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Population Dynamics of the Goby *Trypauchen vagina* (Gobiidae) at Downstream of Hau River, Vietnam

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ABSTRACT

Trypauchen vagina is a commercial fish, but little is known on its population parameters. This study was carried out at downstream of Hau River in the Mekong Delta, Vietnam to provide fundamental information on the population biology of *T. vagina* based on length-frequency distribution analysis of 1,527 individuals. The male to female *T. vagina* ratio was not significantly different within and between seasons, and the parameters of the von Bertalanffy curve of this fish were given as $L_\infty = 24.15$ cm, $K = 0.53$ yr^{-1} and $t_0 = -0.03$ yr^{-1}. The longevity (t_{max}) and the growth performance (Φ') were 5.56 yrs and 2.50, respectively. The fishing, natural and total mortalities of this fish were 1.29 yr^{-1}, 1.44 yr^{-1}, and 2.73 yr^{-1}, respectively, and its exploitation rate was 0.53. There were two recruitment peaks in May and October, and relative yield-per-recruit and biomass-per-recruit analyses gave $E_{max} = 0.735$, $E_{0.1} = 0.656$ and $E_{0.5} = 0.384$. This gobiid could be potential for future aquaculture due to high growth parameter. The goby stock was subjected to overexploitation so that the mesh size of deep gill nets should be increased and avoiding catch fish during the recruitment period for sustainable fishery management.

INTRODUCTION

The growth parameters and mortality rates play a fundamental role for a fish population dynamic understanding (Amezcua *et al*., 2006), and the exploitation rate obtained from the yield-per-recruit analysis is a valuable tool for fishery management (Al-Husaini *et al*., 2002; Afzaal *et al*., 2016). Additionally, the growth performance retrieved from growth and asymptotic length relationship is used to compare the growth rate between gender and geographic locations of a fish species or between species (Pauly and Munro, 1984). Little is known, however, on biological population parameters of fishes, especially gobiid species in the Mekong Delta.

The burrowing fish *Trypauchen vagina* (Bloch and Schneider, 1801) is a goby species in the Gobiidae family, and it is an elongated-bodied fish (Salameh *et al*., 2010; Siokou *et al*., 2013) and widely distributed in the estuaries in the Indo-Pacific regions (Talwar and Jhingran, 1991; Rainboth, 1996), including the Mekong Delta (Tran *et al*., 2013). The information of this goby species is limited to its morphology and environmental requirements (Talwar and Jhingran, 1991; Salameh *et al*., 2010). Although the goby *T. vagina* is a potential commercial fish and has been being increasingly exploited, there has no information on its population parameters, especially in the Mekong Delta. This study aims to provide helpful information on the parameters of the population biology of this goby species, enabling us to improve its stock and fishery management.

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MATERIALS AND METHODS

Study site

This study was carried out along the downstream of Hau River in Soc Trang Province, Vietnam (9°34'12.41"N, 106°13'38.25"E), from October 2014 to September 2015. Soc Trang comprises a long coastline covered by mangroves and a large number of mudflats with the semi-diurnal tide. The dry (January–May) and wet (June–December) are two main seasons in this regions. The average annual temperature of ~27 °C and ~400 mm monthly precipitation in the wet season, representing the typical natural environment in Mekong Delta (Soc Trang Statistical Office, 2012).

Fish collection and analysis

The deep gill nets with 1.5 cm mesh aperture in the cod end were set at the highest tide along the mudflat and mangrove forest and retrieved after 2–3 h during ebb tide to collect monthly fish specimens in the study region. The fish was sexed based on the external morphology of genital papilla shape (female: oval shape and male: triangle sharp), before being stored in 5% formalin and transported to the laboratory. Fish specimens, in the laboratory, were measured total length (0.1 cm) and weighed (0.01 g). The water temperature and salinity at the study site were measured monthly using a thermometer and a refractometer, respectively, to test if the environmental factors influence the sex ratio.

Data analysis

The difference in male and female *T. vagina* ratio was tested by χ^2 performed by SPSS v.21. The population parameters of this species were calculated using FiSAT II software based on monthly total length measurement data (Gayanilo *et al*., 2005). The initial asymptotic length (L_∞) was calculated as a/b and Z/K was defined as $-(1+b)/b$ from the linear regression $\bar{L}-L' = a+bL'$, where, L' is the cut off length; $\bar{L}$ is the mean length of all fish ($\geq L'$, $\bar{L} = \frac{L_\infty + L'}{1+Z/K}$); a is the regression intercept, and b is the regression slope (Powell, 1979; Pauly, 1986; Wetherall, 1986). The preliminary asymptotic length was used to optimize the asymptotic length (L_∞) and the growth parameter (K) using the ELEFAN I procedure (Pauly and David, 1981; Pauly, 1982, 1987).

The total mortality rate (Z) was calculated from the length-converted capture curve (Beverton and Holt, 1957; Ricker, 1975). The natural mortality rate (M) was obtained the equation $\text{Log}M = -0.0066 - 0.279\text{Log}L_\infty + 0.6543\text{Log}K + 0.463\text{Log}T$, where, L_∞ and K were achieved from the ELEFAN I and T was the mean of annual water temperature (°C) in the study region (Pauly, 1980). The fishing mortality (F) was estimated from the equation $F = Z - M$, and the exploitation rate (E) was calculated as $E = F/Z$ (Ricker, 1975). The length-converted catch curve was used to compute the probability of capture for each size class, while the seasonal recruitment pattern was obtained from the length-frequency data set and the fish length entry firstly into the population for catching (L_c) was computed by plotting the cumulative probability of capture against the class mid-length (Pauly, 1987). The back-projected data was maximum likelihood using NORMSEP procedure (Hasselblad, 1966).

The goby stock and yield were estimated from the yield-per-recruit model of Beverton and Holt (1957) (Sparre and Venema, 1992). The yield-per-recruit (Y'/R) was calculated using the equation:

$$Y'/R = EU^{M/K}\left(1 - \frac{3U}{1+m} - \frac{3U^2}{1+2m} - \frac{3U^3}{1+3m}\right)$$

where, $U = 1-(L_c/L_\infty)$ is the fraction of growth to be completed after entering the exploitation phase $m = \frac{1-E}{M/K} = \frac{K}{Z}$, and the biomass-per-recruit relation (B'/R) was computed from the equation $B'/R = {}^{Y'/R}/F$ (Beverton and Holt, 1966).

The maximum yield exploitation rate (E_{max}), the exploitation rate with the minimal increase of 10% of ($E_{0.1}$), and the exploitation rate with the reduction Y'/R of stock to 50% ($E_{0.5}$) were estimated from the knife-edge selection (Beverton and Holt, 1966). A combination analysis of E and isopleth ratio (L_c/L_∞) was used to determine the goby fishing status based on the method of Pauly and Soriano (1986).

The index of overall growth performance (Φ') was calculated from the equation $\Phi' = \text{Log}K + 2\text{Log}L_\infty$, where, K and L_∞ are two parameters of the von Bertalanffy curve, which was used to compare the von Bertalanffy growth parameters of *T. vagina* and other goby fishes dwelling in the same habitat (Pauly and Munro, 1984). The longevity (t_{max}) of *T. vagina* was calculated as $t_{max} = 3/K$, where, K was the growth parameter, and t_0 was the age when the egg was fertilized (Taylor, 1958; Pauly, 1980).

Table I.- The sex ratio of the goby *T. vagina*.

Sampling time	Fish groups X	F	M	Sum	F / M	χ^2	P
10/2014		34	26	60	1:0.76	1.07	0.30
11/2014		88	73	161	1:0.83	1.40	0.24
12/2014	23	22	28	73	1:1.27	0.72	0.40
1/2015	6	90	78	174	1:0.87	0.86	0.36
2/2015	26	39	46	111	1:1.18	0.58	0.45
3/2015	5	39	36	80	1:0.95	0.12	0.73
4/2015		55	44	99	1:0.80	1.22	0.27
5/2015		53	48	101	1:0.91	0.25	0.62
6/2015		27	35	62	1:1.30	1.03	0.31
7/2015	7	107	99	213	1:0.93	0.31	0.58
8/2015	24	107	101	232	1:0.94	0.17	0.68
9/2015		90	71	161	1:0.79	2.24	0.13
Dry	37	276	252	565	1:0.91	1.09	0.30
Wet	54	475	433	962	1:0.91	1.94	0.63
Sum	91	751	685	1,527	1:0.91	3.03	0.08

X, unsexed; F, female; M, male.

RESULTS

A total of 1,527 individuals were caught comprising 751 females, 685 males and 91 unsexed fish in the study region. The male to female *T. vagina* ratio was close to 1:1 during the study period and the number of males were not significantly different from that of females within and between seasons ($P > 0.05$, Table I). There was no significant different in water temperature between the dry (29.07±1.32 °C) and wet seasons (28.41±0.90 °C, t-test, $P > 0.05$); but the water was more salter in the dry (8.86±3.75‰) compared to the wet season (2.68±2.28%, t-test, $P < 0.001$).

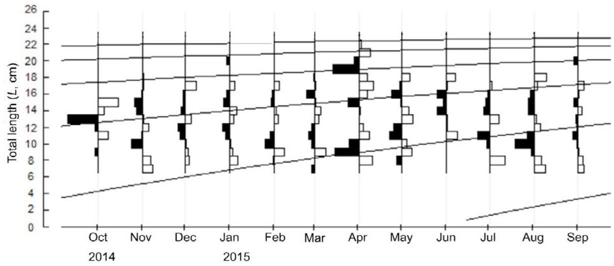

Fig. 1. Length-frequency distribution of *T. vagina* (n = 1,527). The curves show the increase of fish length over time.

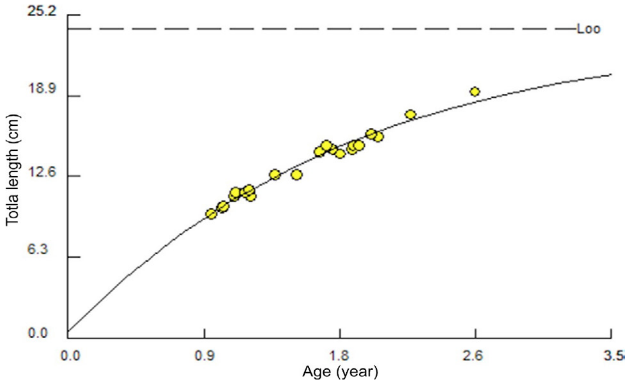

Fig. 2. The von Bertalanffy of *T. vagina* based on growth increment analysis (L_∞ = 24.15 cm, t_0 = –0.03 yr^{-1}, K = 0.56 yr^{-1}).

The population parameters including asymptotic length, growth rate, longevity, mortality, recruitment, exploitation indices and yield-per-recruit were estimated based on the length-frequency analysis of 1,527 individuals (6–23 cm in TL). There were six fish size groups, *i.e.,* six growth curves represented by six dark lines (Fig. 1) in the population of *T. vagina* in this study area, and the bigger fish grew more slowly than small fish due to the slight slope in the larger fish compared to small fish. The growth increment data, which was obtained from NORMSEP procedure, analysis showed that the von Bertalanffy growth curve of *T. vagina* was $L_t = 24.15\ (1 - e^{-0.56(t+0.03)})$ (Fig. 2).

The length-converted catch curve analysis revealed that the total (Z), fishing (F) and natural (M) mortalities of the goby *T. vagina* were 2.73, 1.29 and 1.44, respectively (Fig. 3A). The exploitation rate of this fish was 0.53, and there was a variation in fishery recruitment over time of this goby with two recruitment peaks occurred in May and October (Fig. 3B). The fish length at first capture (L_c or L_{50}) estimated from the capture probability analysis was 13.75 cm (Fig. 3C).

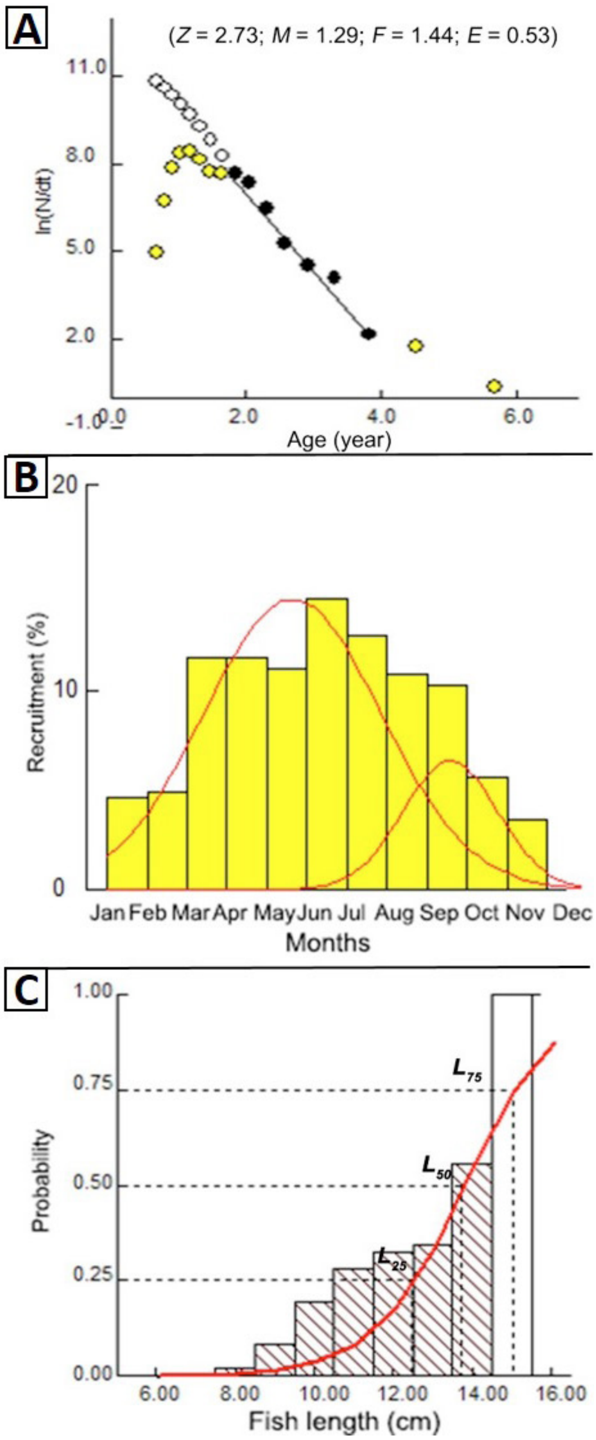

Fig. 3. The length converted catch curve (a), recruitment pattern (b), and the probability of capture of *T. vagina* (c, L_{25} = 11.27, L_{50} = 13.75 and L_{75} = 15.02 cm, estimated from the logistic transform curve, *e.g.,* red line).

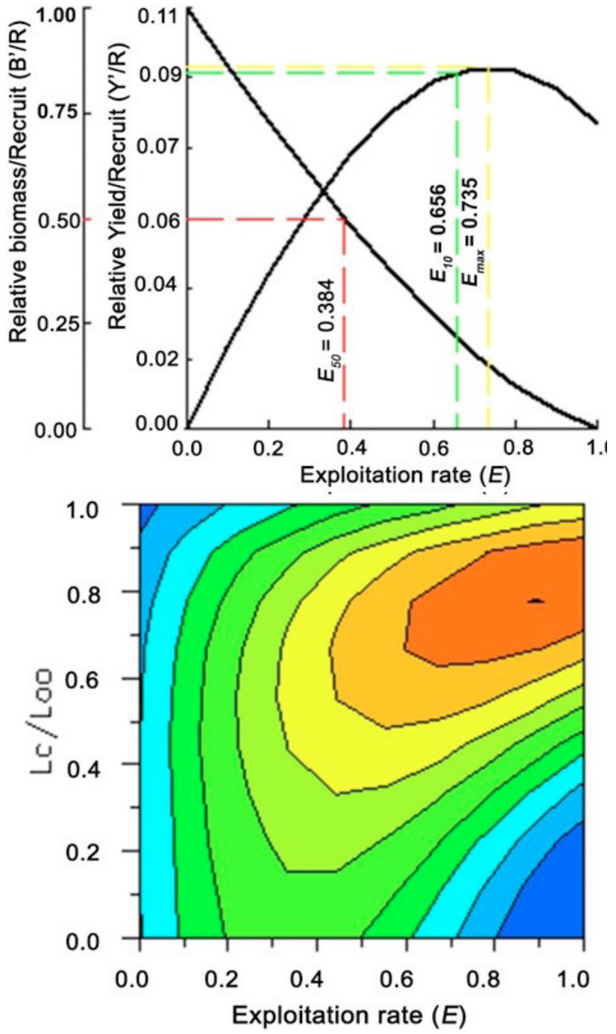

Fig. 4. The relative yield-per-recruit and relative biomass-per-recruit (a, E_{max} = 0.735, $E_{0.1}$ = 0.656 and $E_{0.5}$ = 0.384), and the yield isopleths (b) for *T. vagina*.

The yield-per-recruit and biomass-per-recruit of this goby *T. vagina* were analyzed showed that the optimum yield ($E_{0.1}$), the yield at the stock reduction of 50% ($E_{0.5}$) and the maximum sustainable yield (E_{max}) were 0.384, 0.656 and 0.735, respectively (Fig. 4). The yield isopleths (L_c/L_∞) of this fish was 0.57, and its growth performance and longevity were 2.50 and 5.56, respectively.

DISCUSSION

The sex ratio of some fish was strongly regulated by temperature variation, e.g., *Pomatoschistus minutus* in Thun Lake, Sweeden (Wedekind *et al*., 2013). However, the male to female of *T. vagina* ratio in this study was close to 1:1 that is also found in some gobies living in the same habitat of *T. vagina* such as *Pseudapcryptes elongatus* (Tran, 2008), *Boleophthalmus boddarti* (Dinh, 2015) and *Parapocryptes serperaster* (Dinh *et al*., 2015), suggesting that variation in temperature (26.5–30 °C) did not significantly influence the sex ratio of this goby.

The fish population structure analysis requires at least 1500 fish of specimens collected over six months with distinct peaks in length-frequency distribution (Pauly, 1987). In the present study, the fish samples (*e.g.,* 1527 individuals collected during 12 months) adopted this sampling criterion for analysis of population parameters. Moreau *et al*. (1986) found that the growth performance index (*Φ'*) is the best growth index compared to another growth index $\omega = K \times L_\infty$ since *Φ'* exhibits the least degree of variation when comparing growth parameters between different tilapia populations. The growth parameter *Φ'* is usually similar within the related taxa and have narrow normal distributions (Moreau *et al*., 1986; Tran *et al*., 2007). When study on the population parameters of *P. serperaster*, Dinh *et al*. (2015) showed that the difference in growth performance (*Φ'*) between some gobiid fishes result from the variation of growth parameter (*K*) and asymptotic length (L_∞). Likewise, *K* and L_∞ of *T. vagina* were smaller than those of *Periophthalmus barbarrus* (Etim *et al*., 2002), *P. elongatus* (Tran *et al*., 2007), *P. schlosseri* (Mazlan and Rohaya, 2008) and *P. serperaster* (Dinh *et al*., 2015) (Table II), resulting in *Φ'* of *T. vagina* was lower than that of other gobiid fish *P. elongatus* (Tran *et al*., 2007), *P. schlosseri* (Mazlan and Rohaya, 2008) and *P. serperaster* (Dinh *et al*., 2015), but higher than that of *Periophthalmus barbarrus* (Etim *et al*., 2002) (Table II).

Table II.- Population parameters of various gobiid fishes.

Species	L_∞	K	t_{max}	Z	F	M	L_c	E	Φ'	Sources
Periophthalmus barbarus	21.60	0.55	5.45	4.21	2.86	1.35	10.2	0.68	2.41	Etim *et al.* (2002)
Pseudapocryptes elongatus	26.00	0.65	4.35	2.91	1.47	1.44	11.75	0.51	2.64	Tran *et al.* (2007)
Periophthalmodon schlosseri	29.00	1.40	2.14	-	-	-	-	-	3.10	Mazlan and Rohaya (2008)
Parapocryptes serperaster	25.52	0.74	4.05	3.07	1.57	1.51	14.6	0.49	2.67	Dinh *et al.* (2015)
Trypauchen vagina	24.15	0.56	5.56	2.73	1.29	1.44	13.75	0.53	2.50	Present study

The goby *T. vagina* had more potential for practice artificial spawning due to the high value of longevity that enable this fish spawn numerous time. The low value of growth parameter of *T. vagina* may result in its longevity was higher than that of other gobiid species in the Gobiidae family such as *P. elongatus* (Tran *et al*., 2007) and *P. Serperaster* (Dinh *et al*., 2015) in the Mekong Delta, and *P. barbarrus* in Nigeria (Etim *et al*., 2002) and *P. schlosseri* (Mazlan and Rohaya, 2008) in muddy flat in Malaysian water (Table II). The different geographic latitude, predation and fishing activities are also resulted in the variation of longevity among gobies (Dinh *et al*., 2015).

The goby in this study can adapt well to its habit compared to other co-occurring gobiid fish including *P. elongatus* (Tran *et al*., 2007) and *P. serperaster* (Dinh *et al*., 2015) as the natural mortality of *T. vagina* was lower than *P. elongatus* and *P. Serperaster* (Table II). The fishing mortality of *T. vagina* was similar to *P. elongatus* (Tran *et al*., 2007), but higher than *P. serperaster* (Dinh *et al*., 2015) (Table II), being caused by *P. serperaster* has been fishing increasingly due to its economic valuable (Dinh *et al*., 2015) or by different fishing gears. Similarly, the differences in economic value or fishing gears may lead to the different in fishing mortality between *T. vagina* in the present study region and *P. barbarus* in Nigeria (Etim *et al*., 2002) and the differences in length at first capture of *T. vagina* and other gobiid fishes (Table II). Although the L_∞ of *T. vagina* was shorter compared to *P. elongatus* (Tran *et al*., 2007), its length at first capture was longer (Table II), suggesting the fish stock of *T. vagina* was more suitable exploitation than that of *P. elongatus*. Like *P. elongatus* (Tran *et al*., 2007) and *P. serperaster* (Dinh *et al*., 2015), *T. vagina* was two recruitment times from May to November, seeming recruitment is influenced by environmental factors though it is specific-species.

The goby stock was overfishing in the present study region as its exploitation rate was higher than that of E_{50}. Moreover, the combination of yield isopleths (L_c/L_∞) and exploitation rate (E) analysis showed this goby had been being fishing since its L_c/L_∞ (0.57) and E (0.53) fell into developed fishery quadrant described by Pauly and Soriano (1986). Therefore, the mesh size of fishing gears should be increased and avoided fishing in the period of recruitment for sustainable fishery management.

In conclusion, the sex ratio of *T. vagina* was close to 1:1, and its fish stock was subjected to overexploitation in the study region. This species was high in population recruitment and could be potential for future aquaculture due to high growth constant. However, mesh size of deep gill nets should be increased for future sustainable fishery management.

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Statement of conflict of interest

Authors have declared no conflict of interest.

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