ASSESSMENT OF FISH COMMUNITY DISTRIBUTION AND COMPOSITION IN THE PERAK RIVER IN ORDER TO DETERMINE BIOLOGICAL INDICATORS FOR FRESHWATER HEALTH

MAT ROSLI YEUP ZAINUDIN

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By

MAT ROSLI YEUP ZAINUDIN

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ALT	Altitude
ANOVA	Analysis of variance
APHA	American Public Health Association
AVE	Average
ANZECC	Australian and New Zealand Environmental and Conservation Council
BHI	Biological Health Index
BOD	Biochemical Oxygen Demand
C	Celsius
CDI	Community Degradation Index
Cdt	Conductivity
CIV	Confident Interval
cm	Centimeter
CPUE	Catch per unit effort
Cur	Current
DDW	Deionized Distilled Water
Dep	Depth
DFE	Distance from estuary
DGSM	Department of Geological Survey of Malaysia
DID	Department of Irrigation and Drainage
DNA	Deoxyribonucleic acid
DO	Dissolved Oxygen
DOM	Department of Meteorology
DOE	Department of Environment
DOS	Department of Statistics
E	Evenness, Index of Shannon-Weiner
EDS	Environmental Data Services
EIFAC	European Inland Fisheries
EPA	Environmental Protection Agency
F	F-value of statistic
FAO	Food and Agricultural Organization
GCCCR	Glass Column Cadmium Copper Reduction
GPS	Global positioning system
H	Hour
H'	Shannon-Weiner Index

H_a	Alternative hypothesis
H_o	Null hypothesis
HP	Horse power
IPUPM	Institut Perundingan Universiti Pertanian Malaysia
JCS	Jaccard's Coefficient of Similarity
JICA	Japan International Cooperation Agency
kg	Kilogram
km	Kilometer
L	Light
LC	Lethal concentration
m	Meter
MHWS	Mean high water spring
MLWN	Mean low water neap
MSL	Mean sea level
N	Number of individual
NAUI	National Association of Underwater Instructors
NH_3-N	Ammoniacal Nitrogen
NO_2-N	Nitrite Nitrogen
NO_3-N	Nitrate Nitrogen
nm	Nanometer
p	Probability
PH	PH; Hydrogen ion concentration or activity
PO_4-P	Ortho-Phosphate
ppt	Part per thousand
r	Coefficient of correlation
RCC	River Continuum Concept
RMN	Royal Malaysian Navy
S	Number of species
Sal	Salinity
SCI	Sequential Comparison Index
SCT	Salinity-Conductivity-Temperature
SP	Species
SPSS	Statistic Package of Social Science
SS	Sum square
SSC	Sum square column
SSE	Sum square error
SSR	Sum square row

ST	Station
STDEV	Standard deviation
T	Temperature
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
TW/TC	Total weight per total catch
µS	Micro-Siemens
UKM	Universiti Kebangsaan Malaysia
UM	Universiti Malaya
U. S.	United States
USGAO	United States General Accounting Office
USEPA	United States Environmental Protection Agency
UPM	Universiti Pertanian Malaysia
USM	Universiti Sains Malaysia
UTM	Universiti Teknologi Malaysia
W	Body weight (kilogram: kg)
WCD	World Commission on Environment and Development
WHO	World Health Organization
WQ	Water quality
YSI	Yellow Spring Instrument

ABSTRAK

PENAKSIRAN TABURAN DAN KOMPOSISI KOMUNITI IKAN DI SUNGAI PERAK UNTUK PENENTUAN PENUNJUK-PENUNJUK BIOLOGI KESIHATAN AIR TAWAR

Kajian korelasi antara biodiversiti ikan dan kualiti air telah dijalankan dengan mengambilkira faktor-faktor perbezaan jarak dari muara, altitud, komposisi dasaran dan musiman selama setahun. Sebanyak 7 stesen kajian telah dipilih di sepanjang saliran utama Sungai Perak, merangkumi zon rendah, zon tengah dan zon hulu. Populasi ikan telah disampel menggunakan peralatan perikanan dan kaedah teknikal yang piawai. Alat penangkapan yang digunakan ialah 5 set jaring rentang dengan pelbagai saiz mata-jaring (2.5 cm, 5.0 cm, 7.5 cm, 10.0 cm dan 12.5 cm), 5 set bubu raya dan serawan jala. Kualiti air dan komposisi substrat dasaran dianalisis menggunakan kaedah-kaedah piawai. Sebanyak 4733 spesimen ikan telah dikumpulkan dan dikelaskan kepada 92 spesies, 63 genera, 33 famili dan 12 order. Gerakbalas populasi setiap 92 spesies telah dianalisis pada pelbagai aras pengeluaran ikan, komposisi taksonomi dan trof. Zon rendah mempunyai 11 order (29 famili, 63 species), zon tengah mempunyai 8 order (15 famili, 48 species) dan zon atas mempunyai 6 order (12 famili, 33 species), menunjukkan nisbah 2.86 : 1.67 : 1.00 berdasarkan jumlah spesies, 2.16 : 1.00 : 1.60 berdasarkan jumlah individu dan 3.01 : 1.00 : 3.05 berdasarkan jumlah biojisim, manakala Cyprinidae menunjukkan nisbah 1.05 : 1.44 : 1.00 berdasarkan jumlah spesies dan 1.29 : 1.00 : 1.62 berdasarkan jumlah individu, menunjukkan contoh-contoh adanya perbezaan proses ekologi dalam setiap zon masing-masing. Ini juga ditunjukkan oleh komposisi species yang berbeza, dimana 71% komposisi species adalah berbeza antara zon rendah dan zon tengah, 69% berbeza antara zon rendah dan zon tinggi, manakala antara zon tengah dan zon tinggi adalah 58%, berdasarkan Koefisien Jaccard. Secara keseluruhan, kualiti air adalah semakin merosot di sepanjang pengaliran dari zon atas ke zon rendah, mempengaruhi pertambahan bilangan spesies ke arah zon rendah dan mempengaruhi kriteria biologi seperti di atas. Empat tren populasi telah dikenalpasti, iaitu spesies-spesies yang menghuni dalam satu zon tertentu (65.2%), kepadatan populasi yang sama antara zon-zon (24.0%, $p > 0.05$), populasi yang meningkat ke arah zon atas (9.8%, $p < 0.05$) dan ke arah zon rendah (1.0%, $p < 0.05$). Jumlah spesies, jumlah individu, jumlah biojisim, komposisi taksonomi (order, famili, spesies), dan komposisi aras trof (kumpulan pemakanan, pengguna-pengguna), menunjukkan perbezaan corak perubahan entiti-entiti kefungsian iaitu gerakbalas populasi terhadap perubahan persekitaran seperti kualiti air dan kriteria habitat yang berlaku pada perubahan jarak dari muara, altitud, pencemaran atau gangguan tempatan dan karakteristik di sesuatu tempat. Keseluruhannya, komposisi spesies-spesies terancam adalah merangkumi sehingga 84% spesies-spesies ikan. Sejumlah 41 spesies ikan tawar (63%) menunjukkan ketoleranan terhadap penurunan kualiti air ke arah zon rendah. Secara siknifikan, sejumlah 8 spesies telah dipilih sebagai spesies penunjuk, berdasarkan korelasi dengan 12 parameter kualiti air dikalangan 92 spesies yang dikaji. Gabungan biologi 8 spesies penunjuk menunjukkan keadaan kualiti air yang merosot sebanyak 83.6% di zon rendah dan 62.7% di zon tengah berbanding dengan zon atas yang digunakan sebagai kualiti piawai tempatan dan dikenalpasti sebagai kawasan rujukan penting yang mempunyai produktiviti primer yang tinggi. Zon tengah memain peranan sebagai saluran pengangkutan manakala zon rendah sebagai kawasan yang kaya dengan nutrien. Corak perubahan kriteria biologi telah ditaksir dalam tujuh pendekatan yang dicadangkan untuk penilaian ekosistem sungai dan evolusi habitat dari segi fungsi-fungsi dan entiti-entiti komuniti ikan dan kualiti air. Ini berdasarkan analisis pengelasan komuniti ikan, model-model paparan, contoh-contoh grafik, nisbah-nisbah pada pelbagai aras penaksiran dan peratusan kualiti kawasan-kawasan kajian daripada kawasan rujukan, iaitu kawasan yang tidak tercemar di zon atas.

ABSTRACT

A one-year research had been carried out to study the correlation between fish biodiversity and water quality in terms of the differences in distance from estuary, altitudes, bottom substrates and seasons. Seven study sites were chosen and located in the main channel of the Perak River comprising the lower zone, middle zone and upper zone of the river system. The water quality and bottom substrates were determined by using the standard methods. The fish populations were sampled by using the standard fishing gear and technical methods. Several fishing gear, such as five sets of gill net with various mesh sizes (2.5 cm, 5.0 cm, 7.5 cm, 10.0 cm and 12.5 cm), five sets of hoop net and a cast net were used. A total of 92 species comprising 12 orders, 33 families and 63 genres were identified among a total of 4733 specimens. Response of population for each of the 92 species had been analyzed at the multi level of fish production, taxonomic and trophic compositions. The lower zone has 11 orders (29 families, 63 species) while the middle zone has 8 orders (15 families, 48 species) and the upper zone has 6 orders (12 families, 33 species), showed a ratio of 2.86 : 1.67 : 1.00 in total species, 2.16 : 1.00 : 1.60 in total abundance and 3.01 : 1.00 : 3.05 in total biomass, whereas for Cyprinidae was 1.05 : 1.44 : 1.00 in total species and 1.29 : 1.00 : 1.62 in total abundance, which are some of the examples for the different ecological processes in each zone respectively. This was also shown by the difference in species composition, whereby 71% of species composition is different between the lower zone and middle zone, 69% different between the lower zone and upper zone while between the middle zone and upper zone it was 58%, based on Jaccard's Coefficient. Overall, the water quality has decreased in the flowing water from the upper zone towards the lower zone, influenced the increase of the number of species towards the lower zone and influenced the biocriteria as above. As the response of fish population towards the difference in habitat criteria, four trends of species distribution had been identified, namely that are present in a specific zone (65.2%), similar abundance either in 2 or 3 zones (24.0%, p>0.05), population increased towards the upper zone (9.8%, p<0.05) and lower zone (1.0%, p<0.05). The total species, total abundance, total biomass, taxonomic composition (order, family, species) and trophic level composition (feeding-groups, consumers) showed a different pattern of changes of functional entities as their response to the environmental changes such as water quality and habitat criteria in terms of changes in distance from estuary, altitude, pollution or local disturbance and characteristic of certain areas. Overall, the composition of endangered species reached to 84% of fish species. A total of 41 species of freshwater fish (63%) showed tolerance to the decrease of water quality towards the lower zone. Significantly, a total of 8 species have been chosen as the best indicator species, based on the correlation with 12 water quality parameters, distance from estuary and altitude among the 92 species studied. The biological integrity of the 8 indicator species, showed the condition of freshwater health has decreased about 83.6% in the lower zone and 62.7% in the middle zone compared to the upper zone, which was used as the local benchmark quality and identified as an important reference site with higher primer productivity. Meanwhile, the middle zone took the role as the transportation channel and the lower zone as the nutrient richness area. The pattern of changes in biocriteria had been assessed in seven approaches, and they are proposed for the evaluation of river ecosystem and evolution of habitat functions and entities of fish community and water quality. These were based on cluster analysis of fish community, facial models, graphic representatives, ratios at the multi-level of assessment and percentage of quality at the test sites from the reference site, which the undisturbed area of the upper zone.

1.0   INTRODUCTION

1.1   The Importance Of The Study

The changes in water quality in the stream ecosystem were not only caused by the local pollution and disturbance (Vogl, 1980) but also the factors of seasons and characteristics of geophysical regime. Many studies have shown that water quality variabilities are very complex and have a lot of fluctuations which can be under the influence of hydro-chemical, hydro-biological and hydro-dynamical factors and processes (Tushinsky, 1991; McIntire & Colby, 1978). In short, controlling chemical water quality alone does not assure the ecological integrity of water resources (Karr *et al.*, 1986). This study is related to the perspective of local water resource management (SMHB, 2000; Ranhill, 1999 & 1992) that needs a stronger foundation in ecological information (Countemanch, 1995; DOE & IPUPM, 1994) where the three major factors above have been focused.

In the last decade, biological criteria and the ecological region have been developed to improve the environmental assessment and protection (Davis & Simon, 1995; Gaston, 1996; USEPA, 1990). In the context of conservation strategies, Soule (1991) distinguishes five divisions: genes, population, species, assemblages (associations and communities) and whole systems at the landscape or ecosystem level. Another three interdependent sets of attributes by Noss (1990) are compositional levels (identity and variety of elements), structural levels (physical organization or pattern of elements) and functional levels (ecological and evolutionary processes).

The biodiversity, which is an abstract concept, is also taken as a measurable entity and a social-politic construct (Gaston, 1996). Biodiversity and ecological function in geographic variation, reflects the regional and local diversity patterns of the relationships to environmental variables (Davies *et al.*, 2000; Martinez, 1996; Baur & Schmid, 1996). The development of a successfully predictive and general theoretical core that relates

biodiversity to function could do much to enhance scientific achievement and increase human society's abilities to rationally address our current biodiversity crisis (Martinez, 1996).

For the aquatic environmental assessment, vertebrate and invertebrate communities are excellent sources of information for the biological integrity of the environment (Countermanch, 1995). The patterns of the changes in the levels of trophic compositions and the indicator species (keystone species) are useful to identify the evaluation in the whole ecosystem and impact of stressors on certain local areas in the ecosystem (Hellawell, 1986; Resh, 1995; Southerland & Stribling, 1995; Collins & Benning, 1996; Welch, 1992).

Inherent to the Ecological Risk Assessment framework (based upon the probability of harm to ecological integrity; Cairns & McCormick, 1992), the stressor-response analyses that quantifies the relationship between the stressor and the environmental value to be protected (USEPA, 1992a). This approach is useful in diagnosing the causes of observed changes in the multiple biological metrics (Davis & Simon, 1995).

The river channel study is an essential information (Nielsen, 2000) for the river management works to monitor the condition of freshwater ecology, irrigation, sedimentation, erosion and pollution. Today, our freshwater habitats are exposed to high risks of pollution and stressors. The various sources of pollution and problems either from inland or river corridors, affected the aquatic habitat (Mason, 199; Forrester, 1994).

The Perak River ecosystem is said to be the most important ecosystem. It supports the local economic activities such as agriculture, fishery, eco-tourism, irrigation, hydro-electricity and water supply for domestics and industries. The importance and roles of the ecosystem influenced the urbanization and economic activities that converged along the river corridors.

The increasing urbanization and socio-economic activities have an impact on the ecosystem (Werner, 1993). For example, land development and various sources of pollution exerted the fish population (Lee & Ismail, 1996). A nearby river, the Gombak River has lost more than 40% of its original fish composition due to land development (Zakaria-Ismail, 1994). As a result, a case of mass mortality of fish community, birds and other riverine wildlife caused by water pollution were reported by Niemi (1988), Pitkanen *et al.* (1990) and Kauppi (1993).

This study, being one of the strategies focuses on fish biodiversity as potential indicator for the environment health monitoring and assessment, which was recommended by DOE & IPUPM (1994). Ecosystem studies with focus on complexity of relationship between fish stocks and environment are needed to protect the aquatic habitat from the effects of pollution and forms of environmental degradation, mentioned by Zakariah & Ali (1996).

Most current ecological research focuses on spatial and temporal heterogeneity and variability, which have been referred to as a new paradigm (Kolasa & Pickett, 1991; Murdoch, 1991; Stewart & Loar, 1994). Freshwater biological monitoring and assessment have generally been focused in identifying structural changes in the species present and their abundance resulting from the introduction of a stressor or alteration of the physical habitat (Norris & Georges, 1993). The changes in the environmental condition in the study were detected by the changes in the biological criteria of the ecosystem region and local patterns.

Understanding the physical, chemical and biological processes is essential for developing a model of water quality and biological criteria in the local ecosystem (Harper & Ferguson, 1996; Treweek, 1999 ; Brinson *et al.*, 1981; Steward & Loar, 1994). Without understanding, it is not possible to formulate sensible models and without models it is not possible to qualify the effects of polluting discharges (James & Elliot, 1991) and balance the ecosystem management (Vogt *et al.*, 1997).

The study on population, community and ecosystem processes are at a higher scale (Vogt *et al.*, 1997). In organization scheme, the biological spectrum is recorded to move from the smallest scale to the largest, starting with protoplasm-cells-tissues-organs-organ systems-organisms-populations-communities-ecosystems-biosphere (Odum, 1959). Detecting the ecological and ecosystem change (ecological risk assessment), requires baseline monitoring and evaluation of the best potential indicators, where the positive and negative feedbacks of ecosystem functions can be predicted or captured by ecological model representative (Vogt *et al.*, 1997; Treweek, 1999).

Fish species have been used as biological indicator to show the level of environmental quality towards the threats of aquatic pollution. One way of determining the environmental level is by "measuring" the biological diversity of fish community and comparing this with the non-threatened standard community (McDowall & Taylor, 2000; Karr, 1996 and Whitfield, 1996).

Using fish communities as a biological indicator has been implemented systematically and has spread widely to many countries (Whitefield, 1996; Ramm, 1990; Fatimah & Mohsin, 1994; Subasingha *et al.*, 1994 and Hocutt, 1981).

In Malaysia, this method has been suggested as a research project so that it can be implemented at the Department level (source from DOE Perak and DOE & IPUPM, 1994). The previous studies were basically concerned with species checklist, fisheries status and biological aspects (Siti Azizah *et al.*, 2001; Ali, 2000, 1988a, 1988b; Ali & Kathergany, 1987; Kelvin *et al.*, 1993; Lee & Ismail, 1996; Patrick *et al.*, 1993; Sabariah & Ismail, 1995; Subasinghe *et al.*, 1994; Zakaria-Ismail, 1984; Zakariah & Ali, 1996; Zakariah, 1997; Mohsin & Ambak, 1983; Kvernevik, 1997; Khan, 1991, Zakaria-Ismail, 2002).

In the course of the study, the interaction with and crossing of disciplinary boundaries have been attempted **(**Figure 1). The relations between biotic and abiotic components indicators related to the environmental condition. such as fish biodiversity (zoology and biology), water quality (aquatic chemistry and hydrology), geophysical characteristics (geography and geology), seasons (meteorology) and aquatic plants (botany), are essential in determining the biological.
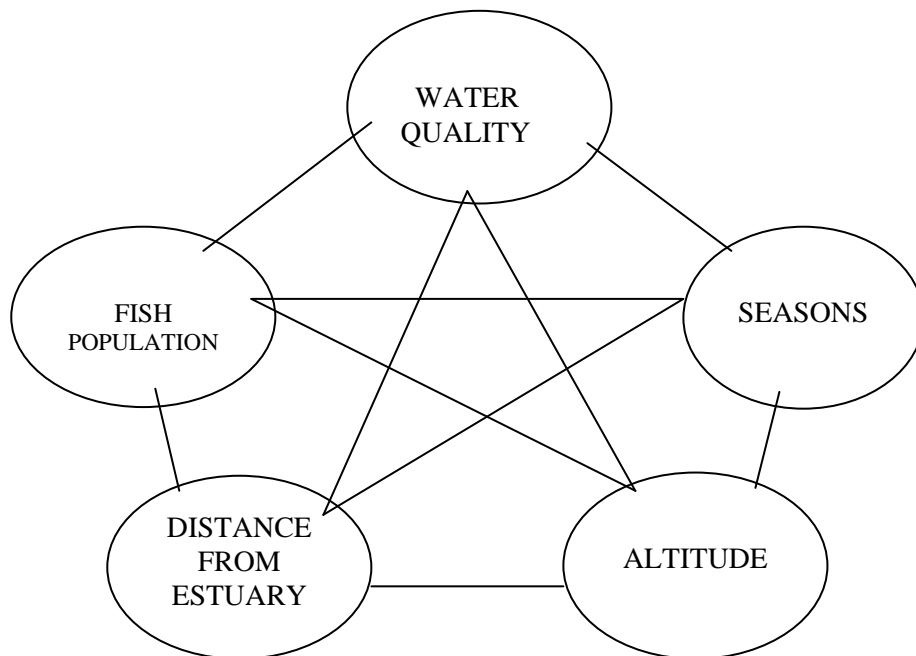
Figure 1.   The conceptual in relationships between the natural components in the ecosystem of this study. Fish population is connected to the influential natural components.

1.2 Objectives Of The Study

The core of the study was based on the objectives as below:

i.   To represent the biological criteria of the lower zone, middle zone and upper zone of the Perak River in terms of fish community, water quality and geophysical criteria by using numeric biocriteria, facial models, graphic representative and cluster analysis.

ii. To identify the pattern of changes in water quality criteria in the main channel of the Perak River from the upper zone towards the lower zone.

iii. To analyze fish community structures in the lower zone, middle zone and upper zone of the Perak River and identify the pattern of changes at the multi level of fish production (total species, total abundance, total biomass), taxonomic composition and trophic levels in their response towards the differences in geophysical criteria (water quality, seasons, distance from estuary and altitude).

iv. To identify the pattern of changes in the ecological processes and functional entities of the main river zones in order to study environmental changes in terms of pollution and evolution in the Perak River system and its importance.

v.   To determine indicator species in order to assess changes of freshwater health in the lower zone, middle zone and upper zone of Perak River ecosystem.

2.0   LITERATURE REVIEW

2.1   The Management Of Aquatic Environment

In the management of an environment, it is imperative to understand the function and structure of each component in the ecosystem. Management, ecology and geomorphology are 3 components that should be linked in a study on pollution (Gabriel & Kreutzwiser, 2000).

A balanced management of development must take into account the varied socio-economic needs of man, maintaining the stability of ecology and the ecosystem, and total justice in social rights (Gardner, 1989). This balance between the socio-economic needs and ecology should be studied in terms of short-term and long-term factors (WCD, 1987).

Rundel *et al*. (1998) discovered that urbanization and agricultural activities have affected the landscape to the extend of creating serious environmental problems. The relationship between landscape and life-diversity should first be studied so as to address the possible conflict between them. Linking terminologies to methodologies in order to identify the key components in the reactive processes of the environment toward pollution is important in the basic theory of interaction models (Gabriel & Kreutzwiser, 2000).

The morphology of nearby areas and landscape plays an important role in contributing the main source that encourages the growth of a community, which is complex and productive in an aquatic habitat. A community in an aquatic habitat depends heavily on the environment at riparian areas. (Riemen *et al*., 2000; Reeves, 1995; Brierly & Fryiers, 2000 and Brierly *et al*., 1999). According to Kay (1991), the ecosystem is complex and dynamic in terms of place and time (Slocombe, 2001) and it has different levels of equilibrium.

Environmental geomorphology, that is the morphology of areas by the rivers, should be studied in order to understand the interactions of the biophysical processes in a river ecosystem. The morphology of these areas includes features such as slope contour and topography, width, forest areas and the areas where there are human activities. These factors influence the components in the river habitat such as water quality, sediments, substrates current and the types of flora or fauna. The changes in one of these habitats can change the river system and this will in turn affect the function of the river as a habitat and aquatic ecosystem (Brierly & Fryirs, 2000; Brierly *et al*., 1999; Barinaga, 1996; Osborne *et al*., 1992; Cousins, 1994 and Richards *et al*., 1997).

2.2   Ecosystem Theories And Management

Ecosystem analysis as a very young branch of science (Jorgenson & Muller, 2000) has been a key concept in the development of modern ecology (Franzle, 2000). Previously, ecosystem theory is applied in ecological modeling (Grant *et al*., 2000). Conservation biology (Dierssen, 2000), ecological engineering (Jorgenson & Mitsch, 2000), assessing ecosystem health (Rapport & Moll, 2000) and ecological economics (Costanza, *et al*., 2000) are some of the applications of ecosystem theoretical aspects.

The essential of ecosystem management is to provide an opportunity to avoid crisis management, a flexible management system, a hierarchy approach to be used to examine process rates and ecosystem functions, sustainable management of the ecosystem and allows us to minimize future risk or reduces negative effects (Vogt *et al*., 1997).

Ecosystem stability has generally included a constancy of numbers, a resistance to perturbation and ability of a system to return to a previous state after displacement, while the increase in diversity is a matter of controversy. The study of the whole system is useful for

management because an ecosystem responds to inputs as an integrated system. (Welch, 1992).

2.3   Definition, Principal And Goals Of Biological Criteria

"Biological criteria, or biocriteria, are numerical values or narrative expressions that describe the reference biological integrity of aquatic communities inhabiting waters at a given designated aquatic life use" (USEPA, 1990). Evaluation of fisheries habitat needs biological criteria (Jalon, 1995).

Biological integrity is defined as "the ability of an aquatic ecosystem, to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity and functional organization comparable to that of the natural habitats of a region" (Karr & Dudley, 1981).

Biodiversity has been traditionally viewed as "the variety of organisms at all the levels (Wilson, 1992) and the expansion of this definition also includes the natural processes affecting biological diversity (Cairns & Lackey, 1992; Hughes & Noss, 1992). The definition of biological integrity includes measures of function, composition and different levels of organization (Hughes & Noss, 1992; Hughes *et al.* 1981, 1992; Karr & Dudley, 1981; Noss, 1990).

Davis & Simon (1995) combined the principle for successful development and implementation of numeric biocriteria based upon developing a reference condition (Hughes, 1995) from regional framework (Omernik, 1995), where appropriate (Yoder, 1991; Yoder and Rankin; 1995 and Hornig *et al*., 1995), a multiple metric characterization of the aquatic

community (Barbour *et al*., 1995; Patil & Taillie, 1976), a habitat evaluation (Rankin, 1995) and ecological integrity (Barkmann & Windlorst, 2000).

The goal of biocriteria is to provide additional support to the state's water quality management and provide a mechanism for assessing aquatic life attainment based on the actual biological condition of water bodies (Southerland & Stribling, 1995).

The use of fish assemblage structure and function as the indicator of biointegrity has been suggested by EPA, and Fish and Wildlife Service of United States of America (*Hughes et al*., 1982; Karr & Dudley, 1981; Karr *et al*. 1986). At least 24 states (in U.S.A) can be described as currently using biocriteria to support their water resources management (Southerland & Stribling, 1995).

Until more reference sites are established, the Division of Water Pollution Control (DPC) is using upstream reference sites to assess stream impacts on a case-by-case basis (Southerland & Stribling, 1995). The United States uses biocriteria for impact assessment, compliance monitoring and program effectiveness monitoring. Gibson (1994) listed five fundamental purposes of biocriteria in the United States water quality programs:

    (i)   Aquatic resource characterization
    (ii)   Refinement of aquatic life uses
    (iii)   Arbiter of use impairment
    (iv)   Identification of impact types
    (v)   Compliance (point source) and effectiveness (nonpoint source) monitoring.

The protection of aquatic life requires the use of biocriteria for all the five activities, enhances the state's water quality program, although the use of biocriteria in different approaches by individual states (Southerland & Stribling, 1995).

2.4   Biological Detection Criteria And Impairment Criteria.

The term "biological detection criteria" establishes the expected biological condition at any site whereas the term "biological impairment criteria" establishes the amount of change that would be considered impairment to a biological community (Bode & Novak, 1995).

The impairment criteria used the paired-site method of comparing the down stream condition to an upstream control condition. Biological impairment criteria were derived from biological detection criteria, which consisted of expected values of water quality, ranging from non impacted to severely impacted. (Bode, 1988).

2.5 Selection Of Reference Site For The Benchmark Quality

The reference of natural condition is used as a control. It represents the desired state of living resource based on the undisturbed habitat representative of the region. The upstream site, or "before", condition is the desired state that provides an appropriate reference benchmark, which can then be used to measure departure of reference site and test site (Hughes, 1995).

Pollution impact studies often used inferential statistics to determine significant differences of aquatic community sampled upstream and downstream, or before and after, of a suspected perturbation (Resh & McElravy, 1993).

2.6   Quantitative Model

By plotting metric and index values against well-distributed disturbance values or natural variables, one can estimate reference conditions through curve fitting (Davis, 1995). For example, Fausch *et al*. (1984) used such an approach to develop maximum species richness lines for stream fish assemblages by plotting against stream size. Hughes *et al*. (1982) plotted the percentage of native fish species against physical habitat quality to determine expected conditions at minimal disturbance. This approach can also be expanded to multivariate linear regression models as long as the relationships are linear (Davis, 1995).

2.7   Multi Metric Approach

The accurate assessment of biological condition requires a method that integrates biotic response through an examination of patterns and processes from individual to ecosystem levels (Karr *et al*., 1986; Shackleford, 1998). The indicator species concept has dominated biological evaluations (Kremen, 1992; Menge *et al*., 1994). As one of the types of environmental research, Omernik (1995) suggested the use of multi indicator species (to investigate or relate) at any single level of individual, ecosystem, components and stresses (Schindler *et al*., 2000).

Ecological studies typically focus on limited number of parameters that might include one or more of the followings; species distributions, abundance trends, standing crop and production estimates (Barbour *et al*., 1995). In contrast, the best-documented responses to environmental stressors (Gray, 1989) are:

(i)   reduction in species richness,

(ii)   change in species composition,

(iii)   reduction in mean size of organism.

The strength of the multimetric approach is its ability to integrate information from individual, population, community and ecosystem levels and to allow evaluation with reference to biogeography as a biologically based indicator of water resource quality (Karr *et al*., 1986; Platkin *et al*., 1989; Karr, 1991; Karr & Kerans, 1991). In combination, strengths of individual metrics, when integrated, minimize weaknesses that they may have individually (Ohio EPA, 1987a,b).   Current research is being conducted to test the efficacy of this application (multimetric concept) to lakes, reservoirs, estuaries and large rivers (Ohio EPA, 1987b; Karr & Dionne, 1991; Master, 1992; Gerritsen & Bowman, 1994).

For multimetric usefulness (Barbour *et al*., 1995), it must be:

(i)   relevant to the biological community under study and to the objectives,

(ii)   sensitive to stressors,

(iii)   able to provide a response that can be discriminated from natural variation,

(iv)   environmentally benign to measure in the aquatic environment,

(v)   cost effective to sample.

The general principles used in defining metrics seem consistent over wide geographic areas (Miller *et al*., 1988). Fishes assemblage metrics are generally grouped into three classes (Karr, 1981, 1991; Gray, 1989):

(i)   species richness and composition,

(ii)   trophic composition,

(iii)   abundance and condition.

Based on the 1992 Australian water quality guidelines (ANZECC, 1992), four biological indicators can be considered:

      i.   species richness
      ii.   species composition
      iii.   primary production
      iv.   ecosystem function

Many researchers have noted the advantages in monitoring the biota (rather than physicocheminal surrogates) to provide a better indication of ecosystem health (Norris *et al.,* 1995). Five key factors influencing ecosystem health, which are flow regime, habitat quality, water quality, riparian vegetation and sediment quality (Hart, 2002).

However, using the integration of information from several metrics, especially a grouping of metrics of the major classes of attributes (community structure, taxonomic composition, individual condition and biological processes), improves and strengthens the bioassessment process (Resh, 1993). These metrics have a strong ecological foundation and enable the biologist to determine biocriteria (Barbour *et al*., 1992). Taxa richness is used as a key in multimetric. (Barbour *et al*., 1995). Metrics of individuals have been implemented successfully in fish multimetric indices. However, in the field, behavior measures are difficult to assess. (Barbour *et al*., 1995).

Gammon *et al*. (1990) and Lyons (1992) found abundance to be higher at moderate levels of degradation (i.e., nutrient enrichment). Catch per unit effort (CPUE) has been retained in most versions of Index of Biotic Integrity. However, some had excluded tolerant species (Ohio EPA 1987b; Lyons, 1992 and Karr *et al*., 1986) suggested using the relative CPUE to set scoring criteria for the total number of individuals metric.

2.8   Biological Processes

Trophic dynamics encompasses functional feeding groups and measures the condition of the food web for the system. Examples involve the relative abundance of herbivores, carnivores and detritivores. Without relative stable food dynamics, the population of the top carnivore seemed stressed. If production of the site is considered high based on organism abundance and /or biomass, and high production is natural for the habitat type during the study (as per reference conditions), biological condition would be considered good. (Barbour *et al*., 1995).

2.9   Functional Measures

Functional diversity is defined as the variety of interactions with the ecological processes (Martinez, 1996). Lawton & Brown (1993) suggested that ecological process and ecosystem function are synonymous.

Ecological processes are those activities that result from interactions among organisms and between organisms and their environment. A function may be defined as an interaction with process (Martinez, 1996). Functional includes both the levels of functional anatomy and trophic relationships of organisms (Williams & Hamphries, 1996). Functional diversity among organisms is expected to have value for maintaining the integrity of ecosystem (Walker, 1992; Schulze & Mooney, 1993; Golley, 2000; Muller & Windhorst, 2000).

Frost *et al*. (1995) defined ecological function in terms of the effects of a given species on the population growth rates of all the species in the community. Vitousek & Hooper (1993) and Tilman & Downing (1994) described several frequently reiterated potential relationships between species richness and ecosystem function.

Stability is theoretically defined to measure whether or not a system returns to equilibrium following a perturbation (Pimm, 1991), where species diversity is used as a measurement of stability (Svirezhev, 2000) while the ecosystem function refers to the processing and dynamics of resources (nutrients, organic matters, biomass) and energy through systems (Collins & Benning, 1996; Royama, 1992). The processing is accomplished by a multitude of interacting species, which are classified into functional groups. Function diversity then refers to the number of such groups in a community (Smitch & Huston, 1989).

Collins & Benning (1996) assumed the broad objective of linking the dynamics of ecosystem function as follows:

(i) communities and ecosystems are dynamic in space and time.

(ii) individual species affect community and ecosystem dynamics at different spatial and temporal scales.

(iii) species diversity may affect ecosystem structure and function

According to Franklin (1988), Noss (1990) and Martinez (1996), "Structure is the physical organization or pattern of a system, from habitat complexity as measured within communities to the pattern of patches and other elements at a landscape scale. Function involves ecological and evolutionary processes (Pond, 1993), including gene flow, disturbance, and nutrient cycling".

The importance of functional groups (Poff, 1995) is widely acknowledged, and the lost of an entire group would lead to the loss of a crucial ecosystem process. The number of substrate utilized and the rates of reaction differed among communities support different functional assemblages. Thus, communities and ecosystems are dynamic; and species (or functional

groups) have significant impacts on community and ecosystem dynamics. (Collins & Benning, 1996; Minshall *et al*., 1983).

Some of the functional feeding group measures such as the percentage of shredders, scrappers, collector-filters, ratio of scrappers/collector-filterers, ratio of trophic specialist/generalist, types of functional feeding-groups and functional group similarity are also appropriate for use. (Resh, 1995; Newrkla, 1983).

Species are functionally similar when different sets of species may produce the same impacts on ecosystem function even though species may provide a variable suite of characteristics. Functional similarity should be focused at the process level and determined by estimating the number of individuals, regardless of taxonomic affiliation, in assemblages that contribute to that function. Functional similarity may exist at the community or ecosystem level. Redundancy and functional similarity have been improperly focused at the species level. (Collins & Benning, 1996).

Community dynamics can be related to certain species either because they are highly abundant, or because some of their activities have disproportionate impacts on structure and function. Most of the communities comprise a collection of species that differ in abundance, yet all contributes in one way or another to ecosystem structure and function. For example, all producers contribute to biomass production, which is considered to be a primary ecosystem function. (Collins & Benning, 1996).

2.10　　Fish As Biological Indicator

In freshwater habitats, the number of fish species are often small and it may prove to be an insensitive technique. Fish condition factors and community diversity were compared with

physicochemical data and a biotic index by Laurent & Clavet (1977) who suggested that data from fish survey could be utilized by less highly specialized staff than would be required for other methods. Fish species are generally identified easily but the manpower resources are required to collect samples of fish and adequate information on water quality (Hellawell, 1986).

Many pollutant fish are unable to detect sub-lethal concentrations and even if they are able to do so may not be repelled by them (Summerfelt & Levis, 1967). The killing out of populations by the toxic pollutants may affect ecosystems. For example, the lost of one group of organisms can have serious repercussions on other groups (Hellawell, 1986).

The decomposition of large quantities of plant materials may cause severe de-oxygenation of the water, while the release of nutrients during decomposition may stimulate the growth of algae, causing the blooms and resulting in fish-kills (Hellawell, 1986). Some species are very sensitive to the organic pollution and some species can develop a tolerance to pollutants, which enable them to survive in highly polluted habitats. The mechanisms of tolerance to pollution are extremely complex, involving several metabolic systems and overcoming the presence of pollutants in different ways (Hellawell, 1986).

Fishes are mobile and are able to avoid polluted water, returning when conditions are favorable. Many factors associated with individuals or populations could be used to assess environmental quality. It has long been known that the growth of fishes is correlated with water quality. Environmental conditions, which impaired growth and development or reproductive success, would become evident in populations. (Hellawell, 1986; Schlosser, 1995).

Changes in the balance between autotrophs and heterotrophs are a common feature of organic or nutrient enrichment (Knopp, 1961). A possible change in the community composition and total biomass may be dynamic and functional changes have been reported by Hellawell (1977), where the patterns are:

    (i)   biomass changes (but the community structure is the same)

    (ii)   community structure and biomass changes (but the species are same)

    (iii)   species and community structure changes (and the biomass may change)

In the study of fish ecology, two main factors namely factors, which threaten fish population and habitat, and factors, which increase fish population, and habitat should be focused. Excess and deficit of a species are influenced by factors within the habitat, which are closely related to the needs of the species ecology, effects of pollution and other disturbances in the habitat.

The distribution of fish species can be divided into several zones in the river habitat (Yap *et al*., 1997). Ali (2000) has identified the main zones in the ecosystem of the Perak River. This has been done based on the differences in altitude, and it can be used in further studies of fish ecology.

Beginning from the egg stage, fish have been exposed to environmental changes, which have great influences on the homeostatic and physiological system both short term and long term. Minimal effects of environmental changes can result in a reaction, which is not chronic, for example, low growth rate and delayed maturity. Fish can show reactions of overcoming the changes in the environmental parameters by adapting mechanisms such as biochemistry adaptations, physiology behavior, and even from the aspect of morphology, acute and chronic reactions may be visible at the individual stage, population stage or community

stage. Reactions shown by fish population can be applied as a biological indicator in monitoring the environmental changes (Fatimah & Mohsin, 1994).

Fatimah & Mohsin (1994) reported that several species could live in various trophic levels. These species are *Tilapia spp, Pangasius spp* (Patin) *Trichogaster pectoralis* (Sepat), *Helostoma temmincki* (Termakang), *Osphronemus goramy* (Kalui), *Anabas testudinus* (Puyu), *Channa spp* (Haruan), *Beta pugnax* (Pelaga), *Hypophthalmichthys molitrix* (Kap Perak), *Channa Siamensis* (Seriding), *Doryichthys martensii* (Paip) and *Toxotes jaculatum* (Sumpit-Sumpit).

Tilapia, Clarias, Channa and *Lebistes* reticulates can be found in a polluted habitat where the water flows (not stagnant). In a polluted habitat where the water does not flow, *Tilapia, Trichogaster, Anabas, Clarias, Channa* can be found. *Tilapia,* which was originated from Africa, is well known for its resilience and has a high tolerance to critical environment. Those species, which live in an environment with clean water quality with flowing water are *Probarbus jullieni, Puntius schwanefeldi* and *Acrossocheilus deauratus*. Most Cyprinids can be found at areas where the water does not flow (Ali, 2000; Fatimah & Mohsin, 1994).

The Cyprinidae family is dominant at Selangor and Perak River. They can withstand the different land habitat in the highlands where the temperature is low, the water is clear, and the oxygen content is high. Two of these species are *Poropuntius smedleyi* and *Neolissocheilus soroides.* They are found in high mountain ranges. *Cyclocheilichthys apoqon, Puntius schwanefeldi* and *Osteochilus hasselti* are always found at the lowlands. *Channa striatus* and *Notopterus* can be found in muddy areas and areas with low oxygen concentration (Ali, 2000 and Yap *et al.*, 1997).

Sabariah & Ismail (1995) reported a high tolerance among the *Hampala macrolepidota* and *Osteochilus hasselti* species. They were found at depths between 2 to 28 meters at the Temenggor Lake habitat. Here, the dissolved oxygen content was less than 2 mg/*l*, the temperature was < 23.5°C and the pH was < 6.0. *Puntius bulu* was not found at depths more than 8 meters (DO < 4.5 mg/*l*, temperature < 25.2°C, pH < 6.2) and *Mystus nemurus* was not found at depths more than 12 meters (DO < 4.5, temperature < 23.5°C, pH < 6). *Hampala macrolepidota* is a predator species which is found to be dominant at all levels of depths in the lake.

According to Yap *et al*. (1997), the number of species increases at the lower zones of the Selangor River systems. Only 5 species were found at the highland zones (upstream) at the base where it is sandy and stony, the number of species is small (8 species), the number of species increases (10-12 species) at the river mouth where the riverbed is muddy and salty. These species can withstand and are tolerant to the turbidity and low oxygen content at the Selangor River.

Fish migration should not be seen as a weakness of the biological indicator method. The pressures in the environment causes the fish to migrate to an area, which is more suitable in the species ecology niche. This fact strengthens the use of fish as a biological indicator. (McDowall &Taylor, 2000).

Mohsin & Ambak (1983) have listed a total of 118 fresh water species in Peninsular Malaysia identified as extinct or rarely found, another 59 species threatened. According to Alfred (1965), the main factors that cause the extinction of the fish fauna in Peninsular Malaysia are pollution and silt from mines, land development, effluents from housing estates and industries, agriculture waste and all kinds of poison.

2.11   Stressors On Fish

There are various sources of stressors on fish such as physical disturbance (suspended solids, heat, pH), organic enrichment (organic discharges), toxic materials (inorganic and organic poisons, heavy metals, pesticides, polychlorinated biphenyls) and development activities (channel modification, construction of dams and land development) (Hellawell, 1986). There are approximately half a million chemicals currently used and many of these eventually enter freshwaters (Goodman, 1974). The stressors, which are divided into the biotic and abiotic components, are shown in Figure 2. The stressors were subjected to water pollution.
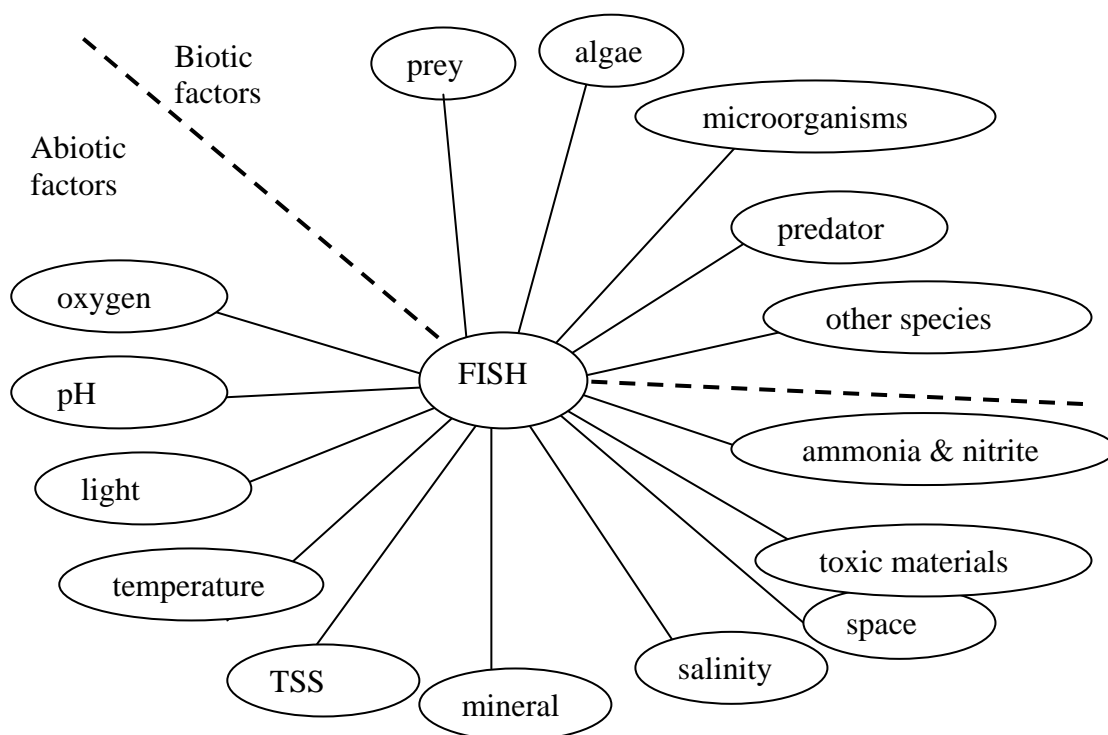

Figure 2.   Stress factors on fish community. (Sources: Su, 1991; Hellawell, 1986).

Seven categories of human activities, which are endangering animal and plant (McDonald, 2003) are habitat destruction, hunting, introduction of alien species, international trade in items such as ivory or animal and plant parts used in medicines, drainage of wetlands, pollution, and the incidental destruction or removal of species.

2.12   Water Quality

2.12.1 Water Quality Changes And pollution

Detailed observation of the effects of pollution upon aquatic life and human health have been made for over 150 years. Chadwick (1842), Flin (1965), Hassall (1850) and Cohn (1853) have often been credited as the first to use the aquatic organisms as indicators of environmental pollution (Davis, 1995). The River Soar (Leicester, England) was reported to be a "common sewer for the drainage of the town" in late 1700s and in the 1830s "the Soar became so corrupt that fish could not live in them and consequently disappeared entirely" (Chesbrough, 1858).

In water resources integrity, there are five principal factors identified by Karr *et al*. (1986) and modified by Karr (1995);

(i)   chemical variables (water quality; Karr, 1995)

(ii)   flow regime

(iii)   biotic factors (biotic interactions; Karr, 1995)

(iv)   energy source (food source; Karr, 1995)

(v)   habitat structure

Previously, only a few possible measurements were required in most studies. All of the various environmental parameters can be grouped into dissolved gases, dissolved solids and particulate solids. The substances, which pass through the pores in a 0.45 μ filter are

generally considered to be in the dissolved phase. Nutrients of PO_4-P and NO_3-N are included to inorganic dissolved solids. The suspended or particulate solids in water include both inorganic and organic materials. (King, 1971).

The inorganic fraction is made up largely of silt, sand and clay soil particles, while the organic fraction may be either living or dead organic matter (King, 1971). Golterman *et al.* (1978) recognized the fractions of water samples as live particulate, dead particulate, dissolved inorganic (generally inorganic) and dissolved organic (bound inorganic).

The parameters of pH, dissolved oxygen (DO), temperature (T) and carbon dioxide levels are likely to increase the toxicity of the toxicants. For example, Cyanide (Downing, 1954), ammonia (Merkens & Downing, 1957), monohydric phenols, lead and copper (Lloyd, 1961).

The water quality criteria is based on toxicology test both chronic and acute (Hellawell, 1986), while the concepts and terminology in toxicology have been provided by Brown (1973). The water quality criteria for freshwater fish and aquatic life, polluting and dangerous substances present in industrials effluents could be referred to EPA (USA; recommendation by Alabaster & Lloyd, 1980) and EIFAC (Europe; recommendation by Train, 1979) guidelines. A lethal limit to fish for some important substances could refer to the reports by such as Mayer *et al.* (1977), Macek & McAllister (1970), Post & Schroeder (1971), Henderson *et al.* (1959), Newbold (1975), Hellawell & Bryan (1982), Chapman & Stevens (1978), Alabaster & Lloyd (1980), Kovacs & Leduc (1982), Cairns & Cornn (1979), Herbert & Shurben (1964), Broderius *et al.* (1977), Hellawell (1986) and others.

Pollution means chemical contamination (Karr, 1995). A more appropriate definition is " [hu] manmade or [hu] man-induced alteration of the physical, chemical, biological, or radiological integrity of water" present in 1987 Clean Water Act (U.S.). Under this definition, humans may