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Additional data on species diversity of gobies (Actinopteri: Gobiiformes) in Xuan Thuy National Park, Nam Dinh Province

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Abstract. Xuan Thuy National Park, located in the Red River Delta Biosphere Reserve, is a biodiverse area that supports a variety of flora and fauna, including fishery resources that benefit residents. This study aimed to provide new data on goby fish in this area by conducting monthly collections from 2018 to 2019. Based on morphological analysis, this study determined a total of 43 species of gobies, 27 of which were tropical fish. The study added three new goby records to the fish fauna of Vietnam, three to northern Vietnam, and eight to the study site. The goby community was dominated by two species, namely *Glossogobius olivaceus* and *Glossogobius giuris*. Besides, the goby community of Xuan Thuy National Park was nearest to that of Tien Hai Wetland Nature Reserve but was far different from that of Halong Bay. This study area had a more diverse goby community than other northern Vietnam locations. These findings further suggest the importance of this mangrove forest for gobies, which will be fundamental data for conservation and sustainable exploitation.

Keywords: Ba Lat estuary; Goby fish; New records, Sustainable exploitation, Mangrove forests

1 Introduction

Owning more than two thousand species widely distributed worldwide from saltwater to freshwater, Gobiiformes shows one of the most diverse orders in terms of species diversity, inhabiting estuarine and mangrove environments [1]. In Vietnam, about 102 species have been recorded in this order [2]. Many of them have high commercial value, namely four-eyed sleeper (*Bostrychus sinensis*) [3] or *Glossogobius olivaceus* [4], and are ecosystem engineers such as shuttles hoppfish (*Periophthamus modestus*) when their burrows become a suitable shelter for other animals [5].

As the first wetland area to be announced as a Ramsar site in Southeast Asia since 1989, Xuan Thuy National Park is a precious part of the Red River Delta Biosphere Reserve's core zone, which serves an important role in biodiversity conservation. It is also a hot spot for protection because it is often under pressure from aquaculture and fisheries activities [6]. The mangrove forests are well developed in the park, with about 4000 ha of mangrove land [7], and they play a significant function in providing nutrients, a habitat, reproduction, and growth for plants and animals [8-10]. Applying artificial neural networks, Do & Tran [11] and Do et al. [12] determined potential nursery grounds and demonstrated the role of this area for fish at the early stages.

Up to now, gobies have been investigated within the ichthyo-fauna surveys in Xuan Thuy National Park, e.g., Ho Thanh Hai and Hoang Thi Thanh Nhan [13] and Nguyen et al. [14]. Besides,

the number of gobies seems underestimated since previous works have yet to use specific gears for goby collections, especially within the mangrove forests, and they used specimens bought from local fishers. Thus several small-size gobies might be ignored. As a result, new records might also be added to this mangrove forest and Vietnam. The present study utilized monthly collections of gobies within the mangrove forest of Xuan Thuy National Park to update a list of goby fish in this national park. Furthermore, a comparison of ichthyofauna between the study site and other areas in northern Vietnam will be examined to demonstrate the function of mangrove forests for gobies. The current results will be valuable for aquatic resources management in a tropical estuary mangrove forest.

2 Materials and Methods

2.1 Study area

The study was conducted in a well-developed mangrove forest of Xuan Thuy National Park along the Red River Delta, northern Vietnam (see Fig. 1). The research area is in the tropical monsoon region. The rainy season is from May to October, the dry season from November to April, and the annual temperature range is 6.8 to 40.1 °C, with an average of 24 °C [6]. The average rainfall is 1175 mm per year. Northeast monsoons prevail during the dry season [6].

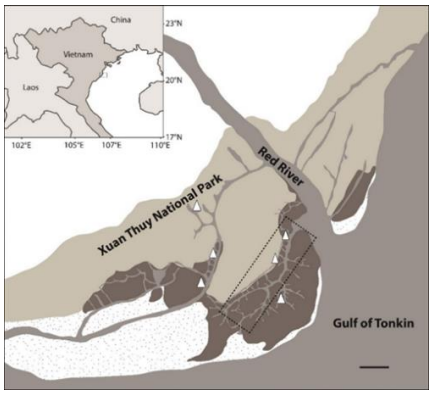

Fig. 1. A map showing sampling sites where surveys were carried out in the Xuan Thuy National Park, northern Vietnam. Dash rectangles indicate where goby specimens were collected using a fishing trap net (10 mm mesh size) from March 2018 to February 2019. White triangles indicate where a hand net (2 mm mesh size) was used to collect gobies in March, June, September, and December 2018

2.2 Fish collection

Gobies were collected using a fishing trap net (mesh size 10 mm) set at a certain area within the mangrove forest from March 2018 to February 2019. A hand net (mesh size 2 mm) was also used to collect gobies within the mangrove forests in March, June, September, and December 2018 (see Fig. 1). After collection, specimens were fixed in a plastic bottle containing 8–10% formalin solution before being transferred to 75% ethanol in the laboratory. All specimens were deposited in the Department of Zoology, Faculty of Biology, Hanoi National University of Education, Vietnam.

2.3 Fish identification

Specimens were identified at the species level based on external morphology according to Nguyen [2], Kottelat [15], Nakabo [16], Tran et al. [17], and relevant materials. A list of families and orders was compiled following Fricke et al. [18]. The climate zone of goby species (template, subtropical or tropical species) was in accordance with Froese and Pauly [19].

2.4 Data analysis

The goby fauna of the other ten adjacent areas in Northern Vietnam was collected and recorded as presence or absence data in our previous study [20]. The data were subjected to cluster analysis utilizing the UPGMA method based on a similarity matrix with qualitative information. This analysis was performed using NTSYSpc version 2.2 software [21].

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3 Results and Discussion

3.1 Species composition

Based on a total of 1747 specimens collected in the Xuan Thuy National Park, 43 species of 25 genera and two families of goby were identified (see Table 1). Of which, Gobiidae was more diverse in the present study than others (37 species belong to 22 genera, accounting for 86% of the total species). The result is the first intensive list of goby fish in Xuan Thuy National Park. Amongst identified species, *Bostrychus sinensis* is listed in the Vietnam Red Data Book at the CR level [22].

Climate distribution

Based on data from Froese and Pauly [19], most gobies in the study site were from the tropical zone, and they are distributed on northern Vietnam's coast. Of 40 identified species in Xuan Thuy National Park, twenty-seven species were from the tropical region (accounting for 67.5%), six temperate fish (accounting for 15.0%), and seven subtropical fish (accounting for 17.5%). This phenomenon is also reported by Ta et al. [23].

Monthly occurrence

The number of species collected monthly ranged from 8 to 22 (see Table 1). Amongst collected fish, eight species were found in more than ten sampling times (months) during a year-round survey, including *Glossogobius giuris*, *Glossogobius olivaceus*, *Bostrychus sinensis*, *Periophthalmus modestus*, *Butis koilomatodon*, *Aulopareia unicolor*, *Gobiopsis macrostoma*, and *Tridentiger barbatus* (see Table 1).

3.2 New records of goby

Of 43 species collected in the study area, it indicates that three species were new records for the ichthyofauna of Vietnam, i.e., *Acentrogobius suluensis*, *Apocryptodon punctatus*, and *Oxyurichthys cornutus*. The number of species as new records was 3 and 8 for northern Vietnam and Xuan Thuy National Park, respectively (see Table 1 and Fig. 2) [14, 20, 24, 25].

Table 1. List of goby fish collected in mangrove forests in Xuan Thuy National Park, northern Viet Nam

Order	Name	Month												Month occurrence	Climate
		Mar 2018	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2019	Feb		
	Eleotridae														
1	*Bostrychus sinensis* Lacepède, 1801	x		x	x	x	x	x	x	x	x	x	x	11	Tr
2	*Butis butis* (Hamilton, 1822)						x			x	x	x		4	Tr
3	*Butis koilomatodon* (Bleeker, 1849)	x	x	x	x		x	x	x	x	x	x		10	Tr
4	*Eleotris fusca* (Forster, 1801)								x	x				2	Tr
5	*Eleotris melanosoma* Bleeker, 1853							x		x				2	Tr
6	*Eleotris oxycephala* Temminck & Schlegel, 1845						x	x	x					3	S
	Gobiidae														
7	*Acanthogobius flavimanus* (Temminck & Schlegel, 1845)	x				x	x		x			x		5	T
8	*Acanthogobius hasta* (Temminck & Schlegel, 1845)							x	x	x			x	4	T
9	*Acanthogobius* sp.				x					x	x			3	

Order	Name	Month												Month occurrence	Climate
		Mar 2018	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2019	Feb		
10	*Acentrogobius moloanus* (Herre, 1927)	x	x	x	x			x	x	x	x		x	9	Tr
11	*Acentrogobius suluensis* [1,2,3] (Herre, 1927)		x											1	Tr
12	*Acentrogobius viridipunctatus* (Valenciennes, 1837)	x		x	x	x			x	x	x		x	8	Tr
13	*Apocryptodon madurensis* (Bleeker, 1849)		x	x	x				x			x		5	Tr
14	*Apocryptodon punctatus* [1,2,3] Tomiyama, 1934		x	x										2	S
15	*Aulopareia unicolor* (Valenciennes, 1837)	x	x	x	x	x	x	x	x			x	x	10	Tr
16	*Boleophthalmus boddarti* [3] (Pallas, 1770)		x	x										2	Tr
17	*Boleophthalmus pectinirostris* (Linnaeus, 1758)		x						x					2	Tr
18	*Caragobius urolepis* (Bleeker, 1852)								x					1	Tr
19	*Eugnathogobius illotus* (Larson, 1999)	x			x									2	Tr
20	*Glossogobius aureus* Akihito & Meguro, 1975			x		x				x				3	Tr
21	*Glossogobius giuris* (Hamilton, 1822)	x	x	x	x	x	x	x	x	x	x	x	x	12	Tr
22	*Glossogobius olivaceus* (Temminck & Schlegel, 1845)	x	x	x	x	x	x	x	x	x	x	x	x	12	T
23	*Gobiopsis macrostoma* Steindachner, 1861	x	x	x	x		x	x	x	x	x	x		10	Tr
24	*Gobiopterus chuno* (Hamilton, 1822)	x			x									2	Tr
25	*Mugilogobius abei* (Jordan & Snyder, 1901)	x			x									2	S
26	*Mugilogobius chulae* [3] (Smith, 1932)	x												1	Tr
27	*Odontamblyopus rubicundus* Keith, Hadiaty, Busson & Hubert, 2014		x	x					x					3	S
28	*Oxuderces denctatus* Eydoux & Souleyet, 1850		x					x						2	Tr
29	*Oxyurichthys cornutus* [1,2,3] McCulloch & Waite, 1918	x												1	Tr
30	*Oxyurichthys* sp.			x										1	
31	*Oxyurichthys tentacularis* [3] (Valenciennes, 1837)			x			x							2	Tr
32	*Parapocryptes serperaster* (Richardson, 1846)		x											1	Tr
33	*Periophthalmus modestus* (Regan, 1908)	x	x	x	x	x	x	x	x	x	x		x	11	S

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Order	Name	Month												Month occurrence	Climate
		Mar 2018	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 2019	Feb		
34	*Psammogobius biocellatus* (Valenciennes, 1837)		x		x		x	x		x		x		6	Tr
35	*Pseudogobius poicilosoma* (Bleeker, 1849)	x			x									2	Tr
36	*Pseudogobius* sp.	x												1	
37	*Pseudogobius taijiangensis* [3] Chen, Huang & Huang, 2014	x												1	S
38	*Scartelaos histophorus* (Valenciennes, 1837)		x											1	Tr
39	*Taenioides eruptionis* (Bleeker, 1849)								x					1	Tr
40	*Tridentiger barbatus* (Günther, 1861)	x	x	x	x		x	x	x	x	x	x		10	T
41	*Tridentiger bifasciatus* [3] Steindachner, 1881		x	x	x				x	x	x	x		7	T
42	*Tridentiger trigonocephalus* (Gill, 1859)	x						x	x			x		4	T
43	*Wuhanlinigobius polylepis* (Wu & Ni, 1985)	x												1	S
	Total	21	22	19	18	18	8	13	15	21	17	12	13		

Name: [1,2,3] indicate new records for Vietnam, northern Vietnam and the study site; Climate (by Froese and Pauly, [19]): Tr: Tropical, S: Subtropical, T: Temperate.

The three new records for Vietnam have the following diagnostic characteristics: *Apocryptodon punctatus* having dorsal fin ray VI-I, 22, first and second dorsal fin connected by a small membrane; large mouth, its extension to the behind posterior edge of the eye; five small dark blotches on the body from trunk to caudal-fin base, connected by dark horizontal lines [26]. *Acentrogobius suluensis* has the dorsal fin ray VI-I, 9; no scales on the head; on gill cover with a blue margin; brown spots on the head and upper half of the body; five rectangular blotches on the body from the base of the upper pectoral fin to base of the caudal fin; with 2-3 blue spots between each blotch [27]. *Oxyurichthys cornutus* has a first dorsal-fin spine elongate and much longer than head length; fin spines banded with rows of black flecks; lower pectoral rays with rows of distinct dark spots; upper lip not constricted; tentacle on the dorsoposterior surface of the eye; anterior nares with dense black speckle medially; scales on the dorsum with many distinct round dark spots at posterior margins; five round blotches along mid-side of body, blotch at caudal base smallest and often triangular; five rectangular saddles on dorsum; but not pronounced saddle on caudal peduncle [28] (see Fig. 2).

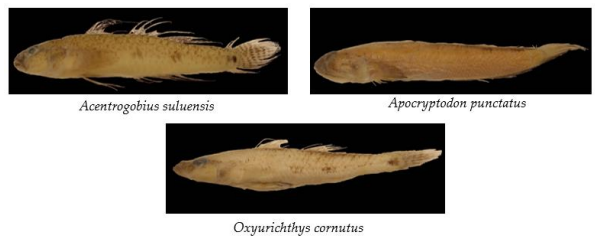

Fig. 2. Photos of new records of goby for Vietnam collected in the study site

3.3 Species composition comparison between the study area and others in northern Vietnam

The cluster diagram based on presence/absence data of different areas using UPGMA shows that the goby community in Xuan Thuy National Park was the most similar to that in Tien Hai Wetland Nature Reserve. It was the most distant from that in Halong Bay (see Table 2 and Fig. 3). Despite the similarity in the presence of mangroves, the goby community in the study site is far different from that in Phu Long (see Table 2 and Fig. 3).

Mangrove forests provide a suitable environment for the development and growth of gobies since the goby community is diverse, and several species perform positive growth [3, 4, 25, 35, 36]. The number of goby species in the study site, a well-developed mangrove forest in northern Vietnam, is almost similar to that in the Red River and Halong Bay and much higher than in the remaining areas (see Table 2). The sampling site in the present study is located within the mangrove forest in the Red River basin. However, the number of species was nearly equal to that of the Red River and Halong Bay, which resulted in several previous surveys [14] (see Table 2). That fact implies a high diversity of gobies in this estuary mangrove forest. The present study added 16 species for the goby fauna in the Red River basin (see Table 1). The figure indicates that the current survey conducted a more intensive collection than previous ones at the Red River mouth. In addition, this study tried to collect small fish inside the mangroves, which is different from the sampling sites in Nguyen et al. [13], who conducted surveys along the mainstream of the river and in its tributaries. Sampling areas may contribute to differences in the species composition recorded. This is also represented by a low coefficient similarity of gobies between Xuan Thuy National Park and the Red River even though the former is a part of the latter (0.613) (see Table 2 and Fig. 3). This case further provides clear evidence to suggest the important role of mangroves for goby fish.

Table 2. The similarity of the goby community between the study area and others in northern Vietnam

Areas	Ba Che River	Tien Yen River	Ha Long Bay	Phu Long Mangrove Forest	Bach Dang River	Van Uc River	Tien Hai Wetland Nature Reserve	Red River	Ma River	Xuan Thuy National Park
Source	Tran and Ta, [29]	Tran and Ta, [29]	Kimura et al., [30]	Nguyen et al., [31]	Nguyen et al., [32]	Nguyen et al., [33]	Tran et al., [25]	Nguyen et al., [14]	Duong, [34]	This study
Number of species	16	16	42	11	21	20	25	44	20	43
Ba Che River	1									
Tien Yen River	0.868	1								
Ha Long Bay	0.604	0.623	1							
Phu Long Mangrove Forest	0.802	0.783	0.557	1						
Bach Dang River	0.783	0.745	0.557	0.736	1					
Van Uc River	0.811	0.849	0.566	0.783	0.821	1				
Tien Hai Wetland Nature Reserve	0.764	0.783	0.613	0.698	0.735	0.821	1			
Red River	0.717	0.698	0.471	0.613	0.650	0.736	0.651	1		
Ma River	0.830	0.811	0.566	0.764	0.764	0.830	0.783	0.717	1	
Xuan Thuy National Park	0.632	0.669	0.481	0.574	0.604	0.726	0.811	0.613	0.670	1

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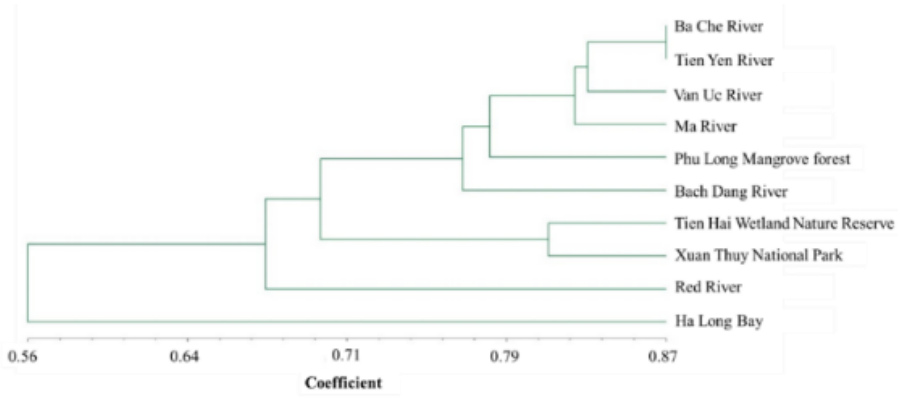

Fig. 3. Similarity of species composition of goby species occurring in several coastal waters in northern Vietnam. Sources of data are available in Table 2

A similar picture is observed in the present study site and Halong Bay, where the goby community is the most distant from each other (see Fig. 3). In Ha Long Bay, Kimura et al. [30] conducted surveys from 2009 to 2016, and they also bought fish specimens in local markets. Thus several typical gobies from the coastal or marine areas (e.g., *Amblyeleotris gymnocephala* and *Oxyurichthys uronema*) were collected, probably making the two goby communities different. However, the number of species listed in Kimura et al. [30] is also nearly equal to that of the present study. These facts would have demonstrated a high diversity of the goby community in this mangrove forest. It also can be seen from the extrapolated species richness based on quantitative data that the number of new records would continue to rise if the sample size increases (see Fig. 3).

In the same river basin, the mangrove forests are more developed in Xuan Thuy National Park than those in Tien Hai Wetland Nature Reserve. It is stated that mangroves help to enhance the fish community well [37], and dense mangroves support the fish community better than spare ones [38, 39]. Hence, a higher diversity of goby species in Xuan Thuy National may relate to the density of mangroves [25]. In addition, several species of gobies were reported to have faster growth in Xuan Thuy National Park, such as *P. modestus* [34], *B. sinensis* [3] and *G. olivaceus* [4]. The species composition was almost shared among the two study sites (see Fig. 3), which may be due to having similar hydrological conditions influenced by the water discharge of the Red River.

The goby community in Xuan Thuy National Park is quite different from that in the Phu Long mangrove forest regarding species richness and composition (see Table 2). In Phu Long, two surveys were conducted in 2011, and only 11 goby species were collected, much lower than those in the present study. The difference in the number of species between the two sites may be due to differences in areas of mangroves. The area of natural mangrove forest in Phu Long is much smaller than that in Xuan Thuy National Park (38.6 ha vs. 1.855 ha) [6, 39]. However, another aspect, a greater sampling effort (monthly collection) in Xuan Thuy National Park, also may contribute to higher diversity of goby in this area compared to Phu Long. Notably, the species composition was far different between the two sites. The present study site is strongly and frequently influenced by the water discharge from the Red River, and the water has lower salinity, which is different from the Phu Long mangrove, which is strongly influenced by the tide; thus, water salinity is always high. The species comparison showed that only three species are

occurring in both sites, i.e., *Acentrogobius viridipunctatus*, *Taenioides eruptionis*, and *Psammogobius biocellatus*. This result suggests that the goby community in the mangroves of Xuan Thuy National Park is characterized by the estuarine habitat. Thus, the estuary mangrove seems to be an excellent place for goby fish in the tropical zone. However, further investigations in other regions will be necessary to compare and confirm this phenomenon.

Above all, the higher diversity of goby fish in the mangrove forest in the Ba Lat estuary, if compared to other sites (see Table 2), would have related to the location and topography of this estuary. Ba Lat is the largest estuary in northern Vietnam, characterized by an expansive tidal flat with fringed mangroves [40]. The estuary receives amounts of sediment from the Red River, ca. 115 million tons/per year [6]. Salinization occurs inland to over 20 km in the dry season due to tidal rising. This area has a diurnal tidal cycle with an average range of 1.5 to 1.8 m, and the largest tide reaches 4.5 m [6]. Furthermore, mangrove trees provide shelters and surface sediments, which are essential for different primary producers of mangrove-inhabiting fauna [41]. These diverse and typical habitats in the study site might contribute to the diversity of aquatic organisms, especially gobies, which dominate mangrove forests and estuaries [5, 13, 28, 42, 43]. Compared to other areas in northern Vietnam, the study site has a larger mangrove forest and a bigger estuary, which are probably important factors in explaining the diversity of goby fish in this tropical estuary mangrove.

4 Conclusions

A total of 43 species of 25 genera and two fish families were identified in Xuan Thuy National Park, northern Vietnam. The present study added three new records to the ichthyofauna of Vietnam, three to Northern Vietnam, and eight to Xuan Thuy National Park. It is likely that the number of gobies in this study area could be higher if increasing the sampling effort. The most abundant goby species in Xuan Thuy National Park were *Glossogobius olivaceus* and *G. giuris*. The species composition in Xuan Thuy National Park was found to be similar to that in Tien Hai Wetland Nature Reserve. However, it differed significantly from that in Halong Bay and Phu Long mangroves due to the unique characteristics of the mangrove forests in the largest estuary in northern Vietnam and the sampling frequency. These findings further display the importance of a tropical estuary mangrove for gobies.

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