EFFECTS OF LAND USE ON FISH ASSEMBLAGES IN INUNDATED AREA OF PLEIRAN RIVER AND DANUM RIVER SECTIONS OF MURUM RESERVOIR, BELAGA, SARAWAK

ANGIE SAPIS1*, GABRIEL TONGA NOWEG2, LEE NYANTI1 and JONGKAR GRINANG2

1Faculty of Resource Science and Technology, Universiti of Malaysia Sarawak, Malaysia
2Institute of Biodiversity and Environmental Conservation, Universiti of Malaysia Sarawak, Malaysia
*E-mail: angiesapis@gmail.com

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ABSTRACT

Land use changes and degradation of riparian zone had been proven to have effects on water quality and eventually affecting fish communities of newly impounded tropical reservoirs. For the case of newly impounded Murum reservoir in Sarawak, Pleiran and Danum catchments showed a significant disturbance due to logging, plantation and subsistence farming. A drastic change of land use is observed in Pleiran catchment, whereas Danum catchment is relatively less disturbed. This study aims to investigate fish assemblages at inundated areas of both catchments for one year. A total of 5,367 individuals of fish representing 36 species and eight families were caught. Results of multivariate analysis showed significant land use changes in both catchments, which contribute to significant differences in water quality. Pleiran catchment had significantly higher water temperature and TSS, but lower concentrations of Chl-a and DO. While Danum catchment showed otherwise. In this relatively good aquatic environment, the fish assemblage comprising the intolerant species: Tor douronensis and Osteochilus spp. The results imply that conversion of forested area at riparian corridor to open area led to changes in physicochemical characteristics, and subsequently resulted in habitat partitioning by fish species according to their environmental tolerance limit.

Key words: Malaysian reservoir, fish composition, land use change, riparian zone

INTRODUCTION

The impoundment of river by dam construction in the highland area has opened ways for exploitation and conversion of forested areas into agriculture area or other land use purposes. Construction of dam has not only provided roads for various economic activities, but also facilitated deterioration of the natural environment as large area of forest is being cleared, often followed by anthropogenic activities. This environmental degradation influenced the distribution and composition of fish communities in the natural river and newly inundated habitats. Murum reservoir is a man-made lake that receives water source from two major rivers, the Pleiran and Danum. The Pleiran and Danum catchments have been disturbed at different magnitude by logging, plantation and subsistence farming. Nislow and Lowe (2006) reported that streams with more riparian vegetation or forest density have the tendency to host higher abundance of aquatic life. The impoundment of the river directly affected stream ecosystems and communities through alteration of hydrological regimes and water quality, and acted as barrier to the movement of fish towards upstream and thus influence and change the fish assemblages and compositions. The effects of land use changes and forest conversion on fish assemblages in inundated area of the Pleiran and Danum rivers are of great concern. Penczak (2004) reported changes in fish assemblages are often associated with stream habitat characteristics. The habitat characteristics, on the other hand, are affected by the land use in the adjacent river or within the catchment. Although the impacts of impoundments on land use changes in the watershed that influences fish assemblages has received detailed investigation in the other region of the world and West Malaysia, the information on the effects of dam impoundments and land use changes...
on the fish fauna community and river ecosystem, in Sarawak, are relatively scarce and not well documented. Therefore, this study was conducted to investigate the relationships of land use, riparian vegetation and habitat changes in the respective areas on fish assemblages.

MATERIALS AND METHODS

Study sites
The study was conducted in inundated areas of two important tributaries of Murum River: the Pleiran River and Danum River. Both tributaries with their respective lower catchments substantially inundated by the Murum reservoir. A total of eight stations were selected for fish fauna sampling, land use and habitat survey and plant inventory. Figure 1 showed location of sampling stations in Murum Reservoir. Four stations were selected at the inundated area of Pleiran River and Danum River, respectively. The samplings of fish, water quality and land use survey were conducted 6 times from May 2014 to Dec 2015.

Water quality
Water temperature (Temp), pH, conductivity (Cond), dissolved oxygen (DO) and turbidity (Turb) were measured in-situ using a portable YSI Multiparameter Water Quality Sonde 6820 V2. While, for ex-situ parameters such as total suspended solids (TSS), five-day biochemical oxygen demand (BOD₅) and chlorophyll-a (Chl-a), water samples were collected in triplicates at subsurface level and brought back to laboratory for further analysis.

Assessment of type and intensity of land use
Land use types in the catchments were categorised into six types. This categorization was based on prevailing vegetation cover types observed for the whole of Murum catchment with the aid of existing vegetation maps, aerial photographs, satellite images and ground inspection. These categories include water body (WB), open areas (OA), bare land (BL), flooded and dying vegetation (FDV), regenerated vegetation (RV), forested areas (FA) and plantation area (PA). The intensity of the land use was quantified twice: during early stage of impoundment in 2014 and after full impoundment in 2015. Beginning of the study, existing land uses in Pleiran catchment were mainly oil palm, logging and forest plantation. In comparison, land use in Danum catchment was relatively lesser than in Pleiran catchment, coming to the end of logging activities. The size variation between bare land, open area, plantation area, flooded and dying vegetation and regenerated vegetation were significant at Pleiran area during 2014 study period (26915.8 ha, 11407.3 ha, 40788.0 ha, 320.9 ha and 11726.4 ha respectively) and 2015 period (34873.9 ha, 14128.4 ha, 40788.0 ha, 112.7 ha and 942.0 ha, respectively). For each major forest type, plot inventories were carried out for two main reasons; to confirm the validity of published secondary data for the relevant parameters, and to supplement existing secondary data or information for the specific forest type in question. The plot inventories were carried out in the primary forests, young and old secondary forests and subsistence farm lands of the local native communities.

Fig. 1. Location of fish, land use and plant inventory sampling stations.
Fish sampling and identification
Fish fauna sampling was conducted by using four methods, three-layered net (with mesh sizes 2.5, 7.6 and 12.7 cm), monofilament gill net (with mesh sizes 2.5, 5.0, 7.6, 10.2, 12.7, 15.2 and 17.8 cm), cast net (mesh size 2.5 cm) and electroshocking technique. Fishing nets were deployed at both upstream of Pleiran River and Danum River. Three-layered net and monofilament gill nets were deployed and left in the water for a period of 48 hours. Equal catch per unit effort was employed at every sampling station. Fish were identified in-situ. Fish identification was made down to the species level using keys available in Inger and Chin (2002) and Kottelat et al. (1993). FishBase (Froese & Pauly, 2017) was used to verify of taxonomic status of the species.

Data analysis
Land use data sets were further treated to explore the significant difference in land use types among sampling area within the catchment and during 2014 and 2015 periods. Data were standardized and transformed using arcsine-square root. Then, Multi-Response Permutation Procedure (MRPP) was used to test significant differences in land use types and riparian/habitat characteristics within the catchments between sampling areas and years (2014 and 2015). The test was conducted with Sorenson’s distance (Bray-Curtis), weighting factor and made pairwise comparisons. Principal Component Analysis (PCA) was carried out on correlation matrix data to determine the distribution of fish assemblages in response to the environmental variables and to determine parameters that are indicative for each sampling station at $p < 0.05$. The analysis was tested for significance with 1000 permutation procedure. Later, Canonical Correspondence Analysis (CCA) was used to determine relationships between environmental variables and variation in the fish assemblage structure. Data were standardised using Hill’s Method (Hill, 1979). Randomization test with 1000 number of runs were employed. MRPP, PCA, and CCA analyses were performed using PC–ORD 5.10 for windows (McCune & Mefford, 2006).

RESULTS AND DISCUSSION
The MRPP results indicated that there were significant differences ($A = 0.170, p = 0.000$) in land use types and riparian/habitat characteristics, among sampling areas and both years (2014 and 2015). Land use cover of Pleiran and Danum areas in 2014 and 2015 were shown in Figure 2.

A total of 5,367 individuals of fish from 36 species belonging to 8 families were recorded from inundated area of Pleiran River and Danum River. Cyprinidae was the dominant family (62.1%) in the study as it had the highest number of species (23) recorded. The most dominant species from family Cyprinidae was Barbodes binotatus, which were made up of 23.8% (1,277 individuals) of the total individuals caught. The dominance of Cyprinidae was also reported in other reservoirs in Malaysia such as Pedu Reservoir, Kedah (Isa et al., 2012), Temenggor, Bersia and Chenderoh reservoirs in Perak (Kah-Wai & Ali, 2001; Hamid et al., 2012), Kenyir reservoir, Terengganu (Kamaruddin et al., 2011), and Subang reservoir, Selangor (Yap, 1992). In contrast, Oreochromis niloticus from family Cichlidae was the most dominant species recorded in Murum reservoir with a total of 1954 individuals (36.4%) caught.

In inundated area of Pleiran River, a total of 2,694 individuals comprising of 31 species belonging to 7 families were caught and recorded. About 71.8% of the total catch was represented by Cyprinidae, while 26.6% was represented by Cichlidae. Cyprinidae was represented by 20 fish species and the most dominant fish species was B. binotatus (38.8%). The Cichlidae was represented by only one species, O. niloticus (716 individuals). In comparison, the inundated area of Danum River has a total of 2,673 of fish individuals representing 23 species belonging to 6 families. Similarly, Cyprinidae was the dominant family with 23 species recorded in this area. The most dominant species from this family was Osteochilus vittatus (18.8% of all individuals caught). The most dominant species in the Danum area was O. niloticus from Cichlidae, with 46.3% (1,238) of total number of individuals recorded. The presence of the alien species, O. niloticus is suspected to be the result of
release of the cultured fish from community ponds during reservoir impoundment. In addition, slow flowing of water and the fact that this non-native species has greater adaptation to the environmental conditions were the factors that promote the rapid colonization of this species in the study site (Rodríguez, 2001). The presence of exotic species such as *O. niloticus* can affect native species by altering the food chain, food competition and even the importation of parasites and diseases (Ng et al., 2014). *Barbodes binotatus* was widely distributed in all study areas thus indicating that it was the most common species found in all stations.

From the Principle Components Analysis (PCA), the prominent types of land use were best explained by PCA1 and PCA2 at significant level of *p* < 0.01. PCA1 and PCA2 have the total variance of 78.4%, which associated with two major gradients (Figure 3). The first gradient is associated with plantation area, open area, bare land, forested land and regenerated vegetation, whereas the second gradient comprises the bank erosion, verge vegetation, canopy cover, bank vegetation and flooded and dying vegetation. Catchment in Pleiran is associated mainly with the second gradient, whereas Danum catchment has both types of land use.

Results also showed that bare land and open area were created extensively between 2014 and 2015. The size of forested area that were cleared increased and were seen to be mainly located in the Pleiran catchment. This catchment was found to be a prime site for anthropogenic activities which include oil palm plantation, logging and forest plantation. The long arrows (Figure 3) indicates that land use coverage is best described by bigger size of open areas in 2015. For riparian habitat characteristics, the percentage cover of bank vegetation, verge vegetation and forest canopy cover were observed higher at inundated area of both Pleiran River and Danum River for 2015 compared to in 2014. In terms of bank characteristic in the inundated area of Pleiran River, there were significant active erosions observed with sizable areas of bare banks. Overall, PCA ordination showed that the Pleiran catchment was congregated on the right of the diagram. The catchment was clearly defined by high coverage of open area and most part of it were within the plantation area. Besides, the banks of the reservoir, streams and river valley were mainly occupied with flooded and dying vegetation. The size of the Pleiran catchment (107,581.58 ha) was also bigger as compared to the Danum catchment (17,584.48 ha). Danum catchment was separated at the upper part of the diagram being the result characterised by high coverage of bare land and forested area.

PCA of water quality also yielded 2 axes with eigenvalues greater than 1, explaining 72.7% of the
The effects of land use on fish assemblages in inundated areas were studied. Figure 3 shows a biplot of PCA on types of land use and riparian structure variables relative to studied areas and periods. OA - open areas, BL - bare land, FDV - flooded and dying vegetation, RV - regenerated vegetation, FA - forested areas, PA - plantation area, BE - bank erosion, VV - verge vegetation, CC - canopy cover, and BV - bank vegetation.

PC1 explained 40.5% of total variance mainly characterized with Turb and TSS. Inundated area of Pleiran River with high Turb and TSS were separated to the top right of the diagram, likely associated with high coverage of open area and oil palm plantation in the upstream. The diagram also showed increased of Turb and TSS in the area in 2015. PCA2 (32.2%) shows the variation of Chl-\(a\) and Trans. The long arrows indicated that inundated area of Danum River is best described by high Chl-\(a\).

Increased in human activities increased the rate of loss of vegetation cover. A study done by Ollero (2007) also reported similar scenario in Iberian Peninsula. Forest depletion and encroachment on the Pleiran banks led to severe erosion as reflected in the high turbidity of the water and often leading to decrease in population of aquatic organisms. Our study showed that the riparian vegetation cover in the Pleiran River decreased from 80% in 2014 to 53.8% in 2015. The high percentage coverage of open areas and bare lands in the Pleiran River also contributed to low level of riparian vegetation, canopy cover and habitat suitability. The effects of land use changes on canopy cover in the riparian vegetation is greater in human-altered catchments (Cooper et al., 2013). In other hands, it also leads to high tendency of banks erosion or soil runoff. Allan (2004) added agricultural land use deteriorates rivers through nonpoint sources of pollutants thus affecting riparian and stream habitat characteristics which caused poor habitat quality, reflected in declines in habitat indices and bank stability (Wang et al., 1997). The increase in size of the open and bare land areas are indication of habitat degradation that potentially affect the adjacent bodies.

CCA results showed that fish assemblages were influenced by Temp, TSS, Chl-a, and DO (Figure 5). The species – environmental correlation coefficients were: 0.822, 0.781 and 0.757 for the first, second, and third axes, respectively. The high correlation coefficient suggests a strong relationship among the fish abundance and the environmental variables. Monte Carlo tests were significant (\(p < 0.001\)) for all axes. Only 21.00% of variation in the species data were accounted for by the water quality data measured. CCA1 is clearly reflected the distribution of sites along the pollutant gradient. TSS had the strongest correlations with axis 1, and Chl-\(a\) was also correlated with this axis. High loading of fish species at TSS and Chl-\(a\) showed that these two variables affected them the most.
Fig. 4. Biplot of PCA on water quality parameters relative to studied areas and periods.

Fig. 5. Biplot of CCA in determining water quality parameters that influences fish assemblages.
Most fish species recorded could not tolerate high TSS in inundated area of Pleiran River. While, \textit{O. niloticus} and \textit{O. vittatus} mainly recorded in inundated of Danum River with high Chl-a. This probably related to the high primary productivity due to deeper light penetration, thus resulting in high \textit{O. niloticus} and \textit{O. vittatus} density as both are herbivorous. Besides, temperature also loaded on CCA1. Figure 5 showed that most fish intolerant at area with warmer water thus suggesting that riparian vegetation plays important role in providing shades and shelter for fish in the water. Dense riparian cover along the bank could increase canopy cover in the water which at the same time able to minimize penetration of direct sunlight into the water and become colder. CCA2 was loaded with DO. This also showed that fish species tolerable in areas of higher dissolved oxygen. As a result, area with lower DO tend to have less diversity and subsequently altered the assemblages of fish community. Similar findings were reported by Egbe Reservoir (Edward & Ugwumba, 2013) and Assam Lake (Kar \textit{et al.}, 2006). \textit{Tor douronensis} was recorded in area with sufficient DO. It is known that \textit{T. douronensis} is an intolerant species. Even little exploitation in their habitat could hinder their distribution in the ecosystem. Ideally, optimum DO level for fish is > 5.0 mg/L (Bevelhimer & Coutant, 2006). The results imply that conversion of forested area at riparian corridor to open area has lead to changes in physicochemical characteristics, and subsequently might resulted in habitat partitioning by the fish species according to their environmental tolerance limit.

**CONCLUSION**

This study proved that land use in the catchment areas of Pleiran and Danum has significant contribution to water quality deterioration of the newly impoundment Murum reservoir. Deterioration of the water quality affected fish assemblages, whereby they seem to display habitat partitioning according to their environmental tolerance limit. While threat of anthropogenic activities on fish communities in Murum reservoir is concerned, the bloom of population of \textit{Oreochromis niloticus}, an introduced species in the reservoir should be monitored.

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