Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 24(3): 97- 107 (2020)
www.ejabf.journals.ekb.eg

Population dynamic of *Periophthalmodon septemradiatus* (Hamilton, 1822) living along the Hau River, Vietnam

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ARTICLE INFO

Article History:
Received: February 6, 2020
Accepted: April 28, 2020
Online: May 2020

Keywords:
Exploitation rate,
mortality,
Population dynamic,
P. septemradiatus,
Hau River,
Vietnam

ABSTRACT

This study provides the biology of the population of *Periophthalmodon septemradiatus*, as a basis for species conservation. The result analysis of 3,436 individuals collected on a monthly basis starting from July 2017 to June 2019. Five sites including Long Duc, Long Phu, Soc Trang (LD), An Lac Tay, Ke Sach, Soc Trang (ALT), Phu Thu, Cai Rang, Can Tho (PT), Tan Hung, Thot Not, Can Tho (TH), and Binh Duc, Long Xuyen, An Giang (BD) were conducted along the Hau River from the estuary to the upstream of the river. It showed that the male to female ratio ranged from 1.36:1.00 to 1.87:1.00. Although this species' $L\infty$ was 12.6 cm for all five populations, the growth coefficient (K) and t_0 varied with studied sites. The K value ranged from 0.49 yr-1 (PT) to 1.6 yr-1 (BD), whereas the t_0 was -0.12 in BD and -0.43 in PT. Likewise, the longevity of this species was the lowest value in BD (1.88 yr.) and the highest one in PT (6.12 yr.). The total mortality and natural mortality coefficients of fish populations displayed the highest values in the BD (Z=4.11, M=3.14) and the lowest one in PT (Z=1.68, M=1.46). Conversely, the highest and lowest values of the fishing mortalities (F) were in TH (1.58) and PT (0.22), respectively. The species populations were subjected to overfishing in ALT and TH.

INTRODUCTION

The exploitation rate estimated from the analysis of the yield-per-recruit has a strong relationship with fisheries management **(Beverton and Holt, 1957)**. The growth and mortality parameters are used to assess the fish population **(Ricker, 1975)**. The growth performance with combined analysis of growth and asymptotic length relationship are related to the variations of fish growth rate between genders and locations **(Pauly and Munro, 1984)**. In the Mekong Delta, the gobies diversify yet the data on the population is fragmented for some gobiid species such as *Pseudapocryptes elongatus* **(Tran *et al.*, 2007)** and *Parapcryptes serperaster* **(Dinh *et al.*, 2015b)**. Due to the overexploitation with various fishing gears **(Trinh and Tran, 2012)**, it leads to the reduction of fish species in the Mekong Delta including the gobies **(Diep *et al.*, 2014)**. For example, the population of *Glossogobius giuris* **(Dinh *et al.*, 2017)**, *Boleophthalmus boddarti* **(Dinh, 2017)**, *Stigmatogobius pleurostigma* **(Dinh and Nguyen, 2018)** and *Trypauchen vagina* **(Dinh, 2018a)** have been subjected to overfishing. There is a need for studies on fishing status of gobiid species.

The genus of *Periophthalmodon* (Gobiidae: Oxudercine) has three species including *P. freycineti*, *P. schlosseri* and *P. septemradiatus* **(Murdy, 1989; Murdy, 2011; Murdy and Jaafar,**

2017). Only *P. schlosseri* and *P. septemradiatus* are recorded in Vietnam **(Tran *et al.*, 2013)**. The species *P. septemradiatus* is an amphibious fish **(Martin and Bridges, 1999)** and widely distributes in the mangrove swamps and muddy areas in the Asian regions **(Murdy, 1989; Murdy, 2011; Murdy and Jaafar, 2017)**. In the Mekong Delta of Vietnam, this fish can live from estuary to the upstream of the river systems **(Dinh *et al.*, 2019; Mai *et al.*, 2019; Dinh *et al.*, 2020)**. There is no information on the population biology of this fish, especially from the estuary to upstream sites of the Hau River, where its population tends to be overfished **(Dinh *et al.*, 2020)**. This study, therefore, aims to contribute to the knowledge of the biological features of the species as to further understand of its stock and management.

MATERIALS AND METHODS

Study site

This study was conducted from July 2017 to June 2019 in muddy regions of tributaries of Hau River including Long Duc, Long Phu, Soc Trang (LD; 9°42'55.4"N 106°04'28.4"E), An Lac Tay, Ke Sach, Soc Trang (ALT; 9°49'52.4"N 105°59'44.5"E), Phu Thu, Cai Rang, Can Tho (PT; 9°59'45.06"N 105°48'22.73"E), Tan Hung, Thot Not, Can Tho (TH; 10°12'07.17"N 105°34'43.89"E) and Binh Duc, Long Xuyen, An Giang (BD; 10°24'03.54"N 105°25'10.82"E) (Fig.1). In the studied sites, there are typically two seasons including dry season with little precipitation (January to May) and wet season with roughly 400 mm precipitation per month (June to December). The mean annual temperature in this region is ~27 °C. The tide of the study regions is semi-diurnal **(Le *et al.*, 2006)**. The mudflat characterized by silt, clay, sand, and organic matter, and the distance from the river bank to the riverbed of the mudflat is nearly 2.5 m at the lowest tide **(Dinh *et al.*, 2019)**.

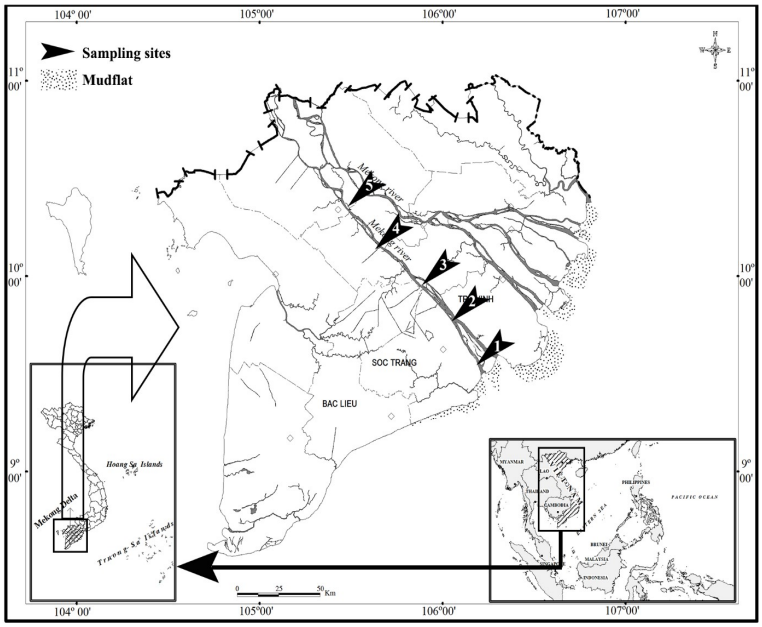

Fig.1. The sampling map in the Mekong Delta
(arrow: Sampling sites; 1: Long Duc, Long Phu, Soc Trang, 2: An Lac Tay, Ke Sach, Soc Trang, 3: Phu Thu, Cai Rang, Can Tho, 4: Tan Hung, Thot Not, Can Tho, and 5: Binh Duc, Long Xuyen, An Giang)

The flora in this area consisted mainly of *Sonneratia caseolaris* and *Nypa fruticans*, and the slopes of the river bank were ~25°. These plant species and *Cryptocoryne ciliata* were predominantly found in ALT. The slopes of the riverbank in ALT were also ~25°. There were no predominant trees found in the flora in PT which was near some industrial zones. *Nauclea orientalis* was the predominant tree of the flora in TH with the riverbank slopes of ~45°. *Sonneratia caseolaris* was still appeared in TH but not in BD where the flora mainly consisted of *Nauclea orientalis*. Like TH, the slopes of the riverbank in BD were near to 45° **(Dinh *et al.*, 2020)**.

Fish collection and analysis

Fish specimens were collected monthly using traps and hands, along with the mudflat and mangrove forests in the studied regions. An area of 30m^2 (15m along the riverbank and 2m from the riverbank to the riverbed) in each site was chosen to collect fish on a monthly basis. Every field campaign lasted five days (one day per sampling site). After visual identification using external characteristics described by **Khaironizam and Norma-Rashid (2003)**, the fish was stored in 4% formalin and transported to the laboratory. In the laboratory, the sex of *P. septemradiatus* was based on the urogenital papilla morphology, which was round in female and narrow in male **(Dinh *et al.*, 2020)**, and fish specimens were measured total length (0.1 cm).

Data analysis

The difference in male to female ratio of 1:1 was confirmed using χ^2 at a meaningful value of 5%. The χ^2 test was performed by using SPSS v.21.

The length-frequency data of these fish were analyzed using FiSAT II software to estimate the population biological parameters **(Gayanilo *et al.*, 2005)**. Using The ELEFAN I, the procedure was performed to determine the asymptotic length (L_∞) and the growth parameter (K) **(Pauly and David, 1981; Pauly, 1982; Pauly, 1987)**. The length-converted capture curve was applied to estimate the total mortality rate (Z) **(Beverton and Holt, 1957; Ricker, 1975)**. The theoretical age parameter (t_0) was calculated from the equation $\log_{10}(-t_0) = -0.3922 - 0.2752\log_{10} L_\infty - 1.038\log_{10} K$ **(Pauly, 1979)**. The equation $\mathrm{Log}M = -0.0066 - 0.279\mathrm{Log}L_\infty + 0.6543\mathrm{Log}K + 0.463\mathrm{Log}T$ (L_∞ and K were achieved from the ELEFAN I and T is the mean annual water temperature (°C)) was used to estimate the natural mortality rate (M) **(Pauly, 1980)**. The fishing mortality (F) was calculated as $F=Z-M$ and the exploitation rate (E) was determined as $E=F/Z$ **(Ricker, 1975)**.

The probability of capturing for each class size (L_c) was estimated using the length-converted catch, and the fish length entry **(Pauly, 1987)**. The knife-edge selection was performed to estimate the maximum yield exploitation rate (E_{max}) with a minimal increase of 10% of Y'/R ($E_{0.1}$) and the reduction of stock to 50% ($E_{0.5}$) **(Beverton and Holt, 1966)**. The growth performance ($\Phi'=\mathrm{Log}K + 2\mathrm{Log}L_\infty$) was used to compare the von Bertalanffy growth parameters of *P. septemradiatus* and other fishes dwelling in and out its habitat **(Pauly and Munro, 1984)**. The longevity (t_{max}) was calculated using $t_{\max} = \frac{3}{K}$ **(Taylor, 1958; Pauly, 1980)**.

RESULTS

Sex ratio

A total of 3,436 fish including 2,081 males and 1,355 females were collected at five sampling sites during the wet and dry seasons (Table 1). Although *P. septemradiatus* can live from estuary to upstream areas of Hau River, the number of fish decreased gradually from LD to BD (Table 1), which could be resulted from the difference in flora among these studied sites. In each sampling site, the number of male *P. septemradiatus* collected was significantly higher than that of females (χ^2, $p<0.05$ for all cases, Table 1).

Table 1. Sex ratio of *Periophthalmodon septemradiatus* along the Hau River

Sampling site	No. of fish	No. of male and female	Sex ratio (M : F)
Binh Duc, Long Xuyen, An Giang	657	396 : 261	1.52 : 1.00
Tan Hung, Thot Not, Can Tho	649	384 : 265	1.45 : 1.00
Phu Thu, Cai Rang, Can Tho	691	418 : 273	1.53 : 1.00
An Lac Tay, Ke Sach, Soc Trang	730	421 : 309	1.36 : 1.00
Long Duc, Long Phu, Soc Trang	709	462 : 247	1.87 : 1.00
Total	**3,436**	**2,081 : 1,355**	**1.54 : 1.00**

Population parameters

The data on the length frequency of *P. septemradiatus* showed that the fish group had the smallest length of 4–5 cm and the largest length group is 12–13 cm (Table 2). Most of fish were caught from 6–7 cm to 10–11 cm in total length (3,191/3,436, ~93%), indicating that the population of

P. septemradiatus was in the growing and breeding groups. The length-frequency data analysis showed that five *P. septemradiatus* populations living at five sampling sites had 5-6 cohorts, e.g., 5-6 growth curves (Fig. 2).

Table 2. The number of *P. septemradiatus* caught from Hau River from July 2017 to June 2019

Month	Total length (cm)									Total
	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	
07/2017	5	4	20	27	23	19	14	9		121
08/2017		5	26	20	17	9	13	3	1	94
09/2017		3	23	22	21	15	10	2		96
10/2017		1	15	27	23	25	6	1		98
11/2017		7	31	26	21	11	8	2		106
12/2017		5	22	40	34	14	16	6		137
01/2018		2	24	28	20	16	7	3		100
02/2018			14	41	26	6	13	6		106
03/2018		4	6	29	28	24	26	5		122
04/2018	1	19	29	31	25	24	23	3		155
05/2018		2	24	47	19	15	20	7		134
06/2018		8	20	16	36	37	26	2		145
07/2018		7	14	37	47	21	22	2		150
08/2018		12	28	23	30	24	22	10	1	150
09/2018		10	35	32	21	30	18	4		150
10/2018		4	27	40	31	24	23	1		150
11/2018		4	26	42	25	24	24	4		149
12/2018			15	30	49	40	14	2		150
01/2019		3	22	53	60	28	12	6		184
02/2019		5	13	42	40	30	44	9		183
03/2019		8	21	52	35	41	31	3		191
04/2019		12	23	40	35	38	36	6		190
05/2019		1	18	27	45	50	38	8	2	189
06/2019		1	13	23	57	49	39	4		186
Total	**6**	**127**	**509**	**795**	**768**	**614**	**505**	**108**	**4**	**3,436**

The von Bertalanffy parameters five fish populations were presented in Table 3. Accordingly, the maximum length (L_∞) of the five fish populations at the five studied sites has the same value of L_∞=12.6 cm, but the growth coefficient (K) and t_0 varied with studied site, ranging from 0.49 yr^{-1} to 1.60 yr^{-1} (K) and -0.12 yr^{-1} to -0.43 yr^{-1} (t_0).

Table 3. Population parameters of *Periophthalmodon septemradiatus* and some other gobiid species

Species	L_∞	K	t_0	t_{max}	Z	F	M	L_c	L_c/L_∞	E	Φ'	Source
Periophthalmus barbarus	21.6	0.55	-0.32	5.45	4.21	2.86	1.35	10.2	0.47	0.68	2.41	**Etim *et al.* (2002)**
Pseudapocryptes elongatus	26.0	0.65	-0.26	4.35	2.91	1.47	1.44	11.8	0.45	0.51	2.64	**Tran *et al.* (2007)**
Periophthalmodon schlosseri	29.0	1.40	-0.11	2.14	-	-	-	-	-	-	3.10	**Mazlan and Rohaya (2008)**
Parapocryptes serperaster	25.2	0.74	-0.22	4.05	3.07	1.57	1.51	14.6	0.57	0.49	2.67	**Dinh *et al.* (2015b)**
Trypauchen vagina	24.2	0.56	-0.03	5.56	2.73	1.29	1.44	13.8	0.57	0.53	2.50	**Dinh (2018a)**
Boleophthalmus boddarti	16.8	0.79	-0.24	3.55	2.13	0.30	1.83	13.0	0.77	0.14	2.35	**Dinh (2017)**
Butis butis	24.0	0.61	-0.04	4.92	3.40	1.98	1.42	10.5	0.44	0.58	2.55	**Dinh (2018c)**
Stigmatogobius pleurostigma	8.6	0.83	-0.07	3.61	3.48	1.17	2.31	3.8	0.44	0.34	1.79	**Dinh and Nguyen (2018)**
Periophthalmodon septemradiatus	12.6	0.68	-0.30	4.41	2.21	0.39	1.82	7.0	0.55	0.18	2.03	The present study
	12.6	0.55	-0.38	5.46	2.86	1.27	1.59	8.0	0.64	0.44	1.94	
	12.6	0.49	-0.42	6.12	1.68	0.22	1.46	7.7	0.61	0.13	1.89	
	12.6	1.10	-0.18	2.73	4.05	1.58	2.47	9.5	0.76	0.39	2.24	
	12.6	1.60	-0.12	1.88	4.11	0.97	3.14	9.2	0.73	0.24	2.41	

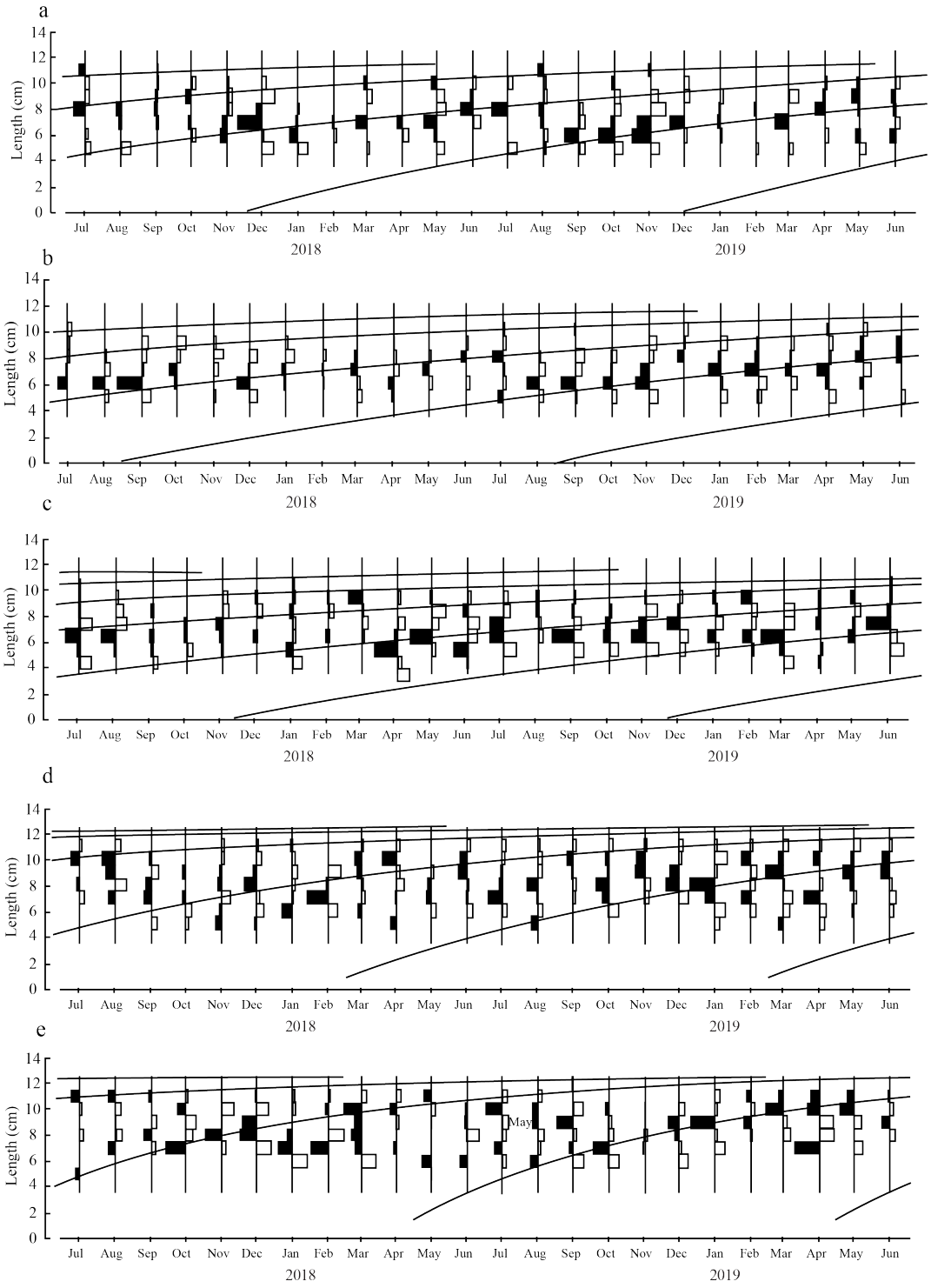

Fig. 2. Length-frequency distribution of *Periophthalmodon septemradiatus*

(The curves show the increase of fish length over time; a: Long Duc, Long Phu, Soc Trang, n=709; b: An Lac Tay, Ke Sach, Soc Trang, n=730; c: Phu Thu, Cai Rang, Can Tho, n=691; d: Tan Hung, Thot Not, Can Tho, n=649; and e: Binh Duc, Long Xuyen, An Giang, n=657)

The total and natural mortalities in BD (Z=4.11 yr, M=3.14 yr) reached the highest values among the five populations due to the high erosion of the channel and in the process of concreting (Fig. 3). Fishing mortality (F=0.22-1.58) of all five populations were smaller than natural mortality (M=1.46-3.14) (Fig. 3).

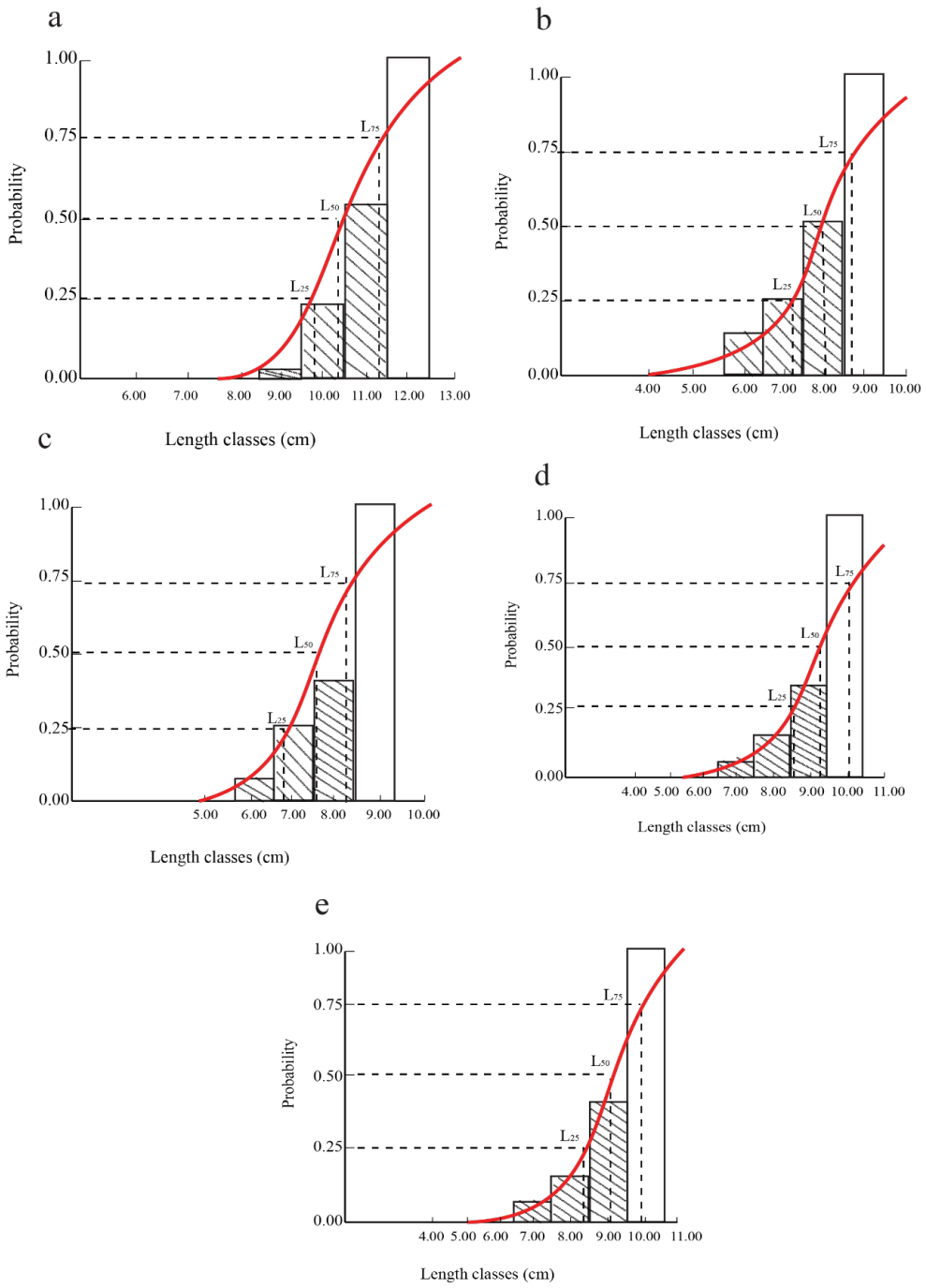

Fig. 3. The length converted catch curve of *Periophthalmodon septemradiatus*
(a: Long Duc, Long Phu, Soc Trang, Z=2.21, M=1.82, F=2.39 and E=0.18; b: An Lac Tay, Ke Sach, Soc Trang, Z=2.86, M=1.59, F=1.27 and E=0.44; c: Phu Thu, Cai Rang, Can Tho, Z=1.58, M=1.44, F=0.14 and E=0.09; d: Tan Hung, Thot Not, Can Tho, Z=4.05, M=2.47, F=1.58 and E=0.39; and e: Binh Duc, Long Xuyen, An Giang, Z=4.11, M=3.14, F=0.97 and E=0.24)

The first catch length (L_c or L_{50}) of the fish population in LD was the lowest (L_c=7.0 cm, Fig. 4) due to the low average length of the fish population (8.12±0.05cm). The L_c of *P. septemradiatus* in TH (9.5 cm, Fig. 4) and in BD (9.2 cm, Fig. 4) were different from those in LD, ALT, and PT since the average total length of this species in BD (TL=9.17±0.05cm) and TH (TL=9.03±0.06cm) was larger than those in LD, ALT, and PT. The L_c/L_∞ of *P. septemradiatus* along the Hau River ranged from 0.55 (LD) to 0.76 (TH).

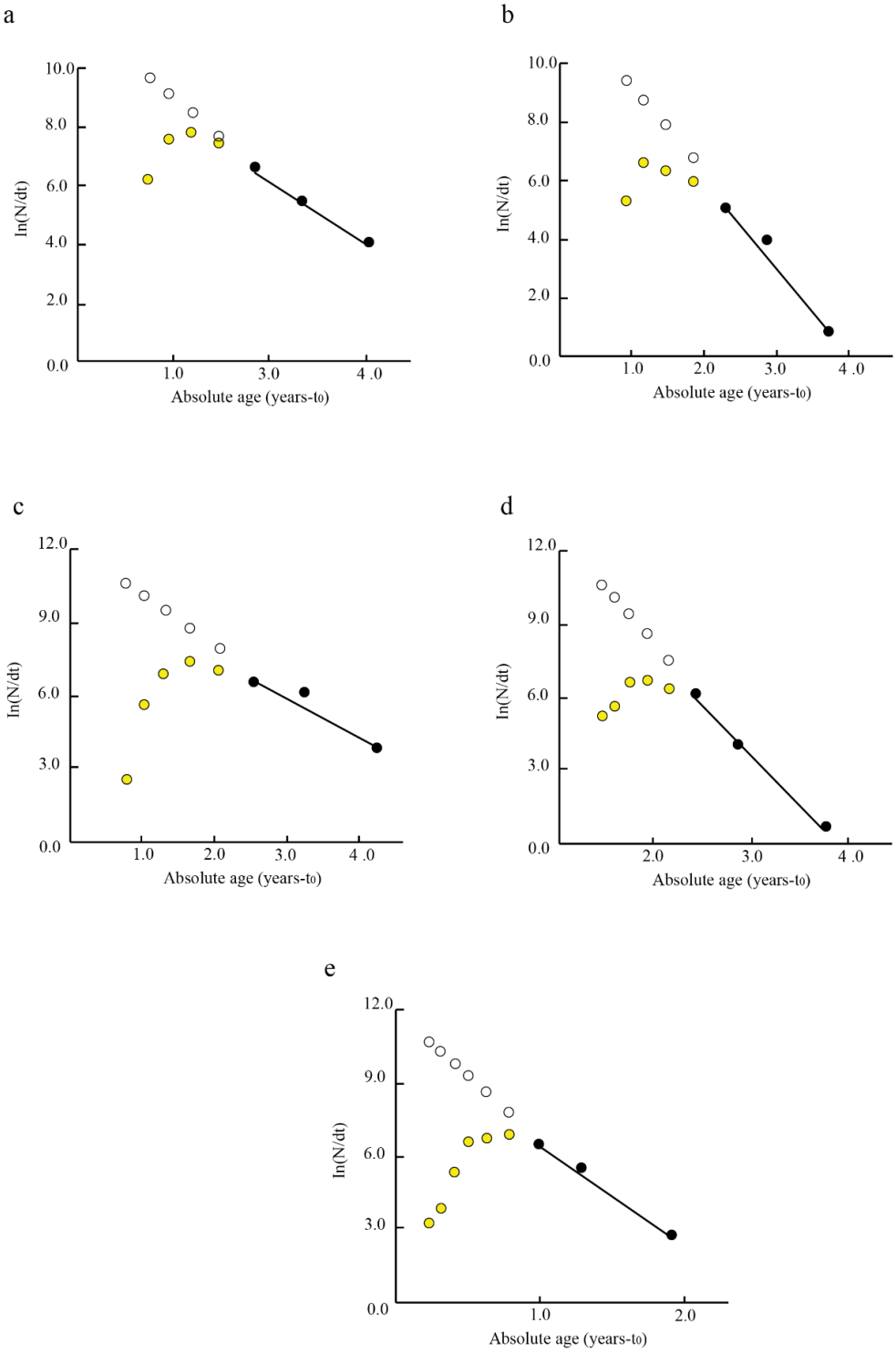

Fig. 4. The probability of capture of *Periophthalmodon septemradiatus*
(a: Long Duc, Long Phu, Soc Trang, L_{25}=6.3, L_{50}=7.0 and L_{75}=7.7 cm; b: An Lac Tay, Ke Sach, Soc Trang, L_{25}=7.1, L_{50}=8.0 and L_{75}=8.9 cm; c: Phu Thu, Cai Rang, Can Tho, L_{25}=8.4, L_{50}=9.2 and L_{75}=9.9 cm; d: Tan Hung, Thot Not, Can Tho, L_{25}=7.1, L_{50}=7.7 and L_{75}=8.3 cm; and e: Binh Duc, Long Xuyen, An Giang, L_{25}=8.6, L_{50}=9.5 and L_{75}=10.5 cm)

The growth performance (Φ') of *P. septemradiatus* ranged from 1.89 to 2.41, reaching the lowest value in PT (1.89) and the highest value in BD (2.41). Conversely, the longevity of this species

(t_{max}=1.88-6.12) reached the highest value in BD (t_{max}=6.12 yr) and the lowest in BD (t_{max}=1.88 yr). This suggested that *Φ'* and t_{max} had a strong relationship and regulated from the environmental condition among five studied sites. In addition, the landslide in BD could narrow down of riverbanks (e.g., fish habitat), leading to the highest value of *K* (1.6) and M (3.14) and the lowest value of t_{max} (1.88) among five studied regions (Fig. 4).

The exploitation rate (*E*) of *P. septemradiatus* ranged from 0.14 in PT to 0.44 in ALT. Two populations in ALT and TH were subjected to overexploitation as the *E* values of these two sites (0.44 in ALT and 0.39 in TH) were significantly higher than permission exploitation rates (E_{50} was 0.402 in ALT and 0.278 in TH, Fig. 5). However, *E* values of the last three fish populations (0.18 in LD, 0.14 in PT and 0.24 in BD) were lower than E_{50} (0.380 in LD, 0.397 in PT, and 0.427 in BD, Fig. 5).

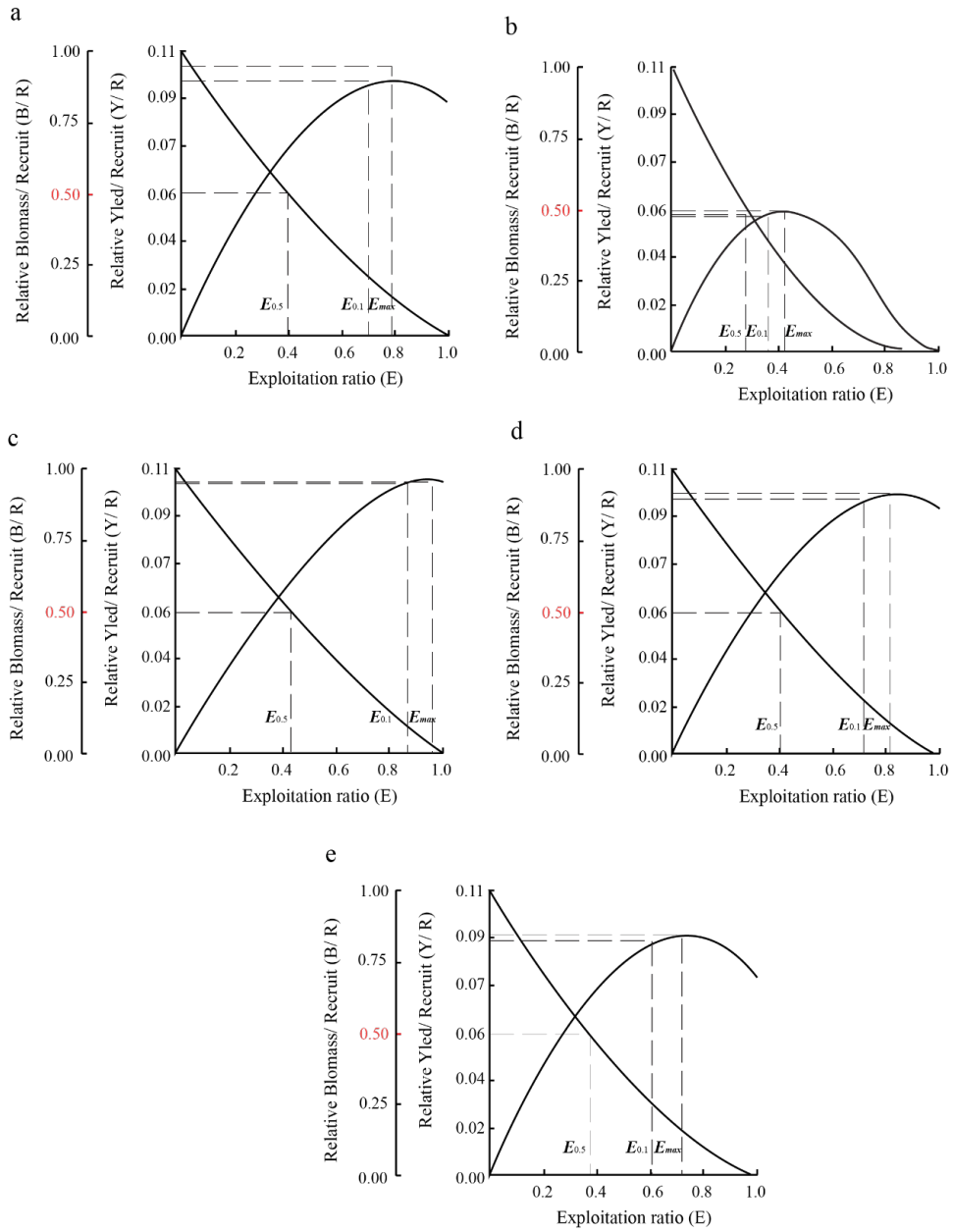

Fig. 5. The relative yield-per-recruit and relative biomass-per-recruit of *P. septemradiatus*
(a: Long Duc, Long Phu, Soc Trang, E_{max}=0.716, $E_{0.1}$=0.608 and $E_{0.5}$=0.380; b: An Lac Tay, Ke Sach, Soc Trang, E_{max}=0.815, $E_{0.1}$=0.713 and $E_{0.5}$=0.402; c: Phu Thu, Cai Rang, Can Tho, E_{max}=0.792, $E_{0.1}$=0.706 and $E_{0.5}$=0.397; d: Tan Hung, Thot Not, Can Tho, E_{max}=0.421, $E_{0.1}$=0.355 and $E_{0.5}$=0.278; and e: Binh Duc, Long Xuyen, An Giang, E_{max}=0.956, $E_{0.1}$=0.868 and $E_{0.5}$=0.427)

DISCUSSION

The more active in the male *P. septemradiatus* than females during the period on the muddy flat could lead to the outnumber of males compared to females, which was also found in some other gobiid species living in and out its habitats such as *Periophthalmus papilio* in Nigeria **(Lawson, 2010)**, *Trypauchen vagina* **(Dinh, 2018b)** and *Stigmatogobius pleurostigma* **(Dinh and Tran, 2018)** in the Mekong Delta. Conversely, the outnumber of females than males was found in *Periophthalmus barbarus* in Nigeria **(Chukwu *et al.*, 2010)** and *Butis butis* in the Mekong Delta **(Dinh and Le, 2017)**. Likewise, the sex ratio of 1:1 was found in some gobies such as *Periophthalmodon schlosseri* in Malaysia **(Mazlan and Rohaya, 2008)**, *Pseudapocryptes elongatus*, *Boleophthalmus boddarti* and *Parapocryptes serpersater* in the Mekong Delta **(Tran *et al.*, 2007; Dinh *et al.*, 2015a&b)**. The difference in sex ratio of these gobies could resulted in the difference in environmental condition of reproductive behavior.

The *K* of this fish increased from the estuarine sites to riverine sites except for PT which closed some industrial zones, whereas the converse trend was true for t_0. This suggested the change of these two population parameters was related to the difference of flora among five studied sites. *Periophthalmodon septemradiatus* tend to be adapted well to the environment than other gobies living in the same its habitats like *Parapocryptes serperaster* **(Dinh *et al.*, 2015b)**, *Boleophthalmus boddarti* **(Dinh, 2017)**, *Butis butis* **(Dinh, 2018c)**, *Trypauchen vagina* **(Dinh, 2018a)**, *Stigmatogobius pleurostigma* **(Dinh and Nguyen, 2018)** and gobies occurring in other places such as *Periophthalmus barbarus* **(Etim *et al.*, 2002)** and *Periophthalmodon schlosseri* **(Mazlan and Rohaya, 2008)** (Table 3). Compared with the L_∞ of some goby species, the L_∞ of *P. septemradiatus* was shorter than that of *Psuedapcryptes elongatus* **(Tran *et al.*, 2007)** and *Parapocrytpes serperaster* **(Dinh *et al.*, 2015b)**, *Trypauchen vagina* **(Dinh, 2018a)**, *Butis butis* **(Dinh, 2018c)** living in the Mekong Delta, and *P. schlosseri* occurring Malaysia **(Mazlan and Rohaya, 2008)** (Table 3).

The total and natural mortalities of *P. septemradiatus* were lower than those in *Pseudapocrytpes elongatus* **(Tran *et al.*, 2007)** and *Parpacryptes serperaster* **(Dinh *et al.*, 2015b)** in the same habitat (Table 3). This suggested that *P. septemradiatus* may adapt well to the environment than other gobiid species. The L_c/L_∞ of *P. septemradiatus* was higher than some gobies in the same habitat such as *Pseudapocrytpes elongatus* **(Tran *et al.*, 2007)** and *Parapocryptes serperaster* **(Dinh *et al.*, 2015b)**, *Trypauchen vagina* **(Dinh, 2018a)**, *Butis butis* **(Dinh, 2018c)** and so on (Table 3). It seemed that *P. septemradiatus* was caught sooner than these gobies.

The *Φ'* value of *P. septemradiatus* was smaller than that of *P. schlosseri* **(Mazlan and Rohaya, 2008)**, but larger than that of *Periophthalmus barbarus* **(Etim *et al.*, 2002)**, *Pseudapocrypes elongatus* **(Tran *et al.*, 2007)** and *Parapocryptes serperaster* **(Dinh *et al.*, 2015b)**, *Trypauchen vagina* **(Dinh, 2018a)**, *Butis butis* **(Dinh, 2018c)**. This could be resulted from the difference in growth coefficients and maximum length between *P. septemradiatus* and other gobies. The t_{max} of this species is higher than that of *Periophthalmodon schlosseri* **(Mazlan and Rohaya, 2008)**, but lower than that of some other species such as *Pseudapocrytpes elongatus* **(Tran *et al.*, 2007)** and *Parapocyteps serperaster* **(Dinh *et al.*, 2015b)**, *Trypauchen vagina* **(Dinh, 2018a)**, *Butis butis* **(Dinh, 2018c)** (Table 3).

Two populations in ALT and TH were subjected to overexploitation due to the higher of the *E* values than the permission exploitation rates. This could result from the exploitation for food and pet demand in these two studied sites. The overexploitation was also found in some other gobies such as *Glossogobius giuris* **(Dinh *et al.*, 2017)**, *Boleophthalmus boddarti* **(Dinh, 2017)**, *Stigmatogobius pleurostigma* **(Dinh and Nguyen, 2018)** and *Trypauchen vagina* **(Dinh, 2018a)** (Table 3). Like the rest three populations in LD, PT and BD, the population of *Pseudapocryptes elongatus* **(Tran *et al.*, 2007)**, *Parapcryptes serperaster* **(Dinh *et al.*, 2015b)** was un-overexploitation (Table 3).

CONCLUSION

The number of males was higher than that of females. The L_∞ was 12.6 cm in all five populations, but *K* and t_0 varied with studied sites. The *K* value ranged from 0.49 yr^{-1} to 1.6 yr^{-1} (BD), whereas the t_0 was -0.12 in BD and -0.43 in PT. The t_{max} was the lowest value in BD and the highest one in PT. Its *Z* and *M* displayed the highest values in the BD and the lowest one in PT. Conversely,

the highest and lowest values of *F* were in TH and PT, respectively. This goby population was subjected to overfishing in ALT and TH.

ACKNOWLEDGMENTS

This research is funded by the International Foundation for Science under grant number I-2-A-6102-1. We are grateful to staff and students at the Department of Biology, School of Education, Can Tho University for helping us to complete this study.

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