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The impact of human activities on the biodiversity of fish species composition in rice paddy field in An Giang Province, Southern Vietnam

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ABSTRACT

This study aims to measure the impact of human activities on the biodiversity of fish in three sampled areas of the An Giang province of Southern Vietnam. The fish samples were collected between August 2018 and July 2019 by fish nets and traps at 6 sampling sites of the regions. Using various trapping mechanisms, the V-shaped net, plastic and bamboo fish traps were applied during rice collection periods. The result found that the biodiversity indexes of the regions were 1.321, 0.078, and 7.579 for Shannon-Weaver's diversity, Simpson's dominance, and Margalef's abundance respectively. These biodiversity indexes suggested the fish assemblage inside the dike both islets and riverine regions to be lower than that of the outside sampled areas due to both the natural factors (tides and precipitation) and artificial factors (intensive farming, demand of crops, uses of agricultural chemicals and flood prevention dike system). It transforms the different dominant fish species where the new species of ichthyofauna in An Giang, Vietnam can be the potential for rice-fish farming in the near future.

INTRODUCTION

All the plants and animals, big and small, along with their tremendously diverse ecosystems on Earth are all parts of what we called "biodiversity". The loss of this biodiversity is a serious concern for many reasons. For a “healthy” biodiversity, it provides natural benefits including ecosystems services (contribution to climate stability, protection of water resources, nutrient storage and recycling, etc.), biological resources (food, medicinal and pharmaceutical resources, diversity in genes and species, breeding stocks and population reservoirs, etc.) and social benefits (research and education, recreation and tourism, etc.) (Dudu, 2015). Despite the importance of it, human activities have seriously impaired the health of the biodiversity across the globe, e.g., the intensive farming, crop broadening and excessive exploitation of species for economic means.

Wetlands, such as rice fields and the associated channels, are the congenial habitats for diff erent species of fish, where it provides the foundation for the rice-fish culture (Aditya et al., 2010; Rothuis et al., 2008). The wetlands are important sites for biological conservation, since they are supporting a rich biodiversity and present high productivity (Aditya et al., 2010; Bambaradeniya et al., 2004; Mitsch and Gosselink, 2000). The rice field channels also contributes to biodiversity conservation in wetlands (Maltchik et al., 2011; Tran et al. (2013)) identified 322 fish species in the Mekong Delta, of which, 312 were collected from the fresh and brackish water regions, and of the 10 species of marine fish, they were collected in estuaries. However, no data on fish composition and the biodiversity of fish, in the rice paddy channels in the Mekong Delta, was recorded.

The An Giang region is one of four provinces, which is a Key Economic Zone of the Mekong Delta, that is located between the Tien River and the Hau River. Consequently, the province has a profuse surface water source that is favorable for rice planting and aquaculture. The natural area of An Giang is 3,406 km^2 and consists of three typical ecological sections such as islets, Hau riverside and limestone mountain regions (Le et al., 2006). The advantages of this province are the abundance in the natural aquatic resources and biodiversity of fish species; for example, the fish assemblage in Hau River in An Phu, which is the riverine district of An Giang province, has 69 fish species belonging to 29 different families and 10 orders (Dinh, 2009). Recently, there has been a significant decline of fish assemblage in both of the regions. The causes of these reductions are mainly due to excessive exploitation of technologies and other means, like the use of electric impulses, the fishing net with small mesh size for fishing and others. Furthermore, the human activities, such as intensive farming to increase crop yield, uses agricultural chemicals and utilization of dike systems, to prevent flooding, made great reduction on biodiversity indexes and resources of fish fauna in the rice paddy channel systems in An Giang. Therefore, this study was conducted to understand the relationship between the human activities and biodiversity indexes of ichthyofauna in the three typical ecological regions in An Giang province, Vietnam.

MATERIALS AND METHODS

Study site

The three ecological regions of An Giang province were studied. They were the limestone mountain (Luong Phi, Tri Ton district; 10°25'53,44"N, 104°56'45,45"E), islets (An Thanh Trung, Cho Moi district; 10°25'53.2"N, 105°27'46.4"E) and Hau riverside (Vinh Thanh Trung, Chau Phu district; 10°33'15.6"N, 105°12'28.5"E). In An Giang, the government uses dike systems to prevent flood from August to October for rice production so that fish were collected from both inside and outside dike system. The dry season is between January to May and the wet season is between June to December. They are the two main natural seasons in An Giang province, where they have an annual average temperature of 28 °C and semi-tidal regime. The crops studied, are classified into three periods, it comprises of Crop 1 is between January to April; Crop 2 is between July to November; and crop 3, is between November to January **(Le et al., 2006)**.

Fish collection and analysis

According to **Pham et al. (2003)**, the fish specimens of different sizes, were collected directly by using fishing tools such as fyke nets, weir nets and cast nets at six sampling sites (three ecological regions × two sides of dike system). At each sampling site, six fyke nets were set at high tide, in an area of 5,000 m^2, in the rice paddy channels for 20 hours and the nets were retrieved afterwards. The fish were then collected and measured during rice planting period. It started from the "rice making" process - the method of differentiation and formation of the reproductive organs, having impacted directly in rice yield - corresponding with three rice crops: crop 1 (3/2019), crop 2 (10/2018), and crop 3 (12/2018). After collection, the fish specimens were stored in 4% formaldehyde. The fishes were obtained indirectly from fisherman with the fishing tools like as V-shaped net, plastic or bamboo fish traps and fishing or wired nets (for 3 consecutive days).

All specimens were identified from species to genus using criteria described by **Rainboth (1996)**. The fish was (1) observing for whole body shape and color, the size of the mouth, eyes, nose, barbells, gill, fins, lateral organs; (2) measuring total length, standard length, head length, body height, eye diameter, distance between eyes; and (3) counting the number rays in dorsal, pectoral, ventral, anal fins; number of scales on lateral side, above lateral side and below lateral side.

The fish specimens were classified using the taxonomic key provided by **Mai (1992)**; **Rainboth (1996)**; **Nguyen and Ngo (2001)**; **Nguyen (2005a), 2005b)** and **Tran et al. (2013)**. The organisation of Order, Families, Genus and Species were sorted using the fish taxonomic system suggested by **Eschmeyer et al. (2019)**.

Data analysis

Biodiversity indexes such as Shannon-Weaver's diverse index $H' = -\sum_{i=1}^{n} p_i \log p_i$ **(Shannon and Weaver, 1949)**, Simpson's dominant index

$\lambda = \sum_{i=1}^{n} (p_i)^2$ **(Simpson, 1949)**, Margalef's abundant index $d = \frac{S-1}{\ln N}$ **(Margalef, 1958)** ($p_i = n_i/N$, n_i: number of individuals of ith species; S: number of species; N: total number of individuals of all species in a research sample) were estimated by PRIMER v.6 **(Clarke and Gorley, 2006)**. According to **Aditya et al. (2010)**, the fish assemblage species were categorized either dominant or rare. If it is proportional to the representation in the sample, then it was either larger or smaller than the average of the evenness value of species (λ). In this study, the value of 0.020 was used for such a division. Lastly, the fish assemblage on the inside and outside the dike, the three ecological habitats and three crops, were determined using the S17 Bray Curtis similarity index performed by PRIMER v.6 **(Bray and Curtis, 1957; Clarke and Gorley, 2006)**.

RESULTS

1,089 fish were collected at six sampling sites from both inside and outside of the three typical ecological regions in the three crops collection cycle in An Giang province (Table 1). A total of 54 fish species in addition to two specimens were classified up to genus levels (*Hemibagrus* sp.1 and *Mystus* sp.1), which belongs to 42 genera, 20 families (Cyprinidae, Cobitidae, Serrasalmidae, Bagridae, Siluridae, Pangasiidae, Clariidae, Loricariidae, Syngnathidae, Eleotridae, Gobiidae, Mastacembelidae, Synbranchidae, Anabantidae, Osphronemidae, Channidae, Soleidae, Cichlidae, Tetraodontidae and Ambassidae) and 11 orders (Cypriniformes, Characiformes, Siluriformes, Syngnathiformes, Gobiiformes, Synbranchiformes, Anabatiformes, Pleuronectiformes, Cichliformes, Tetradodontiformes and Perciformes). *Esomus metalicus* Ahl, found in 1923, was the most abundant species with 206 individuals, followed by *Henicorhynchus siamensis* (Sauvage, 1881) with 142 individuals. With the four species were numbered, *Puntius brevis* (Bleeker, 1849), *Anabas testudineus* (Bloch, 1792), *Trichopsis vittata* (Cuvier, 1831) and *Trichogaster trichopterus* (Pallas, 1770) were a half of *H. siamensis* and a quarter of *E. metalicus*. This is shown in Table 1, where most of fish species were rarely collected with only one or two individuals.

The twelve dominant species collected in An Giang province including *E. metalicus*, *Balantiocheilus melanopterus* (Bleeker,1850), *P. brevis*, *Labiobarbus lineatus* (Sauvage, 1878), *Labeo chrysophekadion* (Bleeker, 1849), *H. siamensis* (Sauvage, 1881), *Mystus atrifasciatus* Fowler, 1937, *A. testudineus*, *T. vittata*, *Trichogaster microlepis* (Günther, 1861), *T. trichopterus*, *Oreochromis niloticus* (Linnaeus, 1758). *E. metalicus* and *P. brevis* were sampled at six sampling sites during the three periods of crops collection. For other species, they were either found inside or outside of one of the two ecological regions for the crop one and two (Table 1). For the 54 species collected, 18 and 20 other species were not found in Hau riverine and islets regions which was found lower than that of the limestone mountain region amongst the 29 species (Table 1).

Cyprinidae was the most common family, followed by Bagridae and Osphronemidae. The other Families are less widespread including Eleotridae, Mastacembelidae, Cichlidae, Ambassidae, Loricariidae, Anabantidae, Serrasalmidae, Pangasiidae and Synbranchidae. The three orders of fish appeared most frequent in the research were Cypriniformes (60%), Siluriformes (40%) and Anabantiformes (10%) …

The abundance was measured by the biodiversity indexes of fish at different ecological regions. This included rice crops and side of dikes presented in Table 2. This revealed that d (Margalef's abundant index) had a wide fluctuation due to the crops and sampling sites (the highest was 7.772 outside and the lowest was 1.674 inside the dike of crop 1). Contrary, H (Shannon-Weaver's diverse index) and λ (Simpson's dominant index) values had a narrow fluctuation (0.540–1.315 and 0.050–0.251, respectively). This showed that the diversity of composition of fish species in the studied area was relatively low but the number of them was abundant and the distribution of individuals between fish species was quite uniform.

Regarding fish specimens collection sites, Fig. 1 showed the similarity index of fish between Chau Phu and Cho Moi (53.58%) more dominant while the least dominant was between Chau Phu and Tri Ton (29.91%). Furthermore, 33.28% showed the similarity index for regions between Cho Moi and Tri Ton. For the sample crops, not too many differences in the similarity index in all three rice crops, ranging from 44.97% (Crop 1 and 3) to 46.10% (Crop 2 and 3) and 49.49% (Crop 1 and 2, Fig. 1). The similarity of fish composition between inside and outside the dike was 46.55% (Fig. 1). It meant that the spatial factor has more effect on the similarity of fish species than the temporal factor.

The similarity index in fish species composition according to the crop periods and site of dike is presented in Table 3. Inside of the dike, the highest indexes found in fish species composition between crop 2 and crop 3 (57.52%) and lowest for crop 1 and crop 2 (12.02%). For the outside of the dike, the highest similarity index was found to be 43.9% for the fish species composition between crop 1 and crop 2. The lowest similarity value was true for crop 1 and crop 3 with 24.39% (Table 3). In terms of the interaction between crops and size of dike, the similarity ranged from 12.02% to 57.52% (Table 3).

Similarities in fish assemblage in terms of ecological regions and side of dike were given in Table 4, ranging from 18.51% to 53.64%. with the highest similarity value in fish assemblage between the inside and outside of dike, found in Tri Ton (53.64%). In terms of ecological region and size of dike, 53.64% was the highest similarity in fish assemblage between inside × Tri Ton and outside × Tri Ton, whereas 18.51% was the lowest for one of the fish assemblage between inside × Tri Ton and outside × Chau Phu.

Table 1. Dominant and rare status fishes collected at in- and out-side dike of three ecological regions in An Giang province

No.	Species	n_i/N										Status								
		N	CM	TT	CP	V1	V2	V3	In	Out	Total	CM	TT	CP	V1	V2	V3	In	Out	Total
1	*Esomus longimanus* (Lunel,1881)	6	0.002	0.000	0.010	0.006	0.000	0.016	0.006	0.005	0.006	R	ab	R	R	ab	R	R	R	R
2	*Esomus metalicus* Ahl,1923	206	0.314	0.022	0.141	0.206	0.108	0.148	0.327	0.053	0.189	D	D	D	D	D	D	D	D	D
3	*Balantiocheilos melanopterus* (Bleeker,1850)	34	0.000	0.000	0.071	0.036	0.000	0.033	0.000	0.062	0.031	ab	ab	D	D	ab	D	ab	D	D
4	*Paraspinibarbus macracanthus* (Pellegrin & Chevey, 1936)	2	0.000	0.000	0.004	0.001	0.007	0.000	0.000	0.004	0.002	ab	ab	R	R	R	ab	ab	R	R
5	*Cyclocheilichthys enoplos* (Bleeker, 1849)	4	0.000	0.000	0.008	0.005	0.000	0.000	0.000	0.007	0.004	ab	ab	R	R	ab	ab	ab	R	R
6	*Puntius brevis* (Bleeker, 1849)	79	0.096	0.127	0.031	0.070	0.027	0.213	0.054	0.091	0.073	D	D	D	D	D	D	D	D	D
7	*Systomus orphoides* (Valenciennes, 1842)	6	0.007	0.000	0.006	0.002	0.020	0.016	0.004	0.007	0.006	R	ab	R	R	D	R	R	R	R
8	*Barbodes binotatus* (Valenciennes, 1842)	1	0.002	0.000	0.000	0.000	0.007	0.000	0.002	0.000	0.001	R	ab	ab	ab	R	ab	R	ab	R
9	*Barbonymus gonionotus* (Bleeker, 1849)	3	0.002	0.011	0.000	0.000	0.020	0.000	0.000	0.005	0.003	R	R	ab	ab	D	ab	ab	R	R
10	*Barbonymus altus* (Günther, 1868)	19	0.021	0.000	0.021	0.016	0.034	0.000	0.006	0.029	0.017	D	ab	D	R	D	ab	R	D	R
11	*Scaphognathops stejnegeri* (Smith, 1931)	21	0.000	0.000	0.044	0.000	0.142	0.000	0.000	0.038	0.019	ab	ab	D	ab	D	ab	ab	D	R
12	*Mystacoleucus chilopterus* Fowler, 1935	4	0.009	0.000	0.000	0.005	0.000	0.000	0.007	0.000	0.004	R	ab	ab	R	ab	ab	R	ab	R
13	*Labiobarbus lineatus* (Sauvage, 1878)	37	0.014	0.000	0.064	0.036	0.034	0.000	0.052	0.016	0.034	R	ab	D	D	D	ab	D	R	D
14	*Labiobarbus leptocheilus* (Valenciennes, 1842)	5	0.000	0.000	0.010	0.006	0.000	0.000	0.000	0.009	0.005	ab	ab	R	R	ab	ab	ab	R	R
15	*Labeo chrysophekadion* (Bleeker, 1849)	32	0.012	0.000	0.056	0.028	0.047	0.000	0.000	0.059	0.029	R	ab	D	D	D	ab	ab	D	D
16	*Henicorhynchus siamensis* (Sauvage, 1881)	142	0.162	0.000	0.152	0.161	0.000	0.000	0.146	0.115	0.130	D	ab	D	D	ab	ab	D	D	D
17	*Puntioplites falcifer* Smith, 1929	8	0.005	0.000	0.012	0.009	0.000	0.000	0.006	0.009	0.007	R	ab	R	R	ab	ab	R	R	R
18	*Puntioplites proctozystron* (Bleeker, 1865)	2	0.005	0.000	0.000	0.002	0.000	0.000	0.004	0.000	0.002	R	ab	ab	R	ab	ab	R	ab	R
19	*Cyprinus carpio* Linnaeus, 1758	2	0.000	0.000	0.004	0.001	0.007	0.000	0.000	0.004	0.002	ab	ab	R	R	R	ab	ab	R	R
20	*Yasuhikotakia lecontei* (Fowler, 1937)	5	0.000	0.000	0.010	0.006	0.000	0.000	0.000	0.009	0.005	ab	ab	R	R	ab	ab	ab	R	R
21	*Syncrossus helodes* (Sauvage, 1876)	11	0.000	0.000	0.023	0.013	0.000	0.000	0.000	0.020	0.010	ab	ab	D	R	ab	ab	ab	D	R
22	*Piaractus brachypomus* (Cuvier, 1818)	6	0.000	0.000	0.012	0.007	0.000	0.000	0.002	0.009	0.006	ab	ab	R	R	ab	ab	R	R	R
23	*Leiocassis siamensis* Regan, 1913	1	0.000	0.000	0.002	0.001	0.000	0.000	0.000	0.002	0.001	ab	ab	R	R	ab	ab	ab	R	R
24	*Hemibagrus* sp.1	6	0.007	0.000	0.006	0.006	0.000	0.016	0.000	0.011	0.006	R	ab	R	R	ab	R	ab	R	R
25	*Mystus* sp.1	1	0.000	0.006	0.000	0.001	0.000	0.000	0.000	0.002	0.001	ab	R	ab	R	ab	ab	ab	R	R
26	*Mystus gulio* (Hamilton, 1822)	2	0.000	0.011	0.000	0.000	0.014	0.000	0.000	0.004	0.002	ab	R	ab	ab	R	ab	ab	R	R
27	*Mystus atrifasciatus* Fowler, 1937	57	0.030	0.133	0.042	0.048	0.074	0.066	0.017	0.088	0.052	D	D	D	D	D	D	R	D	D
28	*Mystus rhegma* Fowler, 1933	2	0.005	0.000	0.000	0.000	0.000	0.033	0.000	0.004	0.002	R	ab	ab	ab	ab	D	ab	R	R
29	*Ompok bimaculatus* (Bloch, 1794)	5	0.000	0.028	0.000	0.002	0.020	0.000	0.000	0.009	0.005	ab	D	ab	R	D	ab	ab	R	R

No.	Species	n_i/N										Status								
		N	CM	TT	CP	V1	V2	V3	In	Out	Total	CM	TT	CP	V1	V2	V3	In	Out	Total
30	*Micronema apogon* (Bleeker, 1851)	1	0.000	0.006	0.000	0.001	0.000	0.000	0.000	0.002	0.001	ab	R	ab	R	ab	ab	ab	R	R
31	*Pangasius larnaudii* Bocourt, 1866	1	0.000	0.006	0.000	0.001	0.000	0.000	0.000	0.002	0.001	ab	R	ab	R	ab	ab	ab	R	R
32	*Pangasianodon hypophthalmus* (Sauvage, 1878)	20	0.002	0.022	0.031	0.020	0.000	0.033	0.004	0.033	0.018	R	D	D	D	ab	D	R	D	R
33	*Helicophagus waandersii*, Bleeker, 1858	3	0.005	0.000	0.002	0.000	0.007	0.033	0.000	0.005	0.003	R	ab	R	ab	R	D	ab	R	R
34	*Clarias batrachus* (Linnaeus, 1758)	5	0.000	0.011	0.006	0.003	0.014	0.000	0.000	0.009	0.005	ab	R	R	R	R	ab	ab	R	R
35	*Clarias garienpinus* (Burchell, 1882)	2	0.002	0.006	0.000	0.002	0.000	0.000	0.004	0.000	0.002	R	R	ab	R	ab	ab	R	ab	R
36	*Pterygoplichthys disjunctivus* (Weber, 1991)	21	0.009	0.028	0.025	0.013	0.047	0.049	0.022	0.016	0.019	R	D	D	R	D	D	D	R	R
37	*Doryichthys boaja* (Bleeker, 1850)	1	0.000	0.000	0.002	0.000	0.007	0.000	0.000	0.002	0.001	ab	ab	R	ab	R	ab	ab	R	R
38	*Eleotris fusca* (Forster, 1801)	5	0.007	0.000	0.004	0.005	0.007	0.000	0.006	0.004	0.005	R	ab	R	R	R	ab	R	R	R
39	*Oxyeleotris marmorata* (Bleeker, 1852)	9	0.007	0.028	0.002	0.005	0.020	0.033	0.004	0.013	0.008	R	D	R	R	D	D	R	R	R
40	*Glossogobius giuris* (Hamilton, 1822)	1	0.002	0.000	0.000	0.000	0.000	0.016	0.000	0.002	0.001	R	ab	ab	ab	ab	R	ab	R	R
41	*Macrognathus siamensis* (Günther, 1861)	18	0.021	0.050	0.000	0.018	0.000	0.033	0.004	0.029	0.017	D	D	ab	R	ab	D	R	D	R
42	*Macrognathus semiocellatus* Roberts, 1986	5	0.002	0.017	0.002	0.006	0.000	0.000	0.000	0.009	0.005	R	R	R	R	ab	ab	ab	R	R
43	*Mastacembelus favus* Hora, 1924	7	0.005	0.000	0.010	0.006	0.007	0.016	0.000	0.013	0.006	R	ab	R	R	R	R	ab	R	R
44	*Ophisternon bengalense* McClelland, 1844	7	0.000	0.022	0.006	0.005	0.014	0.016	0.002	0.011	0.006	ab	D	R	R	R	R	R	R	R
45	*Anabas testudineus* (Bloch, 1792)	63	0.016	0.193	0.044	0.055	0.068	0.082	0.070	0.046	0.058	R	D	D	D	D	D	D	D	D
46	*Trichopsis vittata* (Cuvier, 1831)	65	0.110	0.066	0.012	0.072	0.000	0.033	0.111	0.009	0.060	D	D	R	D	ab	D	D	R	D
47	*Trichogaster microlepis* (Günther, 1861)	24	0.040	0.006	0.012	0.011	0.088	0.016	0.020	0.024	0.022	D	R	R	R	D	R	D	D	D
48	*Trichogaster trichopterus* (Pallas, 1770)	74	0.040	0.149	0.062	0.068	0.095	0.000	0.090	0.046	0.068	D	D	D	D	D	ab	D	D	D
49	*Channa striata* (Bloch, 1793)	6	0.002	0.028	0.000	0.006	0.007	0.000	0.002	0.009	0.006	R	D	ab	R	R	ab	R	R	R
50	*Brachirus siamensis* (Sauvage, 1878)	1	0.002	0.000	0.000	0.000	0.000	0.016	0.000	0.002	0.001	R	ab	ab	ab	ab	R	ab	R	R
51	*Oreochromis niloticus* (Linnaeus, 1758)	28	0.007	0.017	0.046	0.018	0.054	0.066	0.026	0.026	0.026	R	R	D	R	D	D	D	D	D
52	*Pao turgidus* (Kottelat, 2000)	1	0.000	0.006	0.000	0.000	0.007	0.000	0.000	0.002	0.001	ab	R	ab	ab	R	ab	ab	R	R
53	*Parambassis apogonoides* (Bleeker, 1851)	11	0.026	0.000	0.000	0.013	0.000	0.000	0.007	0.013	0.010	D	ab	ab	R	ab	ab	R	R	R
54	*Parambassis wolffii* (Bleeker, 1851)	1	0.000	0.006	0.000	0.000	0.000	0.016	0.000	0.002	0.001	ab	R	ab	ab	ab	R	ab	R	R

n_i: number of the ith fish collected, N: total number of fish collected; CM: Cho Moi district, TT: Tri Ton district, CP: Chau Phu district; V1: crop 2 crop, V2: crop 3 crop, V3: crop 1 crop; In: inside dike, Out: outside dike; ab: absent in collection, R: rare status, D: dominant status.

Table 2. Biodiversity indexes of fish collected from study sites

Category	**No. species**	**N**	**d**	**H'(log10)**	**λ**
Cho Moi	34	427	5.448	1.060	0.151
Tri Ton	25	181	4.617	1.128	0.101
Chau Phu	36	481	5.667	1.299	0.070
Crop 1	22	61	5.108	1.178	0.080
Crop 2	43	880	6.195	1.241	0.093
Crop 3	28	148	5.403	1.258	0.065
Inside dike	27	542	4.130	0.993	0.159
Outside dike	50	547	7.772	1.440	0.050
Inside × Crop 1	4	6	1.674	0.540	0.200
Inside × Crop 2	26	499	4.024	0.983	0.162
Inside × Crop 3	8	37	1.939	0.733	0.218
Outside × Crop 1	20	55	4.741	1.131	0.092
Outside × Crop 2	38	381	6.226	1.315	0.068
Outside × Crop 3	26	111	5.308	1.230	0.073
Inside × Cho Moi	25	257	4.325	0.884	0.244
Outside × Cho Moi	23	170	4.284	1.041	0.140
Inside × Tri Ton	10	53	2.267	0.832	0.161
Outside × Tri Ton	23	128	4.534	1.147	0.092
Inside × Chau Phu	15	232	2.570	0.898	0.165
Outside × Chau Phu	35	249	6.162	1.352	0.058
Cho Moi × Crop 1	9	15	2.954	0.895	0.086
Cho Moi × Crop 2	28	371	4.564	0.996	0.165
Cho Moi × Crop 3	9	41	2.154	0.702	0.251
Tri Ton × Crop 1	7	22	1.941	0.602	0.351
Tri Ton × Crop 2	20	120	3.969	1.040	0.119
Tri Ton × Crop 3	13	39	3.276	1.025	0.089
Chau Phu × Crop 1	9	24	2.517	0.860	0.130
Chau Phu × Crop 2	32	389	5.198	1.232	0.085
Chau Phu × Crop 3	17	68	3.792	1.031	0.126
Total	54	1089	7.579	1.321	0.078

N: total number of fish collected; d: Margalef's abundant index, H'(log10): Shannon-Weaver's diverse index; λ: Simpson's dominant index

Table 3. Similarity index (%) of fish assemblage at three crops in both inside and outside of dike

Category	**Inside × Crop 1**	**Inside × Crop 2**	**Inside × Crop 3**	**Inside × Crop 1**	**Outside × Crop 2**	**Outside × Crop 3**
Inside × Crop 1						
Inside × Crop 2	22.07					
Inside × Crop 3	12.02	57.52				
Outside × Crop 1	12.73	44.42	37.03			
Outside × Crop 2	26.13	24.32	25.84	24.39		
Outside × Crop 3	6.56	33.57	44.22	43.90	32.30	

Table 4. Similarity index (%) of fish assemblage at three ecological regions in both inside and outside of dike

Category	**Inside × Cho Moi**	**Outside × Cho Moi**	**Inside × Tri Ton**	**Outside × Tri Ton**	**Inside × Chau Phu**	**Outside × Chau Phu**
Inside × Cho Moi						
Outside × Cho Moi	35.52					
Inside × Tri Ton	40.35	28.40				
Outside × Tri Ton	21.41	27.40	53.64			
Inside × Chau Phu	52.45	49.82	31.95	30.82		
Outside × Chau Phu	25.01	31.09	18.51	27.05	26.71	

DISCUSSION

The rice paddies ,a popular lowland areas, are the most favorable habitat for fish due to the availability of prey **(Aditya *et al.*, 2010)**. The diversity of the fish fauna in the regions is affected by both abiotic and biotic (e.g., insect and phytoplankton) factors **(Sunish and Reuben, 2001; Sunish and Reuben, 2002; Aditya *et al.*, 2010)**. ***Knight et al*. (2003)** reported that fish fauna in rice fields have various trophic status and most of them can consume insect and phytoplankton due to the dominance of these groups in the rice paddies **(Knight *et al*., 2003)**. Indeed, the present study showed that fish fauna diversified with more than fifty species belonging to many families and orders, and nearly half of these fishes, belonged to Cyprinid, they feed mainly on phytoplankton.

There is a significant difference between the fish species quantity and composition of sample sites and crop seasons. *Esomus metalicus* (Ahl, 1923) is the most common species with more than 150 individuals belonging to Cyprinidae, followed by *Henicorhynchus siamensis* (Sauvage, 1881), *Balantiocheilus melanopterus* (Bleeker, 1850) and other species. It is clear that spatiotemporal factors (the crop season and the types of habitats) have an impact on the number and composition of fish species.

The crop seasons do not affect the distribution of fish species but they do have an influence on their numbers. The numbers of common fish species often appear in the rainy season and at this time, the small-sized freshwater fish began the dominant species. The spatial factor has an unclear influence on the number of individual fish species which is contrary to diversity of fish species. Inside the dike environment with low dissolved oxygen levels, poor food sources, high turbidity, and organic humus was a favorite for the species like *Esomus metalicus* (Ahl, 1923), *Mystacoleucus chilopterus* (Fowler, 1935) and *Pangasianodon hypophthalmus* (Sauvage, 1878), etc. While outside the dike, the environments were the opposite comparing it to the inner dyke. Such channel and river are found to have *Mystus atrifasciatus* (Fowler, 1937), *Helicophagus waandersii* (Bleeker, 1858) *and Oxyeleotris marmorata* (Bleeker, 1852), etc.

Some species appeared on both the sides of dike system for the three ecological regions during the three crop cycles for the natural habitat **(Dinh, 2009; Tran *et al.*, 2013)**. But for the fish assemblage in the rice paddy channels, they differ from natural systems with sixty-nine species in one ecological region **(Dinh, 2009)**. This suggests that the flood prevention dike system, along with chemicals usage for intensive farming, can lead to the changes in the fish fauna between the rice paddy channels and the natural riverine system. Undeniably, the fish species composition in Brazilian wetland is also regulated by habitat and water chemicals (Rolon et al., 2008). The biological diversity of the rice crops in the Netherlands is also affected by the management of irrigated channels and practices, used in the surrounding crops **(Twisk *et al.*, 2000)**.

Moreover, a dozen dominant fish species belonged to Cyprinid indicated that the six species, especially *E. metalicus* and *P. brevis*, found to be adapting well to rice paddy cannels than others and they can be considered as candidates for rice-fish culture.

Alternatively, *A. testudineus, T. vittata*, *T. microlepis, T. trichopterus* and *O. niloticus* would be able to cultivate in rice paddy to improve the fish culture models in the Mekong Delta. Some species are rarely caught in this study even though they were collected in crop 1 [e.g., *Micronema apogon* (Bleeker, 1851), *Pangasius larnaudii* (Bocourt, 1866)] and most fish were found in crop 2. This suggests the seasonal changes can influence the fish assemblage in the studied region.

The number of families outside the dike was richer than inside, e.g., in Tri Ton where 5 families were found outside the dike. Flowing the water body, one family of fish, Osphronemidae was found inside the dike system. In this study, we found the diversity of fish families due to the differences in water bodies created. Cypriniformes was an enormous order of freshwater fish, contained 3,000 or more species. So it is clear why Cypriniformes occupied the highest number found amongst the three rice crops inside and outside of the dike system. Furthermore, the other orders also present were Gobiiformes, Synbranchiformes, Cichliformes, and Perciformes. Based on the data, it reveals that the rarely sample fish can be collected in March. The reason that belongs to the dry season and this is where the water level is very low so it will hard to collect the specimens using the fyke nets.

The fish diversity indexes of fish fauna for the outside of the dike were higher than that of inside. This indicated that the dike can lead to the lower diversity indexes in the inside dike habitat. For example, the fish species composition in Tri Ton outside dike in crop 2 consist of [*Mystus* sp.1, *Ompok bimaculatus* (Bloch, 1794), *Micronema apogon* (Bleeker, 1851), *Pangasius larnaudii* Bocourt, 1866, *Pangasianodon hypophthalmus* (Sauvage, 1878), *Macrognathus siamensis* (Günther, 1861), *Macrognathus semiocellatus (*Roberts, 1986), *Ophisternon bengalense* (McClelland, 1844), *Channa striata* (Bloch, 1793), *Oreochromis niloticus* (Linnaeus, 1758)] is diversify than inside one [*Esomus metalicus* (Ahl, 1923), *Clarias garienpinus* (Burchell, 1882), *Oxyeleotris marmorata* (Bleeker, 1852), *Trichopsis vittata* (Cuvier, 1831), *Trichogaster microlepis* (Günther, 1861)]. The fish fauna displayed high diversity indexes in crop 2 and 3; it coincided with the wet season where the precipitation of 300 mm/month comparing to crop 1 that belongs to the dry season. Moreover, the low value of the fish diversity index for crop 1, could be related to the drought in the dry season affected by climate change **(Le and Chinvanno, 2011)**. The seasonal variation is also one of the main factors, influencing yield components of rice, in an integrated concurrent rice-fish system **(Vromant *et al*., 2002)**. For the two habitats that were regulated by Hau River Basin, comprising Cho Moi and Chau Phu, showed the higher fish diversity indexes, in comparison to the limestone mountain region of Tri Ton, which was far from Hau River. The total number of fish species there, was lower than that in Hau River in An Phu **(Dinh, 2009)**. It suggests that, the fish composition and the diversity indexes were influenced by the flood prevention dike system.

CONCLUSION

In conclusion, the fish assemblage in An Giang has fifty-four species belonging to twenty families and seven orders. The fish species and its composition show changes in the diversity indexes with crops, ecological habitats and dike sites. Also, the impact of human activities including crop harvesting and agricultural chemicals prevented flood dike building up. Other influences that also affecting on fish composition and diversity indexes, are the regulation of the changes in precipitation between three crops harvest. Of the fifty-four species collected, twelve were dominant and considered as candidates for the rice-fish culture. The other two species have not been identified; therefore, a further study should be conducted in order to classify them into the global fish fauna.

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