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Diversity and Distribution of Fish in Irrigation Water Derived from Recycled and Uncontrolled Flow Water Sources in the Muda Ricefields

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ABSTRACT

Study on fish diversity and distribution in rice plots supplied with recycled and uncontrolled flow water was carried out from Season 1/2002 to Season II/2004 (August, 2002 to August, 2004) using a modified electro-shocker. A total of 13 species of fish were identified, with *Cyprinidae* being the dominant family in terms of the number caught (39.5%), followed by *Aplocheilidae* (18.2%), and *Osphronemidae* (12.0%). The number of species identified was lower as compared to those obtained in previous studies at selected irrigation canals in the Muda agro-ecosystem, and this due to different methodology employed. In the rice field plots irrigated by uncontrolled water flow, 13 species were recorded, whereas only 11 species were recorded in the plots irrigated by recycled water. However, based on the Shannon-Weiner Diversity and Evenness Indices, the values for the recycled water plots were higher (0.8764 and 0.8416, respectively) compared to the values obtained for the uncontrolled flow plots (0.8131 and 0.7300, respectively). The clustering analysis showed that the similarity in term of the fish species in both plots is high at 0.8462. In particular, *Esomus metallicus* was the dominant "species catch" (36.4%), followed by *Aplocheilus panchax* (18.2%) and *Anabas testudineus* (10.6%). Most of the species identified were well-adapted to survive under the extreme conditions of the rice fields, such as the lower and higher D.O. and water temperature readings of 0.3-14.8 mg/L and 14.0-41.0ºC, respectively. However, floods that occurred in Season 1/2004 were found to have influenced the fish diversity as some riverine species, such as *Barbodes gonionotus* and *Cyclocheilichthys apogon*, were caught in the studied rice field plots.

Keywords: Fish, distribution, rice fields, flow, uncontrolled flow, MADA

INTRODUCTION

According to Pimental *et al*. (1992), the study of biodiversity associated with agro-ecosystems such as rice fields is of significance for agroecologists and conservation biologists, since maintenance of biological diversity is essential for productive agriculture, and ecologically sustainable agriculture is in turn essential for maintaining biological diversity. In Malaysia, rice crop is cultivated twice a year. The largest rice cultivation area in Malaysia is the Muda rice granary area, which is located in the north east of Peninsular Malaysia (Azmi, 1994). The main season for rice cultivation at the Muda rice agroecosystem is from September to January, whereas the second or "off" season is from March to August (MADA, 2004).

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The Muda rice agroecosystem depends on rainfall as the main source of water supply (56%), followed by dam released water (30%), uncontrolled flow (rivers below the dam) (13%) and recycled water (5%) (Lau and Yeow, 1995). The recycling system was initiated in 1982 to overcome the deficiency of water in the Muda irrigation scheme (Lau and Yeow, 1995). However, the introduction of the recycling system was of great concern to the public, particularly with regard to the safety of re-used water and its impacts on agro-biodiversity (Maimon *et al*., 1998; Sani *et al*., 1992; Shah *et al*., 2006).

It is important to note that the source of water supply influences floodwater chemistry and composition of aquatic biota (Bambaradeniya and Amerasinghe, 2003). Sani *et al*. (1992) noted that the *Escherichia coli* count was higher at recycled areas than non-recycled areas. Similarly, Maimon *et al*. (1998) reported that recycled water harboured higher numbers and taxa of insects and arachnids as compared to non-recycled water. On the other hand, a comparative study on the diversity and composition of zooplankton has shown no significant difference ($p>0.05$) between recycled water and uncontrolled flow rice plots (Shah *et al*., 2008).

The status of fish in the rice agro-ecosystem in Malaysia is poorly understood. Several researchers have studied the importance of sump-ponds and their relation to rice-fish productivity (Ali, 1990: 1992; Shah and Ali, 1994; Tan *et al*., 1973). Other studies included fish taxonomy and distribution (Soong, 1948; Shah and Ali, 1998; Shamsudin, 2001), the effects of double cropping and pesticide/herbicide spraying on the rice-fish community (Tan *et al*., 1973), residual pesticides in fish tissues and their association with farmers' health risk (Chen *et al*., 1984) and toxicity studies on rice-fish (Kok, 1972; Shah *et al*., 2007). However, studies on the impact(s) of different water management systems in rice-field plots on fish distribution and compositions have yet to be carried out.

Thus, the objective of this study was to analyze the relationship between the environmental factors and the fish community, and subsequently to compare fish abundance and diversity in rice plots which are irrigated with recycled and uncontrolled flow water.

MATERIALS AND METHODS

Sampling was carried out at Kampung Alur Sekawan, Mukim Tajar CIII, Pendang, in Kedah, Malaysia (see *Fig. 1* for the location). The study area was divided into two treatment plots based on the different irrigation systems present, i.e. recycled and uncontrolled flow (non-recycled) water. Each plot was further divided into four sub-plots (station) to provide a representative sample of the population and the structure of the rice-fish communities (*Fig. 1*). Meanwhile, the sampling was conducted twice a month (i.e. from August 2002 to August 2004) at each station.

The fish samples were obtained using a modified electro-shocker powered by a 12 V dry battery. The operator walked in a transect line (about 100 m long) on the bund adjacent to each treatment plot and electrocuted the fish at the same time. All the specimens were immediately collected by the co-worker using a scoop net.

All the specimens caught were identified using the standard taxonomic keys (Inger and Chin, 1962; Kottelat *et al*., 1993; Mohsin and Ambak, 1983; Rainboth, 1996), measured to total length (mm) and weighed to the nearest g.

The Jaccards Coefficient of Similarity (JCS), using the Unweighted Paired Group Method (UPGMA), was applied to cluster the fish community groups between the types of water supplied to the plots, using the Multi Variate Statistical Package (MVSP) Version 3.11 (Tongeren, 1987). The Shannon-Wiener Diversity and Evenness Indices were also calculated using the same statistical programme. A rapid appraisal survey, with the plot owner, was carried out to determine the frequency in the use of pesticides.

Prior to fish sample collection, *in-situ* water physico-chemical readings such as dissolved oxygen (D.O. mg/L) and temperature (°C) were measured using the YSI meter (Model 57), whereas the conductivity (μS/cm) and total

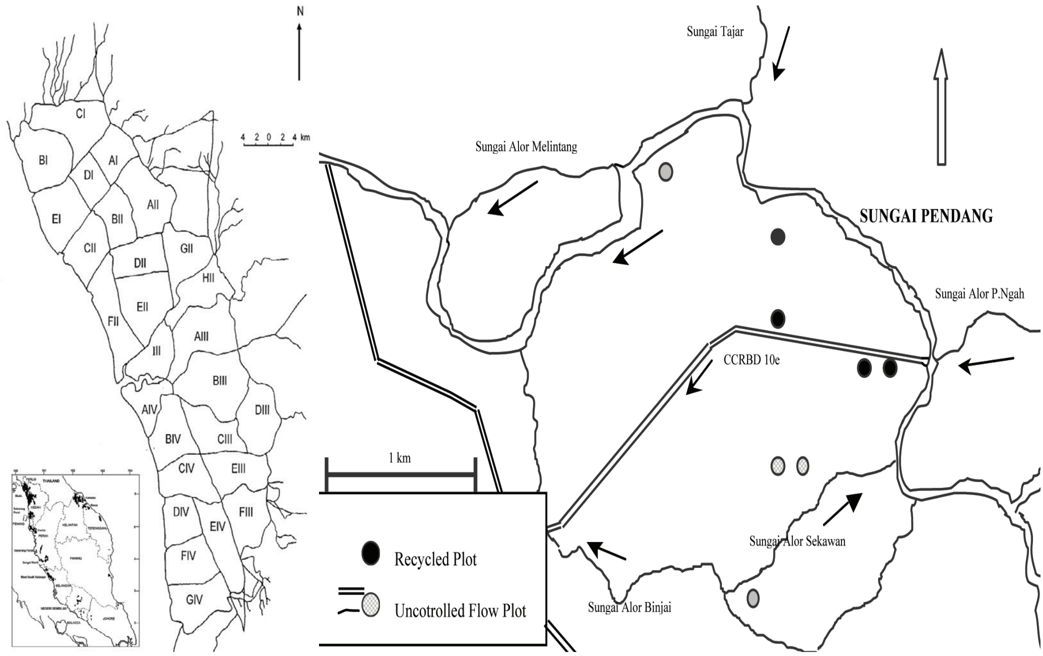

Fig. 1: The location of the main rice granary areas in Peninsular Malaysia, the Muda irrigation scheme and sampling plots at the Kg Alor Sekawan, Mukim Tajar CIII during the study period

dissolved solids (TDS) (mg/L) were recorded with the Hach (Model C0150), and pH with the Orion (Model 230A). A fixed ruler was used to measure the water level at each sampling station.

RESULTS AND DISCUSSION

The mean physico-chemical characteristics of each treatment plot are summarized in Table 1. The recycled plots had higher water levels compared to the uncontrolled flow plots with the means of 8.2 ± 4.5 cm and 7.9 ± 4.6 cm, respectively. The results showed that the dissolved oxygen, conductivity, total dissolved solids, and total suspended solids were relatively higher in the plots with uncontrolled flow than in the recycled plots: 4.8 ± 2.9 mg/L, 66.3 ± 63.1 µS/cm, 33.3 ± 36.3 mg/L, 183.2 ± 443.4 mg/L and 4.4 ± 2.2 mg/L, 62.9 ± 44.3 µS/cm, 29.9 ± 22.0 mg/L, 168.0 ± 270.3 mg/L, respectively (Table 1). Meanwhile, the plots with the uncontrolled flow were slightly more acidic (pH 5.4 ± 0.8) than those with recycled water (5.6 ± 0.7) (Table 1). This might be related to the slightly higher alkalinity readings in the recycled plots (44.0 ± 40.5 mg/L) compared to those in the uncontrolled flow plots (39.8 ± 24.8 mg/L) (Table 1). Generally, the quality of water in the studied plots could be considered as moderate and was able to support a great variety of aquatic organisms such as zooplankton, aquatic insects, and fish (Ali, 1992: 1998; Shamsudin, 2001; Bambaradeniya and Amerasinghe, 2003; Shah *et al*., 2008; Che Salmah and Abu Hassan, 2009). Based on the statistical analysis, there was no significant difference (p>0.05) found between the physico-chemical properties of the water for the different irrigation systems (Shah *et al.,* 2006). Similar results were also reported by Sani *et al*. (1992).

There are several reports made on the relationship between the environmental factors and fish abundance or fish diversity in rivers (Healy and Lonzarich, 2000; Matthias *et al*., 1996; Stoneman and Jones, 2000). A number of environmental factors, such as current

TABLE 1
Summary of the physico-chemical properties of the water in the recycled and uncontrolled flow rice field plots during the study periods
(August 2002 to August 2004)

Plot	Recycle water (n=79)		Range		Uncontrolled flow (n=84)		Range	
	Mean	± s.d.	Min.	Max.	Mean	± s.d.	Min.	Max.
Water level (cm)	8.2	4.5	1	19	7.9	4.6	1	20
Dissolved oxygen (mg/L)	4.4	2.2	0.5	10	4.8	2.9	0.3	14.8
Temperature (°C)	31	4.4	23	41	30.6	4.4	14	39
pH	5.6	0.7	3.6	7.6	5.4	0.8	3.8	8.4
Conductivity (µS/cm)	62.9	44.3	3.4	247	66.3	63.1	13.5	371
Total dissolved suspended (mg/L)	29.9	22	2	115	33.3	36.3	6	221
Total suspended solid (mg/L)	168	270.3	4.8	1548.8	183.2	443.4	2.8	3088.8
Alkalinity (mg/L)	44	40.5	6.9	325.3	39.8	24.8	10	160.1
Orhtophosphate (mg/L)	0.0262	0.0207	0.0001	0.1455	0.0353	0.0456	0.0001	0.2943
Nitrogen-nitrite (mg/L)	0.0003	0.0005	0.0001	0.0037	0.0007	0.0021	0.0001	0.016
Nitrogen-nitrate (mg/L)	0.2379	0.2236	0.0005	0.9644	0.1833	0.1661	0.0002	0.9384

velocity, water depth, degree of plant cover, and water temperature, have been known to affect fish communities. Meanwhile, there is a positive relationship between fish abundance or diversity and the increasing water depth and plant coverage. However, the relationships between fish communities in rice fields are poorly documented.

A total of 13 fish species, belonging to nine families, were recorded in the present study. The number of fish species and their distribution in recycled water and the uncontrolled flow rice plots are shown in Table 2. The list included the "black" fish (e.g. *Channa striata*, *Anabas testudineus* and *Clarias* sp.) and the "white" fish (*Barbodes gonionotus* and *Cyclocheilichthys apogon*) (Welcomme, 1985).

Overall, *Esomus metallicus* was the dominant species (36.4%), followed by *Aplocheilus panchax* (18.2%), and *A. testudineus* (10.6%) (*Fig. 2*). The two former species were found to be dominant in the uncontrolled flow plots, whereas *Anabas testudineus* was dominant in the plots with recycled water (*Fig. 2*). In term of density, *Cyprinidae* was the dominant family (39.5%), followed by *Aplocheilidae* (18.2%), *Osphronemidae* (12.0%), *Anabantidae* (10.6%), *Channidae* (10.4%), *Clariidae* and *Bagridae* (3.4%), *Synbranchidae* (1.4%), and *Notopteridae* (1.1%) (*Fig. 3*). Most of the cyprinids were caught from the uncontrolled flow plots, whereas the other families were more concentrated in the plots with recycled water (*Fig. 3*).

TABLE 2
The fish checklist and its distribution in the recycled irrigation water and uncontrolled flow rice plots

Species	Family	Local name	Recycled	Uncontrolled flow
Anabas testudineus	Anabantidae	Puyu	+	+
Mystus vittatus	Bagridae	Baung	+	+
Betta splendens	Osphronemidae	Karin	+	+
Trichogaster pectoralis	Osphronemidae	Sepat siam	+	+
Trichogaster trichopterus	Osphronemidae	Sepat kedah	+	+
Channa striata	Channidae	Haruan	+	+
Clarias macrocephalus	Clariidae	Keli kayu	+	+
Aplocheilus panchax	Aplocheilidae	Tahi timah	+	+
Esomus metallicus	Cyprinidae	Seluang	+	+
Cyclocheilichthys apogon	Cyprinidae	Temperas	-	+
Barbodes gonionotus	Cyprinidae	Lampam jawa	-	+
Monopterus albus	Synbranchidae	Belut	+	+
Notopterus notopterus	Notopteridae	Selat	+	+

Note: - = absent; + = present

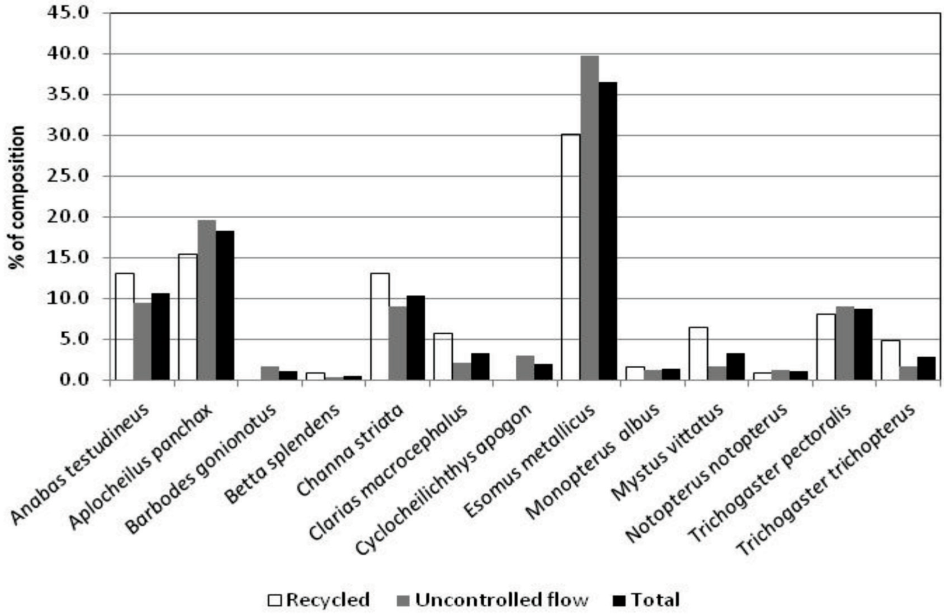

Fig. 2: The percentages in the composition of fish species and the type of water supplied during the study period

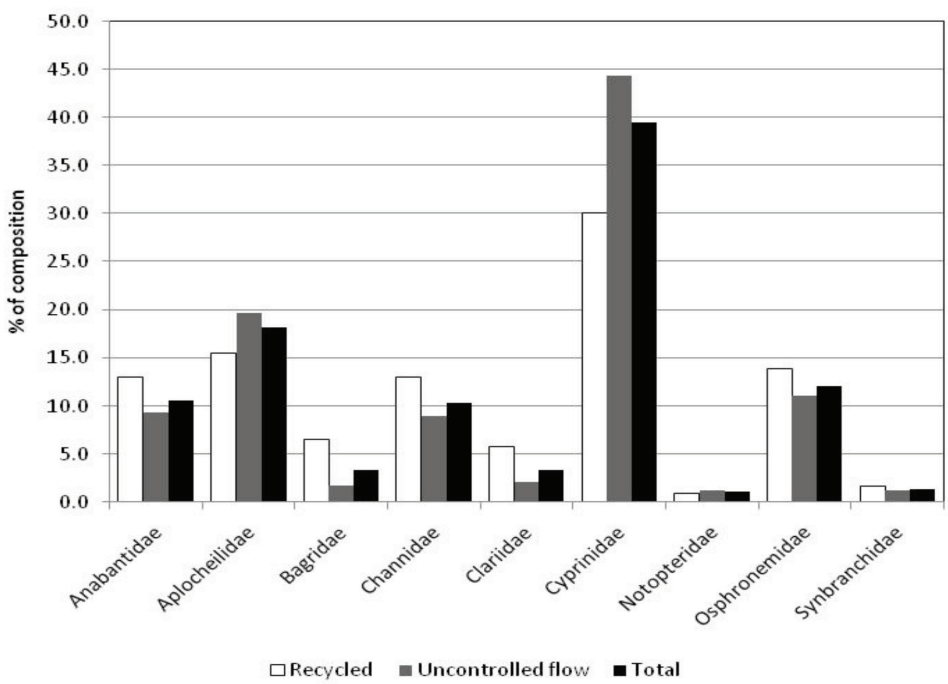

Fig. 3: The percentages in the composition of fish family and the type of water supplied management during the study period

The number of species recorded in this study was slightly higher than those previously reported by Ali (1990) and Shamsudin (2001), whereby only nine and eleven species were recorded in the rice field ecosystem, respectively. Other species such as the walking catfish (*Clarias* sp.), snakehead (*Channa striata*), and climbing perch (*A. testudineus*) are known to have a unique type of respiratory organ that enables them to live under extremely low D.O. levels of 0.3 mg/L and high water temperature conditions of up to 41.0ºC in rice fields (Mohsin and Ambak, 1983; Soong, 1948; Welcomme, 1985).

In the uncontrolled flow plots, thirteen fish species were recorded, whereas only eleven species were recorded in the plots with recycled water. As shown in Table 3, the Shannon-Wiener and Evenness Indices in the recycled water plots were high (0.8764 and 0.8416, respectively) compared to those recorded in the uncontrolled flow plots (0.8131 and 0.7300, respectively) (Table 3). Based on the similarity value, using the JCS analysis, the fish species in both the plots was found to be high at 0.8462.

Based on water quality, the pattern of fish activity in ponds and their adjacent rice fields has not been fully understood. According to Iguchi *et al*. (1999), no component of water quality could fully explain the variation in the fish species diversity in the water systems of the Anji rice field ecosystem. Similar results have been recorded by Matthias *et al*. (1996). Bambaradeniya *et al*. (2004) showed the diversity of biota changes with hydrological regime, where more species recorded during the aquatic phase out of three ecological changes during a single rice cultivation cycle. The distance of the rice plots from the source of water supply, such as irrigation canals or rivers, may also influence the diversity of fish. More species are expected to be found in nearby rivers and canals compared to other sites in the fields. As most of the uncontrolled flow plots are located less than 200 m away from the existing rivers, more fish species were expected to be found there as compared to the number of the fish species in the recycled irrigation canals. Katano *et al*. (2003) reported that the richness and diversity of the fish species in the irrigation ditches with a good connection to rice fields were higher than those in the rice fields. This might be due to the higher water level in the irrigation ditches as compared to that in the rice fields.

Flooding in Season 1/2004 might also have contributed to this factor, as more fish from the Pendang River could freely swim into the nearby rice plots. Two species considered as riverine species or "white" fish, namely *Cyclocheilichthys apogon* (temperas) and *Barbodes gonionotus* (lampam jawa), were caught in the uncontrolled flow plots. However, the total number of both species caught was small (i.e. not more 11 specimens). According to Welcomme (1985), some of the "white" fish species make lateral migration for spawning, especially during the rainy season. This is because the flooded rice fields or other terrestrial habitats which are located near the river provide more food and shelter for the fish for spawning (Fernando, 1993). Katano *et al*. (2003) also recorded that several riverine fish species, such

TABLE 3
The Shannon-Wiener Diversity and Evenness Index of fish in the recycled and uncontrolled flow plots (n = number of species)

Plot	Shannon-Wiener Index	Evenness Index
Recycled (n=11)	0.8764	0.8416
Uncontrolled flow (n=13)	0.8131	0.7300

as *Silurus asotus*, *Cobitis* sp. and *Carassius* spp., are known to spawn in rice fields. Katano *et al*. (2003) reported that the richness and diversity of fish species in ditches were high as fish were able to easily invade the rice fields from the nearby rivers.

The depth of water was also found to influence the diversity of fish species. Among other, Iguchi *et al*. (1999) showed that the species diversity was high in the deeper portions of the rivers and they were gradually reduced in canals, ditches and rice fields, with 25, 12, 8 and 3 species, respectively. Meanwhile, Katano *et al*. (2003) and Shah and Ali (1998) had recorded 19 and 39 species in selected irrigation canals and ditches of Japan and in the Malaysian rice agroecosystem, respectively. On the other hand, Ali (1990) and Shamsudin (2001) recorded only seven and eleven species at the North Krian and Muda rice fields, respectively. The difference in the number of species reported by Ali (1990) and Shamsudin (2001) might be due to the different types of sampling gear used, whereby hand nets were used, along with visual observations, in the first study, as compared to the use of electro-shocker in the second study.

As there were no concrete irrigation canals in the study area, the total number of species in both the recycled irrigation water and uncontrolled flow plots was not very different. Katano *et al*. (2003) showed that the natural stream beds which were not covered by concrete had greater number and biomass of fish than the irrigation ditches made of concrete in the Japanese rice agroecosystem. This is because the natural stream bed provides more niches and food sources for fish as compared to concrete irrigation ditches which have a more homogenous environment.

Nonetheless, the list of species is not complete as some introduced (exotic) species, such as *Oreochromis* sp. and the African catfish (*Clarias gariepinus*), reported to have been released into the rice plots as part of the Integrated Pest Management (IPM) scheme were not caught in the study. According to Matthias *et al*. (1996), *Oreohromis* sp. and *Cyprinus carpio*, which are both exotic species in South East Asia, are popularly cultured in the rice fields to assist in pest management programmes. Therefore, further studies that cover more areas should be carried out in order to obtain more accurate information on the success of these released species in the MADA rice fields.

Based on the species richness and the Shannon-Weiner Diversity Indices, it can be concluded that the water quality of the Muda rice fields is considered moderate with low D.O. (0.3 mg/L) and high TSS (3088.8 mg/L) and it can support several fish species. The uncontrolled flow plots had a slightly higher number of fish species, and only two species are different from the plots with recycled water. This is because most of the uncontrolled flow plots are located near the rivers with larger number of fish species. Therefore, the presence or the absence of such species may closely be related to the changes in water levels and the distance from the sources of water supply. Meanwhile, the flood event in the middle of Season 1/2004 resulted in some riverine species being caught in the uncontrolled flow plots as they got trapped when the water level receded.

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