CHAPTER 5
RESULTS

5.1 Missing data

During dry season sampling, all three sets of ASS were removed at site IC 2 by people in the vicinity. The ASS set at site SC1 were not retrieved because all three sets of samplers were not in the water, as the water level in the canal constantly fluctuated.

In the wet season, two sampling sites were dropped due to loss of ASS. In site ST1 all ASS were buried due to a landslide at the site (Figure 2). ASS at site ST4 were not retrieved as researcher observed people fishing in this site often changed the position of the ASS to set their fishing nets. Therefore these sets of data are not included in later analyses.

5.2 Available colonization surface area of ASS

Stones in the WMC had mean 0.19 $m^2 \pm$ 0.258, WB sampler 0.13 $m^2 \pm$ 0.0005 and MP sampler 0.12 $m^2 \pm$ 0.0005 . Ekman grab and Surber sampler had 0.0225 and 0.0506 m^2 surface area per unit sample respectively.

5.3 Abundance and taxon richness of macroinvertebrates in sampling methods.

List of taxa and number of individuals in each taxa in both seasons are shown in Appendix C 1 - C 8. The mean number of animals per square meter, total number of taxa per sampling unit and families common to all sites, recovered from five different sampling methods in two sampling seasons are shown in table 6.

Table 6 : Mean number of animals per m^2 , total number of families per unit sampler in each sampling method and families common to all sampling sites.

Sampling method/season		Mean no: of animals/m^2	Total no: of families	No: of families common to all sites
WMC	dry	211.18	48	2
	wet	677.2	51	1
WB	dry	476.6	53	4
	wet	564.1	50	1
MP	dry	269.4	47	3
	wet	285.06	46	1
Surber sampler	dry	635.7	56	5
	wet	473.2	43	7
Ekman grab	dry	1396.1	27	0
	wet	751.8	23	0

Ekman grab recorded high abundance of macroinvertebrates and lowest number of families in both seasons compared to ASS. Considering ASS in the dry season WB recorded the highest numbers of animals and taxa while MP sampler recorded the lowest number of animals and families for both seasons. WMC recorded the highest number of animals and taxa for the wet season. The families Baetidae and Chironomidae are common to all sites, except site SC 2 from all methods in both seasons. The families Elmidae and Lumbricidae were common in all sites, except site SC 2 in wooden box in the dry season (Appendix C 1 - C 8).

5.4 Abundance of animals per site using different sampling methods

Figure 9 - 12 compare the numbers of animals per sampling site in the two seasons for each type of ASS and conventional methods. WMC sampler shows highest

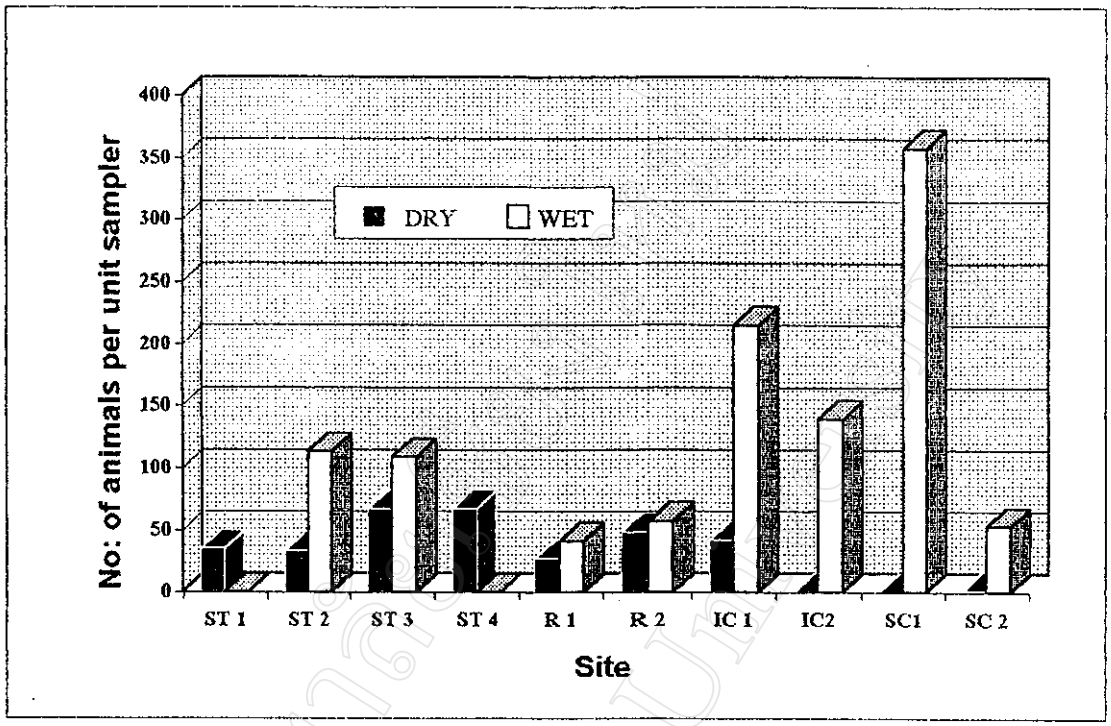


Figure 9: Abundance of macroinvertebrates in WMC sampler per site - Dry and wet season.

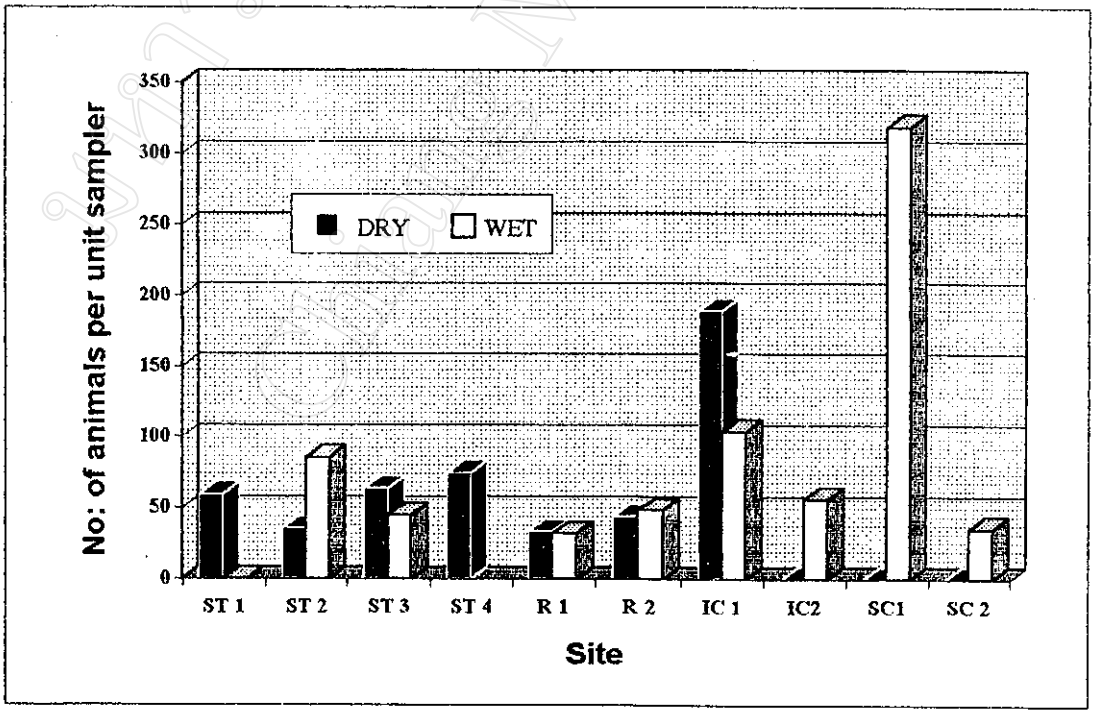


Figure 10: Abundance of macroinvertebrates in WB sampler per site - Dry and wet season.

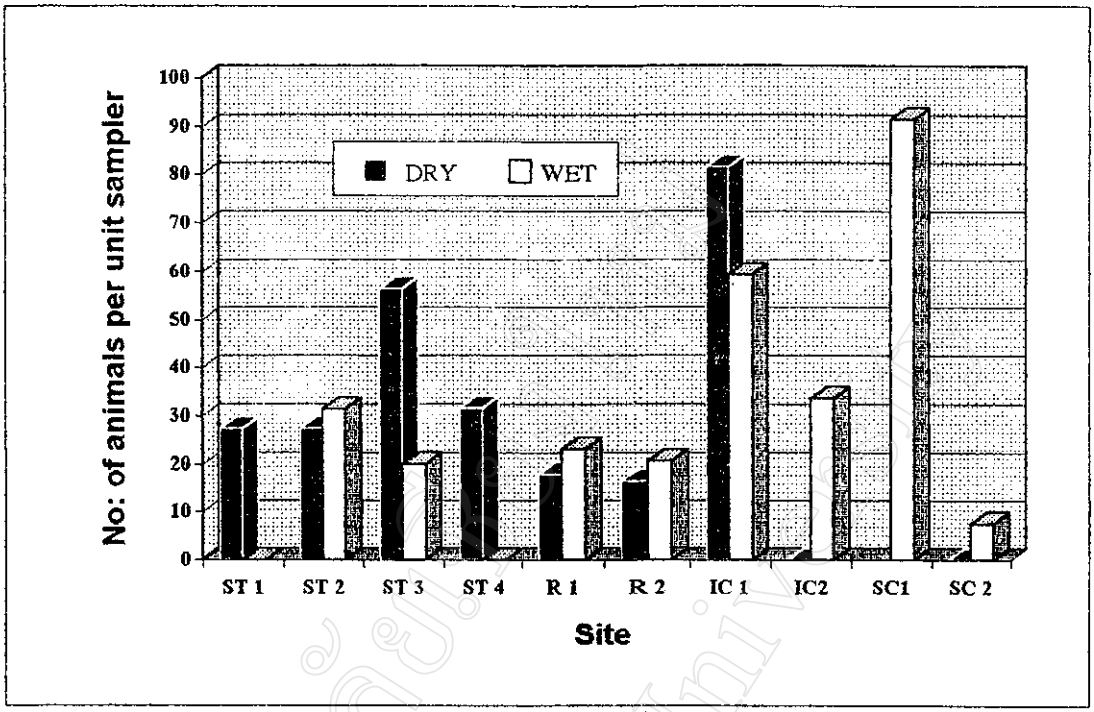


Figure 11 : Abundance of macroinvertebrates in MP sampler per site - Dry and wet season.

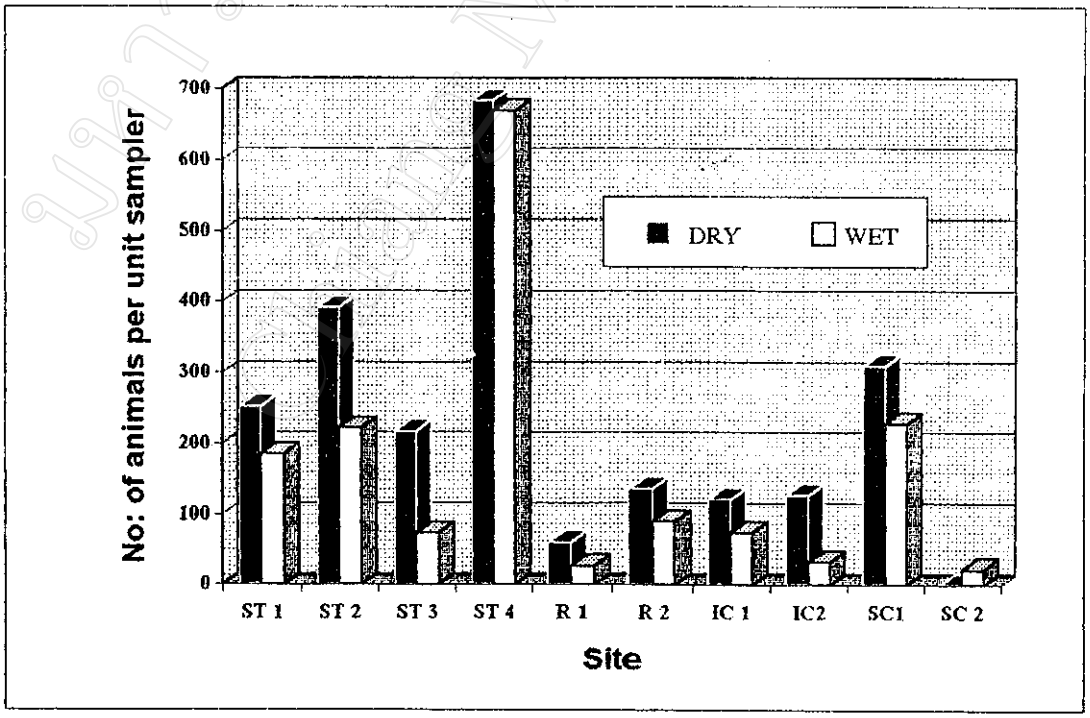


Figure 12 : Abundance of macroinvertebrates in Conventional methods per site - Dry and wet season.

abundance in the wet season than in the dry season in all sites (Figure 9). Sites IC1 and SC1 show the highest abundance compared to other sites in the wet season. There is no regular pattern among sites in abundance changes in the WB sampler in the two seasons (Figure 10). Site SC1 shows the highest number of animals in the wet season, while site IC1 shows a high abundance in the dry season. Similarly, there is no temporal pattern of abundance among sites in the MP samples (Figure 11). Sites ST3 and IC1 show the highest number of animals in the dry season, while sites IC 1 and SC 2 show the highest number of animals in the wet season. Conventional methods collect larger numbers of macroinvertebrates in the dry season than the wet season from all sites (Figure 12). Site ST4 recorded the highest numbers of macroinvertebrates in both seasons.

5.5 Coefficient of variance (CV) in ASS

The mean coefficient of variance (CV) for each sampling method and for individual sites in the two seasons are shown in table 7.

Table 7: Coefficient of variance (CV) in ASS for two season.

Site	WMC		WB		MP		Surber sampler		Ekman grab	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
ST 1	0.43	NA	0.67	NA	0.82	NA	1.38	0.65	-	-
ST 2	0.62	0.57	0.5	0.8	0.34	0.15	0.45	0.87	-	-
ST 3	1.25	0.22	0.9	0.56	0.92	0.14	0.83	1.05	-	-
ST 4	0.81	NA	0.58	NA	0.07	NA	0.38	0.73	-	-
R 1	0.35	0.44	0.654	0.91	0.29	0.87	-	-	0.38	0.47
R 2	0.39	0.25	0.96	0.01	0.37	0.03	-	-	0.00	0.38
IC 1	0.3	0.77	0.29	0.05	0.09	0.53	-	-	0.15	0.11
IC 2	NA	0.62	NA	0.79	NA	0.59	-	-	0.06	0.73
SC 1	NA	0.65	NA	0.41	NA	0.08	-	-	0.03	0.17
SC 2	1.73	0.64	0	0.51	0	0.54	-	-	-	0.13
Mean	0.74	0.52	0.55	0.51	0.36	0.37	0.76	0.83	0.12	0.33

Using mean CV, the Surber sampler shows the highest CV in both seasons compared to other methods. The Ekman grab sampler shows the lowest CV in both seasons. Regarding the ASS in the wet season site R1 shows the highest CV for MP and WB samplers while site IC1 shows the highest CV for the WMC sampler.

5.6 Data transformation

To perform the parametric statistical analyses at least the following requirements should be fulfilled: i) data should be normally distributed ii) the variance between two samples should not be significantly different.

Since the five sampling methods are based on five different surface areas , in order to compare the efficiency of the sampling methods in terms of number of animals recovered, all data were standardized to number of animals per square meter.

A distribution curve based on raw data of mean number of animals/m^2 revealed that the data were not normally distributed. However log n transformed data, $\log_{10}$ (X+1) data and square root transformed data showed clear normal distribution curve (Figure 13, 14, 15, and 16). Raw data and transformed data of number of families per sample unit showed normal distribution curves (Figure 15). Results of the Levene test for homogeneity of variance performed for both number of animals per square meter and number of families per sampling unit are shown in table 8.

Table 8: Values of Levene test for homogeneity of variance for untransformed data and three different transformation methods recorded for independent variable

Data transformed method	No: of animals per m^2	No: of families per sampling unit
Untransformed data	0.000	0.000
Log n	0.620	0.617
Log10 (X+1)	0.620	0.000
Square root	0.003	0.005

Considering both normal distribution pattern of data and values from Levene test for homogeneity of variance, the raw data was transformed to log n to perform ANOVA test.

ANOVA test, data based on number of animals per square meter reveals a significant difference between sites and sampling methods ($p< 0.05$). However there is no significant difference between seasons ($p>0.05$) . Further, there are significant differences between method and season, and method and site interaction ($p< 0.05$) (Appendix D 1).

The results of the ANOVA test performed for number of animals per unit sampler also show significant differences among sampling methods and sites ($p< 0.05$). There is no significant difference between seasons in terms of number of animals per unit sampler ($p> 0.05$) (Appendix D 2).

A high abundance of animals were recorded from site SC1 irrespective of sampling methods and seasons ($2066/m^2$, 95 % confident limits/confident intervals (CL) 1350- 2782) while the lowest number of animals was recorded from site SC2 (122 , CL 46-200). Figure 17 shows mean values, 95% confidence limits/intervals and upper and lower range of animals in respective sites. Least significant difference (LSD) test separated both site SC1 and SC2 from the rest of the sites (Figure 17) (Appendix D 3).

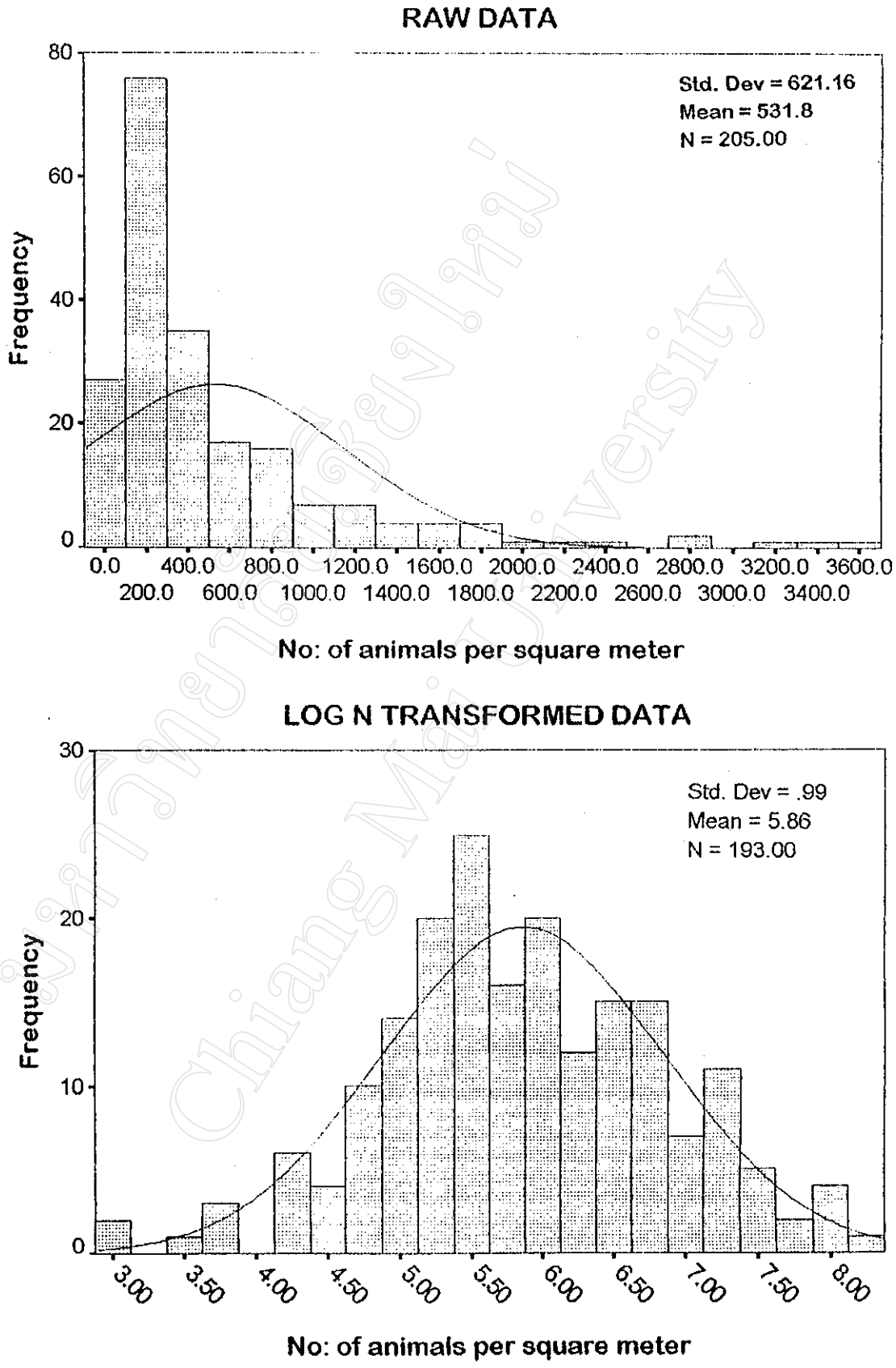


Figure 13: Normal distribution curve for raw data and log n transformed data (abundance per m^2)

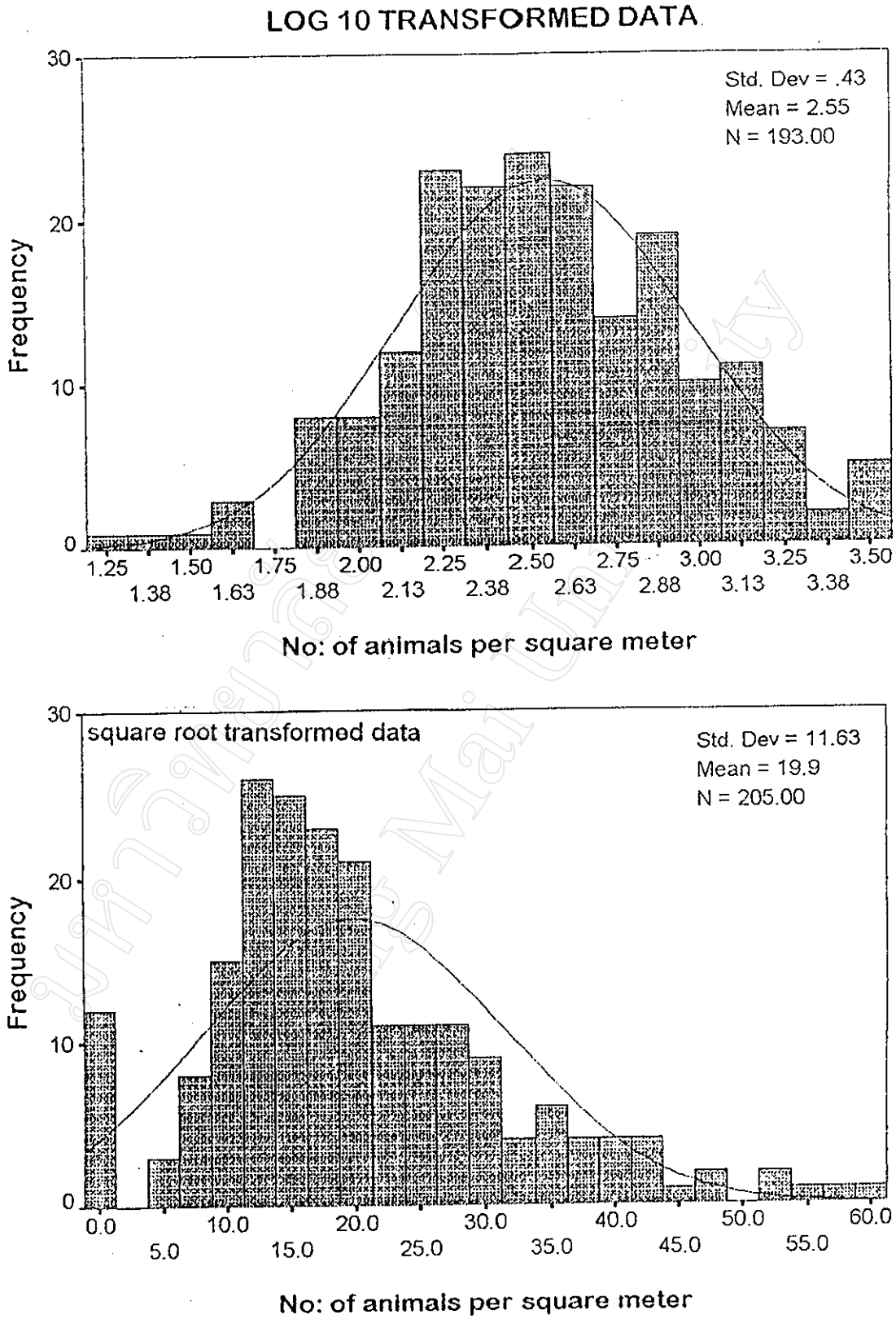


Figure 14: Normal distribution curve for log 10 and square root transformed data (Number of animals per m^2)

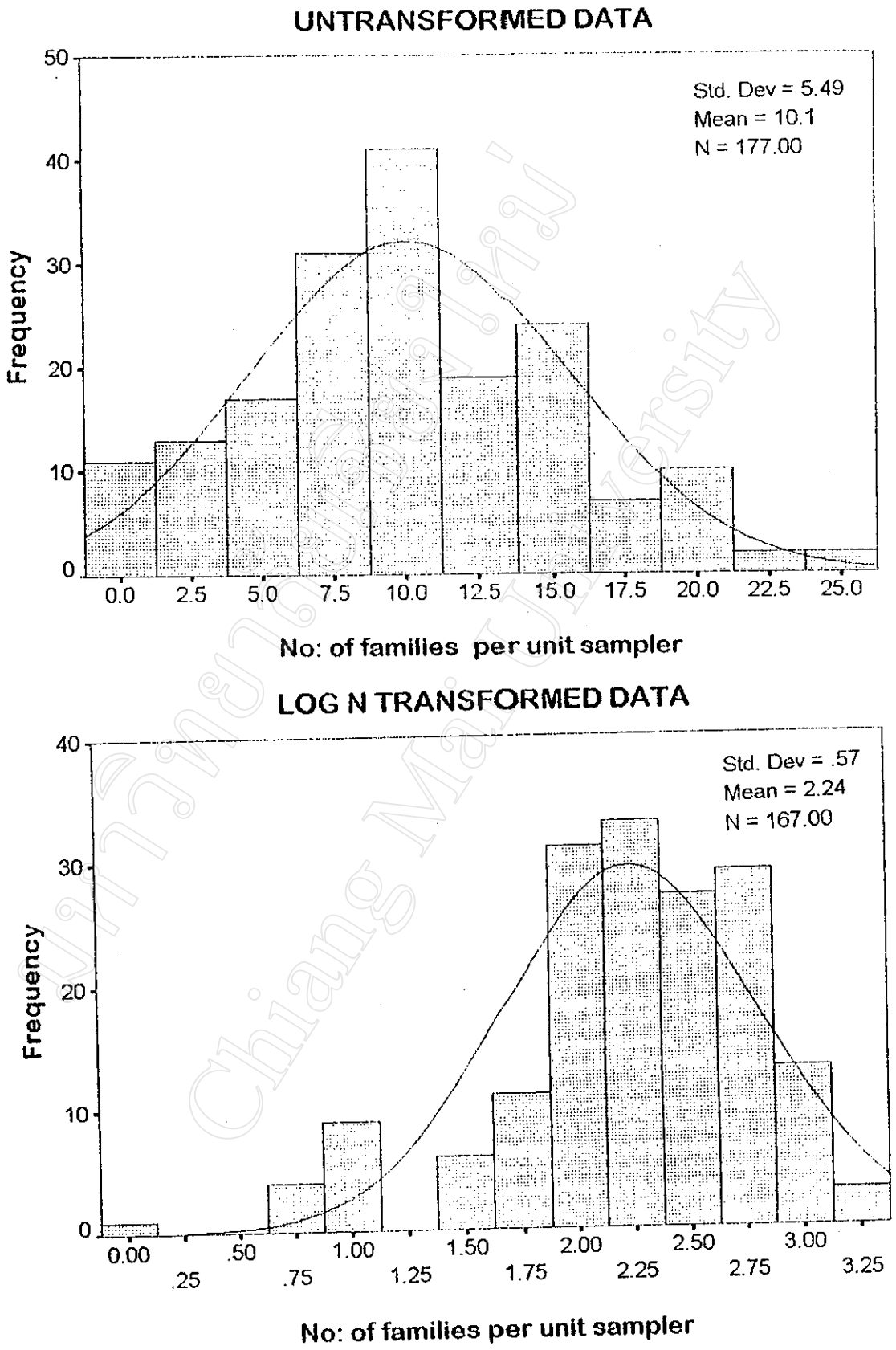
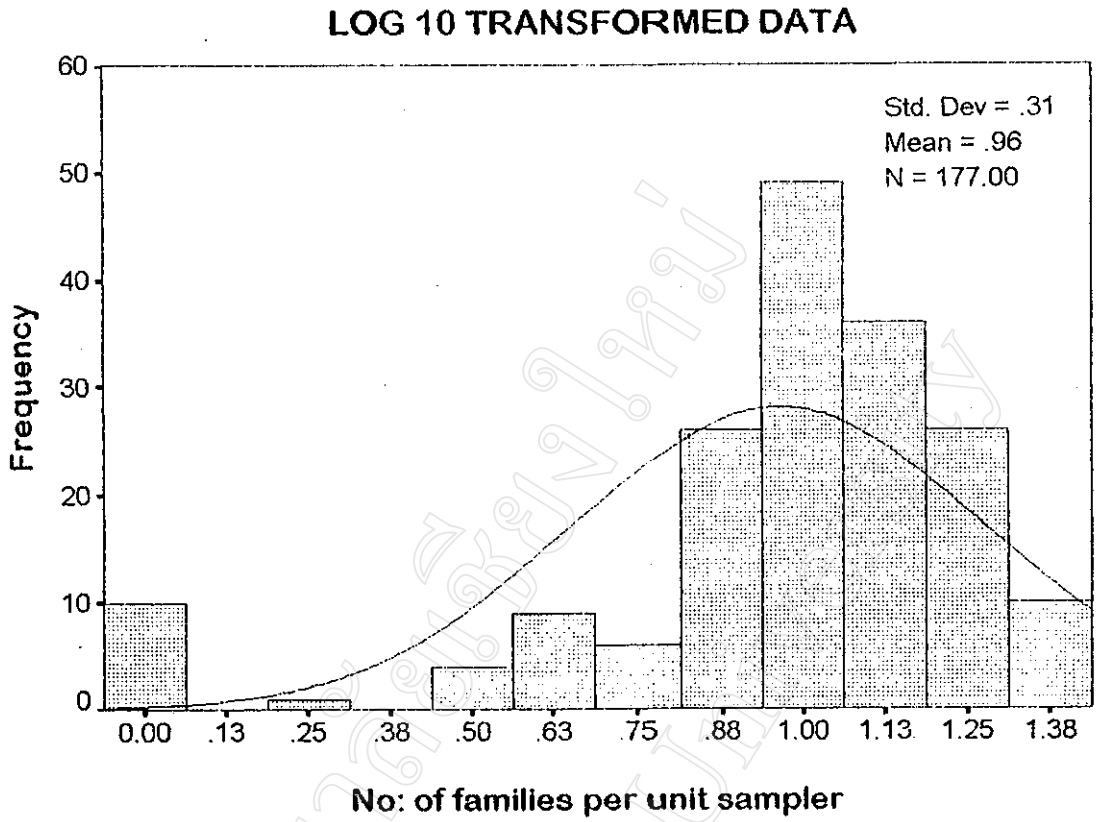


Figure 15 : Normal distribution curve for raw data and log n transformed data (No: of families/unit sampler)



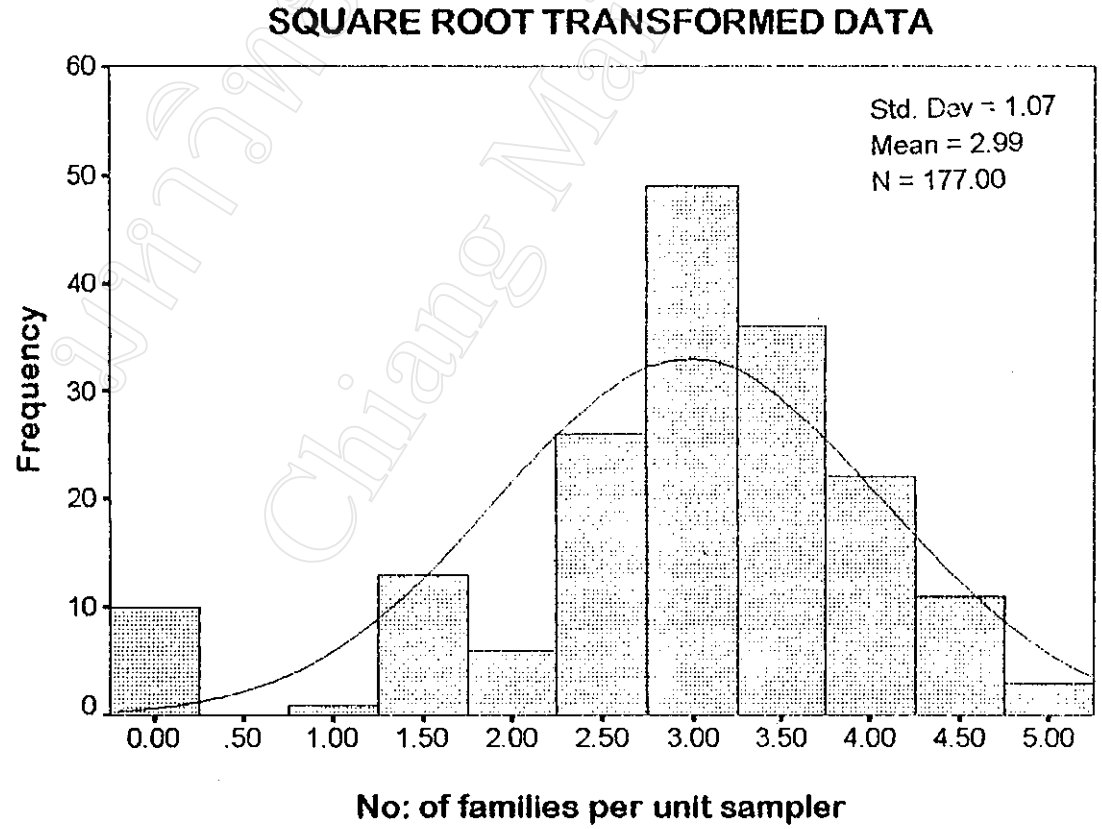


Figure 16: Normal distribution curve for log 10 and square root transformed data (Number of families /unit sampler)

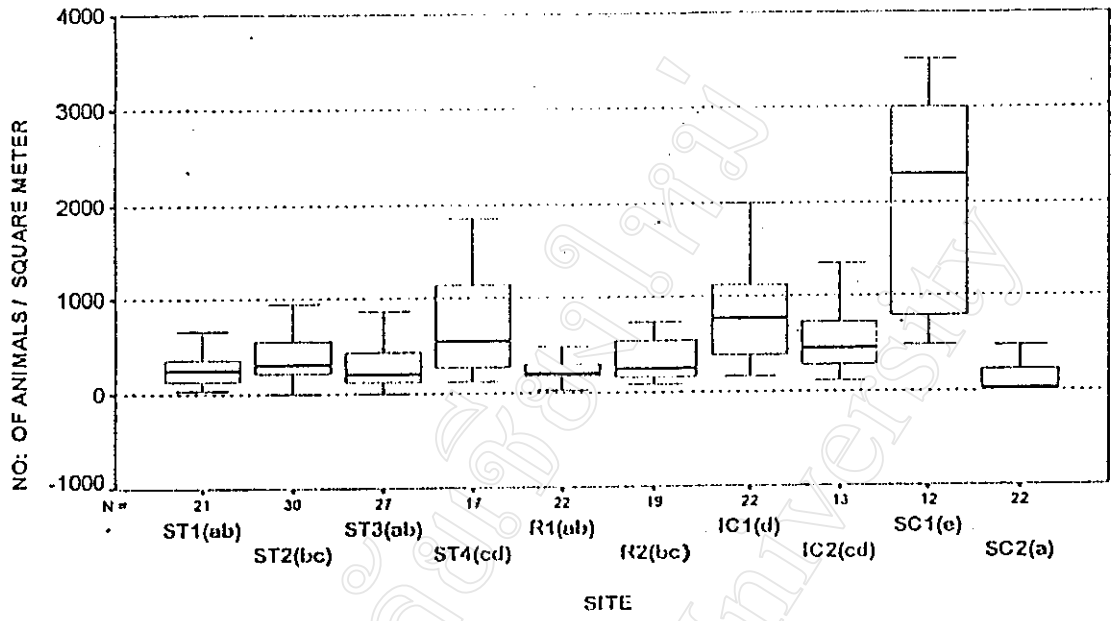


Figure 17 : Mean number of animals/m^2 , upper and lower limits of 95 % confident intervals, upper and lower range of data (Irrespective of seasons and sampling methods)

This separation is only based on the abundance of animals in sites and therefore it does not give an idea about the water quality of respective sites. However, from other evidences sites SC1 and SC2 are considered to be highly polluted sites. In the dry season no animals were collected by any of sampling method from site SC2. However, in the wet season considerable number of animals were collected from both sampling types.

Efficiency of sampling methods calculated using data of animals/m^2 and per unit sampler showed different results (table 9 and 10).

Based on number of animals colonized in ASS per square meter irrespective of sampling sites and season, the WB sampler was significantly different from the WMC sampler and the MP sampler ($P < 0.05$). The LSD test shows no significant difference between conventional methods and the wooden box sampler (Appendix D 3).

Considering ASS, the multiplate sampler is the least efficient and the wooden box shows a high efficiency in terms of number of animals colonized per m^2 (Table 9).

Table 9 : Mean number of animals/ m^2 and 95 % upper and lower confidence limits per sampling method irrespective of sites and seasons.

ASS type	Mean No: of animals/m^2	95% confidence limits
Multi plate sampler	226.26 a	174.67 - 293.04
Wire mesh cage	294.30 a	218.07 - 397.18
Wooden box	434.94 b	339.23 - 557.58
Conventional sampler	466.85 b	356.70 - 611.06

F - test ($P < 0.05$)

However number of animals colonized in ASS per unit area irrespective to sampling sites and seasons MP sampler significantly different from WMC and WB sampler . WMC sampler significantly different from MP sampler and Conventional samplers (Table 10).

Table 10 : Mean number of animals/ unit sampler and 95 % upper and lower confidence limits per sampling method irrespective of sites and seasons.

ASS type	Mean No: of animals/unit sampler	95% confidence limits
Multi plate sampler	34.7 (a)	25.9 - 43.5
Conventional sampler	51.1 (ab)	39.6 - 62.7
Wooden box	73.4 (bc)	50.5 - 96.4
Wire mesh cage	88.1 (c)	54.7 - 121.4

F - test ($P > 0.05$)

WMC sampler shows highest efficiency and MP sampler shows least efficient in terms of animals colonized per unit area (Table 10).

Most of the sites show a higher mean number of animals in the wet season than dry season except sites ST3, IC2 and SC1. In the dry season no animals were collected from site SC2 . Site SC1 shows a higher variance in wet season than dry season, but only two samples were available for the dry season (Figure 18).

5.7 Taxa Richness in ASS

ANOVA test reveals significantly different numbers of taxa between sampling methods and sites ($p < 0.05$). However, there is no significant difference between seasons in terms of number of taxa per unit sampler ($p > 0.05$) (Appendix D 4). LSD test indicates that, site SC2 significantly different from other sites ($p < 0.05$). SC2 site has the lowest number of families (1.5 families per unit sampler). Site ST4 has the highest number of families per unit sampler irrespective of sampling methods and seasons (Table 11) (Appendix D 5).

There are no significant difference in efficiency between the WB, WMC samplers and conventional sampling methods. However, the MP sampler was significantly different from all other sampling methods in terms of number of families in unit sampler (Appendix D 6).

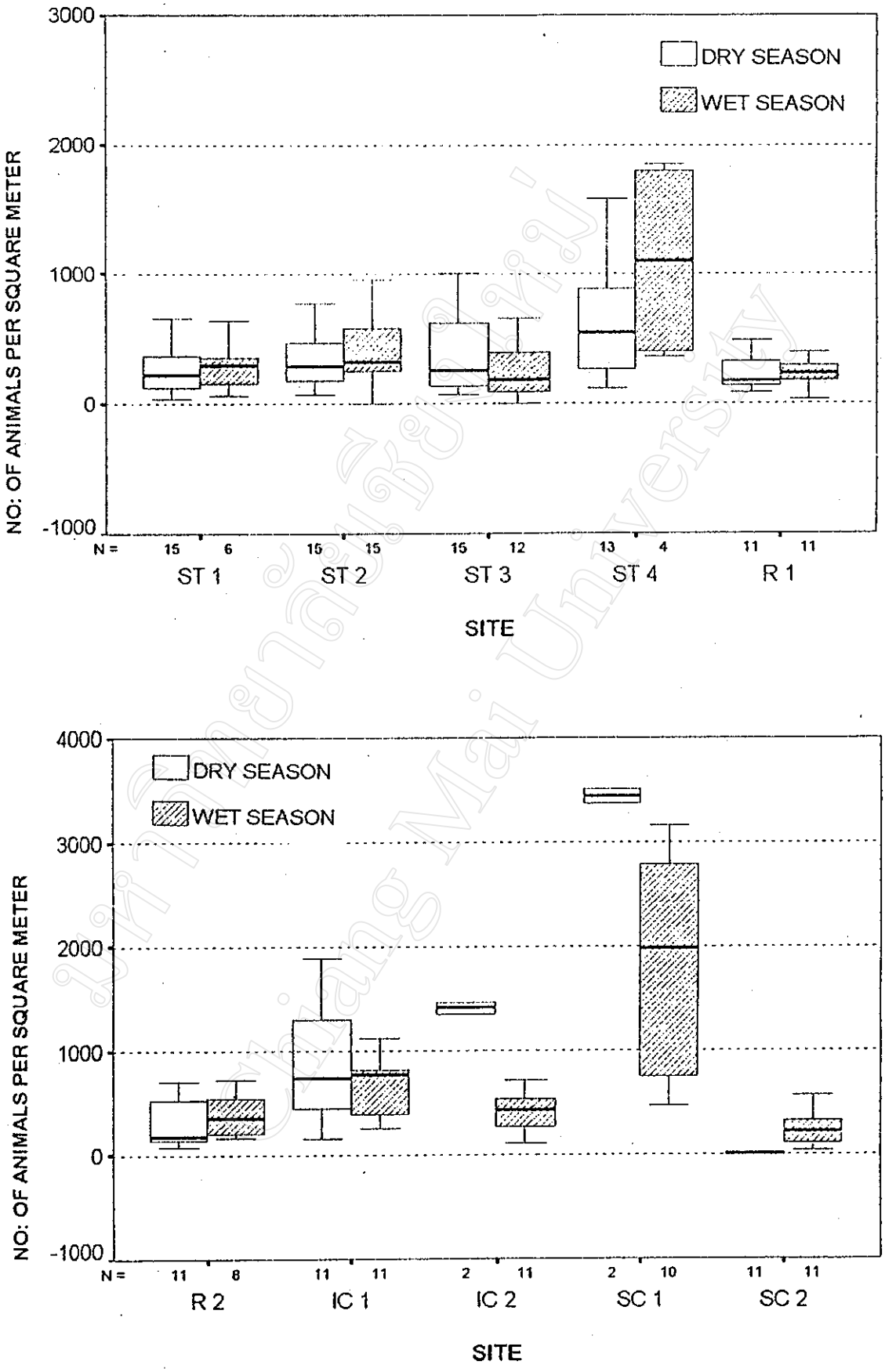


Figure 18 : Comparison of mean number of animals/m^2 in each site in both seasons (irrespective of sampling methods)

Table 11 : Mean number of families per unit sampler and 95% confidence limits recorded from study sites irrespective to sampling methods and seasons

Site	No: of families per unit sampler	95 % Confident limits
ST1	13.1 (d)	9.2 - 17.0
ST2	12.5 (d)	10.3 - 14.7
ST3	11.5 (bcd)	9.3 - 13.8
ST4	13.9 (d)	10.2 - 17.6
R1	9.4 (bc)	7.9 - 10.9
R2	11.9 (cd)	9.9 - 13.9
IC1	11.0 (bcd)	9.1 - 12.9
IC2	10.0 (bc)	7.6 - 12.4
SC1	8.3 (b)	7.2 - 9.3
SC2	1.5 (a)	0.8 - 2.2

Average 7.8, 10.1, 10.5 families per sampler colonized in multi plate, wire mesh cage and wooden box sampler. 12.5 families represent per unit conventional sampler (Figure 19).

5.8 Taxonomic composition of macroinvertebrates in ASS

The percentages of the number of animals in major taxonomic groups for each ASS in dry and wet season are shown in figures 20 and 21. In general, the orders Ephemeroptera, Diptera and, Trichoptera, and the phyla Mollucsa and Annelida represent more than 90% of the total fauna irrespective of sampling site. Ephemeroptera, Trichoptera and Diptera are the dominant orders found in WMC in the dry season. Family Baetidae is the dominant family in order Ephemeroptera and was found in all sites. Chironomids account more than 90% of the order Diptera.

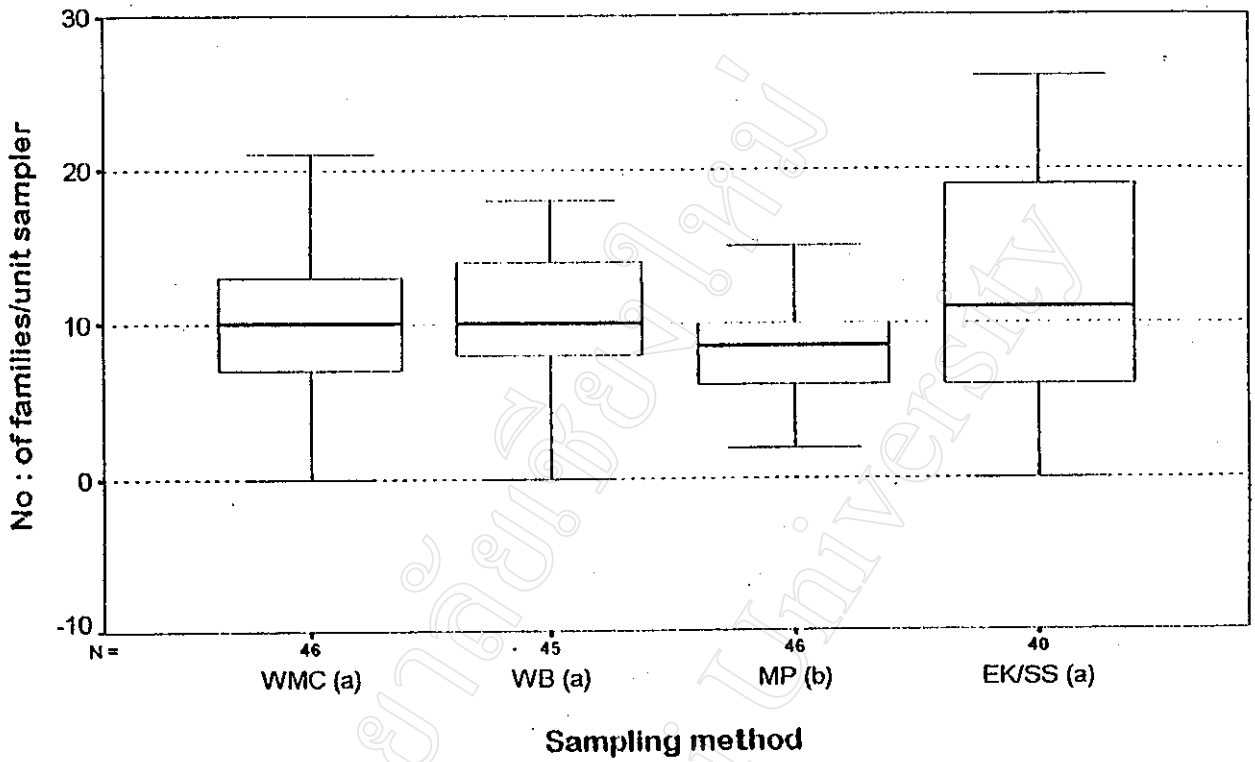
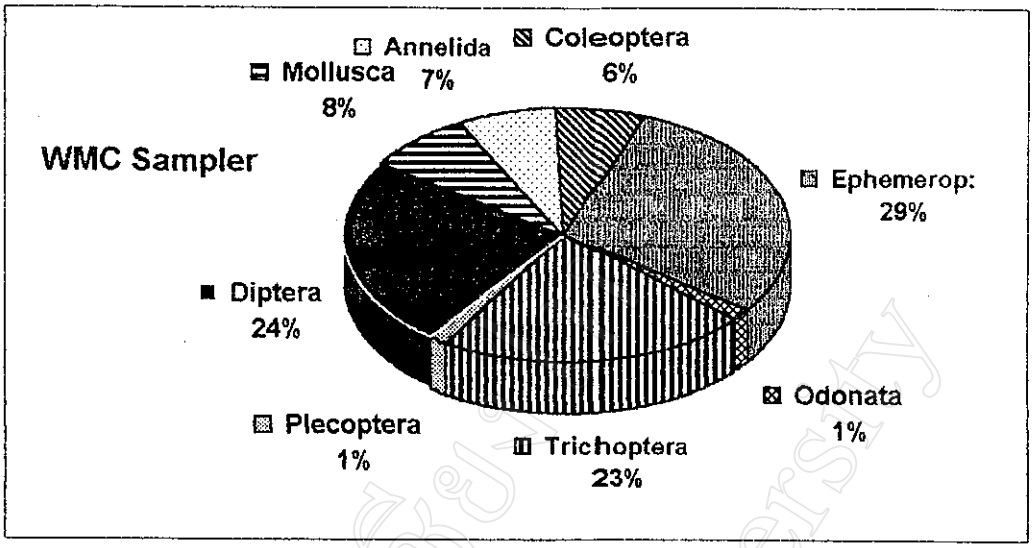
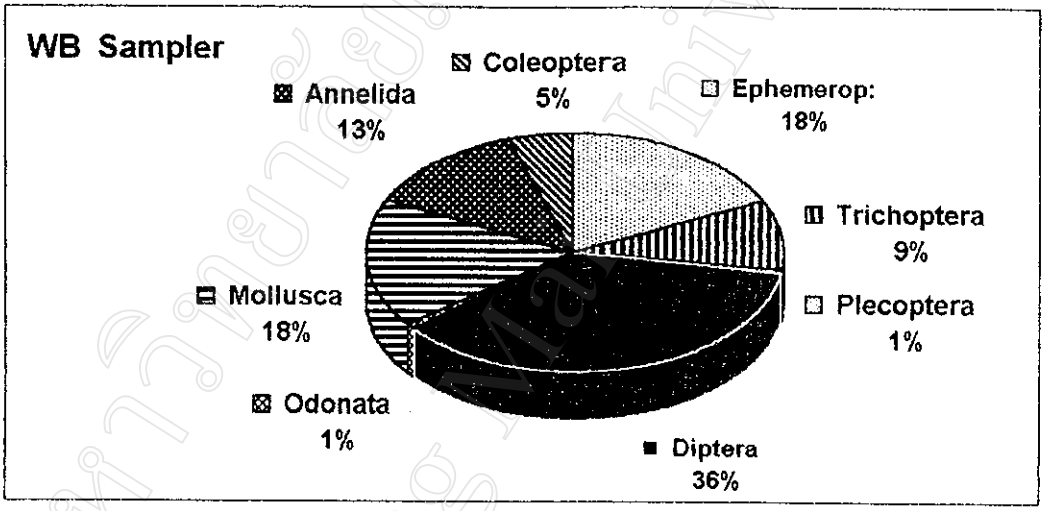


Figure 19 : Number of families (per unit sampler) colonized in sampling methods irrespective of sites and season.

compared to other Diptera families in all sampling methods (Appendix C 1 - C 6). In wet season, Annelids, Molluscs, Trichopterans and Dipterans are dominant and they contribute 90% of the total number of animals.

There is a remarkable increase in annelids and molluscs in the wet season for all sampling methods. For an example , annelids increased from 7 to 31 % from dry season to wet season in WMC sampler, and 13 to 34% in WB sampler (Figure 20 and 21). Trichopterans are dominant in WMC in both seasons. Ephemeropterans and Dipterans are more dominant in the dry season than the wet season for all ASS.





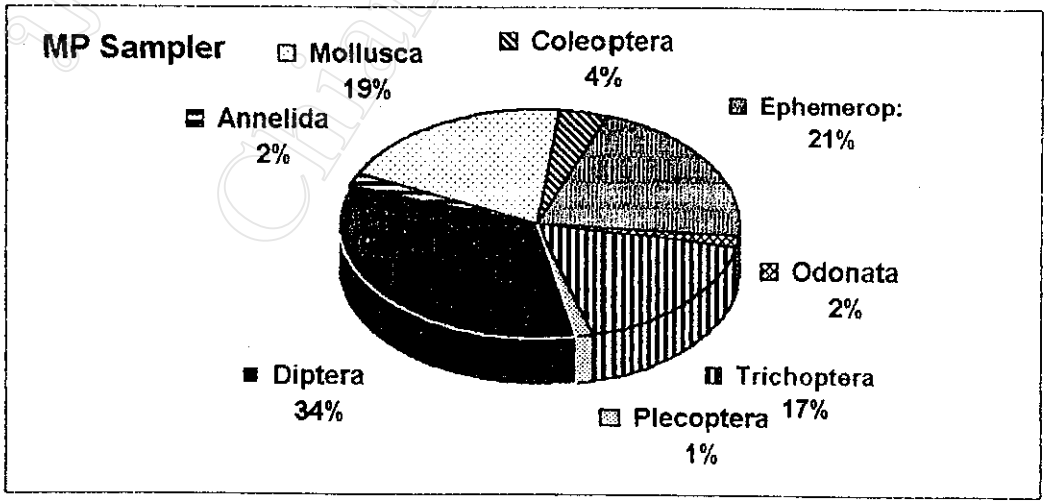


Figure 20 : Taxonomic composition of macroinvertebrates in ASS in dry season

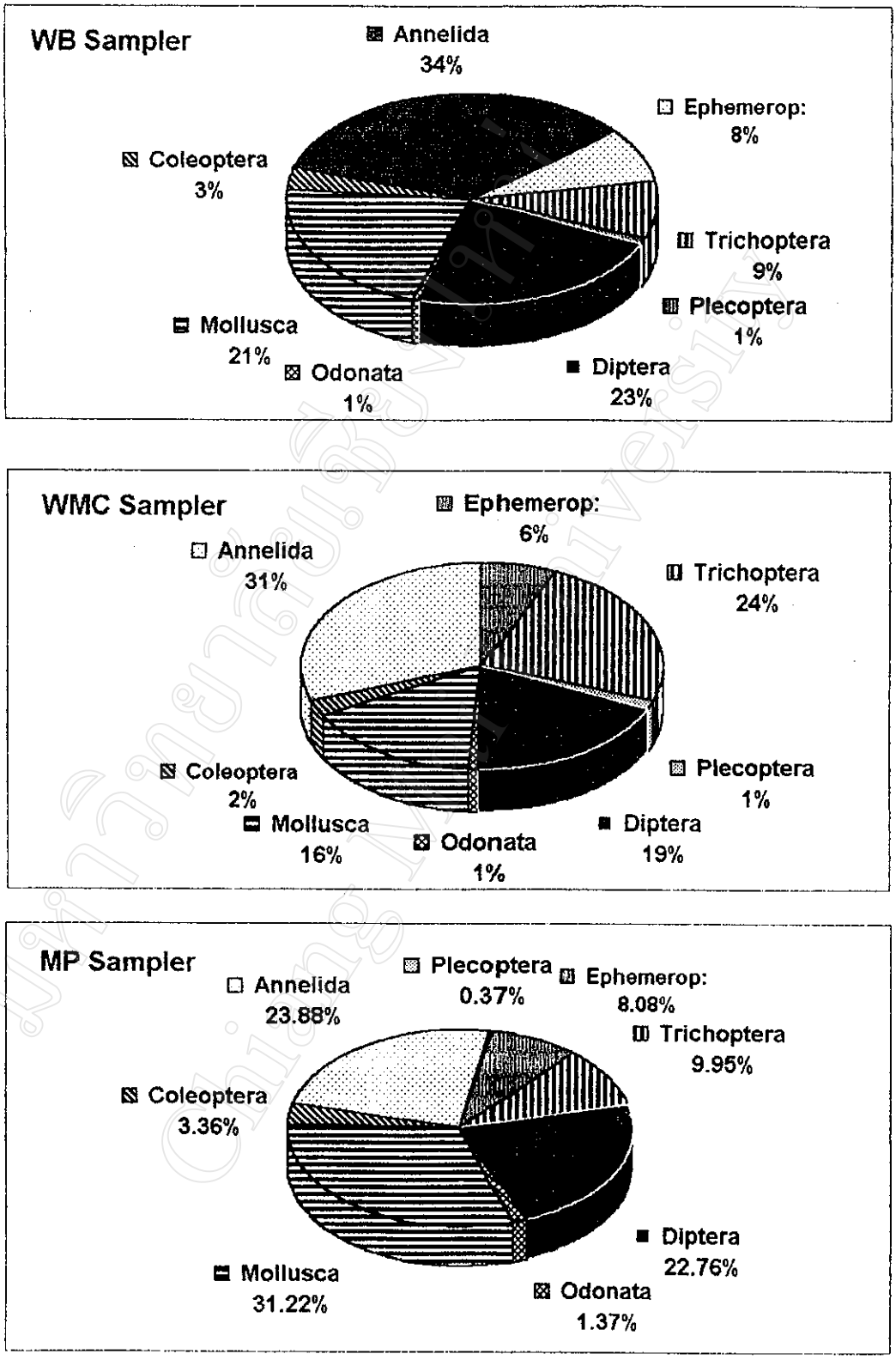


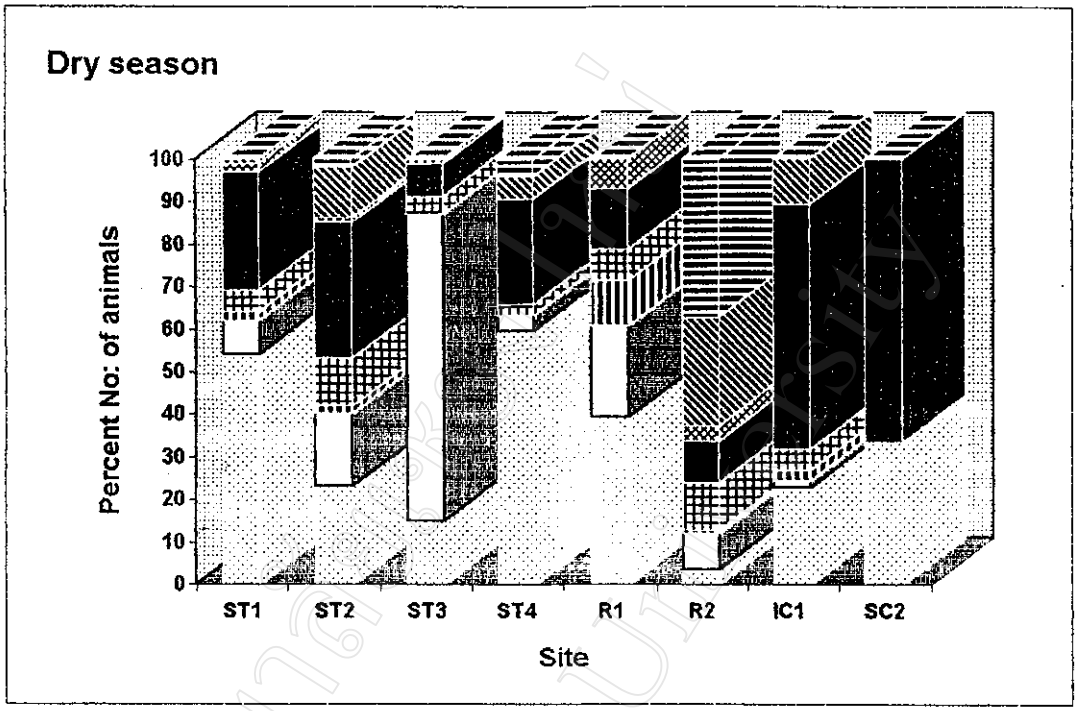
Figure 21 : Taxonomic composition of macroinvertebrates in ASS in wet season

5.9 Taxonomic composition of macroinvertebrates in ASS according to sites.

In WMC sampler Ephemeropterans, Trichopterans and Dipterans are dominant in all sites in the dry season while in the wet season Dipterans, Trichopterans, Annelids and Molluscs are highly abundant. Trichopterans are highly abundant in site ST3 in the dry season and site IC2 in the wet season than in other sites. Dipterans are more abundant in sites IC1 and SC2 than in other sites in the dry season. Annelids are highly abundant in WMC at site R2 in the dry season. The percentage of molluscs and annelids found in the wet season is higher than in the dry season in all sites except site ST 2. In the wet season Annelids are dominant at site SC1 and they account more than 80% (Figure 22).

In WB sampler, Ephemeropterans, Trichopterans, Diptereans, Molluscs and Annelids represent more than 90% of the animals in all sites in both seasons. In site ST2, Annelids colonized only in the dry season, and colonization by mollusc was higher in the dry season than the wet season. In the dry season, no animals were collected from site SC2 from the WB sampler. There is a remarkable increase of percentage of Dipterans in site IC1 in the dry season. Further, in this site Coleopterans and Trichopterans were found in the WB sampler only in the wet season (Figure 23).

Molluscs colonized MP samplers in all sites in all seasons except site ST3 in the dry season and site ST2, SC2 in the wet season. They colonized MP samplers at site R1 more than in any of sites in both seasons. In the dry season no animals were collected from SC2 site, while in the wet season, only Dipterans and Annelids were present. In site ST3 the colonization efficiency of Trichopterans was higher than in other sites, while Ephemeropterans colonized MP samplers in site ST4 more than at other sites (Figure 24). The percentage of Dipterans increased in the wet season at sites ST1, ST2 and R2. However, sites ST3 and IC1 showed the opposite. In the wet season, Odonates were found site ST4 in considerable percentage compared to other



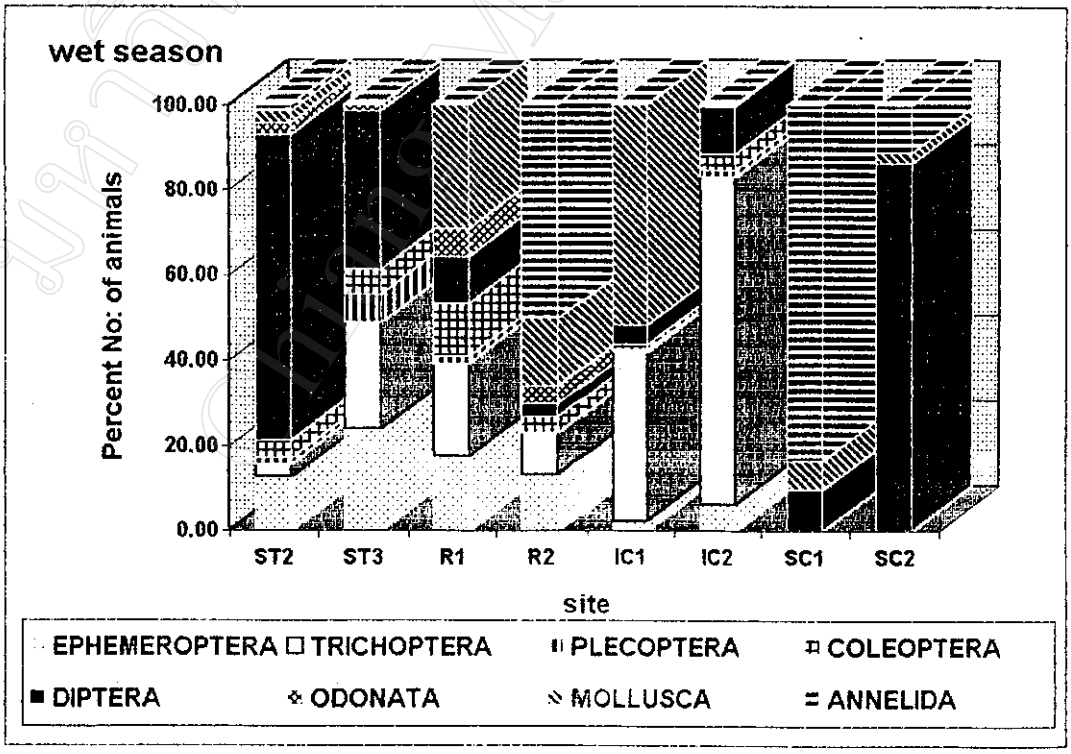
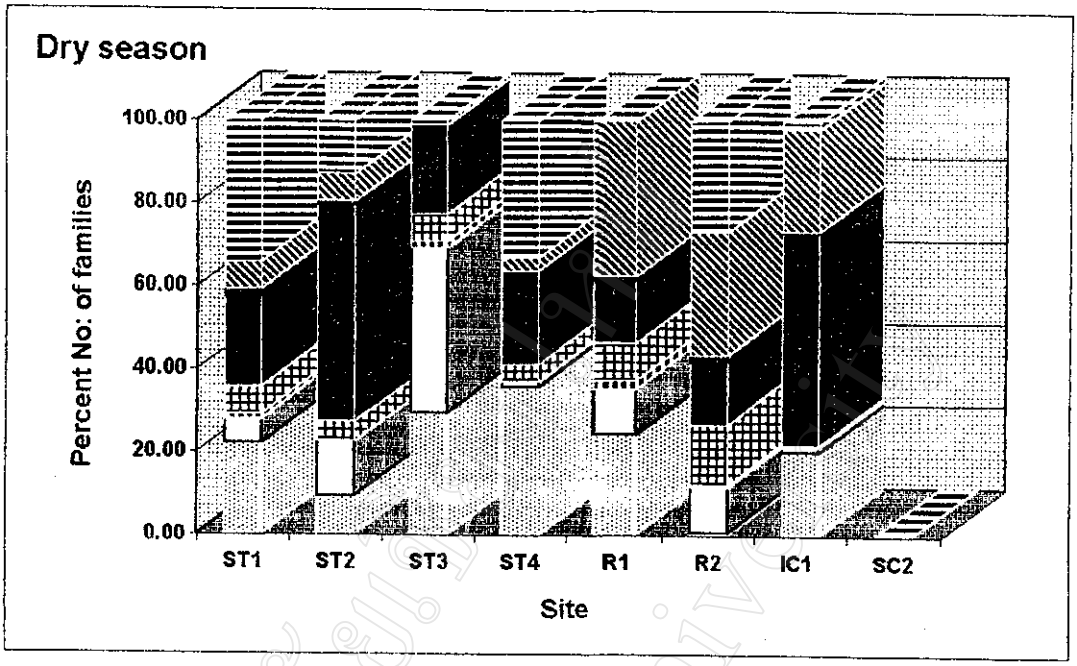


Figure 22: Taxonomic composition of macroinvertebrates in WMC sampler per site in dry and wet season



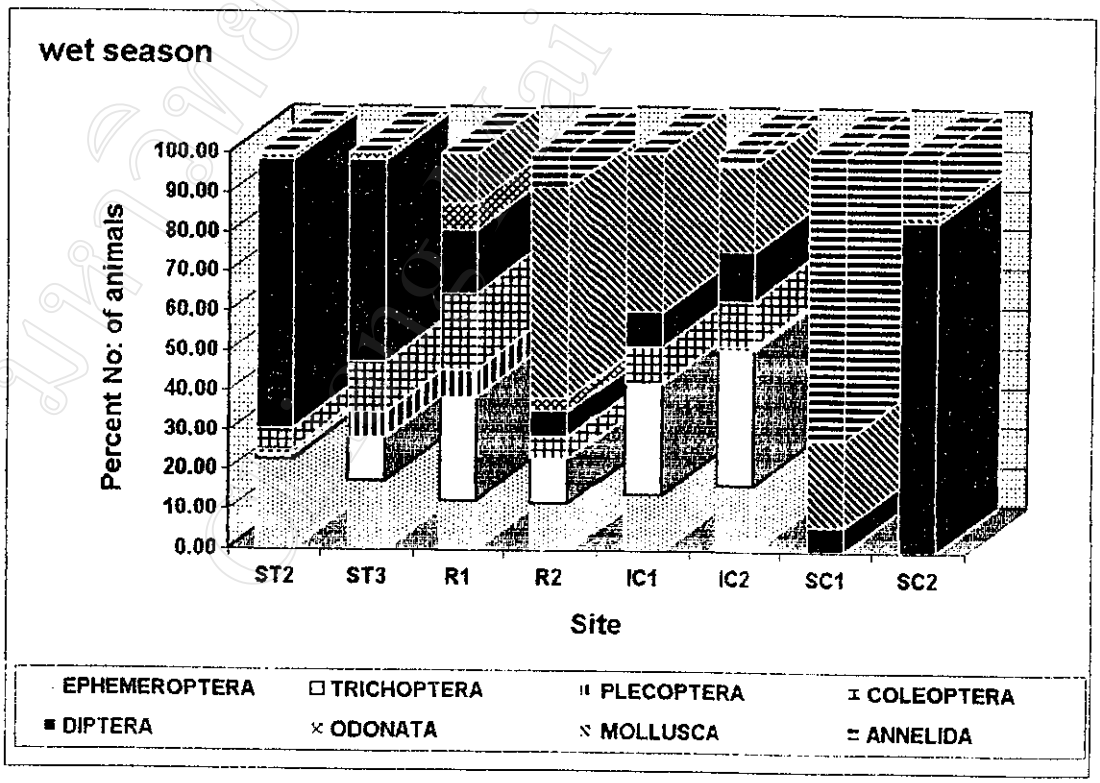


Figure 23 : Taxonomic composition of macroinvertebrates in WB sampler per site in dry and wet season

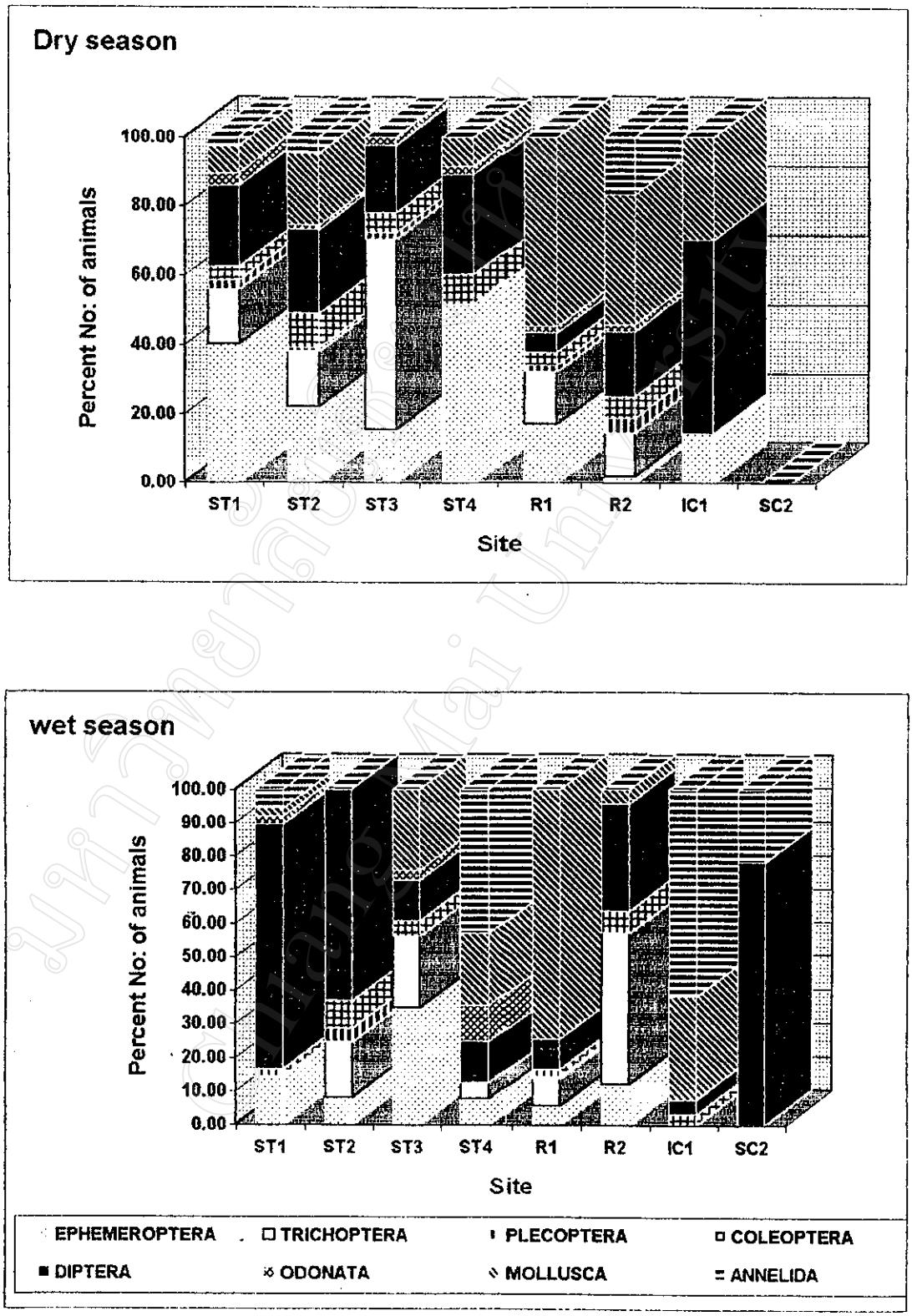


Figure 24 : Taxonomic composition of macroinvertebrates in MP sampler per site in dry and wet season

sites. The highest percentage of Annelids were found in IC1 site in the wet season compared to other sites (Figure 24).

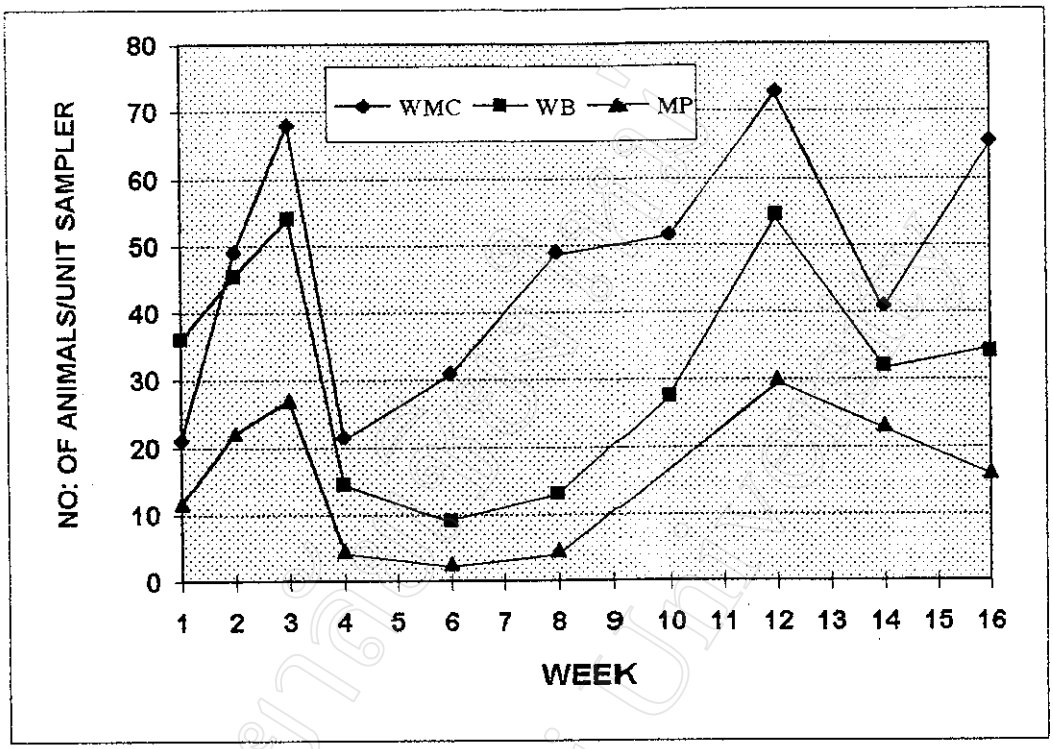
5.10 Artificial substrate preference by macroinvertebrates

Molluscs greatly prefer to colonize MP samplers than WMC and WB samplers in both seasons, while they least prefer to colonize WMC samplers (Figure 20 and 21). Trichopterans prefer to colonize WMC than other ASS, while they least prefer to colonize WB samplers. There is no specific ASS preference by Dipterans. Annelids are found in higher percentages in WB sampler than the other two samplers (Figure 20 and 21).

5.11 The Colonization sequences in ASS.

Colonization curves in ASS in terms of number of animals and families per unit sampler are shown in figure 25. For all ASS colonization gradually increased at the beginning as expected. However due to the high water level and flooding at study site R1 at the beginning of collection week four, the sequence of colonization was changed. If considered colonization is started again from collection week four, colonization rate gradually increased upto collection week eight and then declined. This pattern is followed by all ASS. For the WMC and WB samplers, colonization rate increased again from week 14 (Figure 25).

Number of families in ASS show increasing trends upto collection week 3. Due to the effect of increased water level and flooding, the number of families in all ASS declined from collection week 4 and was followed by a gradual increase upto collection week 12. If we consider recolonization started from collection week four, the maximum number of families occurred in the week 8 and after that taxa richness gradually declined in all ASS (Figure 25).



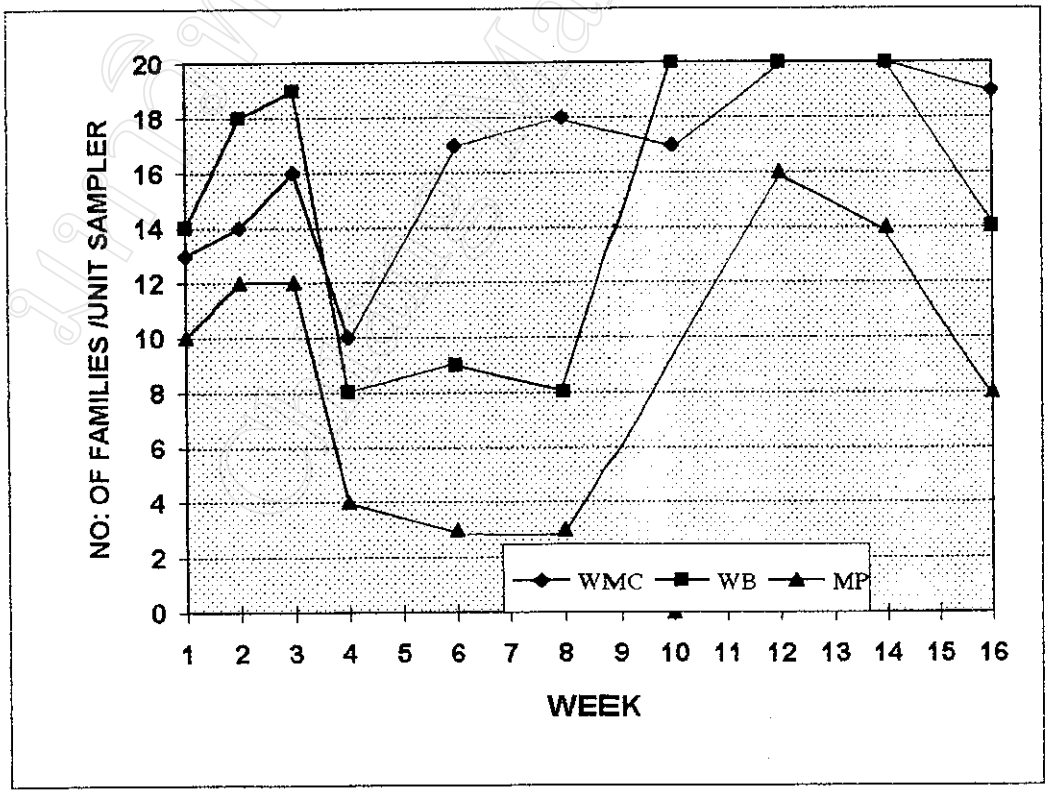


Figure 25 : Colonization sequence for ASS
Above : No: of animals/unit sampler Below : No: of families/unit sampler

Colonization sequence of replicates sample of WMC, WB, and MP are shown in figure 26, 27 and 28 respectively. If considered that a recolonization start from 4th week, one replicate of WMC sampler shows highest colonization in 7th week while other replicate sampler shows highest colonization in 4th and 8th weeks. Two replicates of WB sampler and MP sampler show highest colonization in 8th week. However, mean values of replicates of each WMC, WB, and MP sampler, show highest colonization in 8th week (Figure 25).

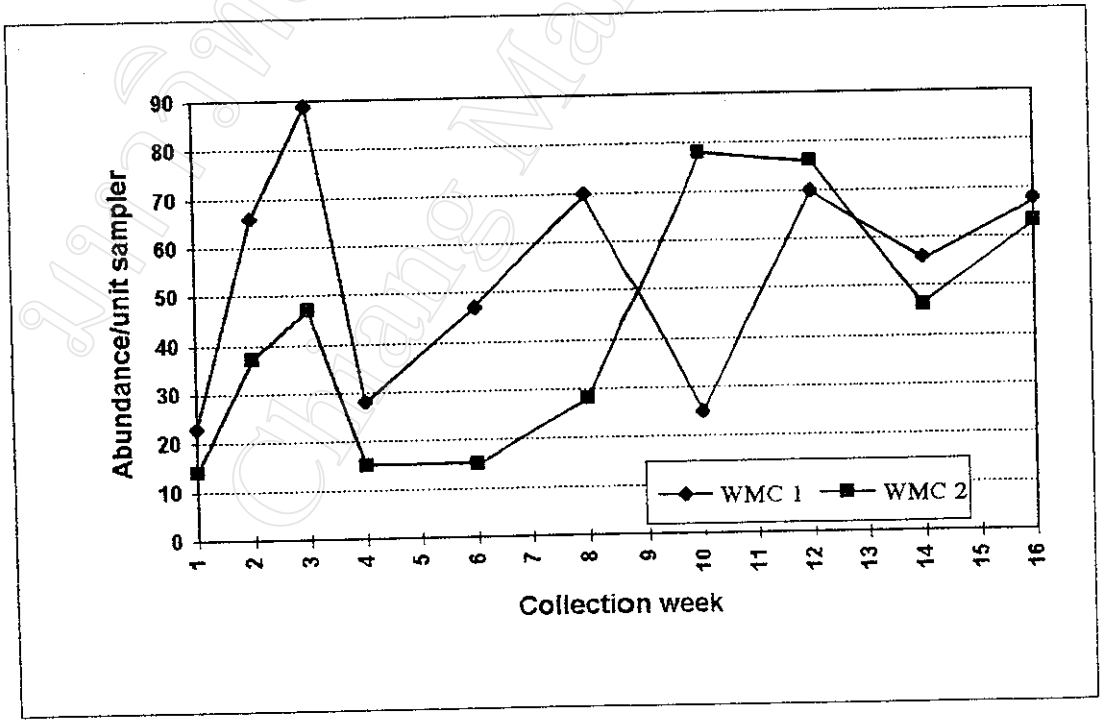


Figure 26 : Colonization sequences in replicate WMC samplers

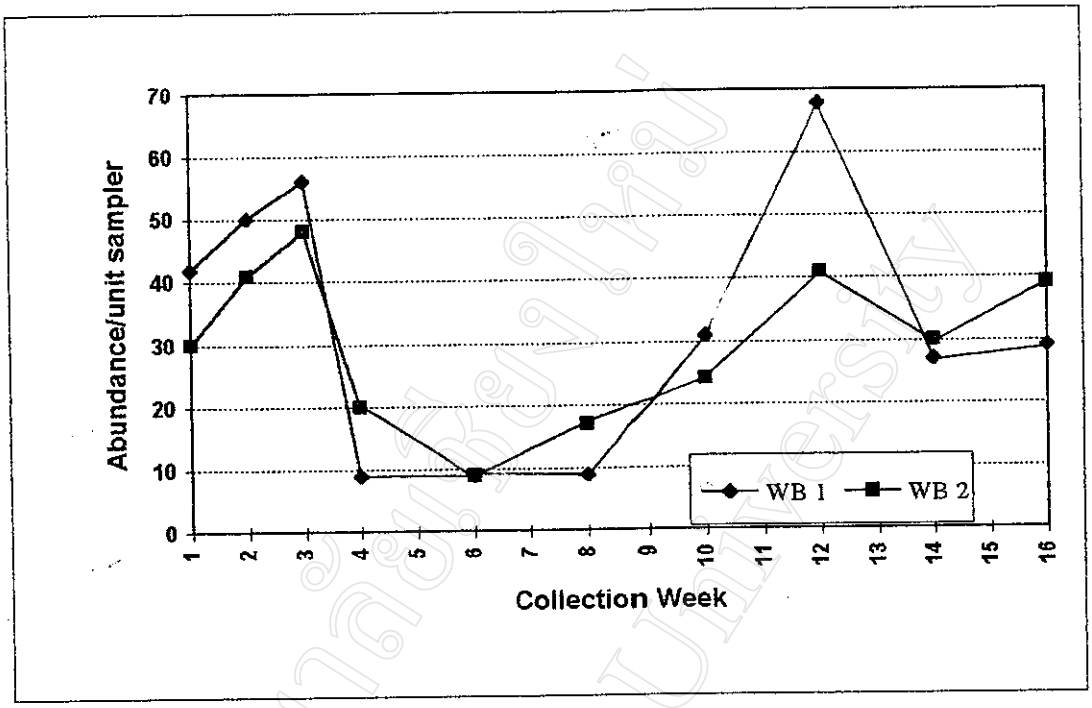


Figure 27 : Colonization sequences in replicate WB samplers

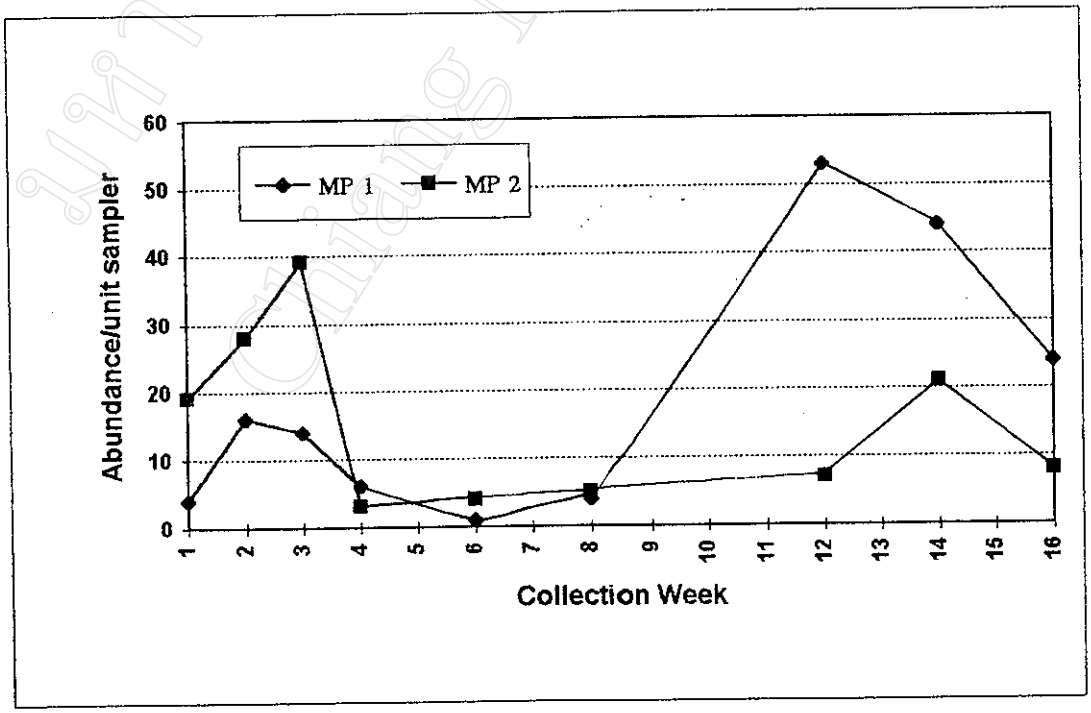


Figure 28 : Colonization sequences in replicate WB samplers

5.12 Effect of increased water level and velocity on abundance of macroinvertebrates in ASS.

Figures 29 and 30 reveal the effects of increased water level and velocity on colonization sequence of macroinvertebrates in ASS. Colonization sequence sharply declined due to the effect of increased water level and velocity in each ASS. When water level and velocity gradually come to normal, abundance gradually increased in all ASS as expected.

The families Baetidae and Elmidae occur in all collection weeks for both WMC and WB samplers (Appendix C 9 and C 10). Six new families colonized in collection week two in WMC while 4 precolonized families were lost and 8 families remained in week two. In collection week 3, families Heptageniidae, Glossosomatidae, Psephenidae and Atyidae were found as new families while 4 families were lost from previous week. The family Chironomidae was found in all collection weeks except week 4, while families Hydropsychidae was also found all collection weeks except collection week 10. Families Tharidae and Philoptomatidae occurred in every collection week except week 2 in WB sampler (Appendix C 9 and C 10).

MP sampler account low number of animals as well as families in each collection weeks compared to WMC and WB sampler. No one family continuously occur in every collection week in MP sampler (Appendix C 11).

5.13 Natural substrate preference by Macroinvertebrates.

Log n transformed data of number of animals found in three different natural substrates types from four study sites in three seasons, shows significant differences in numbers of animals found between sites, seasons and substrates types ($p < 0.05$) (Appendix D 7). Further, the least significant difference test separate sites ST1 and ST3 from site ST4. Site ST4 shows highest mean number of animals irrespective of

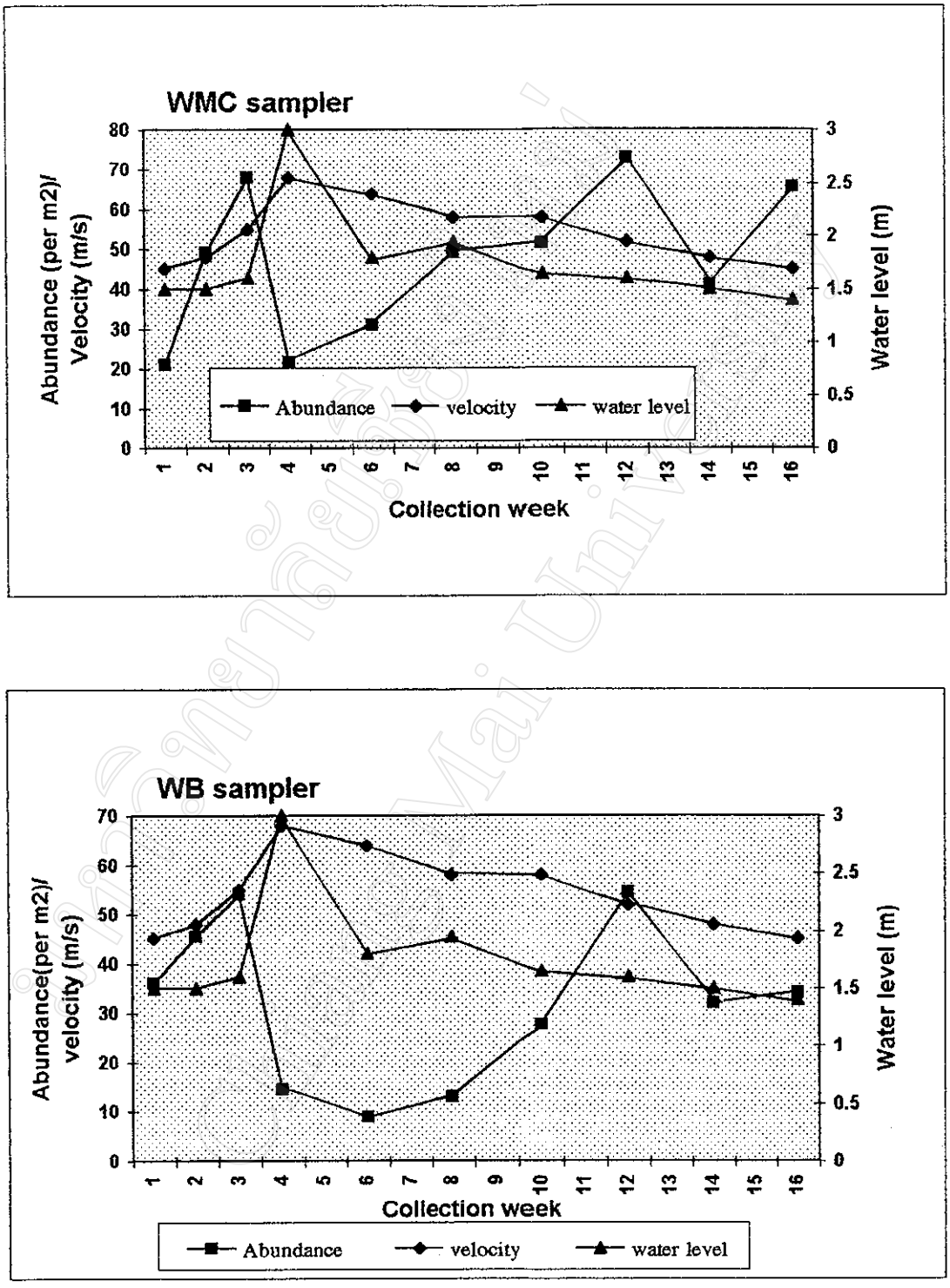


Figure 29 : Effect of water level and velocity on colonization of macroinvertebrates in WMC and WB sampler

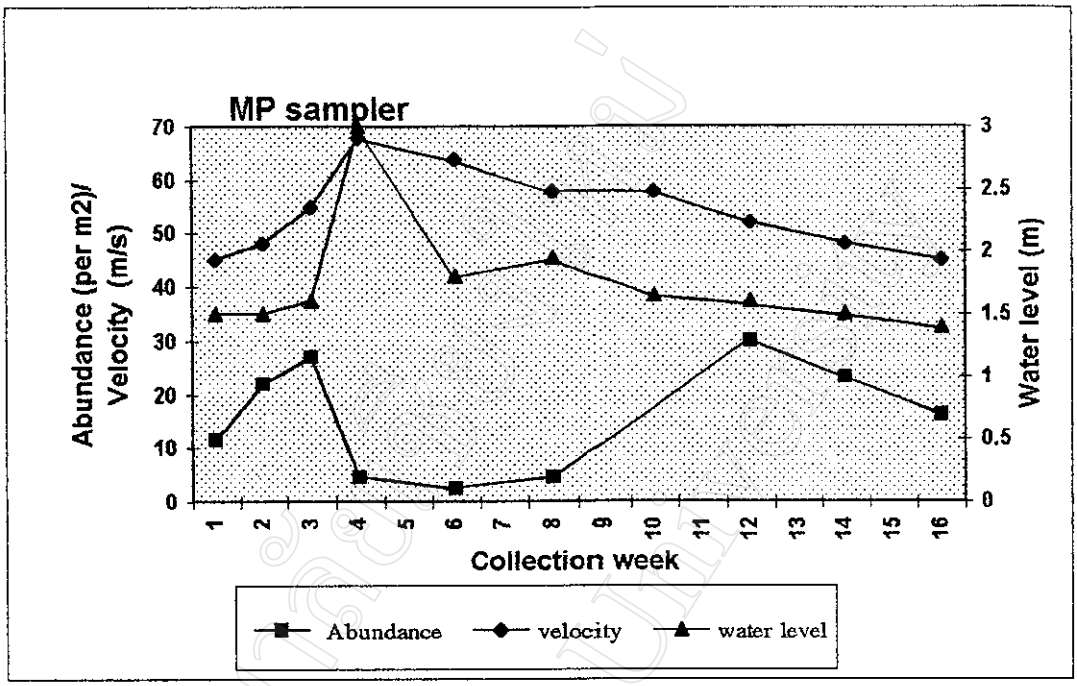


Figure 30 : Effect of water level and velocity on colonization in MP sampler

season and substrate types (108.64 per $m^2 \pm 2.07$). Site ST3 shows the lowest number of animals per m^2 (32.07 $\pm$ 3.28). The mean number of animals found in site ST4 was significantly different from site ST3 and ST 1 ($p < 0.05$) (Table 12).

Table 12: Mean number of animals /m^2 in different sites, substrates and seasons.

Site	Mean (STD)	Substrate	Mean (STD)	Season	Mean (STD)
ST1 (a)	33.83 $\pm$ 2.64	Sand (a)	29.05 $\pm$ 2.86	Dry (a)	41.30 $\pm$ 2.48
ST2 (ab)	59.95 $\pm$ 2.13	Stone (a)	42.90 $\pm$ 2.44	Wet (a)	28.13 $\pm$ 3.11
ST3 (a)	32.07 $\pm$ 3.28	Leaf litter (b)	84.28 $\pm$ 2.38	Cool (b)	92.15 $\pm$ 1.99
ST4 (b)	108.64 $\pm$ 2.07				

The highest mean number of animals was collected in the cool season (92.51 ± 1.99) while the lowest mean number of animals in the wet season (28.12 ± 3.11) irrespective of sites and substrate types. The mean number of animals collected in the cool season was significantly different from animals collected in the wet and dry seasons ($p < 0.05$).

ANOVA test reveals significant differences in mean number of animals found among different substrate types ($p < 0.05$) (Appendix D 7). The highest mean number of animals was found in leaf litter (84.28 ± 2.38) and the lowest number of animals in sand (29.05 ± 2.86). The mean numbers of animals found in sand and stony substrates were significantly different from leaf litter ($p < 0.05$) (Table 12).

5.14 Macroinvertebrates found in different substrate types and seasons according to sampling sites.

A high number of animals were found in leaf litter in each site except site ST3, which recorded the highest number of animals from stones (Figure 31). The variation in numbers of animals found in leaf litter was higher than in other substrate types. The lowest mean number of animals were recorded in sand from all sites.

5.15 Taxa richness according to substrate type and season.

Taxa richness was highest in leaf litter in all sites except site ST3 which shows highest taxa richness on stones. Taxa richness was lowest in sand in all sites (Figure 32).

In site ST1 the same mean number of animals were collected in the three seasons. However in sites ST2 and ST3 the highest number of animals were collected in cool and the lowest in the wet season. In site ST4 the highest number of animals were collected in the wet season (Figure 33).

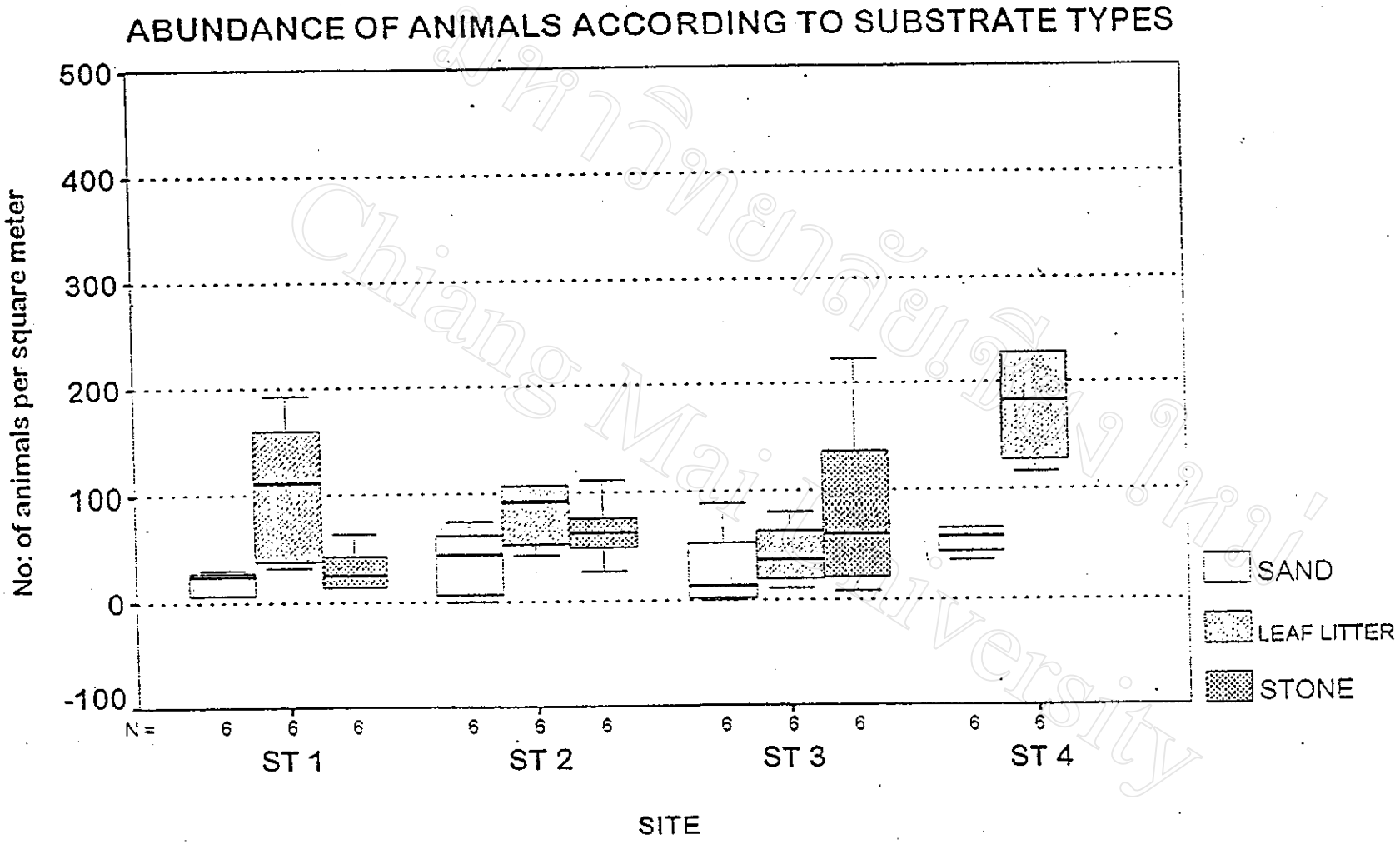


Figure 31 : Abundance of macroinvertebrates in different substrate types in study sites . Mean value, upper and lower limits of 95% CL , upper and lower limits of data.

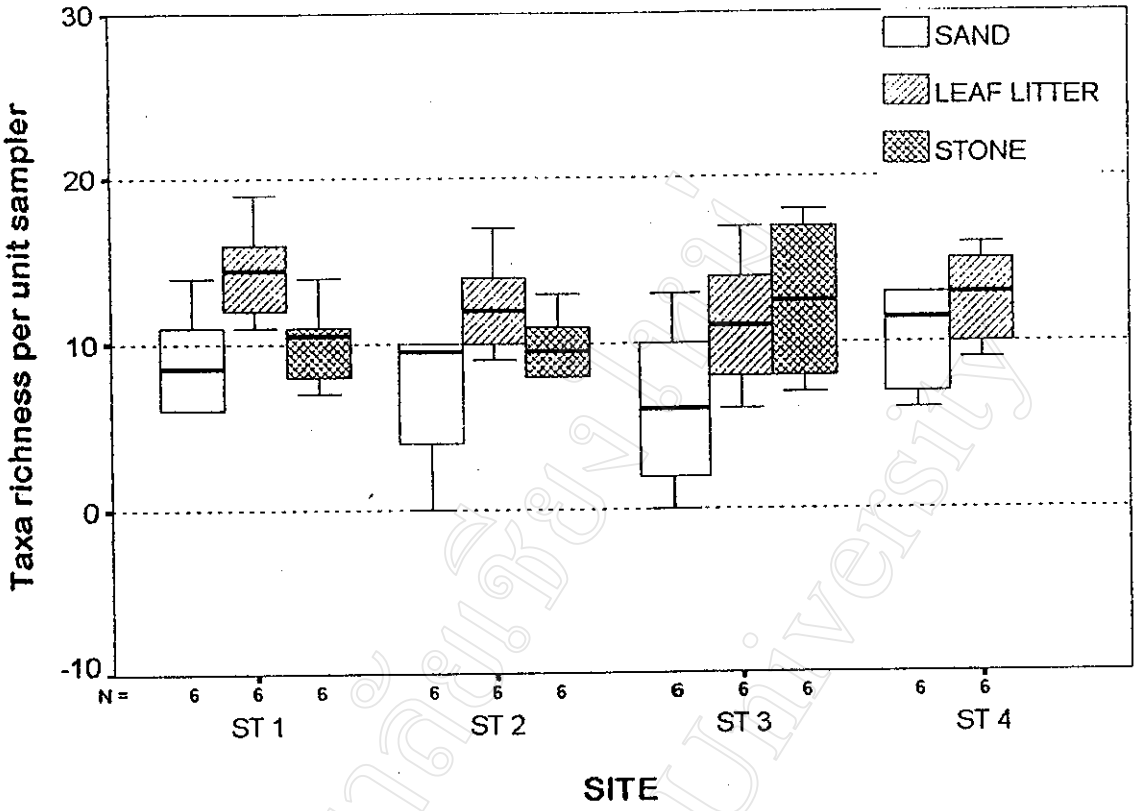


Figure 32 : Taxa richness in different substrate types

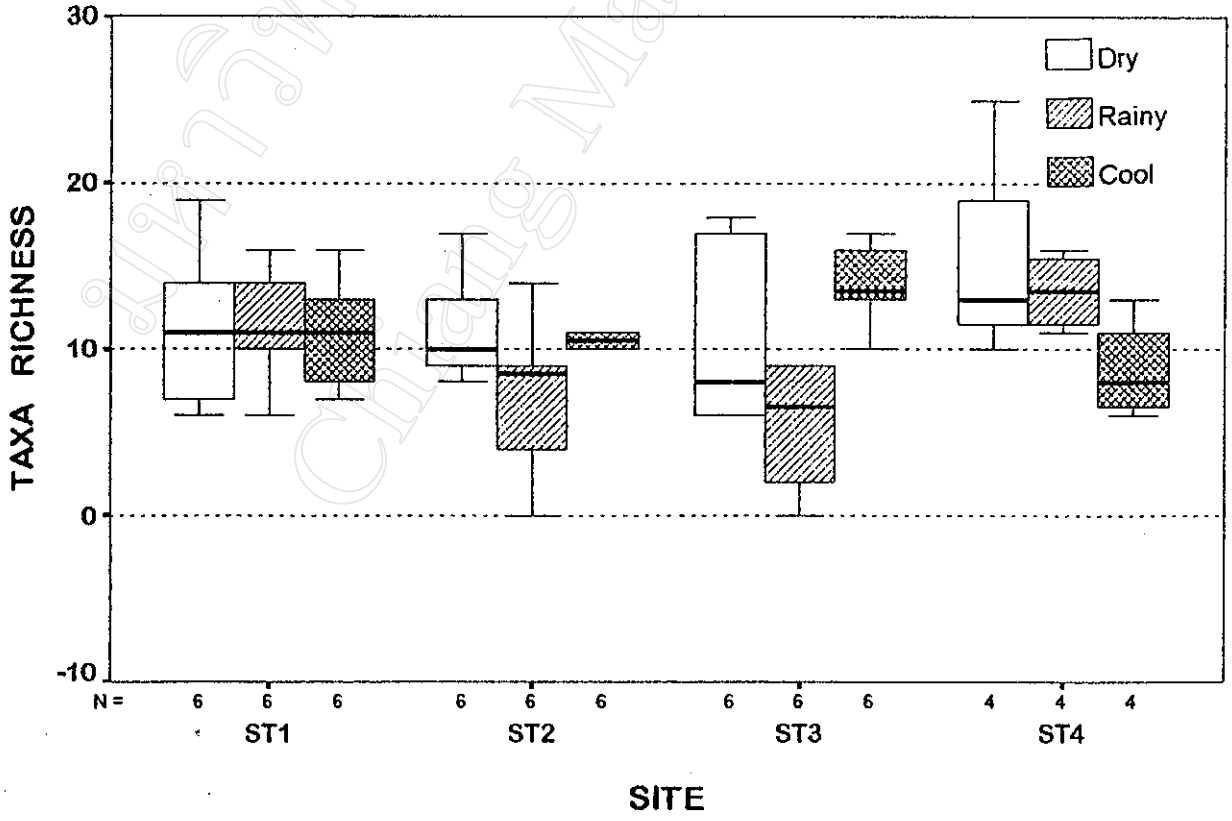


Figure 33 : Taxa richness in different seasons

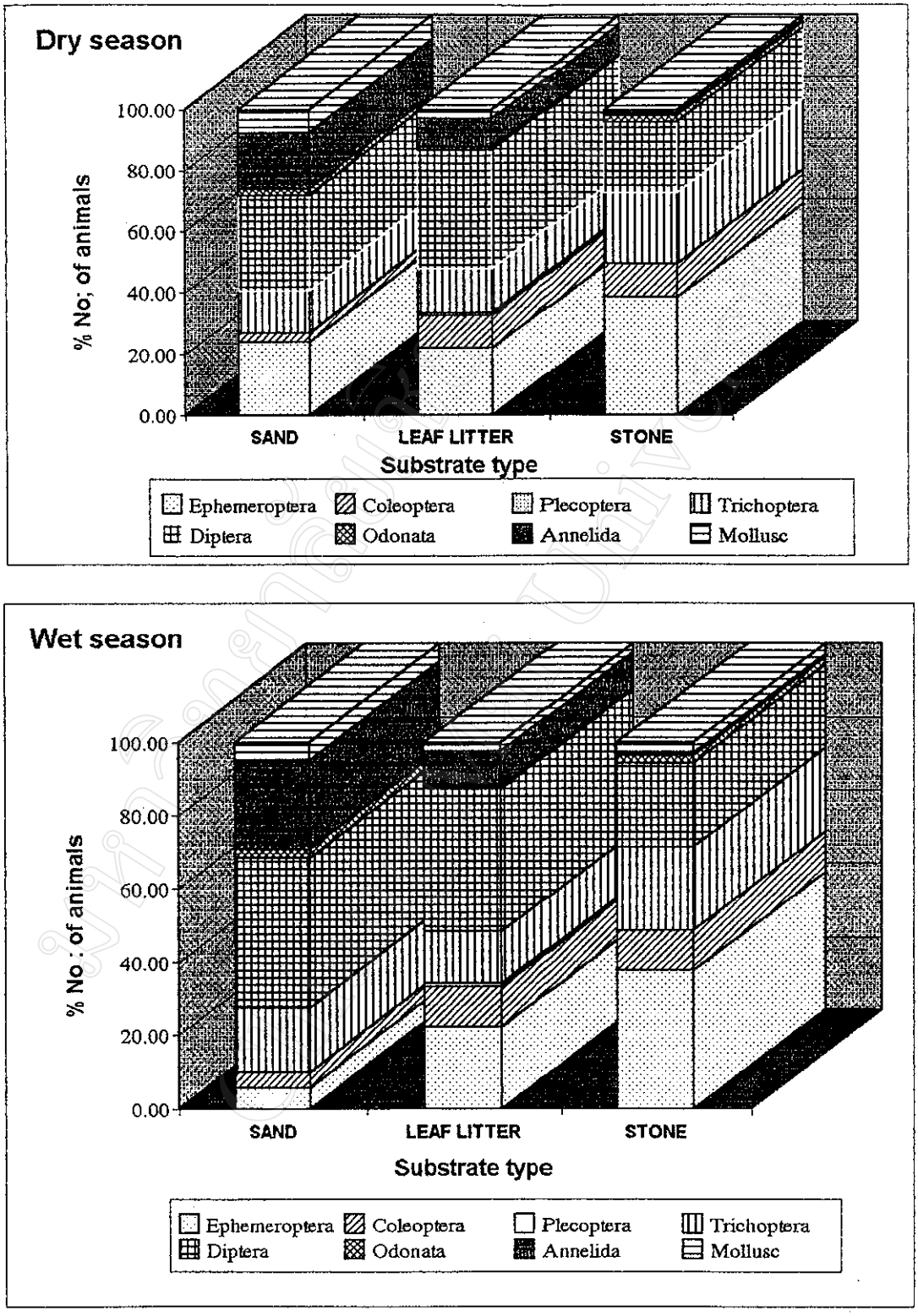


Figure 34 : Taxonomic composition of macroinvertebrates in different substrates according to seasons (all sites combined)
Above : Dry season *Below : wet season*

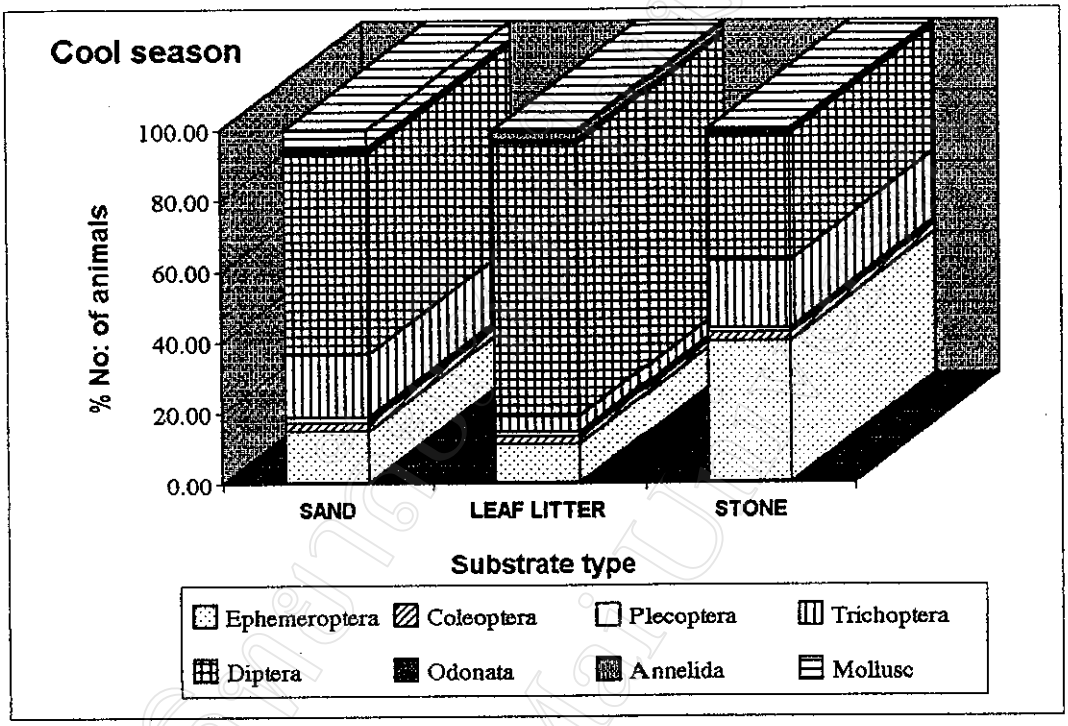


Figure 35 : Composition of macroinvertebrates in different substrates in cool season (all sites combined)

5.16 Composition of macroinvertebrates in different substrates

Substrate preferences of the main taxa in three seasons in terms of percent number of animals found are shown in figures 34 and 35. Dipterans, Trichopterans, Ephermeropterans and Coleopterans contribute more than 90 % of animals in all seasons. In the cool season, Dipterans contribute a highest percent number of animals than other taxa in sand and leaf litter. A stony substrate is equally preferred by Ephemeropterans, Trichopterans and Dipterans. In the dry and wet seasons, annelids found only in sand and leaf litter.

5.17 Evaluation of water quality using Rapid Bioassessment Protocol II (RBP II) based on macroinvertebrates found in WB sampler and conventional methods

5.17.1 Application of RBP (II) for macroinvertebrates collected from the ASS and conventional methods

Based on the ANOVA and LSD test, a high efficiency is shown by the Woodenbox sampler in terms of number of animals and taxa richness. Therefore, to apply the RBP (II) for ASS to assess water quality using macroinvertebrates WB sampler was selected. Tables 13 and 14 show the numerical values of various metrics used in RBP (II) for the wooden box sampler in the dry season and wet season respectively.

Table 13 : Results of the various metrics for the Wooden box sampler (dry season).

Metric	ST1	ST2	ST3	ST4	R1	R2	IC1	SC2
Taxa richness	20	24	21	16	18	24	16	0
BMWP	91	92	80	71	102	95	65	0
ASPT	5.68	5.71	6.15	5.07	6.80	5.27	5.42	0
FBI	5.36	5.18	3.91	5.41	2.76	4.40	5.05	0
No: of EPT family	9	9	12	6	9	7	5	0
EPT: Chironomid	1.49	2	7.28	1.73	2.52	0.85	0.44	0
% Dominant family	29.4	16.9	20.89	23.1	32.1	18.7	48.48	0
Community loss	0.45	0.42	REF	0.82	0.67	0.5	0.81	0
Sorensen's similarity	0.58	0.48	REF	0.43	0.46	0.40	0.43	0
Jaccard's similarity	0.41	0.32	REF	0.28	0.30	0.25	0.28	0

Table 14 : Results of the various metrics for the Wooden box sampler (wet season).

Metric	ST2	ST3	R1	R2	IC1	IC2	SC1	SC2
Taxa richness	17	16	18	18	18	23	11	4
BMWP	55	68	85	57	62	100	23	6
ASPT	5.5	5.7	6.5	4.8	5.6	5.8	2.9	2
FBI	6.21	5.13	3.35	2.28	3.18	3.79	6.58	7.46
No: of EPT family	7	6	8	6	8	10	0	0
EPT: Chironomid	0.36	0.68	2.97	3.7	6.61	5.34	0	0
% Dominant family	62.90	40.06	15.12	25.2	31.56	24.77	54.16	78.81
Community loss	0.47	REF	0.5	0.6	0.5	0.3	1.36	
Sorensen's similarity	0.48	REF	0.41	0.29	0.41	0.46	0.07	0.1
Jaccard's similarity	0.32	REF	0.26	0.17	0.26	0.3	0.04	0.05

Taxa richness is highest in site R2 in the dry season and site IC2 in the wet season. Site R1 recorded the highest ASPT score in both seasons and site IC2 recorded the highest BMWP in the wet season. The highest FBI score was registered by site SC2 in the wet season and site ST1 in the dry season. The ratio of the abundance of Ephemeroptera, Trichoptera, Plecoptera to Chironomids was highest in site ST3 in the dry season and in the wet season site IC 1 compared to other sites. Scores of percent dominant family were highest in site IC1 in the dry season, and site SC2 in the wet season. Site ST1 shows close similarity to the reference site (ST3). Site SC2 shows the lowest scores for all indices in the dry season (Table 13 and 14).

Tables 15 and 16 shows calculated scores for macroinvertebrates collected by conventional methods in dry and wet seasons respectively.

Table 15 : Results of the various metrics for the conventional methods (dry season).

Metric	ST1	ST2	ST3	ST4	R1	R2	IC1	IC2	SC1	SC2
Taxa richness	20	31	29	30	17	17	10	14	8	0
BMWP	81	154	109	97	65	59	36	64	14	0
ASPT	6.20	6.70	5.74	5.39	5.41	4.91	5.14	5.82	2.30	0
FBI	4.71	4.87	4.0	5.44	3.13	4.04	2.57	0.93	7.17	0
No: of EPT family	9	16	11	7	7	5	2	4	0	0
EPT: Chironomids	1.32	3.17	3.97	0.83	6.14	0.41	0.17	1.56	0	0
% Dominant family	22.2	15.4	19.3	34.4	18.2	22.8	28.1	45.6	55.2	0
Community loss	0.8	0.35	REF	0.53	0.94	1.06	2.20	1.62	3.13	0
Sorensen's similarity	0.53	0.6	REF	0.46	0.57	0.48	0.29	0.38	0.22	0
Jacard's ,,	0.39	0.42	REF	0.28	0.38	0.31	0.20	0.23	0.14	0

Note : Surber sampler used in sites ST1,ST2,ST3, ST4 and Ekman grab sampler used in remaining sites.

Table 16 : Results of the various metrics for the conventional methods (wet season).

Metric	ST1	ST2	ST3	ST4	R1	R2	IC1	IC2	SC1	SC2
Taxa richness	34	15	18	22	10	11	12	8	9	4
BMWP	117	45	75	77	31	19	34	31	25	6
ASPT	5.3	5.1	5	5.5	5.17	3.17	4.85	6.2	3.57	2
FBI	4.26	4.69	3.92	6.53	1.44	2.87	0.59	1.34	4.32	6.91
No: of EPT family	9	7	6	8	2	1	3	2	0	0
EPT: Chironomids	2.62	6.47	4.80	0.16	2.50	0.33	2	0	0	0
% Dominant family	30.2	61.1	27.5	57.5	18.7	28.9	41.9	25.0	43.9	77.5
Community loss	0.09	0.47	REF	0.41	1.60	1.36	1.08	1.87	6.78	4.00
Sorensen's similarity	0.58	0.67	REF	0.45	0.14	0.21	0.33	0.23	0.15	0.18
Jacard's ,,	0.4	0.5	REF	0.29	0.08	0.12	00.2	0.13	0.08	0.1

Taxon richness was highest in site ST2 in the dry season and in site ST1 in the wet season. In the dry season the highest BMWP score and ASPT score were showed by site ST2. In wet season these scores highest in site ST1 and IC2 respectively. The highest FBI score was recorded by Site SC1 in the dry season and site SC2 in the wet season. The number of EPT families were highest in site ST2 in the dry season and site ST1 in the wet season. The ratio of individuals of Ephemeroptea, Trichoptera and Plecoptera orders to Chironomids was highest in site R1 in the dry season and ST2 site in the wet season. Both similarity indices are highest in site ST2 in both seasons.

Water quality scores for WB sampler in dry and wet seasons are shown in tables 17 and 18 respectively.

Table 17 :Water quality scores for the Wooden box sampler (dry season).

Metric	ST1	ST2	ST3	ST4	R1	R2	IC1	SC2
Taxa richness	6	6	6	4	6	6	4	0
BMWP	6	6	6	6	6	6	6	0
ASPT	6	6	6	4	6	4	4	0
FBI	4	4	6	4	6	6	4	0
No: of EPT families	2	2	6	0	2	0	0	0
EPT: Chironomid	0	2	6	0	2	0	0	0
% Dominant	6	6	6	6	4	6	0	0
Community loss	6	6	6	4	4	4	4	0
Total point Scores	36	38	48	28	36	32	22	0
% refer to refere: site	75.0	79.2	100	58.3	75.0	66.7	45.8	0.0
Water quality	S	N-S	N	S	S	S	M	SV

Table 18 :Water quality scores for the Wooden box sampler (wet season).

Metric	ST2	ST3	R1	R2	IC1	IC2	SC1	SC2
Taxa richness	6	6	6	6	6	6	0	0
BMWP	6	6	6	6	6	6	2	0
ASPT	6	6	6	4	6	6	0	0
FBI	4	6	6	6	6	6	4	2
No: of EPT families	6	6	6	6	6	6	0	0
EPT: Chironomid	4	6	6	6	6	6	0	0
% Dominant family	0	2	6	4	4	4	0	0
Community loss	6	6	6	4	6	6	0	0
Total point Scores	38	44	48	42	46	46	10	6
% refer to refere: site	86.4	100	109.1	95.4	104.5	104.5	22.7	13.6
Water quality	N	N	N	N	N	N	M	SV

Note : N : Non impaired S : Slightly impaired

M : Moderately impaired SV :Severely impaired

Based on water quality scores in the dry season, site ST3 can be classified as non-impaired site while site ST 2 as non to slightly impaired site. Sites ST1, ST4, R1, and R2 are classified as slightly impaired sites. Site IC1 shows a moderately impaired situation, and site SC2 shows a severely impaired condition. In the wet season most of the sites show improved conditions. All sites except sites SC1 and SC2 can be classified as non impaired conditions. Site SC1 shows a moderately impaired condition and site SC2 shows a severely impaired condition.

Tables 19 and 20 show the water quality of study sites calculated by the samples taken from conventional methods.

Table 19 :Water quality scores for the conventional methods (dry season).

Metric	ST1	ST2	ST3	ST4	R1	R2	IC1	IC2	SC1	SC2
Taxa richness	4	6	6	6	2	2	0	2	0	0
BMWP	4	6	6	6	4	4	2	4	0	0
ASPT	6	6	6	6	6	4	4	6	0	0
FBI	4	4	6	4	6	6	6	6	0	0
No: of EPT families	4	6	6	0	0	0	0	0	0	0
EPT: Chironomids	2	6	6	0	6	0	0	2	0	0
% Dominant family	6	6	6	4	6	6	6	2	0	0
Community loss	6	6	6	2	6	4	4	0	0	0
Total point Scores	36	46	48	28	36	26	22	22	0	0
% refer to reff : site	75.0	95.8	100	58.3	75.0	54.2	45.8	45.8	0.0	0.0
Water quality	S	N	N	S	S	S	M	M	SV	SV

Table 20 : Water quality scores for the conventional methods (wet season).

Metric	ST1	ST2	ST3	ST4	R1	R2	IC1	IC2	SC1	SC2
Taxa richness	6	6	6	6	6	4	4	4	4	0
BMWP	6	4	6	6	2	2	2	2	2	0
ASPT	6	6	6	6	6	0	6	6	2	0
FBI	6	4	6	2	6	6	6	6	6	2
No: of EPT family	6	6	6	6	0	0	0	0	0	0
EPT: Chironomids	4	6	6	0	4	0	2	0	0	0
% Dominant family	2	0	4	0	6	4	0	4	0	0
Community loss	6	6	6	6	2	4	4	2	0	0
Total point Scores	42	38	46	32	38	20	24	24	14	2
% refer to ref : site	91.3	82.6	100	69.6	82.6	43.5	52.2	52.2	30.4	4.4
Water quality	N	N	N	S	S	M	S	S	M	SV

Note : N : Non impaired S : Slightly impaired

M : Moderately impaired SV : Severely impaired

In the dry season, sites ST2 and ST3 show non impaired condition and sites ST1, ST4, R1, R2, show a slightly impaired condition. Sites IC1 and IC2 are moderately impaired, and sites SC1 and SC2 severely impaired in the dry season. The water quality in study sites assessed by conventional methods gives somewhat different results from the WB sampler in the wet season . Sites ST1, ST2 and ST3 show non impaired condition in the wet season. Sites ST4, R1, IC1 and IC2 are slightly impaired. Site R2 and site SC1 show a moderately impaired condition and site SC2 shows severely impaired condition.

The results of water quality from the WB sampler and conventional methods are the same in the dry season but in the wet season the results from the two methods show different impairment in some sites.

5.18 Clustering of macroinvertebrates families found in WB sampler and conventional methods.

Figure 36-39 show, dendrograms using similarity index of macroinvertebrates found in WB sampler and conventional methods in both seasons. Squared Euclidean method was used to calculate similarity among families. Samples of WB sampler in dry season, formed five broad groups. In most of the groups, pollutant tolerant families clustered together (Figure 36). Dendrogram of the WB sampler in wet season, indicated that highly pollutant tolerant families such as Naididae, Tubificidae, Lumbricidae etc.. formed a separate group in it's lower part and family Ephydridae completely separated from other families (Figure 37) .

Dendrogram of the families representing conventional methods in dry season is shown in figure 38. Some of the pollutant tolerant families clustered together and family chironomidae completely separated from rest of the families. Similarities between families were also found in conventional methods in wet season as shown in

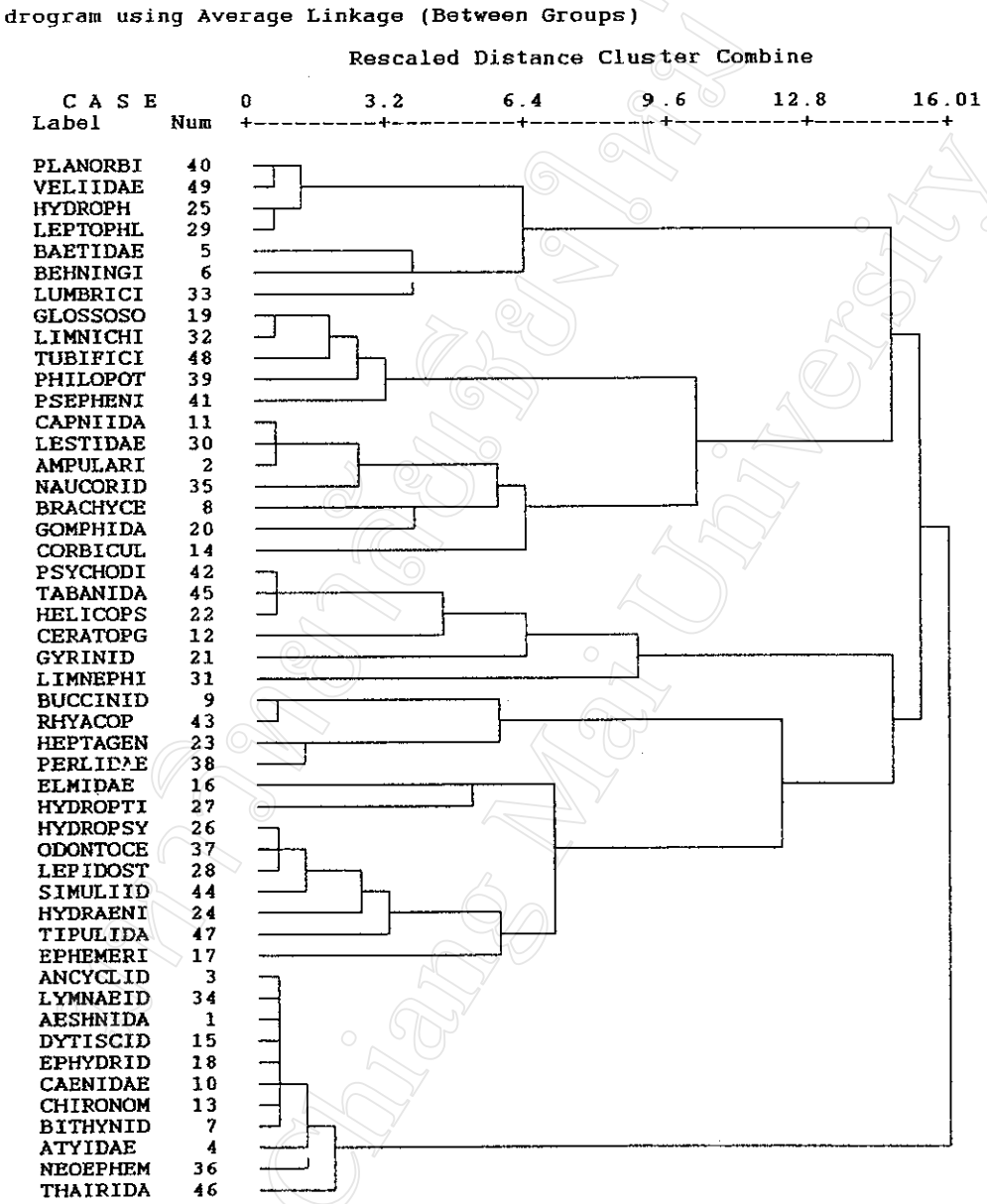


Figure 36: Clustering of macroinvertebrates families found in WB sampler - dry season

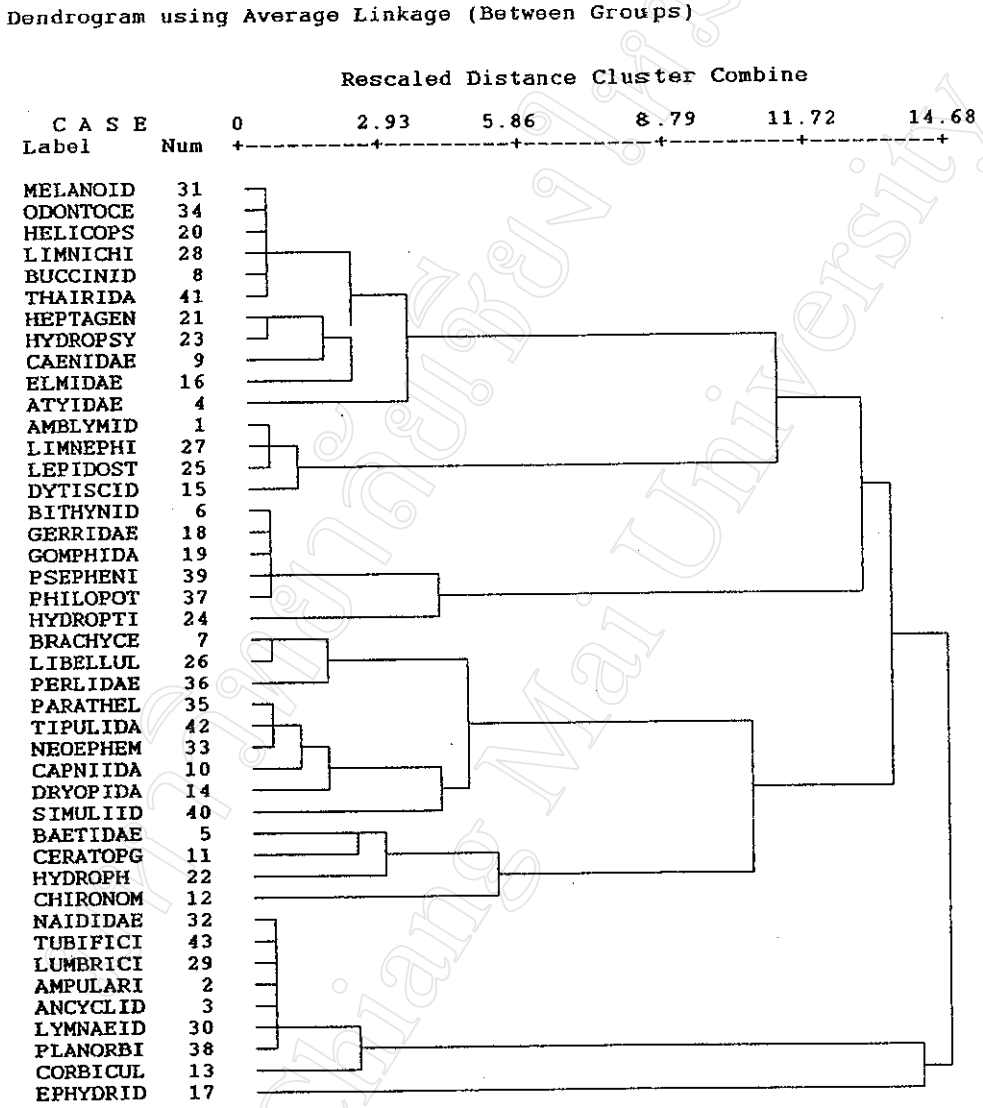


Figure 37: Clustering of macroinvertebrates families found in WB sampler - wet season

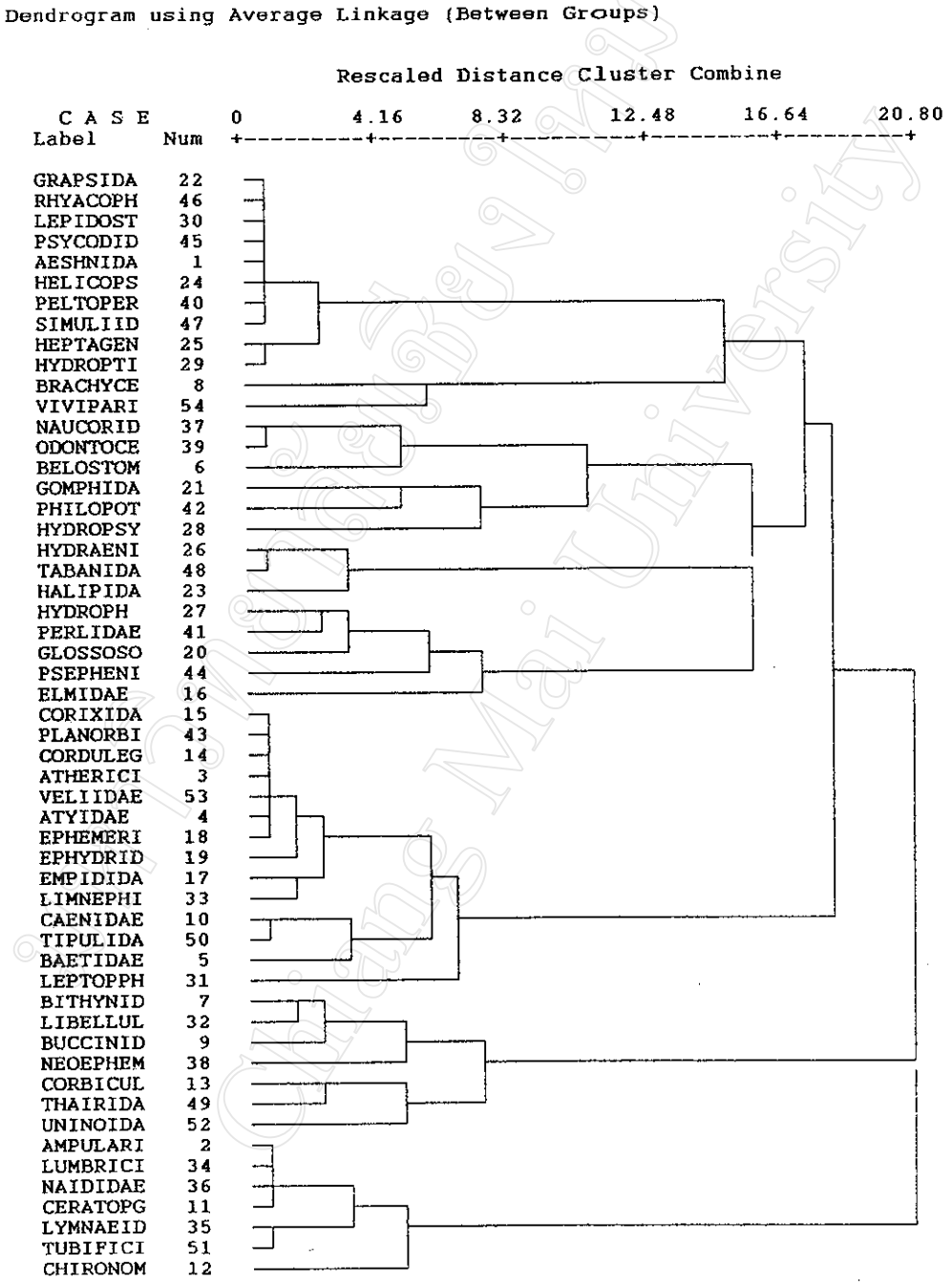


Figure 38: Clustering of macroinvertebrates families found in conventional methods - dry season

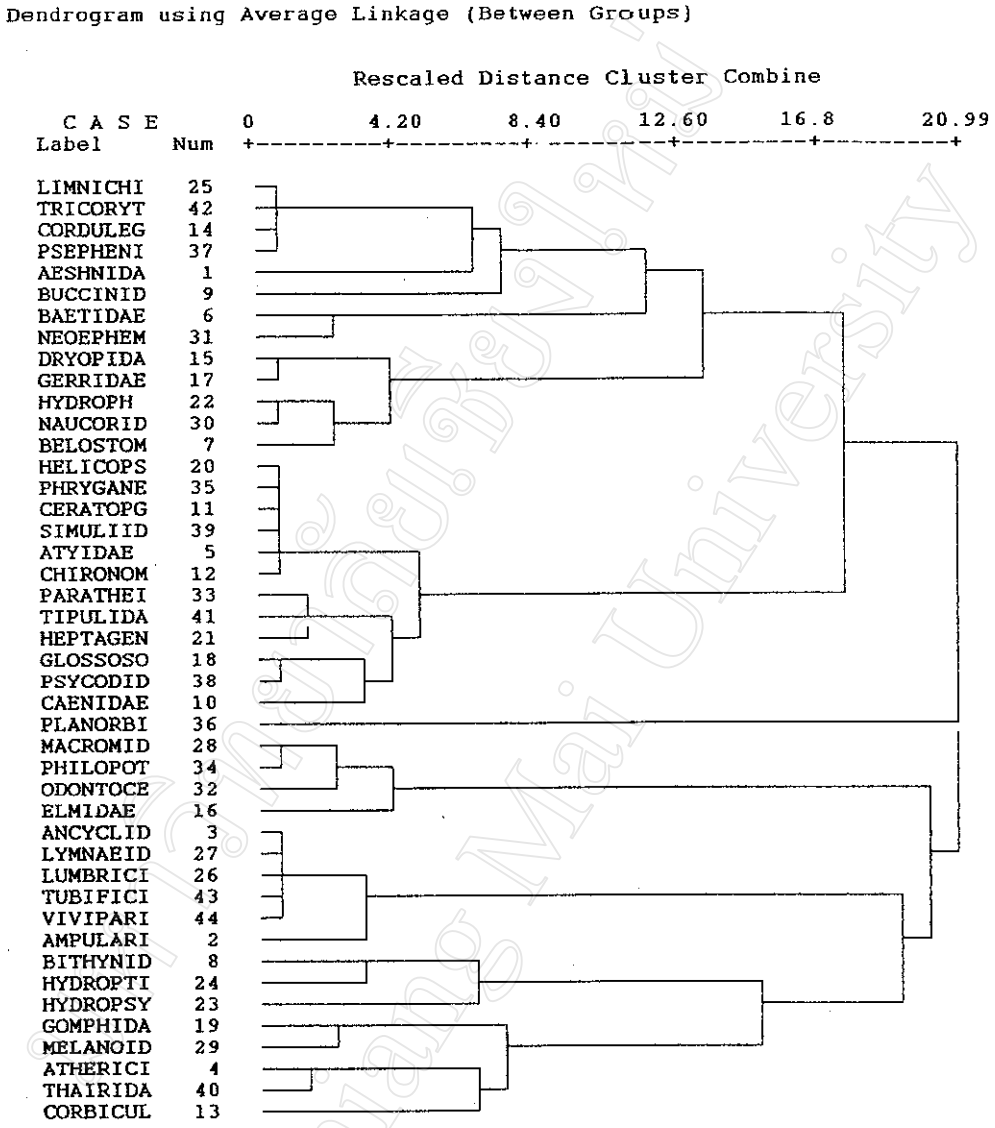


Figure 39: Clustering of macroinvertebrtes families found in conventional methods - wet season

figure 39, Although, in some groups pollutant tolerant and pollutant sensitive families are clustered together, most of the groups formed either pollutant tolerant or pollutant sensitive families in one cluster.

Clustering of sites by hierarchical cluster analysis using families found in WB sampler and conventional methods are shown in figure 40 to 43. Based on the families found in WB sampler in dry season, stream site ST 3 was separated from other stream sites. Since no animals found in site SC 2 it was completely separated from the rest of the sites. River sites and irrigation canal sites formed a separate group (Figure 40). In wet season, only sites ST 2, SC 2, and ST 3 formed a separate group. Site SC 1 completely separated from other sites (Figure 41).

Clustering of families found in conventional methods in dry season, irrigation canal sites and river site R 2 formed a separate group and also stream sites ST 1, ST 2, and ST 3 formed another separate group. Sewage canal site SC 2 was completely separated from the other sites (Figure 42). However in the wet season, stream sites ST 1, ST 2, and ST 3 still formed a separate group. River sites clustered in to one group together with sewage canal site SC 1 (Figure 42).

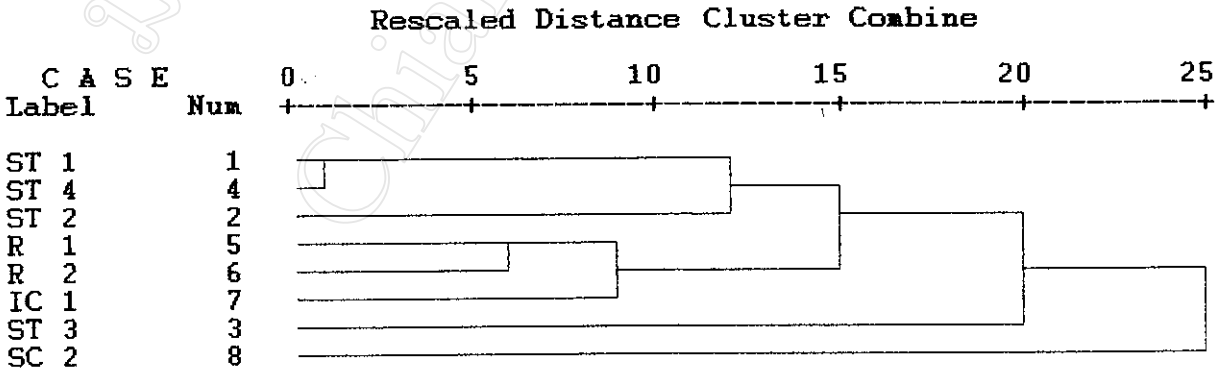


Figure 40 : Clustering of study sites according to similarity of macroinvertebrates families found in WB sampler - dry season

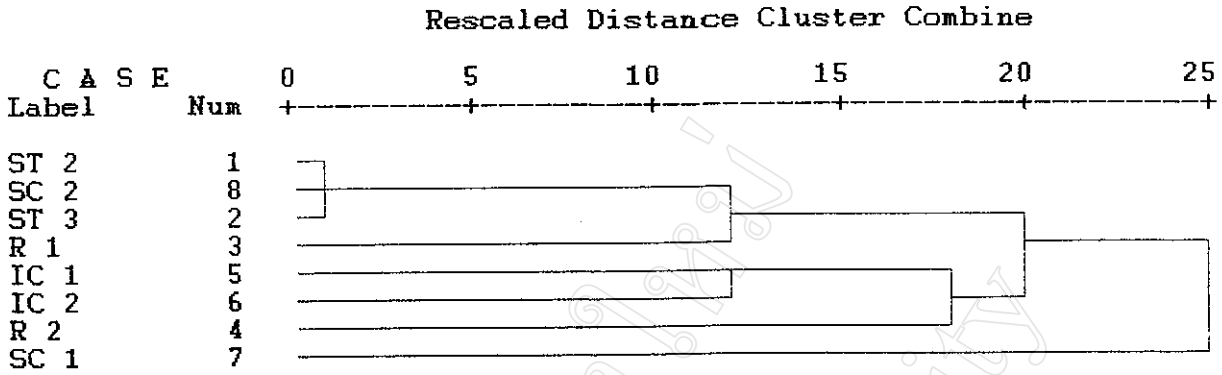


Figure 41 : Clustering of families according to similarity of macroinvertebrates families found in WB sampler - wet season

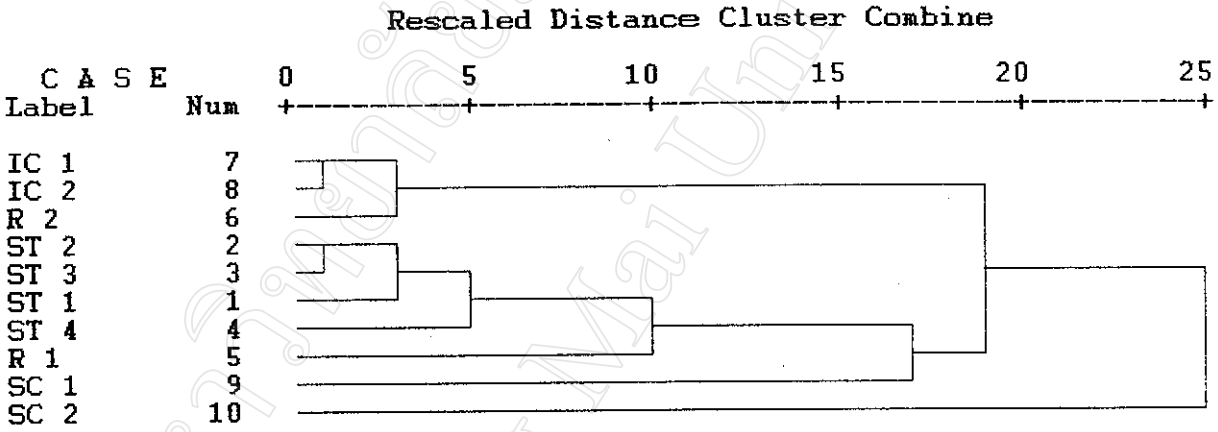


Figure 42 : Clustering of study sites according to similarity of macroinvertebrates families found in conventional methods - dry season

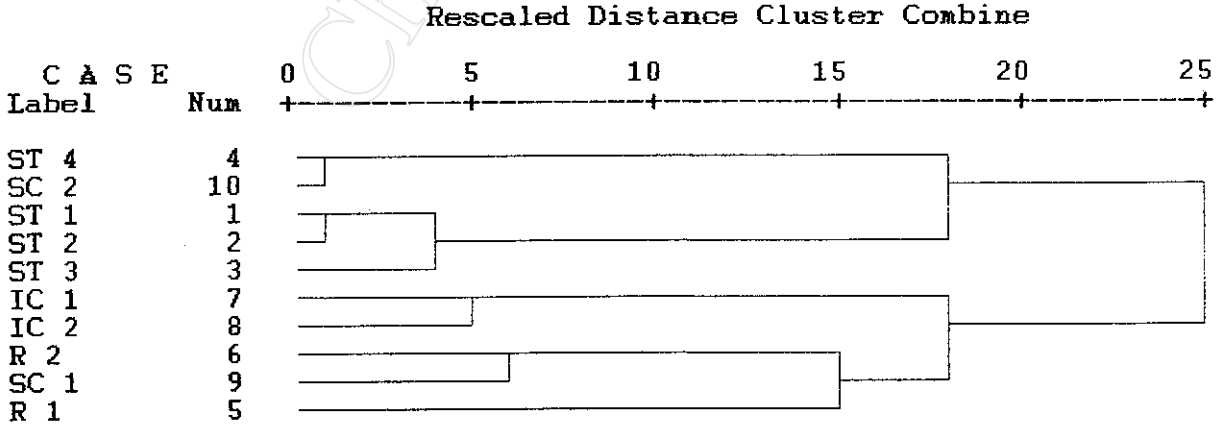


Figure 43 : Clustering of study sites according to similarity of macroinvertebrates families found in conventional methods - wet season