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Ichthyofauna in Rice Agroecosystem at Seberang Perai Tengah, Pulau Pinang, Malaysia with Notes on the Introduced Species

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ABSTRACT

Twenty six species of fishes from 14 families were recorded from various habitats including river, concrete canals, earth ditches and storm drains in the rice field, following three different stages of paddy planting for two seasons of rice cultivation at Seberang Perai Tengah, Penang. Cyprinidae was the most dominant family recorded, that contributed the highest number of species in this study, followed by Osphronemidae, Clariidae and Bagridae. The most abundant families with high number of individuals collected were from Cyprinidae, Aplocheilidae and Anabantidae. There were seven introduced species recorded and two of them are considered as an invasive species namely *Clarias gariepinus* and *Oreochromis niloticus*. The emergence numbers of invasive species can threaten the native species population in the rice field and lead to the local extinction.

Keywords: Rice field, invasive species, introduced species, biological diversity, Malaysia

ABSTRAK

Dua puluh enam spesies ikan terdiri daripada 14 keluarga telah direkodkan dari pelbagai habitat seperti sungai, tali air konkrit, tali air tanah dan parit di sawah padi Seberang Perai Tengah, Pulau Pinang dari tiga fasa berbeza penanaman padi untuk dua musim. Cyprinidae merupakan keluarga dominan yang direkodkan, menyumbang kepada bilangan spesies yang paling banyak, diikuti oleh Osphronemidae, Clariidae dan Bagridae. Keluarga yang mempunyai bilangan individu paling tinggi ialah Cyprinidae, Aplocheilidae dan Anabantidae. Terdapat tujuh species yang diperkenalkan telah direkodkan dan dua daripadanya telah dikenalpasti sebagai spesies penakluk iaitu *Clarias gariepinus* dan *Oreochromis niloticus*. Kemunculan bilangan spesies penakluk boleh mengancam populasi spesies asli di kawasan sawah padi and menyebabkan kepupusan setempat.

Kata Kunci: Sawah padi, kepelbagaian biologi, spesies penakluk, spesies pendatang, Malaysia

INTRODUCTION

Rice field is an agroecosystem that produce staple food (Ali and Ahmad, 1988) and economic enhancer for rural people (Lim *et al*., 1984) in many Asian countries. In 2010, it was estimated that the harvested area of rice around the globe is 162 million hectares and becoming one of the leading food crop (GRiSP, 2013). Rice agroecosystem can be divided into five primary types which are irrigated rice field, rain-fed rice field, deep water rice field, upland rice field and tidal water rice field (Edirisinghe and Bambaradeniya, 2006). The irrigated lowland rice contributes 75% of the world's rice production and Asian region supply 40 - 46% of total production of irrigated lowland rice (GRiSP, 2013).

The short hydrology cycles, usually a few weeks or months within a single rice cultivation period can enhance the development of aquatic fauna and environment in both rice fields and irrigation canals regardless the techniques of flooded-field rice cultivation (Ruddle, 1980). This was supported by Bambaradeniya *et al.* (2004) where the diversity of aquatic organisms in the rice field change due to the variation in the state of water level during rice cultivation processes. Fernando (1993) classified the ecological changes in the rice field into three important phases, namely aquatic, semi-aquatic and terrestrial dry phase. Aquatic phase deputize vegetative and reproductive stages of rice planting with varying water level supplied into the rice plot (Bambaradeniya and Amerasinghe, 2003). During the aquatic phase, flooded water in the rice field will be first colonized by the protozoan, followed by other fauna such as amphibian and fish through irrigation channels (Bambaradeniya *et al*., 2004). Semi-aquatic and terrestrial dry phase represents the ripening stage of rice plant (Bambaradeniya and Amerasinghe, 2003). Semi-aquatic phase is a short phase usually from 5-10 days before terrestrial dry phase begins where water will be drained out from the rice field, and aquatic organism mostly vertebrate will escape into the nearby canals following the water outflow (Bambaradeniya *et al*., 2004).

Rice fields with irrigation system become an important settlement for fish (Halwart, 2006) since the rice field gives suitable niche for aquatic flora and fauna (Aditya *et al*., 2010). The highest diversity of invertebrate provides a natural food source for the fish (Halwart and Gupta, 2004; Yamazaki *et al*., 2010) and there are less numbers of predator in the rice field which consume larval and juvenile fish as their food (Yamazaki *et al*., 2010). Beginning of the flooding seasons, fish will migrate into the rice field for feeding activities (Fernando, 1993; Meusch, 1996) and spawning (Coche, 1967; Fernando, 1993; Grift *et al*., 2001; Yamazaki *et al*., 2010). In spite of that, rice field can be considered as a highly disturbed area (Al-Shami *et al*., 2010; Bahaar and Bhat, 2011), prone to various land alterations (Kim *et al*., 2012) that might be able to induce changes in the aquatic community (Che Salmah *et al*., 1988) and recurring at a rapid cycle. But, organism in the rice field has high tolerance towards the changes and has improvised well with the dynamic environment (Bambaradeniya, 2000; Bahaar and Bhat, 2011). In Malaysia, previous studies on fish diversity in the rice field have been done in North Kerian, Perak by Ali (1990) and Muda rice agroecosystem (Shah and Ali, 1998; Shah *et al.,* 2008; Shah *et al*., 2010). However, the study of fish in the rice field and surrounding water bodies especially in Malaysia is still incomplete. The objective of this study is to determine the ichthyofauna diversity in the rice agroecosystem at different habitats and stages of paddy planting for two continuous rice cultivation cycle.

MATERIAL AND METHODS

Study site

Samplings were conducted in rice fields located at Permatang Pauh (P188) (5°24'09.0"N 100°27'00.5"E), Pulau Pinang, Malaysia (Figure 1). The study was conducted for two complete seasons of rice cultivation in 2014 until 2016 for three different stages of paddy planting. There were four types of habitats surveyed which are river (water inlet), concrete canals, earth ditches and storm drains (water outlet).

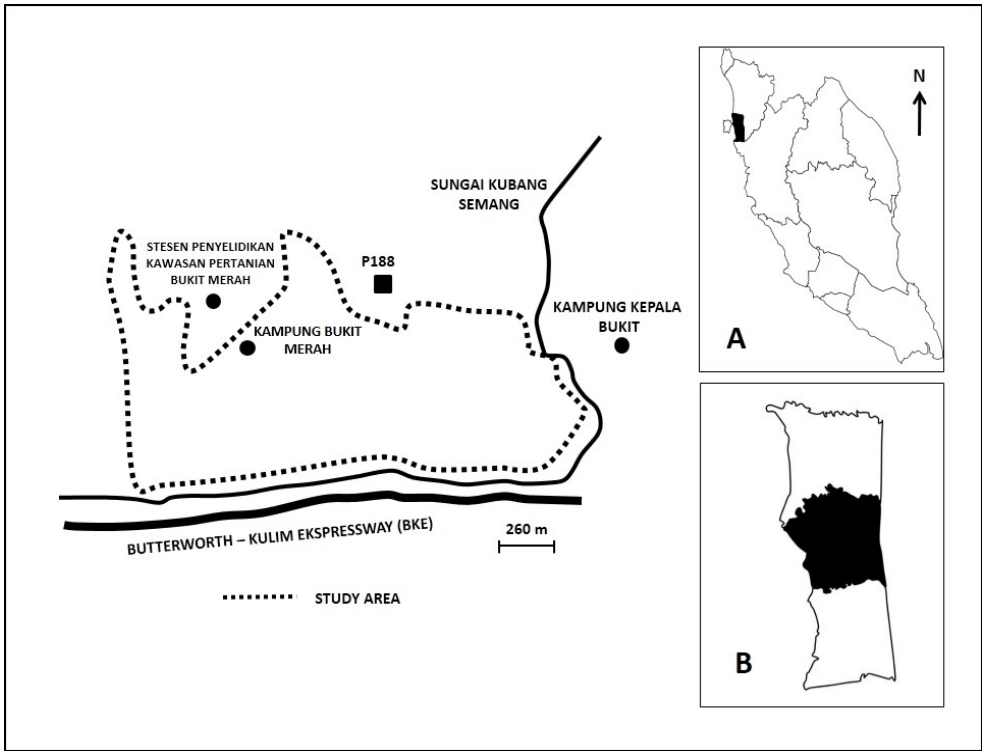

Figure 1 The map of Peninsular Malaysia shows Seberang Perai (A) which are further divided into three districts (B) and the location of the study area, located in Seberang Perai Tengah, in Permatang Pauh (P188) region.

Sample collections

Fishes were caught by using scoop net (45.0 cm x 40.0 cm, mesh size = 0.2 cm), gills net (5.0 m x 1.4 m, mesh size = 2.5 cm) and cast net (2.5 m length, mesh size = 2.0 cm). All the fishes were enumerated and measured for their standard length (cm). The fishes, then were weighed to the nearest gram. The identification of fish was performed based on their physical and morphological appearance with the aid of standard taxonomic keys of Rainboth (1996) and familial arrangement following Kottelat (2013). Voucher specimens were fixed in 10% formalin solution and later were stored in 70% alcohol for long term storage.

RESULTS AND DISCUSSION

A total 26 species of fish from 14 families (Table 1) were recorded in this study with Cyprinidae being the major family contributing 34% of the total species recorded, corresponding to the result reported by various studies on fishes in the rice field (Shah and Ali, 1998; Katano *et al*., 2003; Shah *et al*., 2008; Hortle *et al*., 2008; Shah *et al*., 2010). Osphronemidae is the second major family in the rice field followed by Bagridae and Clariidae for both seasons in terms of family dominance (Figures 2 and 3). But, from the abundance aspect, family Aplocheilidae and Anabantidae show a higher number of individuals eventhough they were represented by a single species. This is because, both Aplocheilidae and Anabantidae possess some characteristic and manage to adapt successfully in the rice field. The cyprinodont, *Aplocheilus panchax* could have continuous reproduction where they spawn during growing season of paddy (Heckman, 1979) meanwhile Anabantidae can reproduce more than once in a year (Fernando, 1993). Such adaptation and reproduction strategy help those species to survive harsh condition in the rice field and becoming abundant at all seasons. Within Cyprinidae, *Esomus metallicus* has the highest abundant compared to the other species, followed by other species from different family which are *Anabas testudineus* and *Aplocheilus panchax*.

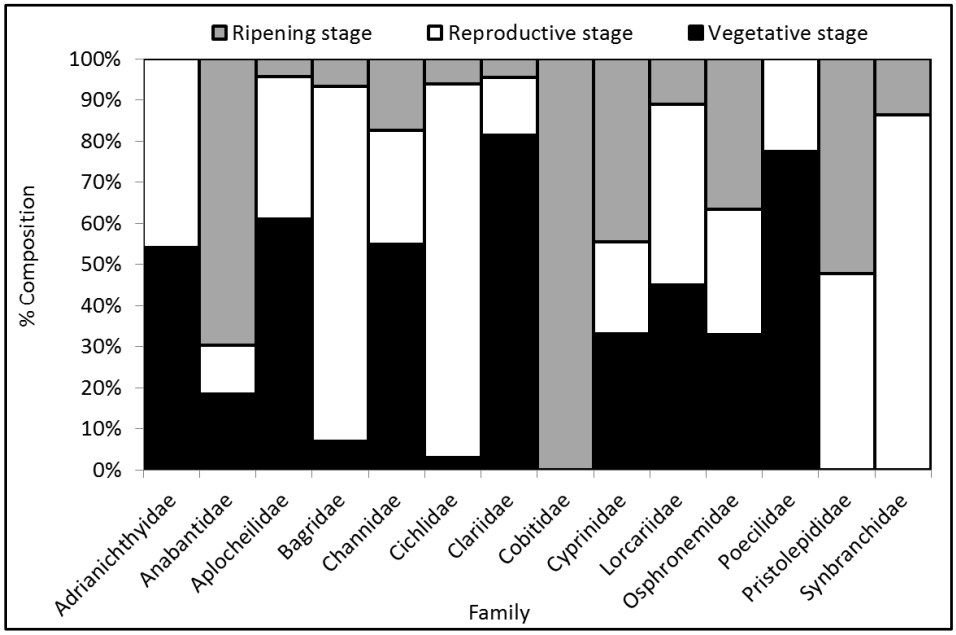

Figure 2 The composition of fish families (in percentage) according to the stage of paddy planting during first season.

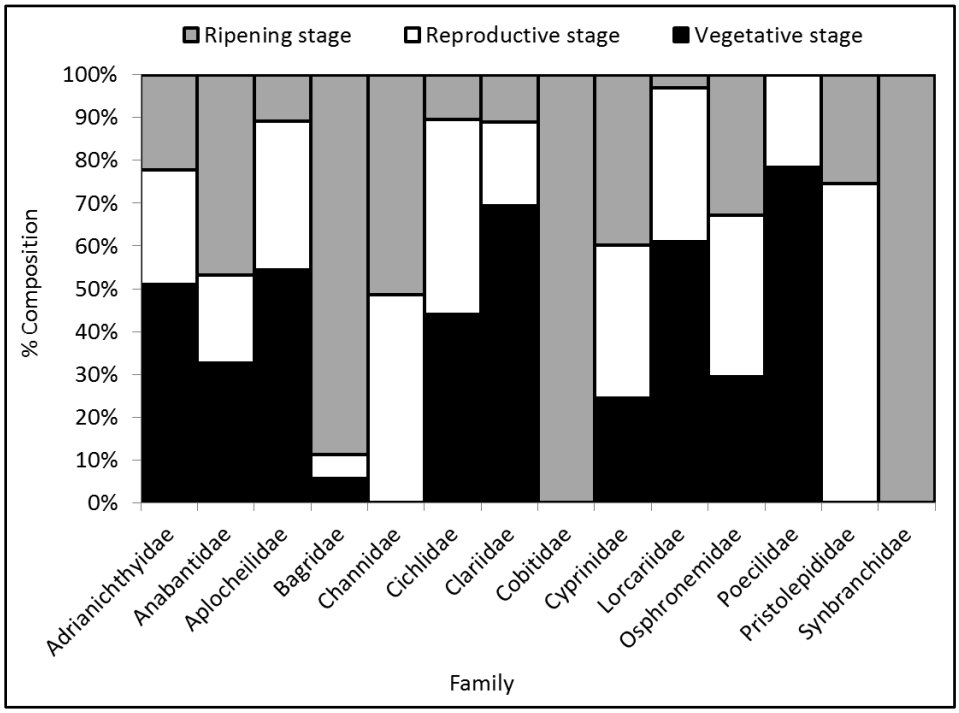

Figure 3 The composition of fish families (in percentage) according to the stage of paddy planting during second season.

The number of species recorded during the present study was higher compared to the previously reported by Shah and Ali (2008) and Shah *et al.* (2010) with 11 and 13 species, respectively in other rice cultivating areas. This might be due to the different gears used and an additional habitat sampled which is a concrete canal in the recent study. Interestingly, *Esomus metallicus* was not recorded from the previous study in rice agroecosystem by Ali (1990) and Shah and Ali (1998) but becoming the most abundant species in Muda agroecosytem in recent year (Shah *et al*., 2008; Shah *et al.,* 2010). Their abundance could be due to the fact that smaller Cyprinidae remains in the irrigation ditches and they can even breed multiple times in a single season of paddy planting (Fernando, 1993). Apart from that, Heckman (1974) found that *Esomus metallicus* present in huge numbers during a year study in the rice field in Laos. This is due to the fact that *Esomus metallicus* secure several alterations of generation throughout the year since they have high gonadosomatic index (GSI) especially during high temperature (Morioka et al., 2012).

Based on the previous study of fish in rice agroecosystem of Peninsular Malaysia, (e.g., Shah and Ali, 1998; Shah *et al*., 2008; Shah *et al*., 2010) *Anabas testudineus*, *Channa striata*, *Clarias macrocephalus*, *Trichopodus pectoralis* and *Trichopodus trichopterus* can be credited as a core species since all authors collected those species in the rice field. Compared to this study, *Aplocheilus panchax*, *Barbodes binotatus*, *Barbodes gonionotus*, *Cyclocheilichthys apogon*, *Esomus metallicus*, *Hypostomus plecostomus* and *Oreochromis niloticus* were also abundant. Some of them were introduced species but already have an established and rigid population in the rice field. The presence of different life stages of introduced species such as *Oroechromis niloticus*, with the size ranging from 0.7 cm to 21.0 cm indicated that introduced species has been well integrated with the environment. Both of *Esomus metallicus* and *Hypostomus plecostomus* also similar where the babies, juveniles and adults can be found in all types of habitats regardless the stage of paddy planting (data not shown). This situation also has been highlighted by Rahim *et al.* (2013), which the introduced species such as *Barbonymus gonionotus*, *Trichopodus pectoralis* and *Oreochromis* species have successfully adapted to the wild and breed naturally since their introduction in the past. Other species such as *Anabas testudineus*, *Channa striata*, *Clarias microcephalus*, *Trichopodus pectoralis* and *Trichopodus trichopterus* were also common species but they only inhabit a particular habitat in the rice field (see Table 1).

Table 1 Species checklist in the rice field in different habitats and stages of paddy planting. SN1: first season, SN2: second season. "*": introduced species.

Species	Habitats								Stages					
	River		Concrete canals		Earth ditches		Storm drains		Vegetative stage		Reproductive stage		Ripening stage	
	SN1	SN2	SN1	SN2	SN1	SN2	SN1	SN2	SN1	SN2	SN1	SN2	SN1	SN2
Barbodes binotatus	1	1	1	1	1	1	1	1	1	1	1	1	1	1
*Barbonymus gonionotus**	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Barbonymus schwanefeldii	1	1	0	0	0	0	0	0	0	0	1	0	0	1
Cyclocheilichthys apogon	1	1	1	1	1	1	1	1	1	1	1	1	1	1
*Esomus metallicus**	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hampala macrolepidota	1	1	1	0	1	0	0	0	0	0	1	0	0	1
Osteochilus vittatus	1	1	1	0	0	0	0	0	0	0	1	0	0	1
Parachela maculicauda	0	0	1	0	0	0	0	0	0	0	0	1	0	0
Rasbora trilineata	1	1	1	1	0	0	0	0	1	1	1	0	1	1
*Trichopodus pectoralis**	0	1	0	0	1	1	1	1	0	1	1	0	1	1
Trichopodus trichopterus	0	0	1	0	1	1	1	1	1	1	1	1	1	1
Trichopsis vittata	1	1	0	1	1	1	0	0	1	1	1	1	1	1
Mystus gulio	0	0	0	0	0	0	1	1	0	0	1	0	0	1
Mystus singaringan	1	1	1	1	0	1	0	0	1	1	1	1	1	1
*Clarias gariepinus**	0	0	0	0	0	0	1	1	0	1	1	1	0	1
Clarias macrocephalus	0	1	1	1	1	1	1	1	1	1	1	1	1	1
Oryzias javanicus	1	1	1	1	0	0	0	0	1	1	0	1	1	1
Anabas testudineus	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Aplocheilus panchax	1	1	1	1	1	1	1	1	1	1	1	1	1	1
*Oreochromis niloticus**	1	1	1	1	1	1	1	0	1	1	1	1	1	1
Channa striata	0	0	0	1	1	1	1	1	1	1	1	0	1	1
Lepidochepalichthys hasselti	1	1	1	1	0	0	0	0	0	0	1	0	0	1
*Hypostomus plecostomus**	1	1	1	1	1	1	1	1	1	1	1	1	1	1
*Gambusia affinis**	0	0	1	1	1	1	0	0	1	1	0	1	1	0
Pristolepis fasciata	1	1	0	1	0	1	0	0	0	1	1	0	1	1
Monopterus javanensis	0	1	1	0	0	0	0	0	0	1	1	0	0	1

The concrete canals in the rice field have proven to harbor among the highest number of fish species which were 22 species compared to river (20 species), earth ditches (15 species) and storm drains (14 species). This is contradicted with Hata (2002) and Natuhara (2013) saying that the implementation of concrete lining is thought to be one of the factors that affect fish abundance and diversity in the rice field. However, the degree of connectivity between concrete canals and river is an important aspect of fish migration which, when connected directly, it permits the movement of fish from the river into the concrete canals (Katano *et al*., 2003).

Fish in the rice ecosystem are sometimes grouped into 'black fish' and 'white fish' as mentioned by Welcomme (1979) and Welcomme (1985). The 'black fish' is the species that stay in the water after the flood and does not migrate too far when the water level subsided. Species from family Osphronemidae, Bagridae and Clariidae are categorized as 'black fish'. Hortle *et al.* (2008) stated that, *Channa striata*, *Anabas testudineus*, and *Trichopodus pectoralis* are the key species in the rice field and they are known as a 'black fish', species with a customized breathing organ that helps them to survive under low oxygen availability and spend their entire life on floodplain habitat. Meanwhile 'white fish' is the species that return back into the flowing water after spawning such as *Barbodes gonionotus* and *Cyclocheilichthys apogon* (Welcomme, 1979; Welcomme, 1985). Both groups of fishes will enter the adjacent river and overflow during high water level or overflow and rice field has provided them with a suitable place to reproduce (Munro, 1990).

Diversity of introduced species in rice ecosystem

Malaysian waters have been known to have many introduced fish species which were introduced for several purposes. Based on comprehensive review by Rahim et al. (2013), *Trichopodus pectoralis* and *Oreochromis niloticus* were introduced from Thailand (aquaculture), *Barbonymus gonionotus* from Indonesia (aquaculture), and *Hypostomus plecostomus* from South America (aquarium fish). The African catfish, *Clarias gariepinus* was introduced from Thailand during late 80's also for aquaculture purposes (Csavas, 1995). *Gambusia affinis* was introduced for biological control from either Mexico or United State (NatureServe (2013) while, *Esomus metalllicus* which originated from Thailand (Vidthayanon, 2012) and usually sold as fish feed in the aquarium shops. The emergence of the introduced species from various countries of origins were also found in the rice fields and their presence have many pros and cons to local communities.

In this study, seven species of introduced species were recognized and at least two of them were considered as aquatic invasive alien species (AIAS), namely *Clarias gariepinus* and *Oreochromis niloticus*. The two species were known for their notoriety to aquatic ecosystem. According to Vitule *et al.* (2006), African catfish has the ability to travel quite a long distance and can colonize wide areas where they were found 15 km away from the cultivation center. Their length is enormous, ranging from 33 cm to 70 cm and stomach contents reveal that this introduced fish feed on native organism including arthropod, mollusk, amphibians and fish. Significant reductions of native fish were also observed in southeastern of Brazil after the introduction of this catfish (Latini and Petrere Jr., 2004). In addition, African catfish having a generalized feeding pattern, consume all types of prey or food including fish, aquatic invertebrate, terrestrial insect, zooplankton and plant matter (Kadye and Booth, 2012), thus can survive in varied habitats. *Oreochromis* spp. can adapt to various types of water condition (Hulsman *et al*., 2008; Jenkins, 2009) and inherit several characteristics as a good invasive species – larger size, high fecundity and fast growing species (Hulsman *et al*., 2008). They will compete for food and space with native fish in the habitat (McCrary *et al*., 2007). A study by Jenkins (2009) shown that Gobiidae and Eleotridae were the most affected species in Fiji after the introduction of *Oreochromis mossambicus* to the island. Fifty five percent of the endemic gobies population on the island is now completely destroyed.

However, some introduced species, including the two former species can be beneficial as well. In a positive way, both were consumed as a food and cheap protein source by local people. Ecologically they are the species that might cause local extinction of several native species in the rice field because of their ferocious feeding habits and better resource utilization, plus both species have the advantages in terms of size, fecundity and survival rate despite living in harsh environment. The other species that were introduced but are not regarded as invasive including *Barbonymus gonionotus* and *Trichopodus pectoralis* which were largely consumed by locals.

Field notes on introduced species

Plate 1 *Barbonymus gonionotus* (SL: 10 cm).
Remarks. This species can be found in all types of habitats in the study. Larger and gravid individuals can be found in the river meanwhile small fish/fries and juveniles were collected in concrete canals. Consumed by local people and caught by using various techniques.

Plate 2 *Esomus metallicus* (SL: 3.5 cm).
Remarks. One of the most abundant species in the rice field. It can be found nearly in all habitats in the rice field. The numbers reduced in the storm drain probably due to the predation by other larger fishes. Newly hatch larvae can be found in the rice plot. This Striped Flying Barb could have been competing with *Rasbora trilineata* in the river. Sold as fish feeders and seldom consumed by local people.

Plate 3 *Trichopodus pectoralis* (SL: 14.5 cm)
Remarks. A common labyrinth fish, poses additional breathing organ which helps them to survive under low oxygen content in the water. They are found mostly in the storm drain where we had confirmed that female adult were abundant and gravid during the study. Consumed by local people in the form of fermented fish.

Plate 4 *Clarias gariepinus* (SL: 34.5 cm)
Remarks. A well-known invasive species and encountered frequently in the storm drain rather than other habitats in this study. Standard length can exceed 40 cm or more in some fish. Sometimes encountered landing on the dense vegetation or river bank after spawning. Personal communication with local people concluded that this species outnumbered the native species in the rice field which nowadays *Clarias macrocephalus* and *Clarias batrachus* become rare or very rarely found or caught in the recent years.

Plate 5 *Oreochromis niloticus*
Remarks. Another invasive species that is now commonly found around the rice field ecosystem. Adults can reach 20 cm SL and found mostly in the river. Most of the fries and the juvenile were found in the concrete canals and earth ditches. Very few juveniles were found in the storm drain.

Plate 6 *Hypostomus plecostomus* (SL: 6.0 cm)
Remarks. This algae eater can be found in all habitats in the study area. Juveniles and adults were collected in the river but the small fish were found frequently in the concrete canals. It does not consume by local people and were left to die if caught.

Plate 7 *Gambusia affinis* (SL: 2.6 cm)
Remarks. This fish is only found in concrete canals and earth ditches. Small fish which schooling just below the water surface. Usually four to nine fish in a group with mostly male. Also known as mosquito fish, which act as a biological control to control the mosquito population, hence it is widely introduced in many parts of the world.

CONCLUSION

Rice field harbors a diverse number of fish species even though the ecosystem is constantly under disturbance including different hydrologic regime and land alterations that destroyed most available habitat from one planting season to another. Many species can be found in the concrete canals and earth ditches surrounding the paddy fields. Core species such as *Anabas testudineus* and *Channa striata* have great commercial value as well as riverine species such as *Barbonymus gonionotus*, despite an introduced species and *B. schwanefeldii*. In addition, the emergence of invasive species can bring negative impact to the population of native species and lead to the local extinction of certain species in the rice field ecosystem. For that, their presence requires some monitoring to avoid further effect to local species extinction.

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