

## Biodiversity in stormwater constructed wetlands: Case study of USM Wetland

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### ABSTRACT

The study was conducted to determine the species present for the phytoplankton, zooplankton, benthic macroinvertebrate, fish and birds, generally from low trophic level until high trophic level, in the stormwater constructed wetlands, USM. The list of the species present will be used to relate the water quality and explain the current condition of species diversity, starting from December 2010 until May 2011. So the aim of this study was to see how the constructed wetland can provide new habitat for each different species and contribute to the conservation of biodiversity. Based on the result obtained, the number of species was high around the inlet Wetland (W1 and W2) for phytoplankton, zooplankton and benthic macroinvertebrate due to high abundance of plant, sufficient amount of nutrient concentration (ammonium, nitrate, nitrite and phosphate), light and dissolved oxygen, which can help to trigger its distribution. The benthic macroinvertebrate species found had gave some information on how the species respond to the recent water quality condition. The number of fish present in the wetland had provided source of foods for local and migratory birds. Due to this reason, diverse of bird species can be found around the wetland. The reason to used 5 different indicators (phytoplankton, zooplankton, benthic macroinvertebrate, fish and bird) for this study was to see the pattern of diversity distribution for each trophic level and how it correlates to each other and to the constructed wetland ecosystem. At the end of this study, the data obtain from this paper can gave an idea on how to improve the stormwater constructed wetland design (in term of types of suitable plant species, soil composition and water level) which can contribute to the species conservation and help to keep the ecosystem healthy as natural. A long term study and monitoring in biodiversity of stormwater constructed wetland is required to justify the affect of population in the long period of time.

*Keywords:* Stormwater constructed wetland; trophic level; biodiversity; conservation.

### 1 Introduction

Wetlands can be defined as an areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water and the depth of which at low tide does not exceed six meters and may incorporate riparian and coastal zones adjacent to the wetlands (Ramsar, Iran, 1971). Wetlands are located between the dry terrestrial systems and permanent flooded deepwater aquatic systems such as rivers, lakes, estuaries and coastal zone. Wetlands are very important and productive ecosystems and play an important role for the environment sustainability such as regulating water level within watershed, help to improve water quality level, control and reduce flood and storm damage and provide healthy habitat for wildlife to live. All this function gave high profit in term of economical value, which the wetland can support hunting, fishing, tourism and other recreational activities. Due to this reasons, humans are continuously design and come out

with the constructed wetland, which can mimic the natural condition of wetland and at the same time fulfill the human life requirement and convenient. Generally, constructed wetland can be defined as an engineered designed to stimulate natural wetland to exploit the water purification functional value for human used and benefit and constructed wetlands consist of former upland environment that have been modified to create poorly drained soils and wetland flora and fauna for the primary purpose of contaminant or pollutant removal from wastewater or runoff (Hammer, 1992).

The purposed to have constructed wetland is particularly depends on the problems that need to be settle such as pollution, heavy metal, leachate and stormwater runoff. Thus, it has to be appropriately design such as suitable gradient and types of soil, suitable densities and types of plants, water depth, water flow rate and others, to have an optimum water treatment and filtration. There are several categories of constructed wetland and basically, it can be divided into two different system; Subsurface Flow (SF) System and Free Water Surface (FWS) System.

However, FWS system was commonly used in Malaysia due to its low construction, operation and maintenance cost. Recent study had showed that the constructed wetland (FWS) treatment system has been successfully used across the country. In Malaysia for example, the Putrajaya wetland, which one of the FWS system, showed the nutrient removal performance up to 82.11% for total nitrogen, 70.73% for nitrate–nitrogen and 84.32% for phosphate (Sim et al. 2008).

Overall, based on the previous studies, the problem related to the water quality and quantity showed successful result and was effectively functioned. However, the problem right now, how the constructed wetland can help to give benefit for other wildlife species. Recently, there are lacks of research conducted on biological aspect, biodiversity, for stormwater constructed wetland. Biodiversity is the variability among living organisms from all sources including wetland, and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. The biodiversity is important component in wetland and it support and stabilize the ecosystem which has highly interrelationship between hydrology and biogeochemistry. The current issue related to the biodiversity was the rapid growth of extinction for certain species due to anthropogenic effect. For example in North America, within the Great Basin, introduction of nonnative species and habitat modification have caused the extinction 16 endemic species, subspecies or other distinctive population since the late 1800s (Sada & Vinyard, 2002). Decline in abundance or distribution were attributable to water flow diversions, competitive or predatory interaction with non native species, pollution recreational and habitat urbanization. As the result, if less number of studied for biodiversity in constructed wetland was conducted, it can become one of the serious issues for future species conservation and protection and issues of extinction may come out later. The man made had altered the surrounding ecosystem and the changes may either give positive or negative impact to the species diversity, eventhough our proposed to construct human made wetland was beneficial for human life.

Due to this concern, River Engineering and Urban Drainage Research Centre (REDAC), which is one of the centre in Malaysia under Universiti Sains Malaysia (USM), has taken an opportunity to be part in the biodiversity conservation, by conducting a holistic research and monitoring in the Bio-Ecological Drainage System (BIOECODS), which is one of the ecological sustainable development in terms of urban stormwater management. One of the important components in the system, which is constructed wetland, was purposely build to enhance the treatment of stormwater quality using treatment train concept (Ab. Ghani et al. 2004) and a few studies was done to evaluate the water quality level (Mohd Sidek et al. 2004; Ayub et. al. 2004). Biological assessment (bioassessment) will be conducted to check and measured the species diversity, starting from the bottom trophic level until the upper most trophic level.

The species diversity will be covered on plankton (phytoplankton and zooplankton), benthic macroinvertebrate, fish and bird. The correlation and integration between species diversity and water quality condition and among the species present will be measured and the information obtained can be beneficially used to determine the quality level of constructed wetland.

## 2 Methodology

Constructed wetland, USM was chosen to be the case study for this research (Figure 1). Table 1 and Table 2 show the detail specification of the wetland. The sampling was done from December 2010 until May 2011. The wetland had been divided into nine parts and each parts become the station for this studied. Each sampling station possessed different density and types of plant present (Figure 2). The stations are Wetland 1 and 2 located near the inlet wetland; Wetland 3 and 4 located in the middle of wetland, beside Wetland 1 and 2; Wetland 5 and 6 located in the middle of wetland, near the Wetland 3 and 4; and Wetland Micropool (WM), which located near the outlet of wetland, was divided into three rows, WMA, WMB and WMC. The row then further subdivided into three sections (eg; WMA (1, 2, and 3)) to measured water quality, phytoplankton, and zooplankton. The reason wetland been divided in such a way due to some environmental factor that need to be consider such as the different composition of plant in the wetland and different depth between Wetland Micropool and Wetland 1-6 (Figure 2). The sampling for in-situ water quality was carried out once every week and for nutrient test had been carried out once in the two week. For biological component such as phytoplankton, zooplankton, benthic macroinvertebrate and fish, the sampling was done once a month. Daily monitoring in specific time during morning and noon had been carried out to measure bird composition as well bird identification.

Table 1 Design criteria for the constructed wetland, USM (Zakaria et al. 2003)

<b>Parameter</b>	
Catchment area	1.214 km <sup>2</sup>
Design storm (3-month ARI)	22.5 mm/hr
Length	155 m
Width	60 m
Wetland surface area	9,100 m <sup>2</sup>
Volume	9,100 m <sup>3</sup>
% Catchment area	0.7
Design inflow rate	0.25 m <sup>3</sup> /s
Mean residence time	3 days
Slope of wetland bed	1%
Bed depth	0.6 m
Mediae	Pea gravel and soil mixture
Hydraulic conductivity of gravel	10 <sup>-3</sup> m/s to 10 <sup>-2</sup> m/s



Figure 1 (a) Map of Universiti Sains Malaysia, Nibong Tebal (b) Location of constructed wetland

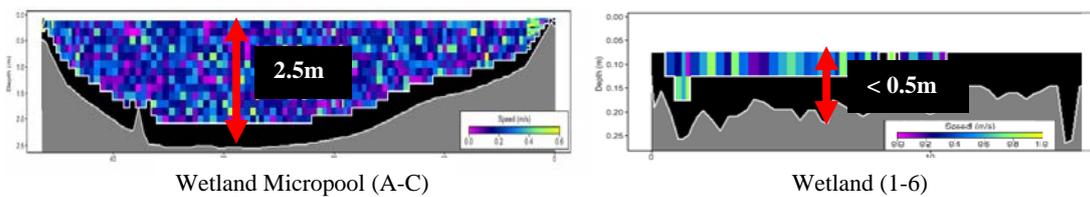


Figure 2 Sampling stations at USM wetland and the different depth between Wetland Micropool (A-C) and Wetland (1-6)

Table 2 Wetland plant species in USM (Zakaria et al. 2003)

Type	Plant name
Type 1 (0.3m depth)	<i>Eleocharis variegata</i>
Type 2 (0.3m depth)	<i>Eleocharis dulchis</i>
Type 3 (0.3m depth)	<i>Hanguana malayana</i>
Type 4 (0.6m depth)	<i>Lepironia articulata</i>
Type 5 (0.6m depth)	<i>Typha augustifolia</i>
Type 6 (1.0m depth)	<i>Phragmites karka</i>

### 3 Data collection and analysis

#### 3.1 Biological sampling

Five types of species or indicators had been chosen to study the biodiversity; phytoplankton, zooplankton, benthic macroinvertebrate, freshwater fish and birds. The reason to choose these indicators are due to their important role in the food web and its distribution, affect by environment quality in the wetland. The main objective was also to see the pattern of diversity distribution for each trophic level and how it correlates to each other and to the constructed wetland ecosystem. The interconnection from each of the indicators can be seen at the end the study from the low trophic level (plankton) until the high trophic level (bird). Each of the indicators had different sampling procedure and strategies. For plankton, the samples was collected at the surface water by filtering forty liters (40L) of water, using plankton net with 35µm (phytoplankton) and 60µm (zooplankton) mesh size. The collected water samples were transferred into sample bottles and formalin 5% was added as preservative. For benthic macroinvertebrate, each sampling station was collected by using D-framed net with a diameter 0.38 meter. The species was transferred by using a pairs of forceps and a pipette (for small insects or larvae). All the aquatic insects and larvae collected were preserved in 70% ethanol in the universal bottles. Some of the invertebrate was identified directly to the naked eyes or by using the magnifying glass. For fish, cast net and hook was chosen as the fishing gear to catch the fish. Fish caught was immediately being preserved in 10% formalin solution or some will take a picture for the references purposed. Finally, for birds, daily visual observation will be carried out and identification will be based on 'A photographic guide to the birds of Malaysia and Singapore' book (Strange, 2000) and 'A field guide to the birds of West Malaysia and Singapore' book (Jeyarajasingam, et al., 1999).

#### 3.2 Water quality sampling

Two 500 ml bottles (representing replicate 1 and replicate 2) was used to collect the water sample. The bottles will initially rinse with the wetland water and then fill with the wetland water samples. The water sample was preserved in the cold compartment (usually used ice box). It must be preserve under low temperature to prevent any biological activity of any microorganisms that can affect the composition of nutrient in the water. The in-situ

parameter was taken at the sampling stations during the sampling. The parameters involved are the physico-chemical parameter including temperature, pH, dissolved oxygen, and conductivity. The parameters will be taken by using YSI Sonde meter. The nutrient analysis were total suspended solid (TSS), nitrite, nitrate, ammonia, biological oxygen demand (BOD), chemical oxygen demand (COD), and ortho-phosphate.

#### 3.3 Laboratory analysis

##### (a) Phytoplankton

In the laboratory, the phytoplankton samples will be processed for identification to the lowest taxon possible. The identification of phytoplankton was based on the taxonomic key from Tomas (1997), Sournia (1978) and Reynolds (1984).

##### (b) Zooplankton

The zooplankton sample will be identify under dissecting microscope according to their major order: copepod, cladocera, and rotifer. The keys taxonomy for identification of zooplankton was according to Smirnov (1996), Korovchinsky (1992), Idris (1983), and Pennak (1978).

##### (c) Benthic macroinvertebrate

In the laboratory, the benthic macroinvertebrates were sorted into petri dish, and identified by using a taxonomical key to the lowest possible level. For large benthic macroinvertebrates, they were sorted by naked eye. Sorting the small fauna will be done under a dissecting microscope. The insects will be identified to genus by using a few references.

##### (d) Fish

The specimen that represents different species will be taken a picture for references. The specimens then will be preserved in 10% formalin with a label. Laboratory works done will be fish identification by using standard key taxonomic references.

##### (e) Birds

Daily visual observation will be carried out and identification will based on a few identification books.

##### (f) Water quality

Laboratory analysis will be carried out to determine the concentration of phosphate ( $PO_4^-$ ) by referring Phosver3 (ascorbic acid) method technique. The concentrations of nitrite ( $NO_2^-$ ) and nitrate ( $NO_3^-$ ) were determined using Diazotization method (0.002-0.3 mg/l) and Cadmium reduction method (0.3-30.0 mg/l). The concentration of ammonia ( $NH_4^+$ ) was determined by referring to Nessler

method (0.02-2.50 mg/l). TSS, BOD and COD experiment will be handling by referring to Standard Methods for the Examination of Water and Wastewater.

#### 4 Preliminary Result and discussion

Based on the result obtained, for phytoplankton, 17 species of phytoplankton was found from December 2010 until May 2011 (Table 3). Wetland 2 (W2) recorded the highest number of species found with 15 species while Wetland Micropool C (2) recorded the lowest with 5 species (Figure 3). The most common phytoplankton species was *Westella botryoides* from Chlorophyta group

while the less common phytoplankton species was *Tetrademus smithii*.

For zooplankton, there were 18 species found from first sampling, December 2010 until May 2011 and 3 groups were found; Rotifera, Cladocera and Copepoda (Table 4). Wetland 1 (W1) recorded the highest number of species found with 15 species while Wetland Micropool C (2) recorded the lowest with 6 species (Figure 4). The most common zooplankton species were *Ascomorpha* sp, *Brachionus caudatus* and *Tricocherca* sp from Chlorophyta group while the less common zooplankton species were *Asplanchna* sp and *Keratella cochlearis*.

Table 3 List of present/absent phytoplankton species at all sampling station of Wetland, USM.

SPECIES	Stations														
	W1	W2	W3	W4	W5	W6	WMA			WMB			WMC		
							1	2	3	1	2	3	1	2	3
<b>Bacillariophyta</b>															
<i>Cyclotella comta</i>	+	+	+	-	-	+	-	+	-	+	-	+	+	-	+
<i>Navicula</i> sp.	+	-	+	+	+	-	+	-	-	-	+	-	-	+	-
<i>Stephanodiscus astraera</i>	+	+	-	-	-	+	-	-	+	-	-	-	+	-	+
<b>Chlorophyta</b>															
<i>Ankistrodesmus falcatus</i>	+	+	-	+	+	-	+	+	+	+	+	-	-	-	-
<i>Closterium microporum</i>	+	+	+	-	+	+	-	-	-	+	+	+	-	-	+
<i>Mougeotia</i> sp.	+	+	-	+	+	-	+	+	+	-	-	-	-	+	-
<i>Pediastrum simplex</i>	+	+	+	+	+	-	-	-	-	-	+	+	+	-	+
<i>Scenedesmus quadricauda</i>	+	+	+	-	-	+	-	+	-	+	-	+	+	-	+
<i>Sphaerocystis schroeteri</i>	-	+	-	+	+	-	+	-	-	-	-	-	-	+	-
<i>Tetrademus smithii</i>	-	+	-	+	-	-	-	+	-	-	-	-	+	-	-
<i>Westella botryoides</i>	+	+	+	-	-	+	+	-	+	+	+	+	-	-	+
<b>Pyrrophyta</b>															
<i>Hemidinium nasutum</i>	+	+	-	-	-	-	+	+	-	-	-	-	+	+	-
<b>Cyanophyta</b>															
<i>Aphanocapsa elachista</i>	+	+	-	-	+	+	-	-	+	-	-	-	+	-	-
<i>Lyngbya limnetica</i>	-	+	+	-	+	-	+	+	-	+	+	-	-	-	+
<i>Oscillatoria prolifica</i>	+	+	+	+	-	+	-	+	+	-	-	-	-	+	-
<b>Chrysophyta</b>															
<i>Coelosphaerium naegelianum</i>	+	+	-	-	-	+	-	+	-	+	-	+	-	-	+
<i>Tribonema affine</i>	-	-	+	-	-	-	+	-	+	-	+	-	+	-	-
<b>Total</b>	13	15	9	7	8	8	8	9	7	7	7	6	8	5	8

Note: + = present  
- = absent

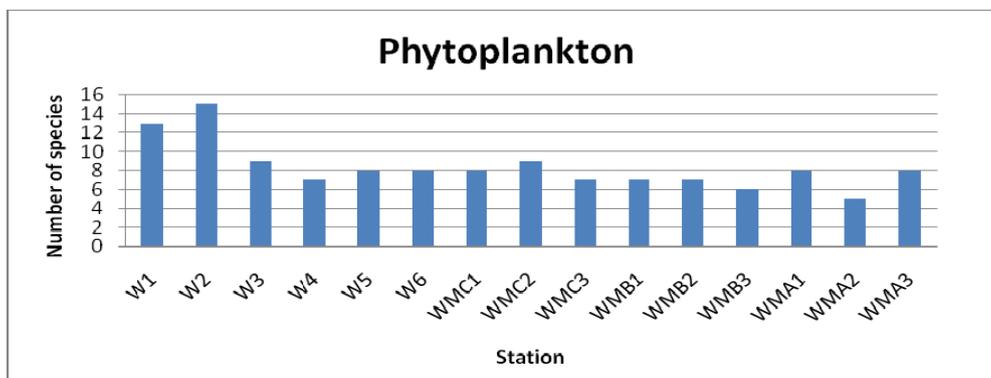


Figure 3 Phytoplankton distribution (by species) at all sampling station of Wetland, USM

Table 4 List of present/absent zooplankton species at all sampling station of Wetland, USM.

SPECIES	Stations														
	W1	W2	W3	W4	W5	W6	1	2	3	1	2	3	1	2	3
<b>Rotifera</b>															
<i>Ascomorpha</i> sp	+	+	+	-	+	+	+	+	-	-	+	+	+	-	+
<i>Asplanchna</i> sp	+	-	-	-	+	-	-	-	-	-	-	-	-	+	+
<i>Brachionus caudatus</i>	+	+	+	+	-	+	+	+	-	+	+	-	+	-	+
<i>B. havaenensis</i>	+	+	+	-	-	-	-	-	+	-	-	+	-	-	-
<i>B. quadridentata</i>	-	+	-	+	+	-	+	-	-	+	+	-	+	+	-
<i>Keratella cochlearis</i>	+	-	+	-	-	+	-	-	+	-	-	-	-	-	-
<i>Lecane</i> sp	-	+	+	+	+	-	+	+	-	-	-	+	+	-	-
<i>Monostyla</i> sp	+	+	-	+	-	-	-	-	-	+	-	-	-	-	+
<i>Playtias</i> sp	+	+	+	-	-	+	-	+	-	-	-	+	-	+	-
<i>Trichoerca</i> sp	+	+	+	+	+	+	+	+	+	+	-	-	+	-	-
<b>Cladocera</b>															
<i>Bosmina longirostris</i>	+	+	+	+	-	+	+	-	+	-	+	-	+	-	+
<i>Ceriodaphnia cornuta</i>	-	+	-	-	+	-	+	+	-	-	-	+	-	-	-
<i>Dadaya</i> sp	+	-	+	+	-	+	-	-	+	+	+	-	-	+	-
<i>Diaphnasma</i> sp	+	-	+	-	+	-	+	+	-	+	-	+	-	-	+
<i>Moinodaphnia maclaeiyii</i>	+	+	-	+	-	+	-	+	-	-	-	-	+	+	-
<i>Scapholeberis</i> sp	+	+	+	+	+	+	-	-	+	-	+	-	-	-	-
<b>Copepoda</b>															
Cyclopoida	+	-	+	-	+	-	+	+	-	-	+	+	-	+	-
Calanoida	+	+	-	-	+	+	-	-	+	+	-	-	+	-	+
<b>Total</b>	15	13	12	9	10	10	9	9	7	7	7	7	8	6	7

Note: + = present  
- = absent

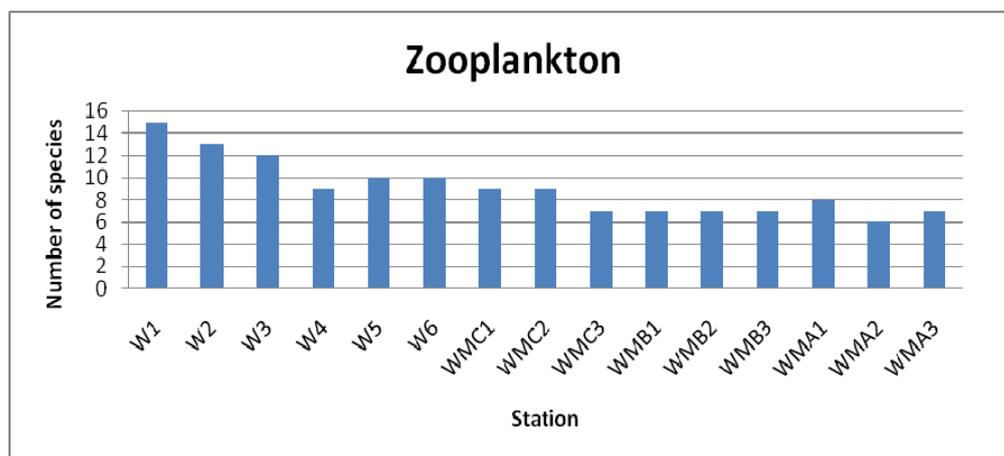


Figure 4 Zooplankton distribution (by species) at all sampling station of Wetland, USM

For benthic macroinvertebrate, there were 14 types of species found from December 2010 until May 2011 (Table 5). Wetland 1 (W1) and Wetland 3 (W3) recorded the highest number of animals found with 12 animals while Wetland Micropool B and C recorded the lowest with 4 animals (Figure 5). The most common macroinvertebrate was Water stick (Kepinding Ranting) from Order Hirudinea, Family Nepidae, while the less

common macroinvertebrate was Leeches (Lintah) Order Hirudinea, Family Hirudinidae. From the list of species in the Table 5, further interpretation can be made by referring to the score (tolerance value) for each of the animals. Each of the animals had different score level based on the tolerance level of that species to the condition of the water and surrounding environment. From the result obtained, overall, all the sampling station were

in the range 5.10-7.50, an each of the area can be classified under clean water and Class II. Wetland 4 and 5 show highest Biological Water Quality Index, 5.80 while

Wetland 2 showed the lowest Biological Water Quality Index, 5.25 (Table 6).

Table 5 List of present/absent benthic macroinvertebrate species at all sampling station of Wetland, USM.

Macroinvertebrate	W1	W2	W3	W4	W5	W6	WMA	WMB	WMC	Score
<b>PHYLUM: Arthropoda Class:Insecta</b>										
<b>Order: Odonata</b>										
<b>Suborder: Anisoptera</b>										
Aeshnid dragonfly, Pepatung Aeshnid (nymph) Family: Aeshnidae	+	+	+	+	+	+	-	-	-	6
Libellulid dragonfly, Pepatung Libellulid (nymph) Family:Libellulidae	+	+	+	+	+	+	-	-	-	6
<b>Suborder: Zygoptera</b>										
Common demoiselle, Pepatung jarum langsing (nymph) Family:Calopterygidae	+	-	+	-	+	+	+	+	+	6
Two-tailed demoiselle, Pepatung jarum ekor dua (nymph) Family:Chlorocyphidae	+	+	-	+	+	+	+	-	+	6
<b>Order: Coleoptera</b>										
Riffle beetle larvae, Kumbang Jeram (larvae) Family: Elmidae	+	+	+	+	-	+	-	-	-	5
Water penny larvae, Kumbang syiling (larvae) Family: Psephenidae	+	+	+	-	-	+	-	-	-	5
<b>Order: Heteroptera</b>										
Water stick, Kepinding Ranting (insect) Family: Nepidae	-	+	+	-	+	+	+	+	+	5
<b>PHYLUM: Mollusca</b>										
<b>Class: Gastropoda</b>										
Pagoda snail, Siput Pagoda Family: Thiaridae	+	+	+	+	-	+	-	-	-	6
<b>PHYLUM: Annelida</b>										
<b>Class: Hirudinea</b>										
<b>Order: Hirudinea</b>										
Leeches (Lintah) Family:Hirudinidae	-	+	-	-	-	-	-	-	-	3
<b>Non-indicator</b>										
Water measurer	+	-	+	-	-	-	+	+	+	-
Pond skater	+	+	+	+	+	+	-	+	-	-
Whirligig beetle	+	+	+	+	+	-	-	-	-	-
Table 5: (continued)										
Macroinvertebrate	W1	W2	W3	W4	W5	W6	WMA	WMB	WMC	Score
Water mite	+	+	+	-	+	+	+	-	-	-
Water fleas	+	-	+	-	-	-	-	-	-	-
Total	12	11	12	7	8	10	5	4	4	

Note: + = present ,  
- = absent

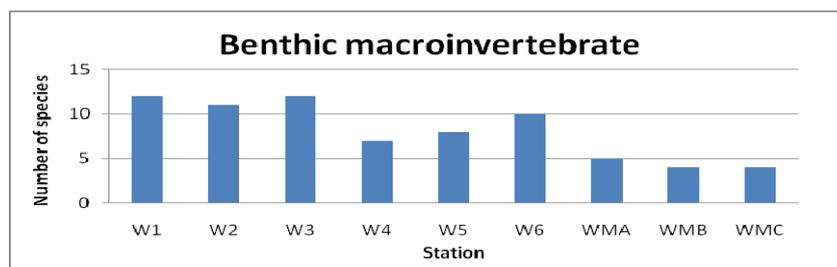


Figure 5 Benthic Macroinvertebrate distribution (by species) at all sampling station of Wetland, USM

Table 6 Classification of water quality in wetland based on Water Quality Index (WQI) and Average Score Per Taxon (ASPT) Average Score Per Taxon

Stations	Total Score	Number of animal (exclude non-indicator)	Biological Water Quality Index
1. Wetland 1	40	7	5.71
2. Wetland 2	42	8	5.25
3. Wetland 3	39	7	5.57
4. Wetland 4	29	5	5.80
5. Wetland 5	29	5	5.80
6. Wetland 6	45	8	5.63
7. Wetland Micropool A (WMA)	17	3	5.67
8. Wetland Micropool B (WMB)	11	2	5.50
9. Wetland Micropool C (WMC)	17	3	5.67

• 7.60-10.00 Very Clean • 5.10-7.50 Clean • 2.60-5.00 Moderate • 1.00-2.50 Dirty • 0.00-0.90 Very Dirty

- Class I: Can be use as drinking water without treatment
- Class II: Need treatment before drink and can be used for bath
- Class III: Need intensive treatment for drinking purpose
- Class IV: Use for irrigated crop and domestic animal drink
- Class V: Cannot be used for any purposed listed from Class I until Class IV

For fish, a total of 11 specimens comprising of 5 species was caught and identified from the first sampling in December 2010 until May 2011 and 3 species were identified based on observation in the wetland area (Table 7). The percentage distribution of can be seen at Figure 6 below. Species of Tilapia (*Oreochromis niloticus*) is the most dominant species, at 35% of total fish composition followed by Tinfoil barb, Lampam sungai (*Barbodes schawananfeldii*) at 30%, Marble goby, Ikan ketutu, ubi (*Oxyeleotris marmoratus*) at 15%, Rohu (*Labeo rohita*) at 10%, Pacu (*Colossoma macropomum*) at 8%, Silver

barb, Lampam jawa (*Barbodes gonionotus*) at 2% and. The other species existing in the wetland are Giant snakehead, Toman (*Channa micropletis*), Snakehead murrel, Harun (*Channa striata*) and Silver catfish, Patin (*Pangasius spp.*).

For bird, a total 15 species of birds were observed in December 2010 until May 2011, which comprise of 10 different families (Table 8). Family Ardeidae was observed to be most abundance family members, consist of 5 species.

Table 7 Fish species checklist and its distribution at Wetland, USM

Species	Local name	Percentage composition by number	Conservation status
1. <i>Oreochromis niloticus</i>	Tilapia	35.0	Exotic species
2. <i>Barbodes schawananfeldii</i>	Tinfoil barb, Lampam sungai	30.0	Native species
3. <i>Oxyeleotris marmoratus</i>	Marble goby, Ikan ketutu, ubi	15.0	Native species
4. <i>Labeo rohita</i>	Rohu	10.0	Exotic species
5. <i>Colossoma macropomum</i>	Pacu	8.0	Exotic species
6. <i>Barbodes gonionotus</i>	Silver barb, Lampam jawa	2.0	Exotic species
6. <i>Channa micropletis</i>	Giant snakehead Toman	Unknown	Native species
7. <i>Channa striata</i>	Snakehead murrel Haruan	Unknown	Native species
8. <i>Pangasius spp.</i>	Silver catfish, Patin	Unknown	Native species

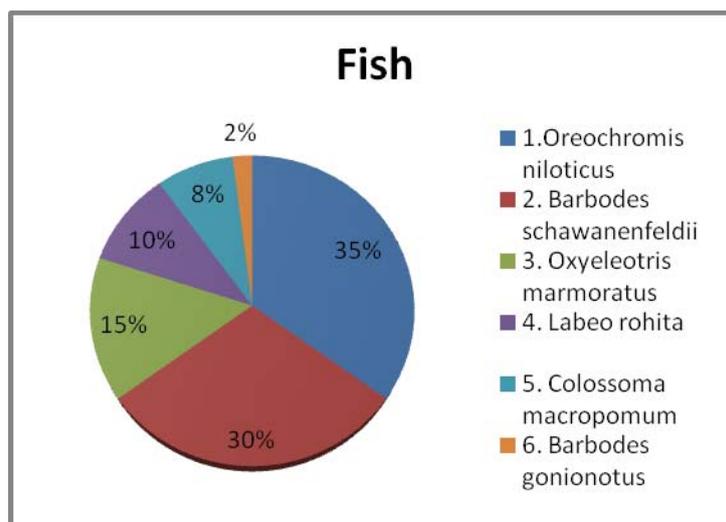


Figure 6 Percentage distribution of fish at Wetland, USM

Table 8 List of bird species found in the Wetland, USM

List of bird species

**Family Ardeidae**

Plumed Egret, Short-billed Egret, Bangau kendi

*Egretta intermedia*

Great Egret, Bangau Besar

*Egretta alba*

Little Egret, Bangau Kecil

*Egretta garzetta*

Purple Heron, Pucung Serandau

*Ardea purpurea*

Cinnamon Bittern, Pucong Bendang

*Ixobrychus cinnamomeus*

**Family Alcedinidae**

Common Kingfisher, Pekaka Cit-cit Kecil

*Alcedo atthis*

White-Throated Kingfisher, Pekaka Belukar

*Halcyon smyrnensis*

**Family Sturnidae**

Common Myna, Tiong Gembala Kerbau

*Acridotheres tristis*

**Family Ploceidae**

Eurasian Tree-Sparrow, Ciak Urasia

*Passer montanus*

**Family Meropidae**

Blue-tailed bee-eater, berek-berek carik dada

*Merops philippinus*

**Family Scolopacidae**

Common Sandpiper, Kedidi Pasir

*Actitis hypoleu*

**Family Dendrocygnidae**

Lesser Whistling Duck, Itik Belibis

*Dendrocygna javanica*

**Family Accipitridae**

Brahminy Kite, Helang Merah

*Haliastur Indus*

**Family Columbidae**

Spotted Dave, Tekukur

*Streptopelia chinensis*

**Family Charadriidae**

Red Wattled Lapwing, Rapang Minta Duit

*Vanellus indicus*

Based on the result obtained, the distribution of species of phytoplankton, zooplankton and benthic macroinvertebrate was high at W1 and W2 as compare to others sampling station. Further sampling can help to find the abundance and distribution of species for each sampling station. Thus, it will give a strong supporting evident, as well as prediction of species tolerance and predict water condition. For phytoplankton, high number of species was found at W2. One of the factors is the depth of this area, which help the light to penetrate easily to the water until the bottom area. The available of light help phytoplankton to undergo photosynthesis process. As

a result, high oxygen can be produce, and this may contribute to high dissolve oxygen obtained (Table 9). The water temperature plays an important role affecting the abundance of phytoplankton species (Chapman & Chapman, 1962). A further sampling is needed to see some species who able to tolerance to the different temperature. The nutrient available is another factor that contributes to the numbers of species present. The high concentrations of phosphate and nitrogen compound (Table 9) contribute to the high numbers of species of phytoplankton.

Table 9 Water quality in the constructed Wetland, USM

Sampling station	Dissolved										
	Temp.	Oxygen	pH	Conductivity	Ammonia	Phosphate	Nitrate	Nitrite	TSS	BOD	COD
Wetlands 1	31.46	7.63	7.09	0.111	0.37	0.43	3.1	0.018	0.0025	3.27	29
Wetlands 2	30.94	7.18	7.06	0.112	0.31	0.45	2.9	0.016	0.0024	2.99	27
Wetlands 3	32.27	9.07	7.23	0.113	0.28	0.3	2.2	0.017	0.0017	2.88	25
Wetlands 4	31.52	8.67	7.25	0.111	0.25	0.28	2.7	0.006	0.002	2.47	27
Wetlands 5	31.33	8.42	7.35	0.111	0.12	0.35	1.3	0.009	0.0021	3.11	16
Wetlands 6	31.64	8.96	7.44	0.107	0.13	0.3	1.8	0.008	0.002	3.02	8
Wetlands Micropool A1	29.19	7.7	7.24	0.104	0.15	0.19	0.6	0.004	0.0012	2.33	9
Wetlands Micropool A2	29.45	7.72	7.18	0.105	0.18	0.09	1.5	0.01	0.0011	2.47	20
Wetlands Micropool A3	29.51	7.8	7.21	0.106	0.11	0.1	1.4	0.009	0.0012	2.66	17
Wetlands Micropool B1	29.55	7.85	7.08	0.106	0.13	0.15	1	0.006	0.0007	2.13	9
Wetlands Micropool B2	29.65	7.75	7.09	0.106	0.1	0.11	1.5	0.004	0.0005	2.78	14
Wetlands Micropool B3	29.73	7.92	7.11	0.106	0.09	0.13	0.9	0.005	0.0009	2.67	6
Wetlands Micropool C1	30.01	8.08	7.12	0.107	0.07	0.22	0.8	0.004	0.0008	2.97	5
Wetlands Micropool C2	29.79	8.14	7.12	0.107	0.01	0.13	0.9	0.007	0.0005	2.43	5
Wetlands Micropool C3	30.3	8.14	7.16	0.107	0.13	0.07	0.2	0.01	0.0009	2.19	13

Based on the result, zooplankton was more diverse at Wetland 1 (W1) and Wetland 2 (W2). Zooplankton diversity, abundance and composition are closely related to the phytoplankton community (Goldyn & Madura, 2007). Selective grazing by zooplankton is an important factor affecting the structure of phytoplankton communities. However, phytoplankton structure also influences the taxonomic composition and dominance of the zooplankton. These animal components are mainly filtrators, sedimentators or raptorial predators (Karabin, 1985). The copepods suppress large phytoplankton, whereas nanoplanktonic algae increase in abundance (Sommer et al., 2003). However, further analysis should be made to see significant affect the distribution, diversity and composition of zooplankton to the phytoplankton community. Environmental parameters also need to further analyze to support and correlate the impact zooplankton community to the wetland ecosystem.

For benthic macroinvertebrate, the result showed high number of species at W1 until W6 as compared to the Wetland Micropool area. However, all sampling station showed clean water level, based on Biological Water Quality Index. Benthic macroinvertebrate respond qualitatively to the physical and chemical variation of water. High dissolve oxygen in water gave sufficient amount of oxygen for animal to breath, for example for Riffle beetle larvae Water penny larvae. The healthy wetland habitat consist high dissolve oxygen, which in the range of 7.1 mg/l to 8.73 mg/l (Barbour et al., 1996). Macroinvertebrate community decrease it numbers and diversity in the aquatic environment which contain low pH value 9 (acidic). Most of the dragonfly can live in the water which

contains pH value in the range of 3.25 to 8.00. The optimum pH for most of the species is 5.0 to 8.0 (Pollard & Berril, 1992). Water temperature is very important for the macroinvertebrate because some of them a favorable in slightly cold water or in slightly hot water. The high water temperature a more favor to some of the Mollusk species except for freshwater limpet.

Based on the fish result obtain, *Oreochromis niloticus*, species of *Tilapia* showed highly in numbers as compare to other species. Overall, the wetland possessed highly diverse species of fish and this was due to some favorable parameters measured in the water. Temperature is one of the major influences for fish to inhabit and sustain in the wetland. Moderate temperature, enhance it growth and maintain its population. Rana (1990) had stated that optimal development of hatching for *Oreochromis niloticus* occurred at 25-30°C. A suitable pH condition, which is in the neutral range, helps the fish to inhabit the place longer. Sufficient amount of oxygen, based on the dissolve oxygen obtained, help the fish to undergo respiration without any obstacle. The low concentration of nutrient, which indicates the wetland was not eutrophic, had influence the diversity of fish to not only favorable to one type of fish species, to inhabit and tolerance to high nutrient concentration. High percentage of lower trophic level (phytoplankton, zooplankton and benthic macroinvertebrate) from the result obtained, contribute to the high diversity percentage for fish in the wetland. However, a further monitoring and sampling for the next coming month needed to justify it distribution to the surrounding environment.

All the result obtained (water quality and biological component) had trigger the diverse species of bird to come. Based on the observation, 9 different families, with 15 different species was identified in the surrounding wetland. The bird is the highest trophic level from the entire biological component sampled. The distribution of bird was highly dependent and based on the performance distribution and diversity of lower trophic level, which include phytoplankton, zooplankton, benthic macroinvertebrate and fish. Some birds need fish as a source of food and some eat insect. If the distribution, composition and diversity of this animal a low, the probability distribution of bird will be low as well. Some of the species a migratory (Family Ardeidae) and the suitable environment condition make wetland are suitable place to stay.

## 5 Conclusion and Recommendation

The high number of species for phytoplankton, zooplankton and benthic macroinvertebrate can be seen in the inlet area (W1 and W2) as compare to the Wetland Micropool area. Based of all result obtained, sequence of food chain can be made up, starting from the distribution of species in phytoplankton and zooplankton and further next to benthic macroinvertebrate, fish and lastly birds in the next analysis by determine it correlation through statistical analysis (Pearson correlation). The result obtained from species diversity in this study can give information on how the constructed wetland can support biodiversity and help in the conservation of species by providing suitable and sustainable habitat for animal and plant to live. However, further sampling are needed to summarize whole effect of community and to see the correlation between the water quality and the all the species assemblage. The performance of constructed wetland in improving water quality helps this species to adapt and undergo reproduction to sustain its population. Nutrient such as nitrite, nitrate, ammonia and phosphate reduce it concentration from the inlet area (Wetland 1 and Wetland 2) until the Wetland Micropool area. The water quality also affected by the climate and the different may can be seen during rainy season and dry season. Even though the concentration overall was low, but it can affected the distribution of biotic component.

Further analyses on biodiversity in constructed wetland are needed such as population dynamic, community structure and seasonal pattern. The information on biodiversity actually helps an engineer on how to design a great stormwater constructed wetland that not only capable to fulfill the technical requirement, but also can maintain a healthy ecosystem and sustain the environment. There are three important criteria to design the constructed wetland; soil, hydrology and plant. For example, a suitable mixture of soil can help the plant to growth and provide a place for benthic animal to live. A proper adjustment on water flow, water level, volume of water in and out and groundwater, help the plant to grow in a different place

which had different level of water. Plants had to be chosen for not only able to improve water quality and nutrient uptake, but also can provide ecological benefit such as comfortable habitat for animal to live. When an engineer able to fulfill the biodiversity criteria for every stormwater constructed wetland design, he or she actually had gave significant contribution in the protection of species population from the major concern of extinction and help to maintain healthy ecosystem for future generation.

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## References

1. Ab. Ghani, A., Zakaria, N.A., Abdullah, R., Yusof, M. F., Mohd Sidek, L., A.H. Kassim & A. Ainan. (2004). *BIO-Ecological Drainage System (BIOECODS): Concept, Design and Construction*. The 6<sup>th</sup> International Conference on Hydrosience and Engineering (ICHE-2004), May 30<sup>th</sup> -June 3<sup>rd</sup>, Brisbane, Australia.
2. Ayub, K. R., Mohd Sidek, L., Ainan, A., Zakaria, N. A., Ab. Ghani, A. & Abdullah. (2005). *Storm Water Treatment using Bio-Ecological Drainage System. Special Issue Rivers'04*, International Journal River Basin Management, IAHR & INBO, Vol. 3, No. 3, pp. 215-221.
3. Barbour, M.T., J. Gerritsen, B.D. Snyder, & B.D. Stribling. (1996). *Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrate, and fish, Second Edition*. EPA 841-B-99-002. U.S. Environment Protection Agency; Office of Water Washington, D.C.
4. Chapman, V.J. & Chapman, D.J. (1962). *The Algae*. Macmillan Press Ltd, London, 2<sup>nd</sup> Edition. 416-417pp
5. Goldyn, R & Madura, K.K. (2008). *Interaction between photoplankton and zooplankton in the hypertrophic Swarzedzkie Lake in the western Poland*. Journal of Plankton Research. Volume 30. 33-42
6. Hammer, D.A., (1992). *Design Constructed Wetland Systems to Treat Agricultural Nonpoint Source Pollution*. Ecological Engineering, 1:49-82.
7. Karabin A. (1985). *Pelagic zooplankton (Rotatoria+Crustacea) variation in the process of lake eutrophication. II. Modifying effect of biotic agents*. Ekol. Pol. 1985;33:617-644.
8. Mohd Sidek, L., Ainan, A., Zakaria, N.A., Ab. Ghani, A., Abdullah, R. & Ayub, K.R. (2004).

- Stormwater Purification Capability of BIOECODS*. The 6<sup>th</sup> International Conference on Hydroscience and Engineering (ICHE-2004), May 30<sup>th</sup> -June 3<sup>rd</sup>, Brisbane, Australia.
9. Pollard, J.B. & M. Berrill. (1992). *The distribution of dragonfly nymphs across a pH gradient in south-central Ontario lakes*. Canadian Journal of Zoology 70:878-885
  10. Ramsar (1971). *The Convention of Wetlands of International Importance Especially as Waterfowl Habitats*. Gland, Switzerland; Ramsar Convention Bureau.
  11. Rana, K.J. (1990). *Influence of incubation temperature on Oreochromis niloticus (L.) eggs and fry: 1. Gross embryonic, temperature tolerance and rates of embryonic development*. Aquaculture, Volume87, Issue 2. Pages 165-181.
  12. Sada, D.W. & Vinyard, G.L. 2002. *Anthropogenic Changes in Biogeography of Great Basin Aquatic Biota*. Smithsonian Contributions to the Earth Sciences [Smithson. Contrib. Earth Sci.]. no. 33, pp. 277-294.
  13. Sim, C. H., Yusoff, M. K., Shutes, B., Ho, S. C., Mansor, M. (2008). *Nutrient removal in a pilot and full scale constructed wetland, Putrajaya city, Malaysia*. Journal of Environment Management 88. 307-317.
  14. Sommer, U., Sommer, F., Santer, B. (2003) *Daphnia versus copepod impact on summer phytoplankton: functional compensation at both trophic levels*. Oecologia, 135, 639–647.
  15. Zakaria, N.A., Ab. Ghani, A., Abdullah, R., Mohd Sidek, L. & Ainan, A. (2003). *Bio-Ecological Drainage System (BIOECODS) For Water Quantity And Quality Control*. International Journal River Basin Management, IAHR & INBO, Vol. 1, No. 3, pp. 237-251.