extinction. In the case of the seahorses in the eastern coast of the Gulf of Thailand, the low numbers and small sizes of both species were surveyed. Fishing operations in this area should be more restricted, such as reducing the number of fishing days, expanding no fishing areas around marine protected areas, increasing marine sanctuary in the areas, and others. An understanding of seahorse biology is necessary in order to provide essential conservation/ population management information. However, long-term monitoring from the three coasts of Gulf of Thailand should be conducted to provide in-depth fundamental information, which will be useful for establishment of fishery regulations and sustainable management of marine animals. In addition, the impact of non-selective fishing gear is an important factor that will affect non-target marine animals, especially habitat destruction and the disruption of seahorse remating during the breeding season, including for monogamous species.

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