การเกิดขึ้นตามฤดูกาลของโคพีพอดที่เป็นปรสิตภายนอกของปลาตะกรับ (*Scatophagus argus* (Linnaeus 1766)) ในทะเลสาบสงขลาตอนล่าง ภาคใต้ ประเทศไทย

Seasonal Occurrence of Ectoparasitic Copepods on Spotted Scat (*Scatophagus argus* (Linnaeus 1766)) in the Lower Songkhla Lagoon, Southern Thailand

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บทคัดย่อ

การศึกษาโคพีพอดที่เป็นปรสิตภายนอกของปลาตะกรับ (*Scatophagus argus* (Linnaeus 1766)) ในทะเลสาบสงขลาตอนล่าง จังหวัดสงขลา ประเทศไทย เก็บตัวอย่างปลาจำนวน 25 ตัว เป็นประจำทุกเดือน ตั้งแต่เดือนกุมภาพันธ์ 2555 ถึงเดือนมกราคม 2556 พบโคพีพอด 3 สกุล 5 ชนิด คือ *Ergasilus* sp. A, *Ergasilus* sp.B, *Caligus epidemicus*, *Caligus rotundigenitalis* และ *Thysanote chalermwati* พบโคพีพอดสกุล *Ergasilus* บริเวณซี่เหงือก 2 ชนิด *Ergasilus* sp.A มีค่า prevalence (52–96%) และค่า mean intensity (8.3–14.6 ind/fish) สูงในช่วงเดือนเมษายนถึงเดือนสิงหาคม 2555 ซึ่งน้ำมีความเค็มในช่วง 12.1–32.2 ppt *Ergasilus* sp.B พบเฉพาะในเดือนมกราคม 2556 มีค่า prevalence 44% ส่วนโคพีพอดสกุล *Caligus* พบ 2 ชนิด โดยพบ *C. epidemicus* บริเวณผิวหนังและครีบ ระหว่างเดือนมิถุนายนถึงพฤศจิกายน 2555 มีค่า prevalence และค่า mean intensity อยู่ในช่วง 36–100% และ 1.3–7.4 ตัว/ปลา ตามลำดับ ซึ่งน้ำมีความเค็มในช่วง 13.1–32.3 ppt ส่วน *C. rotundigenitalis* พบบริเวณซี่เหงือกและผิวด้านในของแผ่นปิดเหงือก โดยพบเด่นในช่วงเดือนกันยายนถึงพฤศจิกายน 2555 ซึ่งน้ำมีความเค็มในช่วง 17.7–32.3 ppt บริเวณซี่เหงือกมีค่า prevalence และ mean intensity อยู่ในช่วง 48–100% และ 3.2–4.2 ตัว/ปลา ตามลำดับ และพบบริเวณผิวด้านในของแผ่นปิดเหงือก มีค่า prevalence และ mean intensity อยู่ในช่วง 64–100% และ 3.4–5.3 ตัว/ปลา ตามลำดับ *T. chalermwati* พบในโพรงจมูกของปลา ในเดือนสิงหาคมและตุลาคม 2555 มีค่า prevalence 20 และ 8% ตามลำดับ นอกจากนี้ยังพบว่าความสัมพันธ์ของความเค็มและความชุกชุมของโคพีพอดสกุล *Caligus* และ *T. chalermwati* มีความสัมพันธ์เชิงบวกอย่างมีนัยสำคัญที่ระดับ $p<0.01$

คำสำคัญ: Ectoparasitic copepods, *Scatophagus argus*, ความเค็ม, ทะเลสาบสงขลา

Abstract

Ectoparasitic copepods on spotted scat or *Scatophagus argus* (Linnaeus 1766) from the Lower Songkhla Lagoon, Songkhla province, Thailand, were examined. Twenty five fish were taken monthly during February 2012 to January 2013. Three genera and five species of copepods were found: *Ergasilus* sp. A and sp. B, *Caligus epidemicus*, *Caligus rotundigenitalis* and *Thysanote chalermwati*. Two species of *Ergasilus* were found on gill filaments. The prevalence (52–96%) and mean intensity (8.3–14.6 ind/fish) of *Ergasilus* sp. A were high during April to August 2012 when the salinity ranged from 12.1 to 32.2 ppt. *Ergasilus* sp. B was found only in January 2013 with a prevalence of 44%. Two *Caligus* species were also found, *C. epidemicus* was found on the skin surface and fins while *C. rotundigenitalis* was found on gill filaments and the inner surface of the operculum. The prevalence and mean intensity of *C. epidemicus* were 36–100% and 1.3–7.4 ind/fish, respectively, during June to November 2012 when the salinity ranged from 13.1 to 32.3 ppt. *C. rotundigenitalis* was dominant during September to November 2012 when the salinity ranged from 17.7 to 32.3 ppt with prevalence and mean intensity of 48–100% and 3.2–4.2 ind/fish on gill filaments and 64–100% and 3.4–5.3 ind/fish on the inner surface of the operculum. *T. chalermwati* was found in nasal cavity in August and October 2012 with prevalences of 20 and 8% respectively. In addition, the relationship between salinity and the abundance of *Caligus* group and *T. chalermwati* was positively significant at $p<0.01$.

Keywords: Ectoparasitic copepods, *Scatophagus argus*, Salinity, Songkhla, Lagoon

Introduction

Songkhla Lagoon, which has a water area of about 1,040 km^2, is the largest lagoon in southern Thailand. It is divided into four parts: lower part, middle part, upper part and Thale Noi. The lower part of Songkhla Lagoon has an inlet that is connected with the lower Gulf of Thailand. The mean salinity in the lower part of Songkhla Lagoon is higher than in the upper part (Pornpinatepong, 2005; Angsupanich, 2012). The lagoon has been a highly productive area for brackish water plants and animals (Sirimontaporn *et al*., 1995). The Lower Songkhla Lagoon is full of stow nets and shrimp traps (Angsupanich, 2012). Most of them belong to small-scale fishermen. The carrying capacity of the numerous fishing gears in the lagoon is not seriously controlled by the government. Moreover, the pollution caused by the discharge of factories, household and transportation has been continuously growing over the years, because there has been no serious enforcement of government regulations. These factors have lead to a current disrupted eco-system and a decreased number of aquatic animals (Angsupanich, 2012). Parasitic copepods are a common fish disease causing mortality in

marine cultured fishes (Johnson *et al.*, 2004). A recent review found that a pathogenic sea louse of wild and captive fish in the Indo-West Pacific region has been increasing (Nagasawa, 2013). However, most studies on parasitic copepods in Thai waters have been conducted on freshwater parasitic copepods (Purivirojkul and Sirikanchana, 2000; Lerssutthichawal and Supamattaya, 2005; Kaewviyudth and Prompiram, 2006; Purivirojkul and Areechon, 2008b). A few studies of copepods on marine fish have been carried out. Caligidae, Lernanthropidae and Ergasilidae were found dominantly in marine fishes collected from the Gulf of Thailand, Chonburi province (Purivirojkul and Areechon, 2008a) and a new finding of *Pseudocycnus appendiculatus* on *Thunnus albacores* in the Andaman Sea was recently reported (Purivirojkul *et al.*, 2011). Ectoparasitic copepods were first observed on some commercial catfish in Songkhla Lagoon (Tassamakorn and Angsupanich, 2014). This study found that *Hexanematichthys sagor* was highly attacked by *Ergasilus* during summer (March) to south-west monsoon (June) with prevalences of 83–100% and mean intensities of 105.7–282.8 ind/fish, while *Arius maculatus* was attacked by *Hermilius pyriventris* during south-west monsoon (August) to north-east monsoon (November) with prevalences of 83–100% and mean intensities of 1.4–24.2 ind/fish. The spotted scat, *Scatophagus argus* (Linnaeus 1766), is another commercial fish in Songkhla Lagoon. Its abundance, however, has been drastically decreasing, for reasons which need to be clarified. Besides water pollution, the infestation of ectoparasitic copepods may be one of the factors reducing the spotted scat population in the area. Thus, the aim of this study was to determine the level of infestation of ectoparasitic copepods on *S. argus* in the Lower of Songkhla Lagoon.

Materials and Methods

Study area

The Lower Songkhla Lagoon (Figure 1), the lowermost part of Songkhla Lagoon, is connected with the open sea. The lower part has a water area of about 182 km^2. It is located at Songkhla province. The water salinity ranges from 0 to 34 ppt depending on the season. It is affected by the SW monsoon during mid-May to mid-October which has light rainfall and thus allows high salinity close to sea levels, and then the NE monsoon during mid-October to mid-February which has heavy rainfall and thus low salinity (Angsupanich, 2012).

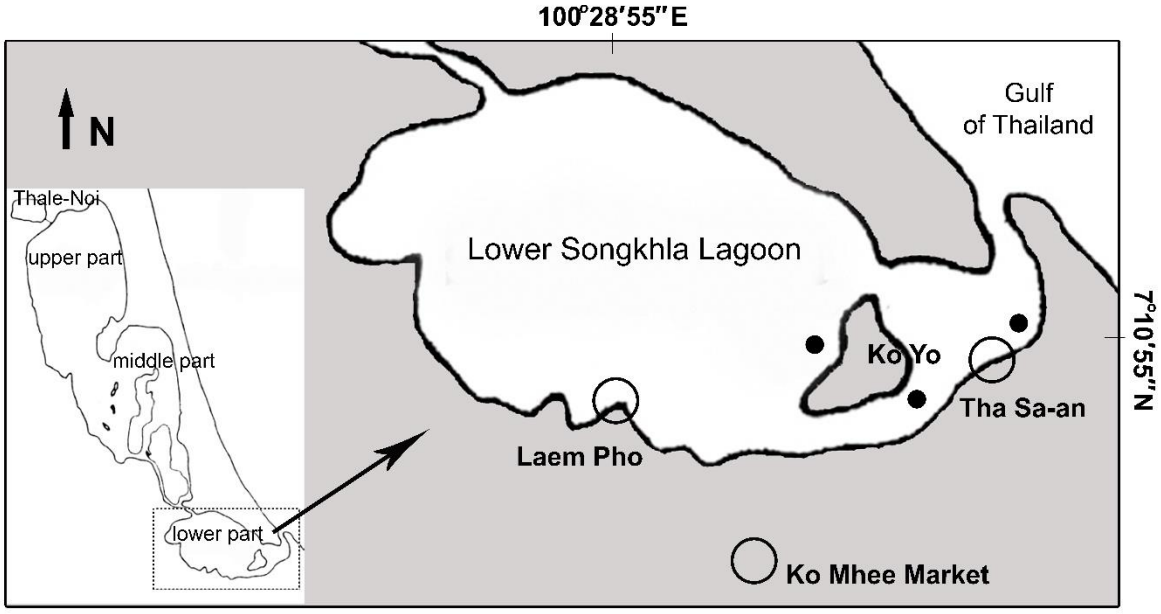

Figure 1 The Lower Songkhla Lagoon and sampling sites: (○) fish sampling and (●) water sampling

Fish parasite samplings and analyses

Fish samples were collected monthly from February 2012 to January 2013 from local fishermen at two different sites in the Lower Songkhla Lagoon and one local fish market (Ko Mhee) near the lagoon. Pool samples of twenty five *S. argus* were kept in plastic bags and chilled in an ice box. In the laboratory, before examination of ectoparasites, fish body weight (BW) in grams (g) and total length (TL) in centimeters (cm) were measured. Each fish was first examined under a stereomicroscope, and the ectoparasitic copepods removed and preserved with 70% ethyl alcohol. After that the gills were dissected and fixed with 10% neutral formalin for re-examination. Copepods were cleared in 85% lactic acid based on the method of Nagasawa *et al*. (2008) for further identification. Pictures were taken with a Nikon DIGITAL SIGHT DS-Fi1 lens on a Nikon SMZ 1500 digital camera. The location of copepods on the fish gills was recorded from fish collected during July 2012 to January 2013. The presentation was modified from Austin and Avenant-Oldewage (2009). In about the same period as the fish samples were collected, the water salinity (ppt) was measured in triplicate at three sites by using U-50 Multiparameter Water Quality Meter (Horiba, Ltd. Tokyo Japan).

Data analysis

Prevalence, intensity, mean intensity and abundance of each ectoparasitic species collected from fish were calculated based on Bush *et al*. (1997).

The correlation between the ectoparasitic copepod abundance and water salinity was analyzed with Spearman's correlation using R software version i386 3.0.2.

Results

Fish

S. argus was found in the Lower Songkhla Lagoon throughout the year. The mean fish body weight and total length ranged from 31.5 to 97.4 g and 9.4 to 14.5 cm, respectively (Table 1). The largest size was found in March 2012 and the smallest size was found in September 2012.

Table 1 Mean body weights (BW, g) and total lengths (TL, cm) of *Scatophagus argus* (N = 25 fish/month)

	2012											2013
	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
BW	41.2	97.4	56.8	40.3	67.5	66.2	90.4	31.5	52.8	62.0	62.0	48.0
(SD)	(12.4)	(19.6)	(42.9)	(9.5)	(16.7)	(11.3)	(22.0)	(22.6)	(9.3)	(6.3)	(6.4)	(16.6)
TL	10.9	14.5	11.2	10.6	12.0	12.0	13.4	9.4	11.3	12.1	12.4	11.4
(SD)	(1.1)	(1.1)	(3.3)	(0.9)	(0.7)	(0.9)	(1.1)	(1.4)	(0.9)	(0.5)	(0.3)	(1.1)

Water salinity

The water salinity ranged from 0.9 to 32.3 ppt (Table 2), which gradually increased from February 2012 (2.7) to October 2012 (32.2) and after that decreased to 0.9 in January 2013.

Distribution of parasitic copepods

Three genera, five species of ectoparasitic copepods and chalimus stages were found on *S. argus.*

Ergasilus

Two species of *Ergasilus*, *Ergasilus* sp.A and sp.B, were found on gill filaments. Both species were significantly negatively correlated with salinity ($p<0.01$, $r = -0.36$ for sp.A, $r = -0.30$ for sp.B). *Ergasilus* sp.A (Figure 2a–b) was found almost throughout the year with the trend of rapidly declining from September through November 2012 during the period of high salinity period (Table 2). *Ergasilus* sp. A occurred with prevalences of 4–96% and mean intensities of 1.0–14.6 ind/fish. Both prevalence and mean intensity tended to be high during February to August 2012 when salinity ranged from 2.7 to 32.2 ppt with the exception of March. In January 2013, the very low salinity month (0.9 ppt), *Ergasilus* sp.A had a low prevalence (36%) even though the mean intensity was high (25.9 ind/fish). In addition, *Ergasilus* sp.B (Figure 2c) was found only in January 2013 with prevalence of 44% and mean intensity of 9.9 ind/fish.

Table 2 Mean of salinity (ppt), prevalences (P, %), mean intensities (MI, ind/fish) with intensities in square brackets and mean abundances (A, ind/fish) with standard deviation in parentheses of *Ergasilus* spp., chalimus stages, *Caligus* spp. and *Thysanote chalermwati* on *Scatophagus argus* between February 2012 and January 2013

		parasitic copepods											
		Ergasilus sp.A			*Ergasilus* sp.B			*Caligus epidemicus*			*Thysanote chalermwati*		
		gill			gill			skin			nostril		
month	salinity	P	MI	A	P	MI	A	P	MI	A	P	MI	A
2012													
Feb	2.7	84	13.2 [2–35]	11.1 (11.1)	0	0	0	0	0	0	0	0	0
Mar	15.3	12	2.0 [1–4]	0.2 (0.8)	0	0	0	0	0	0	0	0	0
Apr	12.1	88	8.3 [1–40]	7.3 (11.2)	0	0	0	0	0	0	0	0	0
May	21.2	56	14.4 [2–29]	8.1 (9.6)	0	0	0	0	0	0	0	0	0
Jun	13.1	96	14.6 [1–38]	14.0 (10.3)	0	0	0	88	6.0 [1–13]	5.2 (3.9)	0	0	0
Jul	29.8	68	8.8 [1–46]	6.0 (9.9)	0	0	0	100	7. 4 [3–13]	7.4 (2.7)	0	0	0
Aug	32.2	52	13.6 [3–53]	7.1 (11.4)	0	0	0	52	4.9 [1–12]	2.6 (3.7)	20	1.0 [1]	0.2 (0.4)
Sep	32.3	4	1.0 [1]	0.04 (0.0)	0	0	0	92	3.4 [1–20]	3.1 (4.4)	0	0	0
Oct	32.2	0	0	0	0	0	0	36	1.3 [1–3]	0.4 (0.8)	8	1.0 [1]	0.1 (0.3)
Nov	17.7	0	0	0	0	0	0	80	3.2 [1–8]	0.04 (0.2)	0	0	0
Dec	5.7	92	3.6 [1–12]	3.3 (2.8)	0	0	0	0	0	0	0	0	0
2013													
Jan	0.9	36	25.9 [8–117]	9.3 (23.6)	44	9.9 [1–33]	4.4 (7.9)	0	0	0	0	0	0

Table 2 (Continued)

		parasitic copepods											
		Caligus rotundigenitalis									chalimus stages		
		gill			inner operculum			total			gill		
month	salinity	P	MI	A	P	MI	A	P	MI	A	P	MI	A
2012													
Feb	2.7	20	2.0	0.4	0	0	0	20	2.0	0.4	0	0	0
			[1–4]	(1.0)					[1–4]	(1.0)			
Mar	15.3	36	2.3	0.8	0	0	0	36	2.3	0.8	40	3.7	1.5
			[1–5]	(1.5)					[1–5]	(1.5)		[1–9]	(2.5)
Apr	12.1	32	11.9	3.8	0	0	0	32	11.9	3.8	28	6.4	1.8
			[1–26]	(7.6)					[1–26]	(7.6)		[1–15]	(3.7)
May	21.2	16	2.0	0.3	0	0	0	16	2.0	0.3	20	3.6	0.7
			[1–3]	(0.8)					[1–3]	(0.8)		[1–6]	(1.7)
Jun	13.1	20	1.6	0.3	0	0	0	20	1.6	0.3	4	2.0	0.1
			[1–3]	(0.7)					[1–3]	(0.7)		[2]	(0.4)
Jul	29.8	16	1.8	0.3	0	0	0	16	1.8	0.3	0	0	0
			[1–3]	(0.7)					[1–3]	(0.7)			
Aug	32.2	40	5.3	2.1	0	0	0	40	5.3	2.1	24	4.7	1.1
			[1–10]	(3.2)					[1–10]	(3.2)		[2–8]	(2.3)
Sep	32.3	100	4.2	4.2	100	5.3	5.3	100	9.5	9.4	56	2.0	1.1
			[1–22]	(4.3)		[1–17]	(3.4)		[1–34]	(7.4)		[1–6]	(1.4)
Oct	32.2	92	3.2	3.0	72	3.4	2.6	100	6.6	5.5	60	1.9	1.1
			[1–8]	(2.3)		[1–8]	(2.2)		[1–16]	(4.1)		[1–5]	(1.3)
Nov	17.7	48	3.7	1.8	64	4.3	2.7	64	7.1	4.8	44	2.1	0.9
			[1–8]	(2.5)		[1–10]	(3.0)		[1–18]	(4.6)		[1–5]	(1.3)
Dec	5.7	0	0	0	0	0	0	0	0	0	0	0	0
2013													
Jan	0.9	24	1.8	0.4	0	0	0	24	1.8	0.4	4	1.0	0.04
			[1–6]	(1.2)					[1–6]	(1.2)		[1]	(0.2)

Figure 2 Parasitic copepods on *Scatophagus argus*. **a**, *Ergasilus* sp.A; **b**, *Ergasilus* sp.A attached on gill filaments; **c**, *Ergasilus* sp.B; **d**, *Caligus epidemicus*; **e**, *C. epidemicus* attached on body skin underneath pectoral fin; **f**, *Caligus rotundigenitalis*; **g**, chalimus stage; **h**, *Thysanote chalermwati*; **i** *T. chalermwati* in nasal cavity (arrow head)

Six hundred and forty three specimens of *Ergasilus* sp. A were found on the gill filaments of 63 fish. Most of them were attached at the proximal anterior of the gill filaments (52.4%), followed by the proximal posterior (23.8 %) and median part (21.6%) of gill filaments (Figure 3). Ninety five *Ergasilus* sp.B specimens were obtained from 11 fish. The highest distribution of *Ergasilus* sp.B was also found at the proximal anterior area of gill filaments (56.9%).

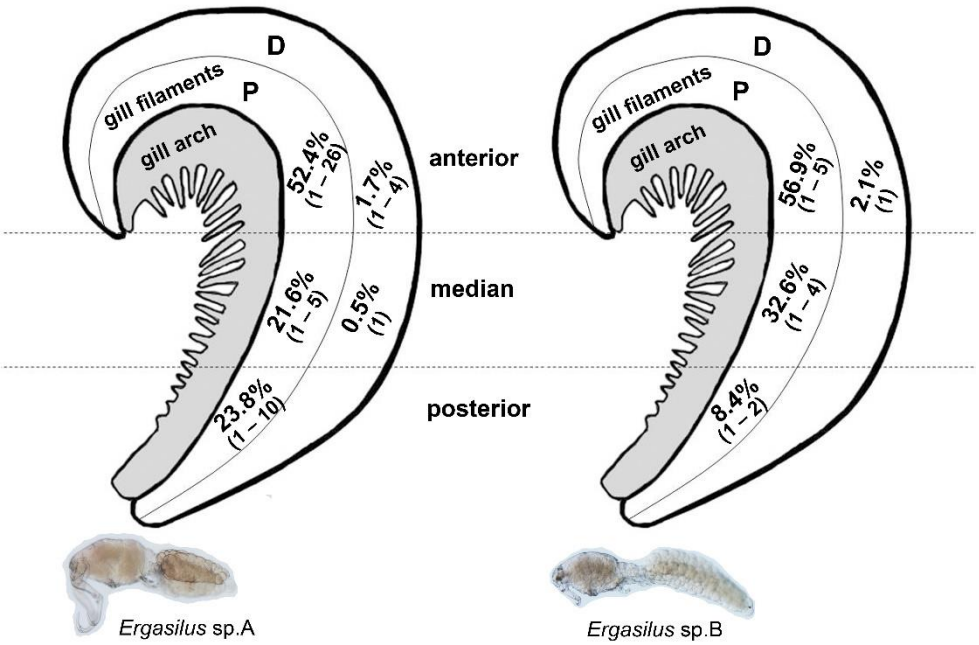

Figure 3 Percentages of *Ergasilus* sp.A (left) and *Ergasilus* sp.B (right) distributed on *Scatophagus argus* gill, intensity in parentheses (ind/gill), P, proximal; D, distal

Caligus

Two species of *Caligus*, *Caligus epidemicus* and *Caligus rotundigenitalis*, were found on *S. argus*. Both species showed a significantly positive correlation with salinity at $p<0.01$ ($r = 0.45$ for *C. epidemicus*, $r = 0.49$ for *C. rotundigenitalis*). *C. epidemicus* (Figure 2d) was found on fins and body skin in the high salinity period during June to November with prevalences of 36–100% and mean intensities of 1.3–7.4 ind/fish (Table 2). The largest number of copepods occurred after the dry season during June to September with salinities of 13.1–32.3 ppt. Most were attached on the body skin underneath the pectoral fin (46.2%, Figure 2e) and other areas of body skin (42.9%). Only 10.9% of the ectoparasites were found on other fins. *C. rotundigenitalis* (Figure 2f) was found on gill filaments almost the year round with prevalences of 16–100% (Table 2) and mean intensities of 1.6–11.9 ind/fish. It was dominant in the continuous high salinity season (September to November), which was opposite to the occurrence of *Ergasilus* sp.A. In September, all fish samples were infested by *C. rotundigenitalis* both on gill filaments and inner surfaces of the opercula with mean intensities of 4.2 and 5.3 ind/fish, respectively. Chalimus stages (Figure 2g) were found on gill filaments mostly in the brackish to sea water period during March to November 2012. The prevalences of chalimus stages were 4–60% and mean intensities 1.0–6.4 ind/fish. Chalimus stages significantly positively correlated with salinity at $p<0.01$ ($r = 0.32$).

Thysanote chalermwati

Thysanote chalermwati (Figure 2h–i) was found in nasal cavities in August and October 2012 with salinity of 32.2 ppt (Table 2) at prevalences of 20 and 8%, respectively. The mean intensity in both months was 1.0 ind/fish. It also showed a significantly positive correlation with salinity at $p<0.01$ ($r = 0.18$).

Discussion

Songkhla Lagoon is a choked lagoon which connects to the sea through a single inlet (Kjerfve, 1994). The salinity of the Lower Songkhla Lagoon is generally brackish water almost all year long, with very low salinity for a few months during the heavy rainy season from December to February (Angsupanich and Rakkheaw, 1997; Angsupanich *et al.*, 2005; Angsupanich, 2012). The seasonal variations of water salinity in Songkhla Lagoon are influenced by tidal currents, land drainage and rainfall, which also affects the diversity of aquatic species (Angsupanich, 2012). However, none of these effects were obvious for *S. argus* in the Lower Songkhla Lagoon as it was found throughout the year, with the largest numbers during the increasing water salinity from March to August. It is a euryhaline fish which is distributed along the shores of the Indo-West Pacific Ocean (Kottelat, 2001; Wongchinawit and Paphavasit, 2009).

Five species of ectoparasitic copepods were found attached to *S. argus* in Songkhla Lagoon, two *Ergasilus,* two *Caligus* and one *Thysanote* species. These numbers are similar to the species found on *S. argus* in Segara Anakan Lagoon, Indonesia during August to November 2004 (Yuniar *et al.*, 2007). Two species of *Ergasilus* were found just on the gill filaments of *S. argus* in Songkhla Lagoon. Yuniar *et al*. (2007) also found two species of *Ergasilus* on the gill filaments, with one of them found on the inner operculum as well. Unfortunately, a comparative study could be carried out at the generic level only because morphological illustrations of *Ergasilus found* on *S. argus* in the paper of Yuniar *et al*. (2007) were not available. Although the distributions of *Ergasilus* in Segara Anakan Lagoon and Songkhla Lagoon occurred in a wide range of water salinity ranges, the higher prevalences and mean intensities of the dominant copepod, *Ergasilus* sp.A in the present study, were found in a wider salinity range (0.9–29.8 ppt) than that in Segara Anakan Lagoon (19–31 ppt). Both *Ergasilus* sp. A and *Ergasilus* sp. B were significantly negative correlated with salinity, but they tolerated different salinity ranges. The optimum salinity for *Ergasilus* sp.A was brackish water, which is normal the Songkhla Lagoon. Its prevalence and mean intensity decreased markedly as the salinity continuously increased to over 30 ppt for a few months, while *Ergasilus* sp. B was found only in January in moderate abundance when the water salinity was near to 0 ppt because of the heavy

rainfall during the previous weeks. Thus, *Ergasilus* sp. B is probably normally a freshwater species, and the short period of a very low salinity environment in the Songkhla Lagoon may limit the distribution of freshwater species. Recently, Tassamakorn and Angsupanich (2014) investigated ectoparasites on catfish, *H. sagor*, in the Lower Songkhla Lagoon. They found two species of *Ergasilus* which were different from those found on *S. argus*. The distribution of parasitic copepods such as Ergasilidae and Caligidae are occasionally related to water salinity levels (Noga, 2010).

In the present study, *Ergasilus* found on gill filaments were mostly congregated on the anterior area near to the median area. This was also noted in the attachment of *Ergasilus gibbus* in European eels, *Anguilla anguilla* (Soylu *et al*., 2013) and *Ergasilus* spp. in Songkhla Lagoon *H. sagor* (Tassamakorn and Angsupanich, 2014). However, *E. gibbus* were found at a high density at the distal part of the gill filaments while *Ergasilus* spp. of Songkhla *H. sagor* (Tassamakorn and Angsupanich, 2014) and *S. argus* were at the proximal area.

C. epidemicus has been reported as a significant pathogenic parasite of wild and cultured fish in the Indo-West Pacific region (Nagasawa, 2013). This species can tolerate a wide range of salinities in the lower reaches of river and estuarine environments (Regidor and Arthur, 1986; Roubal, 1997; Nagasawa, 2013). *C. epidemicus* of the Songkhla *S. argus* also occur in a wide range of salinities, but tend to be more common in highly brackish water (13.1–32.3 ppt), which corresponds with the studies of Yuniar *et al*., (2007) and Roubal (1997). The latter study reported that all *C. epidemicus* were active for at least 40 h in the 30 ppt salinity. The prevalence (4.3%), mean intensity (1.3 ind/fish) and attached location (skin) of *C. epidemicus* on *S. argus* in Segara Anakan Lagoon were less than in the present study. Songkhla *C. epidemicus* were found attached on both the body skin and fins with the highest density on the body skin under the pectoral fins. However, the chalimus stage on the gills of Segara Anakan *S. argus* was found in higher abundance than the Songkhla *S. argus*. Other reports of the chalimus and adult stages of *C. epidemicus* have said they were mainly found on the pectoral fins of *Acanthopagrus australis* (Roubal, 1994) and *Ambassis marinus* (Hallett and Roubal, 1995). In Songkhla catfish, a high prevalence of *C. epidemicus* was also found attached on *H. sagor* on the gill filaments (83%), although with a very low mean intensity (1.0 ind/fish) at a salinity of 17.7 ppt (Tassamakorn and Angsupanich, 2014). In addition, chalimus stages and adult of *Caligus* sp. were also found on gill lamella of *S. argus* in Tebrau Straits, Malaysia (Ihwan *et al*., 2016).

Besides *C. epidemicus* on the skin of Songkhla *S. argus, C. rotundigenitalis* was also found on the gill filaments and inner operculum. Pillai (1985) also reported *C. rotundigenitalis* on *Lutianus malabaricus, Caranx specious* and *S. argus* in China and India. In Southeast Asia, Yuniar *et al*. (2007) found *C. rotundigenitalis* on the inner operculum of *Mugil cephalus* in Indonesia while Leaw

et al. (2012) found *C. rotundigenitalis* on the inner operculum and body skin of *Lutjanus erythropterus* in Malaysia. Although *C. rotundigenitalis* was observed throughout the present study, the highest intensity appeared in the high salinity season. Moreover, the occurrence of *C. rotundigenitalis* was higher than *C. epidemicus*. These results are rather different from a *Caligus* infestation in Malaysian sea bass culture (Muhd-Faizul *et al*., 2012) which found heavy attachment by *C. epidemicus* within a wide range of salinities (5–28 ppt) and a relatively small number of *C. rotundigenitalis* within a narrow salinity range (25–28 ppt). Most unidentified chalimus stages of the present finding were supposed to be life stages of *C. rotundigenitalis* for the following reasons: 1) they occurred mostly in the same period of the adult *C. rotundigenitalis*; 2) fine structures of leg 4 resembled those of adults; and 3) morphological characteristics were different from the chalimus stage of *C. epidemicus,* as described by Lin *et al*. (1996), with at least 2 major differences, the abdomen and leg 4 of the Songkhla chalimus were markedly longer than those of *C. epidemicus.*

In addition, *S. argus* bearing *T. chalermwati* in the nasal cavity was found only in the high salinity season. This species has been described as a new species collected from the nasal cavity of *S. argus* in the Gulf of Thailand (Piasecki *et al*., 2008). *Thysanote* sp. found on *S. argus* from Segara Anakan Lagoon (Yuniar *et al*., 2007) was assumed to be *T. chalermwati* (Piasecki *et al*., 2008).

Conclusion

Five species of ectoparasitic copepods and chalimus stages were found on *S. argus* in the Lower Songkhla Lagoon. The occurrences of the ectoparasitic copepods were correlated to water salinity ranges. The abundances of *Ergasilus* sp.A and sp.B were significantly negatively correlated to salinity while those of the *Caligus* group and *T. chalermwati* were significantly positive. Although each copepod species could tolerate some different degrees of salinity, most were found in the SW monsoon season during June to September. Therefore, this overlapping occurrence of several copepod species may be the cause of the severe infestation in *S. argus* noted in recent years. Further monitoring of fish parasites in the whole area of Songkhla Lagoon should be a priority in order to find a way to control this dangerous parasite.

Acknowledgments

The authors would like to thank Department of Aquatic Science, Faculty of Natural Resources, Prince of Songkla University for providing us support during this research. This study was funded by the National Research Council of Thailand (Year 2013).

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