ECOLOGICAL FACTORS AFFECTING FISH DIVERSITY AND DENSITY IN SUNGKAI WILDLIFE RESERVE, PERAK, MALAYSIA

AHMAD, A.K.,[1]* MOHD SHAM, O.,[2] SHUKOR, M.N.[1] AWENG, EH-R.[3] and **SHUHAIMI-OTHMAN, O.[1]**

[1]School of Environmental and Natural Resources Sciences, Faculty of Science and Technology, The National University of Malaysia, 43600 UKM, Bangi, Selangor, Malaysia

[2]Environmental Health Unit, Faculty of Allied Health Sciences, Universiti Kebangsaan, Malaysia

[3]Universiti Malaysia, Kelantan

*Corresponding author: *abas@ukm.my*

Abstract

The objective of this study was to determine the relationship between various stream (or Sungai) ecological factors as regards to fish population density. Stream ecological factors such as substrate type, stream order, habitat type and disturbance status were investigated to estimate their influence on fish presence and density. Fishes were sampled using electrofishing method (Electrofisher Model 15-D Honda EX 350 engine). Results showed that substrate type, stream type and disturbance have significant influence on fish density. On the other hand, habitat type did not significantly affect fish density. Highest fish density was recorded at the stream segment with sand/gravel substrate (21.47 individuals/m^3) while segments with sand/silt substrate showed the lowest fish density (2.63 individuals/m^3). First order stream had the highest fish density (22.53 individuals/m^3) followed by second order stream (5.86 individual / m^3) and third order stream (0.88 individual/m^3). Undisturbed streams also showed a significantly high fish density (12.17 individual/m^3) as compared to disturbed streams. This study showed that fish density in Sungkai Wildlife Reserve area was very dependent on ecosystem characteristics.

Keywords: fish density, substrate type, habitat type, stream order, ecological factors.

Accepted: October 31, 2011.

Introduction

Habitat features, either biotic or abiotic components, have been identified as the major determinants in distribution and abundance of fishes from earlier times (Arunachalam, 2000). Fish species in an assemblage are separated or partitioned on the basis of the availability of the various macrohabitat and microhabitat features and also of food sources. Niche apportionment by the various species of fish is possible as long as these habitats and resources are available. Inversely, fish assemblages can also be used as indicator of habitat degradation. Loss of or changes in fish assemblages may quantify disturbances that have occurred in the ecosystem.

Interestingly, Moyle and Cech (1982) stated that within tropical stream system, physical and chemical factors often play less important role in determining fish distribution and abundance when compared to biological factors. This is because the tropical area is generally stable either climatically or productivity-wise. With fairly regular temperature and rainfall, climatic stability results in less fluctuation in the physical environmental factors. In addition, continual food production and geological stability also contribute to the overall stability of the environment. However, there are some abiotic factors that may influence ichthyofaunal composition in a tropical freshwater ecosystem, at least in a subtle way. Physical factors that influence fish distribution and abundance include water level fluctuation, water velocity, gradient, stream order, bottom substrate and turbidity, while the chemical factors include dissolved oxygen, pH and dissolved nutrients.

Water level fluctuation plays an important role to many tropical fishes. In many cases, high water level is often associated with abundance food, hence becoming the cue for these fishes for reproduction and growth. Apart from extra food resources, flooding of the terrestrial

© *The Zoologist, 9:*78-84 (2011), ISSN 1596 972X.
Zoological Society of Nigeria.

ecosystem also provides extra microhabitats for the fish. Tree trunk and bushes, initially not submerged, become inundated during the flooding season thus provide more nooks and crooks that can be utilized by many fishes as their temporary habitats. Therefore due to the expanded habitat and food resources, many fish reproduce during rainy season or during high water level.

Gradient, stream order, water flow and substrate characteristics also play a pivotal role in determining the type of fish present in an area. Wikramanayake and Moyle (1989) stated that fish species are segregated on the basis of their positioning in the water column, relative to both velocity and vertical position and in a few species, an affinity to particular substratum types. Stream with higher gradient and lower stream order is characterized by strong water current, loose sandy or gravel bottom substrate hence the absence of aquatic weed. This results in fewer available niches to be exploited by fish (Ahyaudin *et al*, 1988), therefore limits the type of fish that can survive. Ahyaudin *et al* (1988) stated that fish living in hilly streams usually has a streamlined body with optimal hydrodynamic efficiency such as kelah (*Tor tambroides)* and the many other streamlined cyprinids in Africa and Asia, or with specialized body form such as fish from the family Homalopteridae (Arunachalam, 2000) in Asia and the many specialized catfishes in South America.

Chemical changes in water quality in stream and river systems also alter interspecific competition and predation among fish communities, which are regarded as important determinant of fish distribution in streams (Gillian *et al,* 1993). Often in polluted streams, there are fewer fish species, mostly tolerant to low oxygen concentration. Hence, interspecificity may yield less pressure when compared to communities with larger number of species. With reduced competition, tolerant fishes may flourish while others, which need environment with good water quality, may not survive, and eventually face local extinction.

Although Eklov *et al (*1998) reported that only dissolved oxygen content and total phosphorous concentration were responsible for ichthyofaunal community changes in stream in Sweden, the effects of other chemical parameters should not be overlooked. Indirectly, other chemical factors such as pH and dissolved nutrients would influence dissolved oxygen level. An increase in nutrient level and the concentration of chemical compounds with high chemical oxygen demand (COD) will use up the oxygen in the stream system, hence reducing the dissolved oxygen content. Nutrient input, as stated by Abrams (1993) is a pervasive element of human effects on the natural environment, often unintentionally in the aquatic ecosystem especially through by-products of fertilizer runoffs and atmospheric pollution. Abrams (1993) also stated that an increase in nutrient level in an ecosystem might also contribute to a possible decrease in the abundances of all trophic levels when there are more than two species per level. Therefore we can say that any unnatural changes in the chemical content of the stream and rivers, with subsequent unnatural changes in nutrient level and water quality will undoubtedly change the community structure of ichthyofauna in the ecosystem.

Biotic interactions within the stream and river ecosystems also play a profound role in shaping the ichthyofaunal community. In the tropical area, the physical environmental factors, food production and geological state are very stable, if not only with minimal fluctuations. Due to this, Moyle and Cech (1982) concluded that the evolutionary results of interspecific interactions especially predator-prey mechanism and competition are often expressed as extraordinary morphological and behavioural specialization. This may eventually lead to high degree of speciation especially within the Cyprinids species, which also contributes to the high endemism in Southeast Asia. Rainboth (1991) stated that approximately about 70 genera of Cyprinids are endemic to Southeast Asia.

According to Harvey and Stewart (1991), predation risk is often an important factor in habitat selection by animals, and for many taxa, more than one kind of predators may be important. In the case of stream fishes, piscivorous fishes and other predatory vertebrates that wade or dive into the stream may be important predators. This is further confirmed by Grossman and Freeman (1987) who stated that predators have been shown to effect distribution of stream fishes especially through avoidance. Any structural refuges in the form of the various hiding places may help preys avoid predators. However, the predator-prey relationships in tropical freshwater ecosystem are fairly stable. The complexity of the tropical ichthyofaunal communities in this area has led to remarkable specialization. This profound adaptation that represents co-evolution between predator and prey in this region is reflected in the high diversity of fish (Moyle and Cech, 1982).

Competitive interactions also shape the community structure in stream ecosystem in the tropical areas. Wikramayanake and Moyle (1989) stated that the pronounced resource partitioning and complementarities suggest that assemblages have co-evolved to reduce interspecific competition. Feeding specialization and habitat preferences by many tropical freshwater fishes are designed to reduce competition from other fishes. For instance, the fish from the family Homalopteridae has become specialized to live in fast-flowing water at the riffles area (Moyle and Cech, 1982), which is not occupied by many other species, hence reduce the competition they have to face. In order to survive in this demanding area, Homalopterids have developed suckers to anchor on boulders in order to avoid being carried away by the fast and turbulent water flow. In lieu to this, these fishes also feed on the abundant algae living on rocks and boulders in the riffles that are not utilized by many other fishes.

The illustrations above show examples of a remarkable segregation either through choice of food resources and feeding mechanisms or through habitat preferences, which result from evolutionary processes to reduce niche overlap, thus reduce the pressure from competition. In many cases, these factors along with the spatial and temporal segregation do promote coexistence in fish assemblages (Grossman and Freeman, 1987). This study was conducted to determine and ascertain the ecological factors relationship with fish presence and density.

Material and methods

Study-sites

Sungkai Wildlife Reserve is located approximately 96 kilometers north of Kuala Lumpur. According to PERHILITAN (2000), this wildlife reserve was established in 1928 with the original total area of 1,805 ha. In 1940, the area has expanded up to 2,468 ha. The establishment of this reserve was based of five main objectives:

(i) to breed native species in an organized and systematic fashion in order to make sure that they do not face extinction,

(ii) to provide various scientific researches especially to increase efficiency in wildlife management and to yield greater reproductive success,

(iii) to act as an educational center for every level of society, thus helping install greater public awareness regarding conservation efforts in Perak and also in Malaysia,

(iv) to act as a recreational areas for locals and

(v) for tourist attraction. Within the study location, six streams (labeled as Sg. In this paper) of different orders or degree of disturbance were chosen as sampling sites. Each stream were further assigned 5 sampling stations, hence 30 stations were studied in the area (Figure 1).

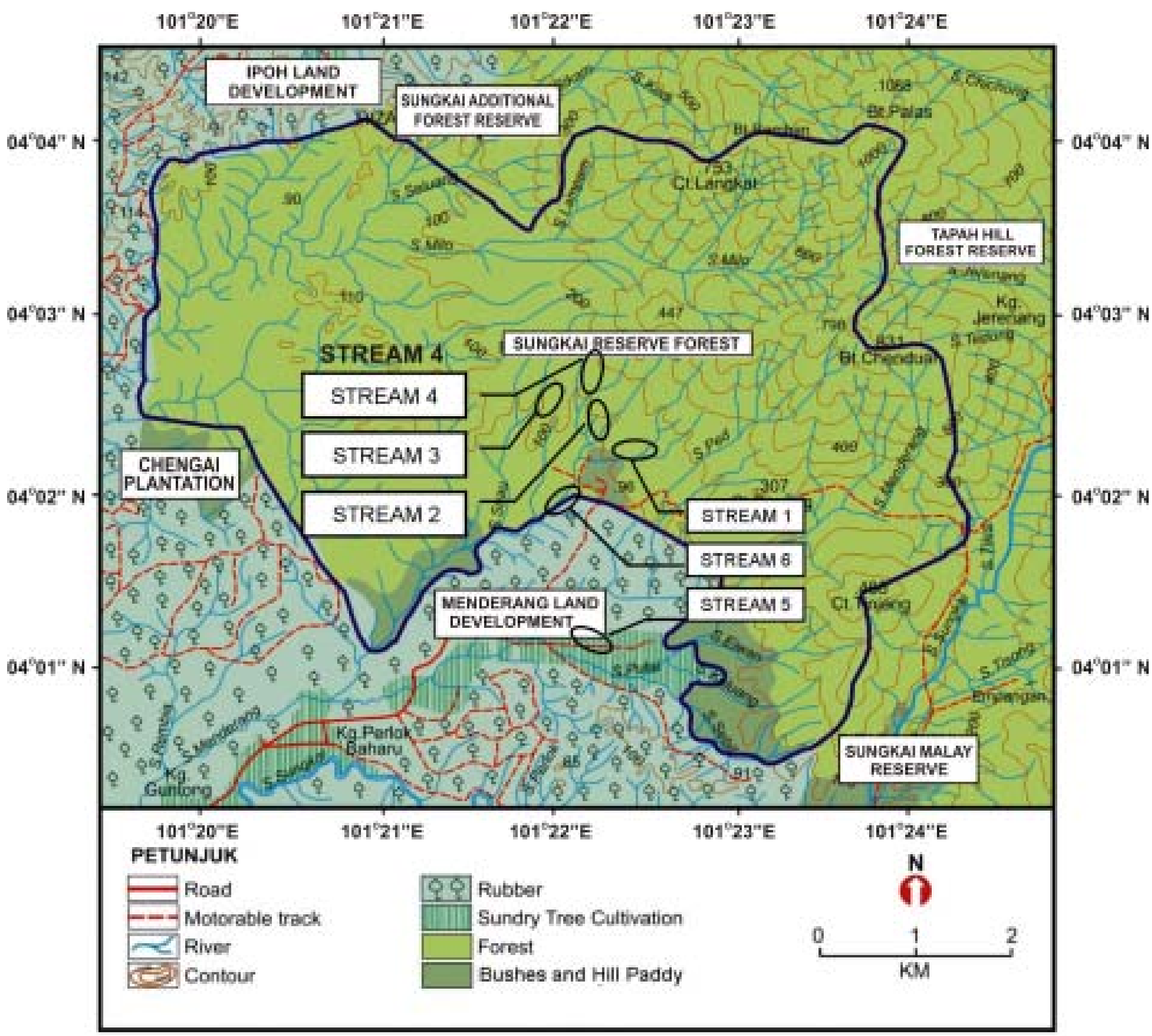

Figure 1: The location of study sites within the Sungkai Wildlife Reserve, Perak, Malaysia.

Stream 1 is a 2nd order stream and is considered as disturbed stream since it meanders through a deer paddock built for the *ex-situ* conservation effort for the sambar deer. This includes for Stations 1, 2, 3, 4 and 5. Five stations in Stream 2 (Sg. Ulu Bikam) consists of disturbed and undisturbed stations. Station 1 of Sg. Ulu Bikam may be considered pristine since located upstream from the any human activities. However since the fish from this station can move freely in and out of the other four stations, especially Station 2, it is expected that the result reperted for this area will resemble the other stations within this stream. Station 2 is considered as disturbed because it is located next to a recreation area (camping and picnic activities). Stations 4 and 5 are disturbed sites because they are located in another deer paddock. Though Station 3 is located upstream of Stations 4 and 5, it was also considered disturbed since it receives water from Station 2.

Stream 3 (Sg. Milo), is a second order stream, and considered as undisturbed because it is not subjected to any major physical changes. Though the stream flows near the gaur (*Bos gaurus*) paddock, it does not cut through the paddock. Therefore it is assumed that no exogenic influences were exerted into this stream. It is also assumed that this stream is also in its natural state. Stream 4 is a second order stream which receives water from two sources. Two stations; 1 and 2 are located at one tributary and 3 and 4 at another tributary. Station 5 is located at the fork that joins both tributaries. All five stations are considered undisturbed because no exogenic influences are detected in this area.

Stream 5 or Sg. Ulu Menderang is located outside the core area of the reserve but still in the vicinity of its buffer zone. This is a highly disturbed area as compared to the other streams because it is located within a traditional village of Kampung Ulu Menderang and expected to be subjected to major effects from human activities. It must also be noted that Sg. Ulu Menderang is a third order stream in which its tributaries are the second order streams from the core area of the reserve.

Stream 6 or Sg. Suar is also located outside the core area, but still within the vicinity of the reserve. It receives water from two streams. Sg. Suar is located near the rubber plantation, which is interspersed with forest. Therefore it is also considered as disturbed even though its degree of disturbance is far less than Sg. Ulu Menderang. Like Sg. Ulu Menderang, Sg. Suar is also a third order stream.

Sampling methods

After determining the sampling sites, the upper and lower ends of the station were blocked with 1 cm mesh stop nets. Fish sampling was done by electrofishing the stream with Electrofisher Model 15-D using Honda EX 350 engine. Higher voltage was used for clear streams while lower voltage was used for the more turbid ones. Sampling was only conducted using electroshocker since casting is very impractical due to the shallow nature of the stream while scoop nets otherwise would be biased because only the visible fish would be captured. Sampling was done randomly at each sampling site and approximately at similar sampling periods and effort. In order to reduce sampling bias, electrofishing was conducted only by similar operator. Due to the impracticality of on-site identification and measurement, all fish were taken to the laboratory for identification. Identification was done using Inger and Chin (1962), Mills (1993), Mohammad Mohsin and Mohd Azmi (1992) and Millidge (1998). Apart from sampling and identification, various ecological factors within the sampling sites were recorded. These include shade range, habitat type (riffles and pools), bottom substrate (sand/silt, sand, sand/gravel), stream order (tributary, stream, small river), disturbance (disturbed and undisturbed) and river water volume.

Result

Fish diversity was found to be vary between each sampling site (Table 1). The one-way ANOVA test demonstrates that fish density was significantly differ between and within streams (< 0.05, df = 29)(Table 2). Fish density ranged from 0.3 individual / m^3 (Station 3 of Stream 5) to 55 individual/m^3 (Station 3 of Stream 4). As regards to mean density, stream 4 (Sg. Ulu Menderang) has the highest fish density with the mean value of 21.5 individual/m^3 while Stream 5 (Sg. Menderang) has the lowest fish density with the value of 0.6 individual/m^3. One-way ANOVA test indicates that fish density was found to be significantly affected by level of disturbance (p<0.05, df = 29), substrate types (p<0.031, df = 29) and stream types (p<0.0001, df = 29). Undisturbed streams had the mean density of 12.2 individual/m^3 while disturbed streams had the mean density as low as 4.1 individual/m^3.

Based on substrate type characteristics, streams with sand-gravel substrate had the highest mean density (21.5 individual/m^3) followed by sand-substrate stream (5.6 individual/m^3) and streams with mixture of silt and sand substrate (2.63 individual/m^3). Stream types (size) also demonstrate a significant difference in term of fish density. Tributaries support higher fish density than larger streams. Mean fish density recorded in tributaries was 21.5 individual/$m^{3,}$ whereas streams and small rivers had 5.86 individual/m^3 and 0.88 individual/m^3 respectively.

Table 1: Checklist of fish caught from five sampling sites.

Family	Genus/species	No. of individual	Stream
Cyprinidae	*Rasbora sumatrana*	*322*	1,2,3,4,5
	Rasbora cephalotaenia	*4*	1,2,3,4
	Hampala macrolepidota	*3*	1,2,3
	Puntius lateristriga	*121*	1,2,3,4,5
	Puntius binotatus	*228*	1,2,3,4
	Accrosocheilus hexagonolopis	*5*	1
	Osteochilus vittatus	*1*	1,3,4,5
	Osteochilus hasseltii	*33*	1,2,3,4
	Labiobarbus lineatus	*58*	1,2,3,4,5
	Tylognathus caudimaculatus	*3*	2
	Epalzeorynchus siamensis	*6*	1,3,4
Homalopteridae	*Homaloptera orthogoniata*	*15*	2,3,4
Cobitidae	*Acantopsis choirorhyncus*	*111*	1,2,3,4
	Botia hymenophysa	*5*	1,2
Akysidae	*Acanthopsis inchsoma*	*2*	4
Bagridae	*Leiocassis leiachantus*	*1*	3
	Mystus nemurus	*13*	1,2,3,4
	Mystus baramensis	*2*	3
Claridae	*Clarias batrachus*	*1*	4
	Propaghorus nieuhofii	*22*	1,2,4
Siluridae	*Silurichthys haseltii*	*11*	1,3,4
Hemiramphidae	*Hemiramphodon pogognathus*	*117*	1,2,3,4,5
Channidae	*Channa striatus*	*28*	1,2,4,5
	Channa lucius	*24*	2,3,4
	Channa micropeltes	*23*	2,3,5
Anabantidae	*Betta pugnax*	*35*	1,2,4
Synbranchidae	*Monopterus albus*	*3*	1,2
Mastacembelidae	*Mastacembalus maculates*	*11*	1,2,3,4

Habitat type (riffles, riffle/pool or pools) however did not show significant differences in term of fish density (one way ANOVA, $p = 0.327$, $df = 29$). Riffles had the density of 6.02 individual/m^3, the combination of riffles and pools had 15.37 individual/m^3 and pools had 1.48 individual/m^3. Though values recorded were notably different, it was still considered insignificant because of large standard deviation.

Discussion

Although, catch index has been popularly used to determine abundance, a more accurate measurement of abundance would have to be the density because it takes into consideration the magnitude of the area studied (Mohd Sham 2000), Since the stream system is a three dimensional system with length, width and depth, the more appropriate spatial measurement would be water volume rather than area. In this study, fish density is defined as the number of individual fish in each cubic meter of water. When we deal with fish density in the six studied-streams in Sungkai Wildlife Reserve, Stream 4 showed the highest fish density while Stream 5 showed the lowest via stream-by-stream analysis. Stream 4 is an undisturbed stream while Stream 5, as previously mentioned, received human activities impacts. The effect of disturbance on the stream may have been responsible for the diminishing fish density in the stream. This is further confirmed when fish density is compared between disturbed and undisturbed streams. Disturbed streams have a lower mean density as compared to the mean fish density of undisturbed streams. Generally, we can assume that disturbed streams have lower fish density than undisturbed streams. In Stream 5, disturbance may have resulted from polluting sources like herbicides, wastes and land clearance. Nickolsky (1969) suggested that water pollution by various substances might have serious adverse effects on fish especially in the destruction of fish reproduction and the disruption of the fish's metabolic activities. In many cases, pollution may also affect other organisms in the ecosystem, which are food sources for fish. Plankton and invertebrates are main food sources for fish, and they are more sensitive than fish due to low mobility. A serious disturbance could demolish their population and affects fish populations. Therefore the lack of food sources will eventually limit the number of fish surviving in streams.

Although this study found habitat types not influence fish density, it also plays an important role in determining fish density of each stream. Generally, result indicates that streams characterized by the mixture of sand and silt substrates had the lowest fish density while streams with the mixture of sand and gravel substrates had the highest fish density. Silt is a fine particle, which normally will precipitate to the bottom to form surface sediments. If there is an increase in velocity or disturbances in the ecosystem, for example due to bio-turbation, the particle will be retained in water body, making the water less clear hence increase turbidity and also increase the concentration of suspended solids. This is not a conducive environment for many fishes because it may clog to the fish's gill and impede respiration. Apart from that, silty water may also hamper navigation and food-finding especially for fishes that rely on vision for such purposes. Excessive precipitation also could affect benthic macro-invertebrates especially at pristine ecosystem. Benthos in pristine ecosystem normally is filter feeders and could not survive at high suspended concentrations.

A stream with the mixture of sand and gravel substrate form a more stable environment for fish. Furthermore the presence of gravel and small boulder would add to the amount of micro-habitats present in the stream by means of providing more nooks and crooks. This may actually provide more microhabitats for fish to specialize and live in, thus consequently enhance fish density in streams. In addition, the presence of gravels also provides micro-habitats that allow some algae and macro-fauna to flourish. The algae may coat the gravel and boulder surfaces while macro-faunas such as the larvae of caddisfly and many aquatic insects may live within it. These organisms eventually provide an additional food sources for many fish species especially the planktivorous and ichthyofauna. The more the micro-habitats provided by the gravels, the more plankton and meio-faunas could grow hence the more food source for fish in the stream.

Another physical factor that is shown to have a significant impact on fish density is the type of the stream itself. Tributaries recorded the highest fish density while small rivers had the least fish density. The result demonstrates that the larger the stream, the lower the fish density. Tributaries often have a higher number of micro-habitats formed by the presence of riffles and pools sections. Larger streams, and in this case, the small rivers of Sungai Ulu Menderang and Sungai Suar do not pocess this unique feature. Furthermore, in small streams, most of the fish are concentrated near the banks, which often provide better shade and refuge for fish. Allochtonous

Table 2: The summary of mean fish density according to various ecological parameters.

Parameter		Mean density (individual/m^3)	Significance value
Stream	1	9.702	
	2	5.063	
	3	2.803	$p = 0.05$
	4	21.533	
	5	0.580	
	6	1.178	
Disturbance	disturbed	4.13	
	undisturbed	12.17	$p = 0.05$
Habitat Type	riffles	6.02	
	riffles /pools	15.37	$p > 0.05$
	pools	1.48	
Substrate Type	sand /silt	2.63	
	sand	5.63	$p = 0.031$
	sand gravel	21.47	
Stream Type (Order)	Tributary (first order)	21.53	
	Stream (second order)	5.86	$p = 0.0001$
	small river (third order)	0.88	

food sources would often enter the stream system from the terrestrial ecosystem via the banks and also the hyporheic zone, which form the transition between the aquatic and terrestrial ecosystems. The middle part of the river is often not really occupied due to lack of shade or even lack of food. Furthermore, the middle part of the small river does not offer refuge for the fish to elude their predators. There, the fish can be easily seen by terrestrial, aquatic or even flying predators. Hence, a large portion of the small river is not fully utilized by many organisms, including fish. This explains why small rivers have less number of individuals per cubic meter of water as compared to streams and tributaries.

The study indicates that fish population within the study-area is easily affected by various factors such as habitat types, stream orders and level of disturbance. Fish population exhibits lower composition at the disturbed streams but more abundant at pristine streams. For pristine streams, habitat characteristics play major role in determining fish composition. This explains the importance of ecological factors in determining fish population and cannot be ignored during the fish study.

Acknowledgements

We would like to thank Dr. Abdullah Samat, Mr. Ak Jalaludin Pg Besar and Mr. Yusuf Ahmad for their assistance in this project. We would also like to acknowledge the assistance rendered by The Director of Research and Conservation, The Department of Wildlife and Parks (DWNP) Peninsula Malaysia along with the management and staffs of Sungkai Wildlife Reserve. Finally we would also like to thank the Director General of DWNP for the permission given to us to conduct this research.

References

Abrams, P.A. 1993. Effects of Increased Productivity in the Abundance of Trophic Levels. *The American Naturalist 141(3):* 351-371.

Ahyaudin, A., K. Mohd Sadik, M. Mashhor and M.B. Mohd Hifni. 1988. Fish Population Distribution in the Perak River: A Comparative Study. Paper presented at Proceedings of 11th Annual Seminar of the Malaysian Society of Marine Sciences.

Arunachalam, M. 2000. Assemblage Structure of Stream Fishes in The Western Ghats (India). *Hydrobiologia 430 (1-3):*1-31.

Eklov, A.G., Greenberg, L.A., Bronmark, C., Larsson, P. and Berglund, O. 1998. Response of Stream Fish to Improved Water Quality : A Comparison between the 1960s and 1990s. *Freshwater Biology 40 (4):* 771-782.

Gillian, J.F., Fraser, D.F. and Alkins-Koo, M. 1993. Structure of a Tropical Stream Fish Community: A Role for Biotic Interactions. *Ecology 74 (6):*1856-1870.

Grossman, G.D. and Freeman, M.C. 1987. Microhabitat Use in Stream Fish Assemblage. *J. Zool. London 212(1):*151-176.

Harvey, B.C. and Stewart, A.J. 1991. Fish Size and Habitat Depth Relationships in Headwater Streams. *Oecologia 87:* 336-342.

Inger, R.F. and Chin, P.K. 1962. *The Freshwater Fishes of North Borneo Fieldiana*: Zoology 45. Chicago Natural History Museum, Chicago.

Millidge, J. 1998. *Freshwater Aquarium Fish a Pocket Companion*: Kent Publisher, USA.

Mills, D. 1993. *Aquarium Fish*: Dorling Kindersley Handbooks, London.

Mohammad Mohsin, A.K. and Mohd Azmi, A. 1992. *Ikan Air Tawar di Semenanjung Malaysia*: Kuala Lumpur.

Mohd Sham, O. 2000. Ecology *and Diversity of Fish In Selected Streams In Sungkai Wildlife Reserve, Perak*. Dissertation Universiti Kebangsaan Malaysia, Malaysia, 522pp.

Moyle, P.B. and Cech, J.J. 1982. *Fishes: An Introduction to Ichthyology:* New Jersey.

PERHILITAN. 2000. Wildlife Reserves. From http://wildlife.gov.my/ecotour5.htm

Rainboth, W.J. 1991. Cyprinids of South East Asia. In. Winfield I.J. and Nelson J.J. (eds). *Cyprinid Fishes Syatematics, Biology and Exploitation.* Chapman and Hall, London. 112-145.

Wikramanayake, E.D. and Moyle, P.B. 1989. Ecological Structure of Fish Assemblages in Wet-zones Streams of Sri Lanka. *J. Zool. London* 218 (3):503-526.

Ahmad, A.K., Mohd Sham, O., Shukor, M.N. Aweng, EH-R and Shuhaimi-Othman, O.
© *The Zoologist, 9:*78-84 (2011), ISSN 1596 972X.
Zoological Society of Nigeria.