Chapter 5

Discussion

The statistical analysis using MANOVA showed that the two streams differed significantly mainly in families composition and different substrate coverage. The dissimilarity of the two streams in terms of faunal groupings were evident from the results of cluster analysis. Physico-chemical parameters did not show statistical differences between the two streams. Seasonal variation was prominent over the year. Seasonal variations mainly for ammonia, percent saturation, pH, velocity and conductivity were noticed between the two streams from MANOVA.

<u>Variation of physico-chemical parameters of water quality</u>

Cluster analysis showed that two major groupings may be formed based on physico-chemical parameters of water quality. A group covering all the sites in November was separated from another group at average linkage distance of .2. Though the dendrogram generated cluster for the month of November separated from June and March, the second groupings were not at significant level. However, the general tendency of clustering pattern for physico-chemical parameters of water quality followed seasonal changes. From all these results, it followed that the physico-chemical parameters of water quality in the study sites were more sensitive to seasonal variation than the anthropogenic or natural input in each of the stream. Seasonal variation in hydrological systems in concentration of different parameter have been mentioned by Royal Commission on Environmental Pollution (1979), cited by Porapongsa et al. (1990).

The values noted for key nutrient parameters like nitrate-nitrogen, phosphorous and ammonia showed remarkable increase in all the sites mainly in the rainy season and cool season (November). The highest nitrate-nitrogen concentration of 1.6 mg/l l was noted for site 1 in the rainy season. This was attributed to agricultural runoff draining directly into the stream. This can be supported by similar findings from a study conducted by Tuyor (1993) in the highlands of Mae Rim District which also showed increased concentration in nitrate and phosphate in water bodies near agricultural fields during rainy season. In this case also, the high values noted for key nutrient parameters were attributed to high rate of washout from agricultural fields due to high discharge and elevated erosion. The rainfall during the rainy season has been considered as one of the major factors diminishing the concentration of the inorganic fertilizers in the soil as it is rapidly washed off by rain (Goldman, 1993). In contrary to the sites near agricultural field, sites 3, 4 and 5 as control sites also showed increasing tendency for key parameters like nitrate, ammonia and phosphorous in rainy season. More elevated concentrations of 1.6, 2.6 mg/l of nitrate -nitrogen was noted at the sites 4 and 5 during early winter season (November) with subsequent increase in ammonia about 80 % as compared to summer season in the same site. The higher concentration of ammonia noted at sites 1 and 2 in November and June were also attributed to fertilizers and decayed vegetables. The decayed vegetables, fertilizers and animal excreta are considered as some of the major source of ammonia (Porapongsa, 1990).

In my case, the fertilizers and decayed vegetables could be possible sources for elevated ammonium concentration near agricultural field in the month of November.

Since, this month was the starting season for vegetable harvest in the agricultural field. Huge dumplings of vegetable pieces and discarded vegetables as a result of insect damage were seen along the road and all over the field. This was a common scenario during this month. Since the crop grown amounted in terms of export quantity, it is likely to cause the impact in the water body due to its natural degradation of leftovers in the field. On the other hand, for sites 3, 4 and 5, the possible factors contributing to the increase in ammonium concentration during June and November could be the result of natural mineralization of the leaves entering into the system. Case studies have revealed that the fate of ammonia to be largely dependent on the level of oxygen present (Abel,1989). However, the toxicity of ammonia is described as less known about its effect on invertebrates, though considerable toxicity have been described for fish toxicity (Albaster and Lloyd, 1980, cited in Abel, 1989). Therefore, the impact of higher concentration in ammonia is expected not to cause so severe damage to stream invertebrates unless the oxygen concentration is lowered due to nitrification and denitrification processes.

The overall values noted for phosphorous (0.1 mg/l) was higher than the highly eutrophic state of the lakes (Goldman, 1983). The higher values noted for phosphorous during the rainy and winter seasons were almost equal to maximum allowance limit in domestic water supply of 0.2 mg/l (Porapongsa et al, 1990). Fertilizers and surface run off are described to be major source of phosphate (Porapopongsa et al, 1990). In this case, fertilizers could be the possible source contributing to the high values of phosphorous in stream A during rainy season following contribution from vegetable decay in winter season. On the other hand the higher values noted for sites 3,4 and 5 could be the result of natural surface runoff. The values above 0.1 mg/l for phosphorous has been commented as being "recently polluted" (National Research

Council, Washington D.C., 1977; cited by Porapongsa et al. 1990). Therefore another possible reason for higher concentration of phosphorous and ammonia noted during November in both the streams could be the result of sampling the stream water immediately after one of the rainy days accompanied by surface runoff.

Lower conductivity noted by Tuyor, (1993) during the rainy season in the stream near agricultural field was not justified by my findings. The conductivity showed increasing tendency in the rainy season with highest conductivity mainly in rainy season in site 1 and 2 (stream A). The conductivity increased very slightly for sites in stream B. The increase in sedimentation has been attributed to increase in ionic concentration in water (Goldman, 1983). Therefore, in my case the increased conductivity could be a synergetic effect of elevated concentration of nutrient parameters with some heavy metals resulting from the use of some fungicide like cupravit in the agricultural field.

The alkalinity noted in all the sites were within the range of maximum allowance limit for surface water quality of 20 meq/l.

The measure of velocity less than 0.4 m/se has been refered as having sandy and silt substratum (Hynes, 1970). The velocity 0.45 to 0.68 m/sec noted in stream B reflected the gravel composition of the substratum of the stream. In contrast to the stream B, the velocity measured for stream A was below 0.44 m/ sec. These findings were supported by results from the field observation.

Silt has been explained as an undesirable habitat for many invertebrate organisms characteristic of stones and gravels (Solbe, 1986). The fine sand and silt particles are liable to block the pores in between the pebbles and gravels thereby hindering the aeration system of the insects living on gravels and stones. Blocking of the gills due to fine sand and silt during respiration can result in elimination of characteristic taxa by obstructing physiological processes. Habitat destruction has been described as another major factor in contributing in elimination of some characteristic taxa by many authors.

Factorial analysis, using physico-chemical parameters of water quality, as a measure to explain the underlying dimension that account for several variables, showed that the two streams differed in factor loading parameters. This explained that different parameters were responsible in explaining the water quality of respective stream.

As explained in the result, the major factor loading parameters for factor 1 in stream A using water quality parameters were phosphorous, conductivity, velocity, nitrate, depth, pH and alkalinity. For stream B, the major factor loading parameters were phosphate, conductivity, velocity, nitrate, dissolved oxygen, percent saturation and alkalinity. Dissolved oxygen was seen to have higher loading for factor-1 in stream B only (0.76) compared to stream A (- 0.59). Since, the factor loading parameters are those which explain how closely the variables are correlated to each one of the factors discovered (Kothari, 1992), variation of dissolved oxygen in case of stream B, pH and depth in stream A ecosystem were considered as reflecting their importance of in the dynamics of the two stream under study. **However, these physico-chemical parameters could explain only the major variations accounted due to seasonal variations .**

Discrimination between the streams

The cluster analysis based on benthic community, using Pearson's correlation coefficient and average linkage clustering showed that the two streams were different in terms of faunal groupings. The sites 1 and 2 always formed a close entities in each season. Similarly sites 3, 4 and 5 formed another group. The two major groups joined together at average linkage distance of 0.1 only. Since the groupings were based on abundance of faunal groupings, it was concluded that the group 1 representing stream A was dissimilar from the group II representing stream B in terms of their faunal groupings. The result of the cluster analysis appeared logical as this findings were supported directly by the result from **MANOVA which showed that the two stream differed significantly in terms of diversity, richness and evenness.**

Although the discrimination between the two streams were clearly seen, it did not explain underlying causes on species differences between the two streams in different sites. Therefore univariate methods like diversity indices recommended by Gray et al.(1992) was implied to see the pollution effects at community level . The application of diversity index is based on the premise that community undergo a reduction in diversity following ecological stress in the form of pollution.

The result from Shannon Wiener diversity index, showed that the sites 1 and 2 in stream A were comparatively poor in family diversity compared to sites 3, 4 and 5 in stream B. Looking at the species richness (N_0), the faunal catching in experimental stream A were lower. 18 to 23 families were recovered compared to stream B where the total catch ranged from 35 to 46 in control stream B. Distribution of abundant families (N_1) and very abundant families (N_2) showed that the community in site 1 and 2 were more dominated by some families during summer season. This can be seen from the evenness values noted at the same time (**Appendix. 8**). The evenness index should be maximum and decrease towards zero as relative abundance of the species diverge away from evenness (Ludwig, 1988). The evenness value was seen increasing following rainy season in stream A (site 1 and 2). This was attributed to the high spates causing increase in normal drift (Hynes, 1970). Since the community in site 1 and 2 were dominated by families like Simuliidae Hydropsychidae and Chironomidae with high abundance, the increase in drift of these families during rainy season could be one of the reasons for decrease in N_2 and increasing E_5 values (Tuyor, 1993). Bishop (1973) also explained the fluctuation of densities of benthic community in Malayan river due to the reoccurrence of floods which reduced fauna. Therefore, the findings that stream A that it has lower diversity than stream B were taken as an indication that stream A was under more ecological stress compared to stream B. The loss of species diversity or change in species composition of streams has been explained as warning signal of chemical pollution or thermal pollution (Karr, 1991; cited by Policansky, 1993). **Therefore, the disturbance was recognized to be at community level.** However this univariate indices (diversity) still could not explain the major factors affecting the community structure and level of disturbance at each site. This just gave an idea that the two streams were different in terms of family diversity.

The findings from the results using diversity indices were in concurrence with the findings from MANOVA using community (diversity, richness, evenness) as variable. The result showed clearly that the two stream differ significantly in terms of faunal groupings along with the substrate type in each of the stream bed.

Maximum diversity has been explained as directly related with environmental heterogeneity (Hellawell, 1970). **Therefore, one of the factor causing significant differences of the two streams in terms of community structure were attributed to lack of heterogenic substrate type in stream A.** This was further supported by the findings that stream A was dominated mainly by sand and silt covering more than 70 % compared to substrate types stone and gravel (rocky substrate) forming more than 85

% in stream B. The estimated values for different substrate type were based on the field observation over nine months of study period.

Considering site 1 and 2 to be a single entities (stream A) and sites 3, 4 and 5 as separate entities (stream B) as a result from hierarchical cluster analysis, diversity index and multiple analysis of variance, lognormal distribution of species were plotted to find the disturbance at population level. The results showed that only 21 families belonged to class I (population size =1 to 10) in stream A . The curve gave shallower look with mainly 3 families dominating the community in stream A where as the similar graph showed that 37 families belonged to the class 1 in stream B and has higher steeper slope compared to site A. The distribution pattern of the families was seen to be more even in case of stream B compared to stream A. This gave an idea about the disturbance of the families in the existing community in terms of abundance and overall and population distribution pattern. All these findings were helpful to draw a conclusion that site differences recognized at community level as mentioned above, were due to **lower number of families and lower abundance of each of the individual families.** Therefore it was considered important to know if the low number of families and lower abundance accounted in stream A were caused by contaminants loading or not (Gray, 1992).

<u>Family distribution pattern present in community data</u>

The ordination of the families were implied as alternative approach to recognize the pattern of family distribution present in community data. The graph was plotted using factor 1 and factor 2 resulting from rotated factor analysis using Varimax. Three distinct groupings formed were named as group I, group II and group III. Since factor-1 and factor- 2 are considered to represent the highest variables within the sample matrix, the groupings formed at high confidence level ($\geq$ 95 %) were considered to represent the significant association in the community data. The cumulative percent of variance for factor 1 and factor 2 were accounted for 34.8 % only. Significant grouping (group II) for Factor 1 comprised families viz. Philopotamidae, Hydrophilidae, Empididae, Glossomatidae, Psephenidae, Perlidae, Helodidae, Siphlonuridae, Leptophlebidae, Ephemeriidae. These groupings were formed at correlation coefficient value $\geq .8$. The other significant grouping (group I) for factor 2 consisted of Palingeniidae, Chloroperlidae, Ptilodactylidae, Notonectidae, Hydraenidae, Taeniopterygidae, Ametropodidae and Pteronarcydae (c.c. $\geq .8$). All the families accounted in group I were found exclusively in stream B only and therefore factor-2 was considered to be representative of unpolluted or control stream. Moreover, the significant groupings of group II represented some families exclusively belonging to stream B and some common families belonging to both the streams. The families which were commonly found in both the streams differed in their abundance. The families accounted in stream A, forming part of group II, were more abundant in stream B. Therefore, in this case factor 2 was taken as best indication of community health and factor 1 as indication of medium state of community health. In case of factor 1, the association was taken for indication that those families forming the association are likely to be vulnerable to extinction if present state of stress continues in the ecosystem. This can be noticed from the reducing abundance of the families present in stream A compared to that of stream B.

The ecology of each of these families forming group I and group II, at high significant level, was expected to answer the question about their limitation in particular ecosystem type only. The ecology of each of them is described as below (McCarhty,1981; Hynes, 1970, Bishop, 1973; Chu, H.F, 1969).

Group 1

1. **Philopotamidae** (Order : Tricoptera)

Larvae occur in riffle areas. They have open ended elongate nets attached to the upstream end (McCarthy, 1981). Larvae live gregariously found in swift mountain streams where they construct net like cases (Chu, F. 1969).

2. **Hydrophlebidae** (Order: Coleoptera)

Adults and larvae live in shallower region of water. They are often associated with dung or rotting vegetation. If water is sufficiently oxygenated, submergence time for these beetles is increased (McCarthy, 1981). Larvae are aquatic or semiaquatic. Feeding habits are more diverse in adult larvae (Chu, F., 1969)

3. **Empididae** (Diptera)

Most species of this family are terrestrial. Larvae are aquatic or semi aquatic . Larvae and pupa of most species live in the rocky bottom of ponds or streams(McCarthy, 1981).

4. **Glossomatidae** (Tricoptera)

Larvae occur primarily in cool streams with considerable current, where they live on periphyton and fine detritus from the substrate remain attached on upper surface of rocks, restricted to surface where algal grazing was possible.

5. **Psephenidae** (Coleopteran)

These usually stay on the stones. Larvae remain attached to stones in stream and rivers with considerable wave action. Larvae are highly adapted for adhering to stones and for feeding on periphyton and encrusted materials associated with the substrate. The larvae are aquatic and attach to stones in swift flowing streams. The pupae are submerged and and firmly attached to stones. Larvae in underside of clean stones, feeding on fine detritus (Chu, F., 1969).

6. **Perlidae** (Plecoptera)

Larvae occur in many lotic habitat, often under stones in riffles and sometimes in sandy substrates. The older larvae can be highly predaceous, utilizing mayflies, midges and small caddisflies as food sources (McCarthy, 1981). Living or decaying sometimes make up a portion of the diet, especially of young larvae. The naiads are all carnivorous and feed on smaller forms of insect life in water (Chu, F., 1969).

7. **Heliodae** (Coleoptera)

Adults of most species are terrestrial, but some regularly occur in the vicinity of water. The larvae are aquatic and some species have large tracheal reservoir for storing air. Larvae are detritivorous (McCarthy, 1981).

8. **Siphlonuridae** (Ephemeroptera)

The aquatic habitat include various litter zone of lentic waters and small streams and sandy bottom substrate. Larvae are excellent swimmer and these are opportunistically feed on other tiny insects when they are available. The larvae live in rapidly running water (Chu, F., 1969) .

9. **Leptophlebiidae** (Ephemeroera)

Larvae are often associated with porous rocks, gravel, woody debris and root banks of the streams. Larvae feed on the stream bottom detritus during the day and on more exposed algae in the night (Chu, F, 1969).

10. **Ephemeridae** (Plecoptera)

These are typical borrowing forms. Tusks lack spines . the larvae are the best borrowers in the silt- sand substrate These are particle feeder and some of them are thought to ingest sediment non selectively. These larvae live in muddy bottom or muddy water. The larvae live in muddy bottoms or muddy water (Chu, F., 1969). Found in clean unsilted bottoms (Bishop, 1973).

Group II

1. **Palinginidae** (Ephemerotera)

Burrowing habit, characteristic tusk, predominate family in silt clay bottom soil.

2. **Chloperlidae**(Plecoptera)

Associated with swift waters and gravel bottom, becoming more abundant as a group in colder water or in mountainous region.

3. **Ptilodactylidae** (Coleoptera)

This is a small family, considered as a rare family in N. America. Larvae occur in streams, where they can burrow in soft substrate.

4. **Notonectidae** (Hemiptera)

These are less adept swimmers (some jerking movement) often utilizing larger but slower immobile prey. Food generally include insects, crustaceans , snails, small fishes. Hibernating at higher altitude beneath ice and often within substrate.

5. **Hydraenidae** (Coleopteran)

Often associated with filamentous algae and leaf detritus. Crawl along the margins of streams, often tangled with roots and debris. Semi aquatic.

6. **Pteronarcydae** (Plecoptera)

Detritivorous and herbivores in mixed substrate, detritus and woody debris of stream and rivers. May occur at considerable depth and some species are more tolerant of warmer waters.

7. **Taentiopterygidae** (Plecoptera)

Occur in diverse habitat ranging from cool spring to warm, sometimes warm and intermittent, sand bottom streams, larvae are often difficult to find as they are sluggish and sometimes covered with sediment or flocullent water.

8. **Ametropodidae** (Ephemeroptera)

The characteristic feature is the claws of the middle, and hind legs o the larvae long and slender, clefted. The larvae are adapted to living in clean shifting sands of rivers, remaining partially buried when at rest. They are thought to be predacious (Chu, F., 1969)

The significant grouping for factor II (group I) were found confined to stream B only. All these benthic community represented a diverse macrobenthic community whose pattern of distribution and abundance of individual taxa across the stream indicated that potential competition for food occupy different microhabitat. This microhabitat probably reflected the availability of particular substrate patches. For example represented different families to have distinct habituation with different niches there by reducing interspecies competition for food. In case of stream A, **lack of heterogenic substrate was seen to be more sensitive factor leading to elimination of those which were not specialized for that habitat** This may be related with the life histories of the different insect fauna. Bishop (1973) describes that availability of wide range of substrate type may provide better insurance against a species population being wiped out by a natural catastrophe such as series of spates. Considering these group of benthic community for the variability accounted in the two streams, **their environmental needs, habitat and feeding behavior was taken as major factors lacking in stream A which cause diminishing of these of benthic community.**

Factor 1 grouping (group II) represented the combination of the families common in both the streams and some exclusively present in stream B as mentioned above. Ecological background for the families of these groupings gave clear cut idea about the distribution of these families on the basis of their preferences on substrate composition and the feeding habit. Among the factor 1 groupings (group-II), the families common in stream A and B were Perlidae, Helodidae, Siphlnuridae, Leptophlebidae. Among the common families, they were most abundant in the stream B compared to that of stream A. This indicated that these group of families have some ecological niches left for their survival in stream A. Their lower abundance in stream A compared to stream B, could be taken as an indication that, if the present state of stress continues for longer time, may be these group will be the first families to be eliminated from stream A.

Moreover the benthic organisms which were specialized in living in and or silty substrate like Taentiopterygidae and Ametropodidae were not accounted in stream A despite of the fact that from the point of view of substrate, these group of families could be expected to be abundant. This indicated that some other factors apart from habitat destruction were involved in eliminating sensitive group of families in stream B.

The findings that the disturbances were at community level with fewer number of families discovered in stream A with lower abundance compared to stream B gave independent idea about the state of community in each of the stream ecosystem. The findings from multiple analysis of variance showed that the two stream differed significantly in terms of substrate composition and community structure but were similar in terms of physico-chemical parameter of water quality. The detection of organochlorine pesticide in comparatively lower concentration in control stream (stream B, indicated possible pesticide impact on benthic community in the stream A, nearby the agricultural field. All of these results did not provide idea about the degree of relationship existing between these different causes as environmental variables affecting the benthic community in each of the stream. Therefore, it would be interesting to know the degree of relationships between the biological measures and various environmental factors considering them to be determinants of the state of the community at that ecosystem.

Relationship of family richness with anthropogenic inputs in each streams

One frequently used measure of similarity is to use correlation coefficient (Krebs, 1989). The correlation coefficient range from -1.0 to 1.0. The assumption is the fact that both environmental and chemical data were taken at the site where the faunal samples were taken. The biological measure of community structure (family richness, diversity and evenness), physico-chemical parameters of water quality, and percent substrate coverage were used as independent variables to compare the degree of relationship among them. Since the organochlorine pesticide detected in each of the stream sediment were too low to cause any direct impact to the benthic community, organochlorine pesticide as environmental factor were eliminated from correlation matrix but were taken as an indication of pesticide inflowing in the stream nearby the agricultural field.

Significant Correlation was found for richness with ammonia, depth, velocity, conductivity, and factor 1. The factor 1 was in turn correlated significantly with pH, velocity, conductivity and richness. In this case, factor-1 was taken as an indication of sediment loading in relation to increase in conductivity with increase in velocity during rainy season and also subsequent increase in depth (appendix 2). The positive relation of factor -1 with family richness (0.9), show that increase in correlated positive factor loading parameter in factor-1 (pH, conductivity, velocity), from correlation matrix cause increase in family richness in stream A. This could be true in case of stream A at present condition because the increase in pH, depth, velocity and conductivity may be favorable to most of only those type of families that already exist or are adapted in stream A. Since the community structure reveal the fact that it mainly comprise of families belonging to order Diptera, followed by Tricoptera, Ephemeroptera, Hemiptera, Odonata and Plecoptera. Most of these families are known for their well adaptation in sand and silty habitat with mainly carnivorous feeding habit. Richness show negative relation with ammonia in stream A.

Richness, in stream B was significantly related with dissolved oxygen only and negatively with ammonia. The positive significant relationship of benthic community richness with dissolved oxygen and significant negative relation with ammonia explain that families forming community structure in stream B are dependent on variation of oxygen concentration. Increase in oxygen value increase family richness in stream B. Where as increase in ammonia decrease the family richness in stream B. The negative relation of ammonia with richness in both the stream could be due to its high toxicity as in case of the fishes. Various cases like blue baby symptoms are well known due to higher nitrogen concentration found in water. This positive factor loading of oxygen in factor-1 seen in case of stream B may be taken as oxygen indicator in relation to family richness, since factor-1 is positively correlated with family richness in stream B.

The correlation matrix was supporting the analysis from the factorial parameters as the positive parameters having positive relation in correlation matrix also have positive factor loadings in factor-1 in both the cases.

Detection of organochlorine pesticide in stream A comparatively in higher concentration than stream B indicate that stream A was likely receiving more pesticidal effects from the nearby fields than the stream B. Since the organochlorine pesticide are known for their high persistence, it was taken as a tool for investigation of possible pesticide impact. Concerning other pesticides used in the agricultural field, the group of pesticides like organophosphates, carbamates and pyrethroids have shorter half life period, therefore were not considered for the analysis. However, the detection of traces of metabolites of different organochlorine group of pesticides indicate that may be the inflow of other group of pesticides are in the same trend causing more impact in stream A. The sudden inflow of other group of pesticides have been reported to cause increase in drift. Subsequent increase in drift may result in loss of sensitive group of benthic community without direct notice. Therefore, measurement of pesticide impact have been suggested to be carried out using drift index as a measure of pesticide impact. However, no field experiment as such were done because of shortage of time. The OC pesticide detected served as a strong evidence of trend of pesticide impact. The difference in textural analysis of the sediment provided with an idea that sediment of stream B were more richer in organic matter content. The higher standard deviation in the analytical result was attributed to difference in sediment texture, difference in organic matter content in the samples analyzed.

Prediction of community health based on biological measures

Multiple regression has been suggested to be used as a explanatory tool to investigate the relationship between a biological index and selected environmental variables with a view in generating a hypothesis that may be tested by environmental manipulation and experimentation (Rosenberg, 1993). Its major use in benthic survey have been explained as development of model that can be used to predict the state of community from one or more environmental variables that provide adequate prediction of biological measure (Norris, 1986, cited in Rosenberg, 1993). Dowing 1986, also cited in Rosenberg, 1993 successfully used regression technique to establish predictive relationship between the number of organisms of several epiphytic invertebrates taxa and the biomass of each macrophyte species.

The regression equation developed in stepwise fashion yielded linear dependence of benthic community richness with factor 1 for stream A. The factor 1 in turn yielded dependent parameters pH and conductivity. These dependent parameters pH and conductivity could not explain any environmental impact except the variations based on seasonal changes. From this point of view, the dependence of richness, in stream A was seen as based on seasonal changes compared to stream B, as control stream. But, this factor alone can not be taken as major explaining reason for lower family richness accounted in stream A as other major factors like habitat destruction, pesticide impact was seen as other possible factors affecting the benthic community as explained above. Therefore, the loss of sensitive group of benthic community in case of stream A was considered as synergetic effect of all these environmental factors resulting in distinct faunal grouping significantly different from that of stream B.

In contrast to stream A, stream B was found more favored by all the environmental factors like diverse substrate, natural vegetation surrounding the stream with natural dynamics governing the stream ecosystem. The regression equation for richness in stream B with dissolved oxygen was seen as determinant factor for higher richness.

The regression equation derived for stream A and B were as follows:

$$\text{Richness Stream A} = 1.76 \text{ factor } 1 + 19.8 \ (r = 0.82)$$

where, $\text{Factor } 1 = 0.16 \text{ conductivity } (\mu s/cm) - 1.06 \text{ pH} + 2.64 \ (r = 0.97)$

$$\text{stream B richness} = -5 \text{ dissolved oxygen(mg/l)} + 77 \ (r = 0.81)$$

However, the separate equation gave idea about separate ecosystem type only. Therefore, in order to have idea about the deteriorating or improving state of community in each of the stream, the combined equation was taken into consideration. The final regression equation showed substrate dependent relationship with the richness in each of the stream and negative relation with ammonia. These findings were strongly supported by the findings from the correlation matrixes of each of the stream and from the result of substrate composition result.

Family Richness = 0.38 % stone coverage - 11.5 ammonia (mg/l)+ 21.81 (r = 0.84)

Though the standardized regression coefficient describes the final model, this does not necessarily indicate the strength of the functional relationship between environmental variables and biological index (Rosenberg, 1993) . This relationship could be established only through further experimentation where environmental factors could be manipulated. Therefore, the result of multiple regression developed above could be taken for the subset of environmental variables that can be considered to be most important parameters to explain the variation in biological measure in the two stream under study only. This model can be used to predict the value of a biological index in an impacted area where only measurement of environmental variables are available and can be compared to the values observed to assess the impact. Confirmation of the study is suggested for monitoring purpose.