CHAPTER 4

RESULTS AND DISCUSSION

The monitoring of physico-chemical and biological properties including aquatic insects were measured. All results were analyzed by Multivariate Statistical Package (MVSP) Program. The classification method cluster analysis (UGPMA) was used to segregate all sampling periods and the Principal Component Analysis (PCA) was used to analyze the correlation at all sampling times, physico-chemical properties and biological indices. Statistical Program for Social Science (SPSS) version 10 was used to compare the mean of the results in each sampling site and season and the differences between the biological indices.

Mae Kham River characteristic are a highland area with a high level of soil erosion especially in the rainy season. During the flooding periods, the water level is normally high. All data were collected in 8 study sites except the site 8 (Mae Pern Pha Mieng Stream) in the rainy season which was flooded and uncollectible. The biological, physical and chemical properties were analyzed and yielded the following results.

1. Biological properties

a) Aquatic insects

Aquatic insect samples were collected 6 times from 8 sites. The analysis was based on over 50,000 aquatic insect samples and covered 241 taxa (morphotaxa) from 86 families in 10 orders. The most abundant family during the year was Baetidae (Ephemeroptera) followed by Chironomidae (Diptera) and Corixidae (Hemiptera). Caddisfly (Trichoptera) had the highest morphotaxa as 52 taxa with 15 families (Figure 4-3). The most abundant of the individuals was order Ephemeroptera (25,110 individuals) and the least was order Megaloptera (3 individuals) (Figure 4-1). The highest number of insects (10,701 individuals) were found at sampling site 4 (Huai

Moh Khang) because the sampling site was a small stream with not so high water current speed, although there were several habitats with aquatic plants, gravels and sand. One hundred and seventy-two morphotaxa were found from site 6 with the highest number of taxa when compared to other study sites (Figure 4-4). Site 6 was upstream with very less human impact. Therefore, numerous aquatic insect families were present, particularly the insects in Trichoptera order. On the other hand, the lowest number (83 morphotaxa) was identified from site 1 which faced very high human impacts such as from agriculture and livestock. Moreover, the substrate of this sampling site was mud and the stream side was built from concrete, which was not suitable for aquatic insects to survive. (Table 4-1)

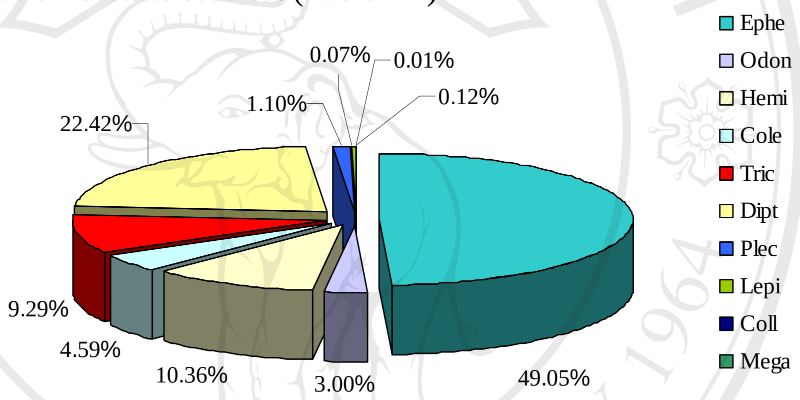

Figure 4-1 Percentage of individuals in each insect order of the Mae Kham Watershed from October 2003 to August 2004

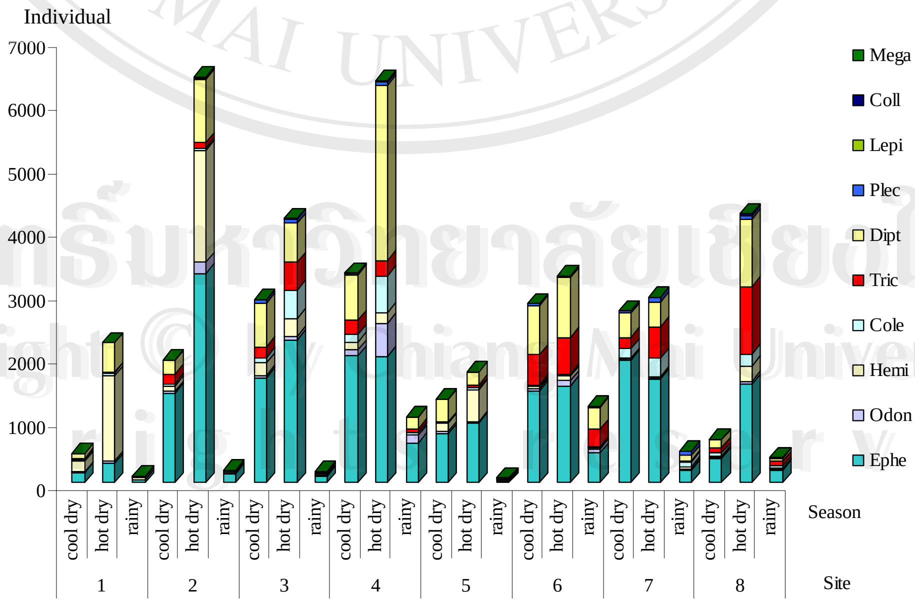

Figure 4-2 Number of insects in each season separated by site of the Mae Kham Watershed from October 2003 to August 2004

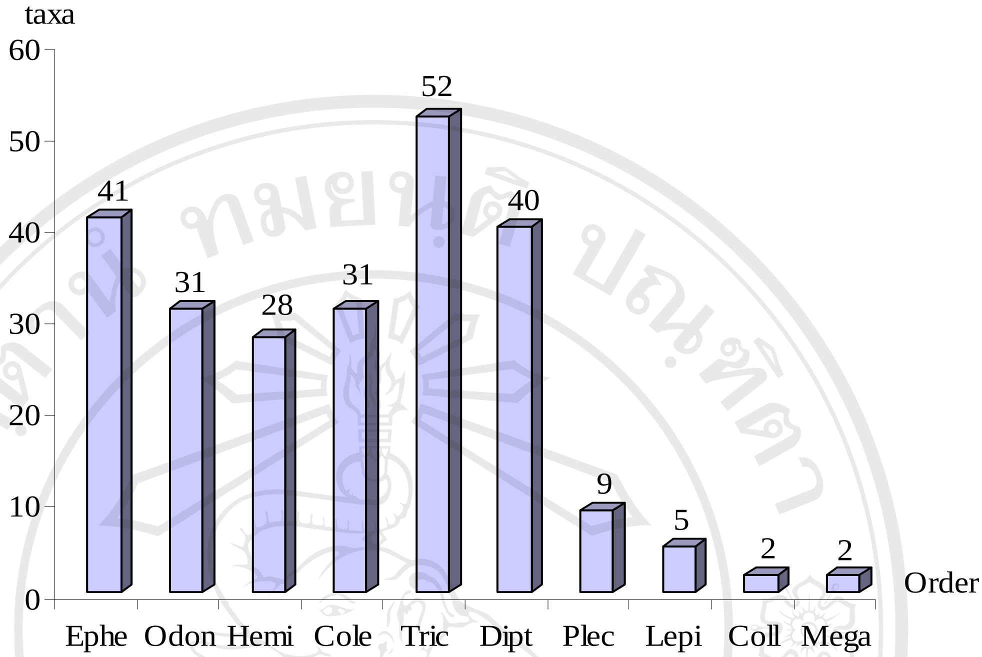

Figure 4-3 Total number of taxa in each insect order of the Mae Kham Watershed from October 2003 to August 2004

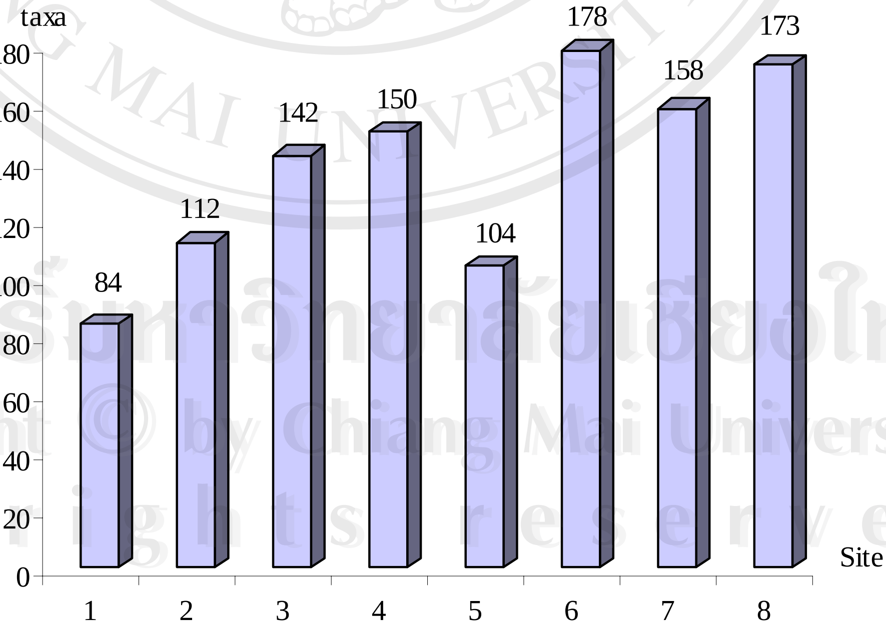

Figure 4-4 Total number of all insect taxa in each site of the Mae Kham Watershed from October 2003 to August 2004

Table 4-1 Aquatic insect samples from Mae Kham Watershed from October 2003to August 2004

Orders/Fam./taxa	Cool dry								Hot dry								Rainy							
	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8
Coleoptera																								
Amphizoidae L1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Anthicidae L1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Dryopidae A1	0	0	0	0	1	1	3	5	0	1	26	9	0	0	45	11	0	0	7	1	0	0	11	1
Dryopidae A2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Dryopidae A3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Dryopidae L1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dytiscidae A1	7	1	0	11	0	0	2	5	31	2	0	4	0	1	2	20	3	1	0	2	0	0	7	19
Dytiscidae A2	0	1	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Dytiscidae A3	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Dytiscidae A4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dytiscidae A5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Dytiscidae L1	9	8	0	35	0	0	2	0	12	1	0	10	0	0	2	1	3	1	0	12	0	0	0	0
Dytiscidae L2	1	0	0	0	0	0	0	2	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0
Dytiscidae L3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0
Elmidae A1	0	5	0	0	0	0	0	0	0	15	1	0	0	1	0	0	0	6	0	2	1	0	0	0
Elmidae A2	0	0	7	0	0	0	27	6	0	0	12	0	0	0	12	0	0	0	0	0	0	0	12	4
Elmidae A3	0	1	1	1	0	0	20	0	0	0	5	2	0	0	15	0	0	0	2	0	0	0	2	0
Elmidae A4	0	0	0	10	0	2	6	9	0	1	2	95	0	0	13	3	0	0	0	0	0	1	0	2
Elmidae A5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0
Elmidae L1	2	1	31	33	3	3	25	7	0	1	170	329	6	2	40	71	0	1	2	10	0	3	7	1
Elmidae L2	0	1	5	2	0	0	16	0	3	2	50	15	5	0	76	27	0	0	0	4	1	0	3	0
Elmidae L3	0	0	2	8	0	4	18	4	0	6	100	91	18	0	41	16	0	0	0	6	0	1	6	0
Elmidae L4	0	0	4	5	0	0	9	0	0	0	12	0	0	0	10	0	0	0	5	0	0	0	3	0
Elmidae L5	0	0	0	0	0	0	3	0	0	0	7	0	0	0	6	0	0	0	0	0	0	0	3	4
Gyrinidae A1	6	10	11	0	0	7	1	0	0	0	5	3	4	18	4	0	5	0	0	0	1	0	0	0
Gyrinidae L1	0	0	0	2	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0
Helodidae L1	0	0	0	1	0	1	0	1	0	0	0	0	0	1	0	14	0	0	0	0	0	1	0	2
Heteroceridae A1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrophilidae A1	0	1	0	1	1	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0

Table 4-1 (continued)

Orders/Fam./taxa	Cool dry								Hot dry								Rainy							
	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8
Hydrophilidae A2	0	0	1	0	0	2	0	0	1	0	0	6	0	0	0	3	0	0	0	0	0	0	0	1
Hydrophilidae A3	1	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	1	0	0	0	0	0	0
Hydrophilidae A4	0	0	2	1	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	1	0	0	0	0
Hydrophilidae A5	0	0	0	4	0	2	2	1	0	0	35	0	0	1	9	0	0	0	1	0	0	1	2	0
Hydrophilidae A6	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrophilidae A7	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Hydrophilidae A8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Hydrophilidae L1	0	1	8	0	0	0	0	0	0	2	5	0	0	0	5	0	0	0	2	0	0	0	3	0
Hydrophilidae L2	0	0	7	9	0	0	10	0	0	0	5	6	0	2	1	0	0	0	0	2	0	0	3	0
Hydrophilidae L3	0	0	0	1	0	0	0	0	7	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0
Hydrophilidae L4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Hydrophilidae L5	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Lampypidae L1	0	0	0	0	0	0	3	0	0	0	0	1	0	0	2	5	0	0	0	0	1	2	1	0
Noteridae A1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Psephenidae L1	1	0	1	1	0	0	0	1	0	0	0	0	0	0	0	6	0	0	0	0	0	3	0	6
Psephenidae L2	0	0	0	0	0	1	0	1	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0
Staphylinidae L1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0
Staphylinidae A1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Collembola																								
Entomobryidae 1	1	0	3	0	0	0	0	0	0	4	0	0	0	1	0	0	0	0	2	0	0	0	0	0
Isotomidae1	1	0	0	5	0	1	2	0	0	15	0	0	0	2	0	21	0	0	0	0	0	0	1	0
Diptera																								
Athericidae L1	4	0	0	0	0	1	0	0	7	0	1	0	0	1	0	1	0	0	1	0	0	1	0	1
Athericidae L2	0	0	0	0	0	0	0	0	0	0	0	0	0	26	0	2	0	0	0	0	0	29	0	0
Ceratopogonidae L1	14	3	19	13	7	27	20	5	17	34	5	76	2	15	18	8	1	0	0	1	0	5	4	1
Ceratopogonidae L2	7	19	150	99	50	51	40	16	18	136	112	665	34	36	20	73	0	2	0	58	0	28	6	6
Ceratopogonidae L3	7	9	100	42	29	78	32	8	66	80	63	136	28	59	43	156	0	0	0	11	0	35	19	0
Ceratopogonidae L4	2	2	44	13	14	80	8	4	28	20	25	30	18	41	46	139	0	0	1	3	0	1	1	0
Ceratopogonidae L5	0	0	0	4	0	0	0	0	0	2	2	11	0	4	12	4	0	0	0	0	0	0	0	0

Table 4-1 (continued)

Orders/Fam./taxa	Cool dry								Hot dry								Rainy							
	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8
Ceratopogonidae L6	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Ceratopogonidae P1	0	0	3	0	1	4	1	3	0	7	6	7	1	10	3	36	0	3	0	0	0	0	0	0
Ceratopogonidae P2	0	0	1	3	0	11	0	0	0	0	7	4	0	37	0	1	0	0	0	0	0	1	0	0
Ceratopogonidae P3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceratopogonidae P4	0	0	0	0	0	0	0	0	0	0	2	0	0	1	2	3	0	0	0	0	0	0	0	0
Ceratopogonidae P5	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Ceratopogonidae P6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Chironomidae L1	8	22	92	31	66	38	74	18	48	75	9	49	9	82	28	29	0	0	6	3	1	11	11	0
Chironomidae L2	26	59	201	250	131	200	57	35	128	176	80	985	62	291	69	358	0	3	1	50	2	32	29	13
Chironomidae L3	0	0	0	2	0	0	4	0	20	46	12	124	3	57	49	103	0	0	0	0	0	1	0	0
Chironomidae L4	0	0	0	0	0	0	0	0	1	0	0	31	0	0	1	8	0	0	0	0	0	1	0	0
Chironomidae L5	0	0	0	0	0	0	0	0	3	0	0	5	0	2	0	0	0	0	0	2	0	0	0	0
Chironomidae P1	4	9	35	40	14	30	18	11	54	95	27	302	17	35	35	68	1	0	1	9	0	5	1	1
Chironomidae P2	0	1	7	9	3	7	5	7	20	51	7	133	2	16	0	9	0	0	0	0	0	0	1	0
Chironomidae P3	1	3	15	17	7	4	4	3	15	24	9	15	0	1	0	28	1	0	0	1	0	0	7	0
Culicidae L1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0
Culicidae L2	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Culicidae P1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Dixidae L1	0	0	0	0	0	1	5	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Dolichopodidae P1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Drosophilidae P1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Empididae L1	0	0	0	7	0	1	5	0	0	1	2	115	0	3	4	1	0	0	0	0	0	0	0	0
Empididae L2	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Empididae P1	0	0	0	0	0	0	0	0	0	1	2	8	0	1	1	0	0	0	0	0	0	0	0	0
Phoridae L1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Psychodidae L1	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1
Psychodidae L2	0	0	0	1	0	0	2	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0
Psychodidae L3	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Psychodidae P1	0	0	0	1	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 4-1 (continued)

Orders/Fam./taxa	Cool dry								Hot dry								Rainy							
	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8
Simuliidae L1	2	80	8	149	12	209	75	0	21	226	201	58	1	177	34	15	0	4	0	6	0	142	2	9
Simuliidae P1	0	1	0	0	0	9	0	1	3	13	0	0	1	5	0	0	0	0	0	0	0	9	0	0
Simuliidae P2	0	0	0	6	0	0	0	0	0	5	2	0	1	0	0	0	0	0	0	0	0	0	0	0
Stratiomidae L1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stratiomidae L2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Tabanidae L1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0
Thaumaleidae L1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tipulidae L1	0	1	4	17	9	10	12	5	0	3	4	6	10	17	6	2	0	0	4	19	0	14	5	8
Tipulidae L2	0	2	0	0	8	0	0	1	0	1	0	0	0	2	0	0	0	0	0	0	0	1	0	0
Tipulidae L3	0	0	2	5	2	1	7	1	0	0	4	6	3	0	3	2	0	0	1	17	0	5	5	1
Tipulidae L4	0	1	5	8	2	2	3	1	1	7	30	1	3	8	14	2	0	0	0	0	0	5	0	0
Tipulidae L5	0	0	0	3	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	7	0	0
Tipulidae L6	0	0	0	0	0	4	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	1	0	0
Tipulidae L7	0	0	0	0	0	0	0	0	5	2	0	0	0	0	0	4	0	0	0	0	0	1	0	1
Tipulidae L8	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
Tipulidae L9	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0
Tipulidae L10	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0
Tipulidae P1	0	0	0	4	0	1	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Tipulidae P2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Tipulidae P3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Tipulidae P4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Tipulidae P5	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ephemeroptera																								
Baetidae1	68	1155	1230	1440	592	560	1358	177	50	2577	891	967	537	586	944	693	5	65	58	295	10	55	27	46
Baetidae2	1	4	0	0	2	0	1	0	0	0	0	0	11	0	0	4	0	0	0	0	0	0	0	0
Baetidae3	22	25	35	145	6	35	104	16	3	143	98	67	36	20	51	25	1	32	7	80	0	23	16	5
Baetidae4	10	23	46	76	10	34	95	40	13	65	147	82	104	44	84	53	0	11	10	25	2	3	7	11
Baetidae5	1	112	84	111	16	24	96	22	7	114	265	127	23	22	86	35	0	28	14	36	2	2	3	17
Baetidae 6	2	10	73	79	25	488	89	6	0	17	164	52	0	1	44	13	0	0	3	35	0	111	12	62

Table 4-1 (continued)

Orders/Fam./taxa	Cool dry								Hot dry								Rainy							
	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8
Baetidae 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Baetidae 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Caenidae1	8	1	14	34	11	10	10	6	126	69	31	263	5	90	21	85	26	0	0	34	0	22	2	3
Caenidae2	32	11	43	92	4	25	19	16	104	212	21	232	4	109	28	147	13	1	0	46	0	29	6	3
Caenidae3	0	0	13	0	0	5	5	0	0	26	10	91	0	41	0	3	0	0	0	13	0	0	0	0
Caenidae4	0	0	14	0	20	0	11	12	0	0	15	0	9	0	17	97	0	0	0	0	1	0	4	0
Ephemerellidae1	0	15	8	0	5	18	6	10	0	3	35	0	2	48	33	23	0	0	0	0	0	31	7	7
Ephemerellidae2	0	0	0	1	0	88	31	13	0	8	16	1	7	281	117	124	0	1	1	0	0	76	5	9
Ephemerellidae3	0	0	0	0	0	0	1	1	0	0	13	2	0	4	5	4	0	0	1	0	0	0	2	0
Ephemerellidae4	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ephemerellidae5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
Ephemerellidae6	0	0	10	0	16	0	7	2	0	1	41	0	52	2	16	6	0	0	0	0	2	0	13	0
Ephemerellidae7	0	0	0	0	0	0	0	0	0	0	0	0	18	0	2	5	0	0	1	0	0	0	6	0
Ephemeridae1	0	0	11	3	8	11	7	3	0	0	7	47	14	119	14	17	0	0	1	2	0	12	5	1
Heptageniidae1	9	31	51	30	32	11	71	29	0	40	407	51	83	29	127	95	0	2	3	39	4	4	35	6
Heptageniidae2	2	8	6	9	4	0	0	0	0	7	25	3	5	2	1	1	0	3	0	15	0	0	1	1
Heptageniidae3	0	0	2	0	0	5	0	3	0	0	7	0	6	16	2	39	0	0	0	0	0	4	0	0
Leptophlebiidae1	1	1	0	0	2	0	0	0	0	1	0	1	17	18	0	11	0	0	2	4	0	7	1	4
Leptophlebiidae2	1	0	0	0	2	11	2	0	0	0	0	0	0	31	4	12	0	0	0	0	0	4	0	1
Leptophlebiidae3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptophlebiidae4	0	0	2	0	9	0	5	9	0	0	14	2	9	6	21	15	1	0	0	0	4	0	7	10
Leptophlebiidae5	0	1	0	0	3	44	3	0	0	0	0	0	0	9	0	0	0	0	0	1	0	7	0	0
Leptophlebiidae6	0	0	0	0	0	17	1	7	0	0	2	1	8	14	2	8	0	0	0	0	0	51	1	0
Leptophlebiidae7	0	0	0	0	0	58	0	14	0	0	4	0	0	18	8	39	0	0	0	0	0	19	0	7
Leptophlebiidae8	0	0	0	0	0	2	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	8	0	1
Leptophlebiidae9	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Leptophlebiidae10	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Leptophlebiidae11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Neoephemeridae1	0	5	3	0	1	0	9	0	0	1	14	0	1	0	9	0	0	0	2	0	1	0	27	0

Table 4-1 (continued)

Orders/Fam./taxa	Cool dry								Hot dry								Rainy							
	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8
Oligoneuriidae1	0	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	2	0
Oligoneuriidae2	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Polymitarcyidae1	0	5	4	0	0	0	2	0	0	13	6	0	0	0	0	0	0	0	0	0	0	0	0	0
Polymitarcyidae2	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0
Potamanthidae1	0	0	11	0	2	0	1	0	0	0	20	0	0	0	1	1	0	0	0	0	0	0	6	1
Prosopistomatidae1	0	0	0	0	2	0	1	0	0	2	0	0	0	0	1	0	0	0	0	0	5	0	0	0
Hemiptera																								
Corixidae1	4	59	48	28	24	1	1	1	263	230	3	23	17	5	1	50	0	0	0	5	0	4	1	0
Corixidae2	136	4	72	44	13	4	1	1	560	1426	21	38	227	27	3	103	1	0	0	0	0	1	0	0
Corixidae3	0	0	0	0	0	0	0	0	19	15	2	1	18	0	0	0	0	0	0	0	0	0	0	0
Corixidae4	0	0	0	0	0	0	0	0	290	35	208	12	213	7	1	10	0	0	0	0	0	0	0	0
Gerridae1	27	2	8	2	9	2	3	3	154	13	2	40	13	16	0	3	28	2	1	3	10	0	7	2
Gerridae2	0	0	0	1	0	0	0	4	42	16	0	17	2	3	1	8	0	0	0	0	1	2	0	0
Gerridae3	0	0	0	0	0	0	1	0	0	0	1	2	1	0	1	0	0	0	0	0	1	0	4	2
Gerridae4	0	0	0	0	0	0	0	0	9	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0
Gerridae5	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	1	0
Gerridae6	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	8	0
Gerridae7	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Hydrometridae 1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Naucoridae1	0	0	4	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0
Naucoridae2	0	0	3	4	1	0	2	1	0	0	16	1	0	3	11	1	0	0	2	0	0	1	5	0
Naucoridae3	0	0	9	0	0	0	6	3	0	2	11	0	0	0	5	6	0	0	0	0	0	0	3	0
Naucoridae4	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
Naucoridae5	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	2	0
Naucoridae6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Nepidae1	0	0	2	0	0	0	1	1	0	1	1	0	0	0	0	4	1	0	1	0	0	0	0	1
Nepidae2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Notonectidae 1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0
Notonectidae 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

Table 4-1 (continued)

Orders/Fam./taxa	Cool dry								Hot dry								Rainy							
	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8
Pleidae1	0	0	1	0	0	2	1	0	0	0	18	0	4	1	2	19	0	0	0	0	0	0	0	1
Veliidae1	0	15	28	22	42	4	3	1	2	7	2	18	12	1	2	2	0	6	0	0	0	0	4	1
Veliidae2	2	10	18	13	42	10	1	9	0	13	1	10	0	1	0	9	0	0	0	1	0	0	3	0
Veliidae3	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Veliidae4	0	0	0	0	0	0	0	0	0	5	0	0	0	3	1	22	0	1	0	0	0	0	0	0
Veliidae5	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidoptera																								
Pyralidae L1	0	0	1	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0
Pyralidae L2	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
Pyralidae L3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyralidae L4	0	0	0	0	0	0	0	0	0	0	1	21	0	0	2	0	0	0	0	1	0	1	0	0
Pyralidae L5	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Megaloptera																								
Corydalidae1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Sialidae 1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Odonata																								
Aeshnidae1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	5	0	2	0	0
Amphipterygidae1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Calopterygidae1	0	0	2	5	0	0	0	2	0	30	24	39	1	0	2	2	1	6	2	15	0	3	4	0
Calopterygidae2	0	0	0	0	0	0	0	0	0	6	0	5	0	0	0	0	0	1	0	2	0	1	0	0
Calopterygidae3	0	0	0	9	0	0	2	0	0	11	16	42	0	0	1	1	0	0	0	10	0	2	4	0
Chlorocyphidae1	3	8	3	7	0	0	0	2	4	1	1	14	0	0	0	22	0	2	4	6	1	5	3	4
Coenagrionidae 1	0	1	0	5	0	0	0	0	6	61	0	134	0	0	0	0	0	0	0	2	0	0	0	0
Coenagrionidae 2	0	0	0	0	0	0	0	0	3	0	0	54	0	0	0	0	0	0	0	0	0	0	0	0
Coenagrionidae 3	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cordulegustridae1	0	0	1	8	0	2	1	0	0	0	2	0	0	8	2	0	0	0	0	0	0	8	0	1
Cordulegustridae2	0	0	0	0	0	7	0	0	0	0	0	0	0	7	0	1	0	0	0	0	0	4	0	0
Corduliidae1	1	0	0	2	1	0	1	0	0	6	0	8	0	0	0	0	0	0	0	0	0	19	0	0
Euphaeidae 1	0	0	0	0	0	11	0	2	0	0	0	0	0	3	0	3	0	0	0	1	0	1	0	0

Table 4-1 (continued)

Orders/Fam./taxa	Cool dry								Hot dry								Rainy							
	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8
Gomphidae1	4	9	7	19	4	1	0	3	0	11	3	10	5	0	2	5	0	2	1	24	0	4	8	10
Gomphidae2	8	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	3	0	21	0	0	0	0
Gomphidae3	0	2	11	21	28	3	5	4	0	5	5	21	4	0	1	5	1	2	1	23	10	5	0	3
Gomphidae4	0	0	0	0	0	2	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	4	2	0
Gomphidae5	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	4	0	1
Gomphidae6	0	0	0	0	0	0	0	0	0	2	2	0	0	0	1	0	0	0	0	0	0	5	0	0
Gomphidae7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Gomphidae8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Gomphidae9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2
Libellulidae1	0	7	1	10	0	9	1	0	0	6	0	75	0	28	0	0	0	1	1	3	2	4	1	2
Libellulidae2	0	0	1	0	0	9	0	0	0	0	0	78	0	36	0	0	0	0	0	1	0	0	0	0
Libellulidae3	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0
Macromiidae 1	0	0	4	5	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	3	0	0	1	0
Macromiidae 2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0
Platycnemididae 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Platystictidae 1	0	1	5	2	0	0	0	0	21	35	1	6	0	0	0	1	0	0	0	1	0	0	0	0
Platystictidae 2	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
Protonneuridae1	0	0	0	0	0	0	0	0	3	6	0	41	0	0	0	0	0	0	0	8	0	0	0	0
Plecoptera																								
Leuctridae 1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2
Nemouridae1	0	0	0	1	0	22	2	11	0	0	1	0	0	13	1	14	0	0	0	0	0	12	0	0
Peltoperlidae 1	0	0	0	0	5	0	0	0	0	0	1	0	2	0	3	5	0	0	0	0	0	1	6	2
Perlidae1	0	6	42	6	5	0	19	3	0	12	34	3	1	3	16	25	0	0	10	2	1	0	26	3
Perlidae2	0	0	5	0	0	3	2	0	1	0	16	0	1	2	6	6	0	0	4	2	3	0	10	3
Perlidae3	0	0	4	6	0	0	1	0	0	3	12	38	0	3	2	1	0	0	0	1	0	0	10	0
Perlidae4	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Perlidae5	0	0	1	0	0	4	8	0	0	3	9	0	0	2	33	8	0	0	0	0	0	0	7	2
Taeniopterygidae1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	1	0	0

Table 4-1 (continued)

Orders/Fam./taxa	Cool dry								Hot dry								Rainy							
	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8
Trichoptera																								
Apataniidae1	0	0	0	6	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Apataniidae2	0	0	0	6	0	0	0	1	1	0	4	5	0	1	0	1	0	0	0	0	0	0	0	0
Apataniidae3	0	0	29	5	0	9	2	0	0	0	22	2	0	10	8	0	0	0	0	3	0	24	1	1
Apataniidae4	0	0	1	5	0	1	0	1	0	1	0	1	0	4	0	0	0	0	0	0	0	0	0	0
Apataniidae5	0	0	4	2	0	0	3	0	0	0	2	18	2	0	1	6	0	0	0	0	0	6	0	0
Apataniidae6	0	0	4	0	0	0	0	0	0	0	1	0	0	18	0	0	0	0	0	0	0	0	0	0
Apataniidae7	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apataniidae8	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	11	0	0	0	0	0	18	0	0
Brachycentridae 1	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachycentridae 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Calamoceratidae 1	0	0	0	0	0	7	0	2	0	0	0	0	0	28	1	30	0	0	0	0	0	8	0	0
Calamoceratidae 2	0	0	0	0	0	0	0	0	0	0	1	0	0	3	2	7	0	0	0	0	1	0	0	0
Calamoceratidae P1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Calamoceratidae P2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
Glossosomatidae1	0	0	0	0	0	3	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Goeridae 1	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	9	0	0	0	0	0	0	0	0
Goeridae 2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	8	0	0	0	0	0	0	0	0
Goeridae 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Helicopsychidae1	0	0	1	8	1	2	0	2	0	0	0	1	0	12	0	24	0	0	1	1	1	9	0	0
Hydropsychidae1	3	143	66	133	5	356	117	26	0	44	183	107	12	118	303	179	4	5	4	41	0	36	4	49
Hydropsychidae2	4	4	0	4	0	0	8	0	0	7	44	30	1	30	19	28	0	0	0	5	0	0	0	8
Hydropsychidae3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydropsychidae4	0	2	6	34	0	44	14	5	0	13	31	23	2	31	66	65	0	1	0	0	0	2	1	4
Hydropsychidae5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Hydroptilidae1	2	0	1	0	1	0	4	0	4	10	8	2	0	10	3	1	0	0	0	0	0	0	0	0
Hydroptilidae2	0	0	0	0	0	1	10	0	0	11	11	19	3	14	12	1	0	0	0	0	0	0	0	0
Hydroptilidae3	0	0	3	1	0	0	0	0	0	0	0	0	0	2	0	6	0	0	0	0	0	0	0	0
Hydroptilidae4	0	0	0	0	0	26	0	0	0	0	1	0	0	112	0	0	0	0	0	0	0	16	0	0

Table 4-1 (continued)

Orders/Fam./taxa	Cool dry								Hot dry								Rainy							
	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8	S1	S2	S3	S4	S5	S6	S7	S8
Hydroptilidae P1	0	0	0	0	0	0	1	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0
Lepidostomatidae1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidostomatidae2	0	0	8	0	0	0	1	0	0	0	33	0	1	3	29	53	0	0	0	0	0	1	0	0
Lepidostomatidae3	0	0	0	0	1	0	0	1	0	2	5	0	1	0	1	26	0	0	0	0	1	1	0	0
Lepidostomatidae P1	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	1	0	0	0	0	0	2	0	0
Leptoceridae1	1	0	0	0	1	1	3	0	0	0	4	20	1	0	0	1	0	0	0	0	0	15	0	0
Leptoceridae2	0	0	2	4	0	0	3	0	0	0	2	0	0	1	3	4	0	0	0	0	0	3	1	1
Leptoceridae3	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptoceridae4	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptoceridae5	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Leptoceridae6	0	0	9	0	0	0	0	7	0	0	2	0	2	0	0	174	0	1	2	0	0	4	0	3
Leptoceridae7	0	0	1	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	4	0	0
Leptoceridae8	0	0	8	1	0	1	0	2	0	0	50	0	1	1	0	18	0	0	0	0	0	5	0	0
Leptoceridae9	0	0	2	0	0	0	0	0	0	0	18	0	1	0	5	0	0	0	0	0	0	0	0	0
Leptoceridae10	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	22	0	0	0	0	0	0	0	0
Leptoceridae11	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Leptoceridae12	0	0	6	0	4	4	6	22	0	0	4	1	9	31	10	281	0	0	0	0	6	65	9	5
Odontoceridae1	0	0	0	4	0	2	0	0	0	0	0	0	0	3	0	3	0	0	0	0	0	0	0	0
Odontoceridae2	0	0	11	7	1	2	3	3	0	1	5	3	1	63	6	23	0	0	2	3	1	41	4	2
Odontoceridae3	0	0	0	3	0	0	0	0	0	0	1	3	0	2	15	47	0	0	0	0	0	4	0	0
Odontoceridae4	0	0	0	0	0	0	0	0	0	0	0	0	0	45	0	0	0	0	0	0	0	2	0	0
Philopotamidae1	0	0	0	0	0	9	2	1	0	0	0	0	0	0	4	9	0	0	0	0	0	6	0	0
Polycentropodidae 1	0	0	0	0	0	0	0	3	0	0	0	3	0	0	0	10	0	0	0	0	0	0	0	0
Polycentropodidae 2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Polycentropodidae 3	0	0	0	0	0	0	0	0	0	0	4	0	5	0	0	3	0	0	0	0	0	0	0	0
Psychomyiidae1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Psychomyiidae2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Stenopsychidae 1	0	0	0	0	0	2	0	4	0	0	0	0	0	0	0	11	0	0	0	0	0	3	0	9

Diversity Index

The diversity of aquatic insects was calculated by using Shanon-Wiener Index (H′), with the highest score of 3.6 at site 6 and site 7 in the rainy season (July 2004). The lowest score was 1.5 at site 5 in the hot dry season, May 2004 (Table 4-2). This variation between seasons was not statistically significant but was significant between sites ($p<0.05$). The result was different from Dudgeon (1992); Prommi (1999); Jitmanee (2004), all of those showed different insect diversity between seasons because they were affected by water current. The mean values of the Shanon-Wiener index of almost all sampling sites indicated that during the cool dry season the values were low with moderate polluted water. Nevertheless, in the hot dry and the rainy seasons the water quality was moderate to good, especially for site 6 and site 8 where there was a good quality. Although, the diversity index could be used to indicate water quality, it had only 3 levels to access water quality. Most of the results showed moderate water quality such as sampling site 6 and site 4. But they had different aquatic insect groups. For example, site 6 was dominated by Trichoptera (sensitive order) but site 4 was dominated by Ephemeroptera and Odonata (moderate order).

BMWP^{Thai} score and ASPT

The ASPT calculated from BMWP^{Thai} score showed the highest score of 7.4 from site 5 in the rainy season (July 2004) because during the sampling periods, water velocity was high with fewer aquatic insects (22 individuals) found but they presented the highest BMWP^{Thai} score of 10 from Lepidostomatidae and Leptoceridae family in order Trichoptera. So, they caused the ASPT to be high when compared with the results from May at site 5 which worked in the opposite way, also with fewer insects (25 individuals) but at low ASPT because they had Chironomidae family (BMWP^{Thai} score = 2) which would cause ASPT to be a low score. From the previous reason, it could be concluded that the ASPT varied in lesser insect quantity condition. The smallest score occurred at site 1 in the hot dry season (May 2004) as 4.7 (Table 4-2). The water quality was good to fairly good when the score of accessing the water quality level was compared. Site 1, site 2 and site 4 had fairly good water quality in all seasons. Because the downstream sites might be contaminated by human activities which were related to water quality, it was polluted to fair good water quality. The water quality in all seasons at site 6, site 7 and site 8 were good because they were upstream sites with low pollution levels. The results revealed significant differences in ASPT values between sites but no differences in seasons ($p<0.05$).

EPT ratio

EPT total ratio was based on the abundance of three pollution sensitive orders. The results included 0.09 (lowest) at site 1 to 0.86 (highest) at site 7 in the same sampling in the hot dry season (May 2004) as shown in table 4-2. The differences between the %EPT values were obtained at the sampling sites and the seasons were not significant ($p<0.05$). The EPT index showed 4 different water quality levels. In this study, the EPT ratio were very changeable including all levels of water quality as poor, marginal, acceptable, and good in different sites and seasons, most of which were acceptable water quality. The poor quality occurred in the hot dry season from site 1, site 4 and site 5 and in the rainy season at site 1 because those 3 sampling sites were located downstream. From the results of three indices, they were similar and there were no differences between seasons. However, there were differences between sampling sites and the water quality could be indicated by biological properties related to some physical and chemical properties.

HBI index

The HBI score was recorded from 3.37 to 6.11. Site 6 in the hot dry season (May 2004) showed the lowest score and the highest score was at site 4 in the hot dry season (March 2004) as shown in table 4-2. The HBI values showed a significant difference in each site and season ($p<0.05$). The HBI index has seven levels to indicate water quality, ranging from excellent to very poor. This research found water quality from fairly good to excellent. In the cool dry season, the water quality from all sites was of good quality. The water in the hot dry season at site 1 and site 4 was fairly good quality. At site 5, site 6 and site 8 it was very good to excellent in the hot dry and rainy seasons. HBI index is different from other indices, with differences between seasons and at the sampling sites. Site1 tended to have high value while sampling site 8 tended to have a low value. This could be because HBI index included several macroinvertebrate groups such as Subphylum Chelicerata (water mites), Subphylum Crustacea, Phylum Mollusca, Phylum

Annelida, Phylum Platyhelminthes, Phylum Coelenterata and Phylum Nemertea which were not the scope of this work. Further, HBI index was not appropriate to be used in small streams in which almost all macroinvertebrates were insects.

Table 4-2 Comparison of biological indices in each sampling time of the Mae Kham Watershed from October 2003 to August 2004

Site	Month	Diversity	ASPT	EPT ratio	HBI
1	Oct	2.7	5.8	0.56	5.16
	Dec	2.1	5.8	0.25	5.29
	Mar	2.5	5.2	0.17	5.63
	May	2.4	4.7	0.09	5.39
	Jul	1.8	5.4	0.18	5.40
	Aug	1.9	5.0	0.53	5.46
2	Oct	1.7	6.4	0.85	4.94
	Dec	1.9	6.2	0.77	5.02
	Mar	2.2	6.2	0.50	5.24
	May	2.3	6.1	0.73	5.24
	Jul	2.0	6.2	0.81	4.93
	Aug	2.3	5.5	0.61	4.73
3	Oct	2.0	6.4	0.74	5.13
	Dec	2.7	6.7	0.60	5.28
	Mar	3.1	6.7	0.67	4.63
	May	3.3	7.0	0.58	4.20
	Jul	2.7	6.8	0.79	4.29
	Aug	2.4	6.2	0.66	4.57
4	Oct	2.4	5.9	0.65	5.39
	Dec	2.3	6.3	0.71	5.05
	Mar	2.5	5.9	0.20	6.11
	May	3.3	6.3	0.59	5.61
	Jul	2.7	6.2	0.68	4.86
	Aug	2.9	6.1	0.60	5.08

Table 4-2 (continued)

Site	Month	Diversity	ASPT	EPT ratio	HBI
5	Oct	1.8	6.3	0.70	5.30
	Dec	2.5	7.2	0.56	5.29
	Mar	2.6	7.0	0.58	4.77
	May	1.5	5.0	0.24	3.86
	Jul	1.9	7.4	0.55	3.63
	Aug	3.0	7.1	0.59	3.76
6	Oct	2.1	6.8	0.81	4.86
	Dec	2.9	6.6	0.61	4.94
	Mar	3.1	6.7	0.57	5.14
	May	3.4	6.8	0.81	3.37
	Jul	3.6	6.7	0.65	3.79
	Aug	3.2	6.5	0.62	4.38
7	Oct	2.2	6.8	0.73	5.05
	Dec	2.3	6.7	0.82	4.89
	Mar	3.0	7.0	0.72	4.45
	May	1.9	6.6	0.86	4.63
	Jul	3.6	6.8	0.61	3.99
	Aug	3.3	6.6	0.42	4.27
8	Oct	2.8	6.8	0.65	4.77
	Dec	3.3	6.8	0.71	4.64
	Mar	3.3	6.7	0.60	5.07
	May	3.4	6.9	0.74	3.88
	Jul	-	-	-	-
	Aug	3.3	6.6	0.72	4.28

The results of all indices were related to physical and chemical properties. There were differences between sampling sites ($p<0.05$) at all indices and velocity, conductivity, ammonia-nitrogen, alkalinity and turbidity. From the results, it can be concluded that the water quality in each sampling site was different because of the impacts from several types of land use along the streams.

B) Total Coliform bacteria

From this work, total coliform bacteria showed the range at 23 to above 24,000 MPN/100ml. The smallest value occurred at site 6 in the hot dry season (March 2004). There were 7 sampling times at site 1, site 2 site 5 and site 6 in the hot dry season (May 2004) and site 2, site 3, and site 5 in the rainy season (July 2004), all of which had the highest values but were not acceptable according to the water quality standard of Thailand. The total coliform bacteria values were not significantly different between sites and seasons ($p<0.05$). Coliform bacteria are in the family Enterobacteriacea which can be found in the digestive track of mammals released by feces and during the sampling time it might be contaminated from livestock and toilets of communities along the stream. In addition, coliform bacteria might be contaminated from soil due to the sampling times, high velocity and turbidity that were detected. July was considered to have the highest total coliform bacteria in each sampling site except site 7 and site 8. Because this month was in the rainy season with high rain fall there were high discharges of coliform bacteria from the soil. That was similar to the work of Tang in 2003 where the total coliform was found to be the highest in rainy season. The total coliform bacteria values in each sampling period of the Mae Kham Watershed from October 2003 to August 2004 are shown in Figure 4-5.

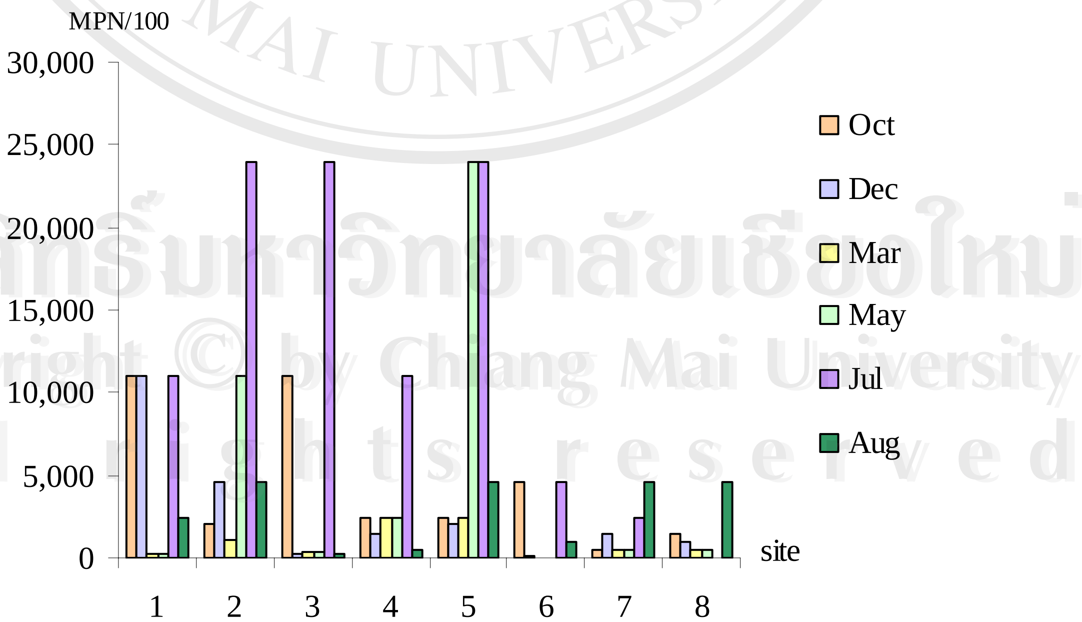

Figure 4-5 Total coliform bacteria in each sampling times of the Mae Kham Watershed from October 2003 to August 2004

2. Physical properties

Altitude

The elevation of all sampling sites varied from 385 to 466 m above sea level. There was not much difference between each sampling site. Therefore, it did not much affect the diversity of aquatic insects. Unlike what the previous studies of Prommi (1999) and Silalom (2000) were reported. Diversity and distribution of Trichoptera adult and larvae were different following the altitude on Doi Suthep-Pui National Park. There was not only Trichoptera species that were affected by the elevation. Rajchapakdee (1992) concluded that some benthos species were restricted to the lower range above 380 m. above sea level. Some species were restricted to the higher range above 1,475 m. above sea level. Although, some species could be found at almost any range. The elevation in each sampling site is shown in Figure 4-6.

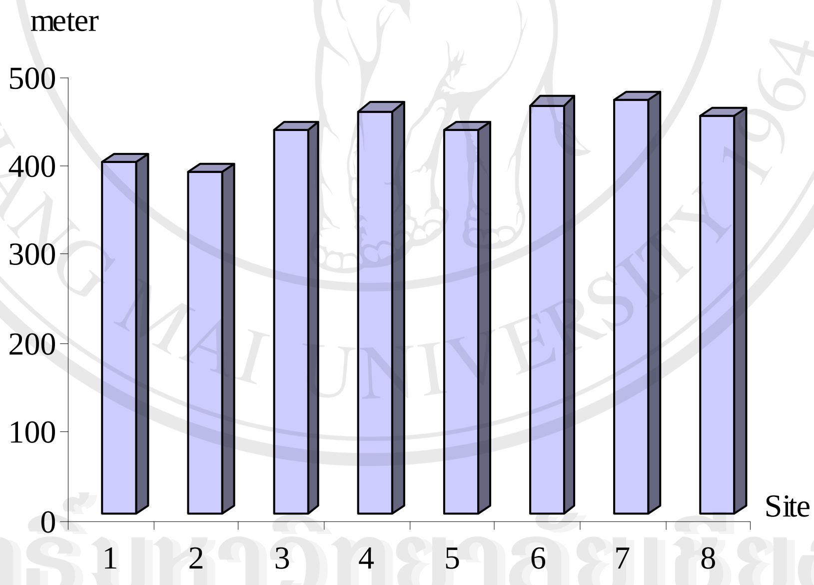

Figure 4-6 Altitude in each sampling site of the Mae Kham Watershed

Air temperature

The air temperature was measured in the area near the streams. It was not significantly different between seasons and sites at $p<0.05$. The lowest temperature (15.5 ^{o}C) was detected at site 1 in December. Whereas, the highest temperature (35.3 ^{o}C) was measured at site 2 in October. The lowest air temperature tended to be in December when compared with other months because it was in the middle of the cool dry season.

Moreover, the air temperature depended on the sampling time. In the morning or evening, the temperature might be lower than in the afternoon, as indicated by the work of Sopsop (1995) when the sun light would also affect the air temperature. Air temperature in each sampling period of the Mae Kham Watershed from October 2003 to August 2004 is shown in Figure 4-7.

Water Temperature

Water temperature was measured during the year. The results showed that the lowest temperature (17.4 ^{o}C) was detected at site 1 in the cool dry season (December 2003). Thirty three degrees Celsius was the highest water temperature at site 1 in the rainy season (August 2004). The difference of the water temperature may depend on the climate and the environment nearby the stream as well as, sampling times, wind, water mixing, elevation and the amount of sun light. Although, there was no significant difference ($p<0.05$) between sites. But there was significant difference between seasons – the hot dry season and the cool dry season. The results showed that the water temperature in December 2003 and March 2004 was lower than other months in all sampling sites, because in those years the cool dry season started late and the weather continued to be chilly until March. Water temperature affected the amount of aquatic macroinvertebrates and each species in each group could live in specific ranges of water temperature because of their respiratory rate and metabolism, as reported by Vijarnranakorn (2003). Water temperature in each sampling period of the Mae Kham Watershed from October 2003 to August 2004 is shown in Figure 4-8.

Turbidity

The turbidity values of water were not different in each season. However, it was significantly different at $p<0.05$ between sites. Site 5 was different from site 3, site 4, site 6 and site 7 and there were also differences between site 2 and site 8. The Mae Kham River (site 5) tended to have higher turbidity than other sites, with the highest value of 184 FTU in the rainy season (July 2004). The greatest reason for high turbidity in this watershed was soil erosion which is a widely known problem in the highland area in the Northern part of Thailand. This was largely due to water velocity, landscape morphology and seasonal influence (Inmuong *et al*., 1996). At site 5 Mae Kham the river had many branches and contained high values of turbidity especially in the rainy season of July 2003. There was a high amount of suspended solids at site 1 Mae Pern and site 2 Mae Salong throughout the year. Because they were lower elevation sites with fewer plants to cover the area on the stream-sides. Furthermore, there was much sediment to create alluvial at site 2. At site 8 the turbidity values could not be detected resulting in 0 FTU in the rainy season (August 2004). This sampling site was at the upper stream in the forest area. A lot of plants covered the area along the stream and helped decrease the soil erosion problem. Also the substrate of the stream consisted of small stones and gravel. The turbidity in each sampling period of the Mae Kham Watershed from October 2003 to August 2004 is shown in Figure 4-9.

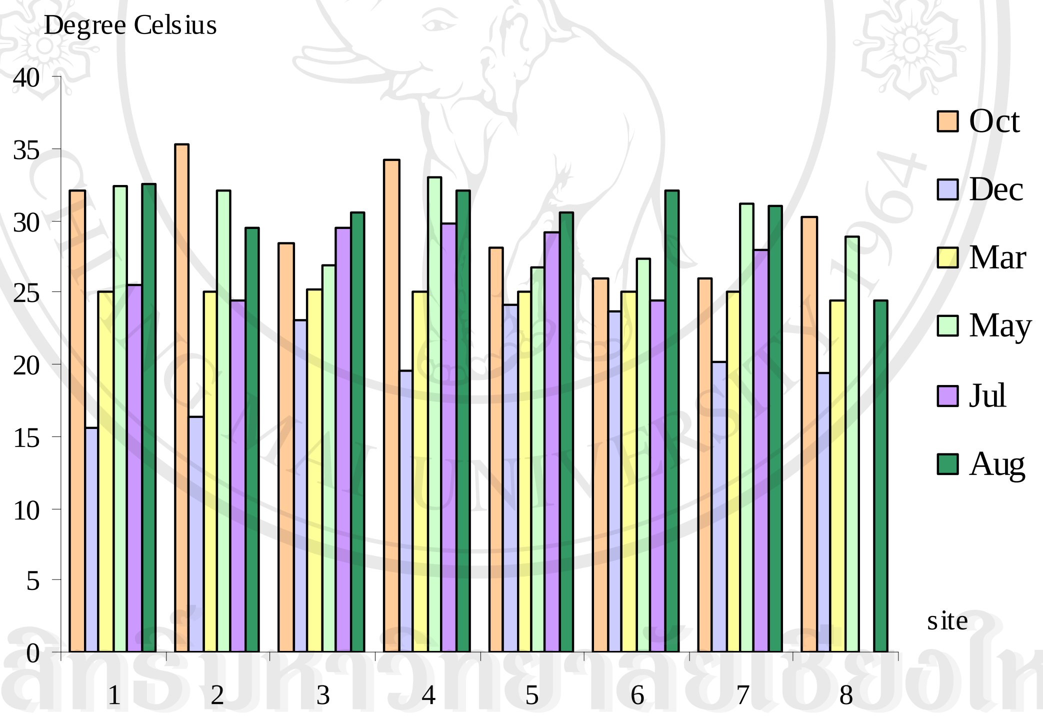

Figure 4-7 Air temperature in each sampling period of the Mae Kham Watershed from October 2003 to August 2004.

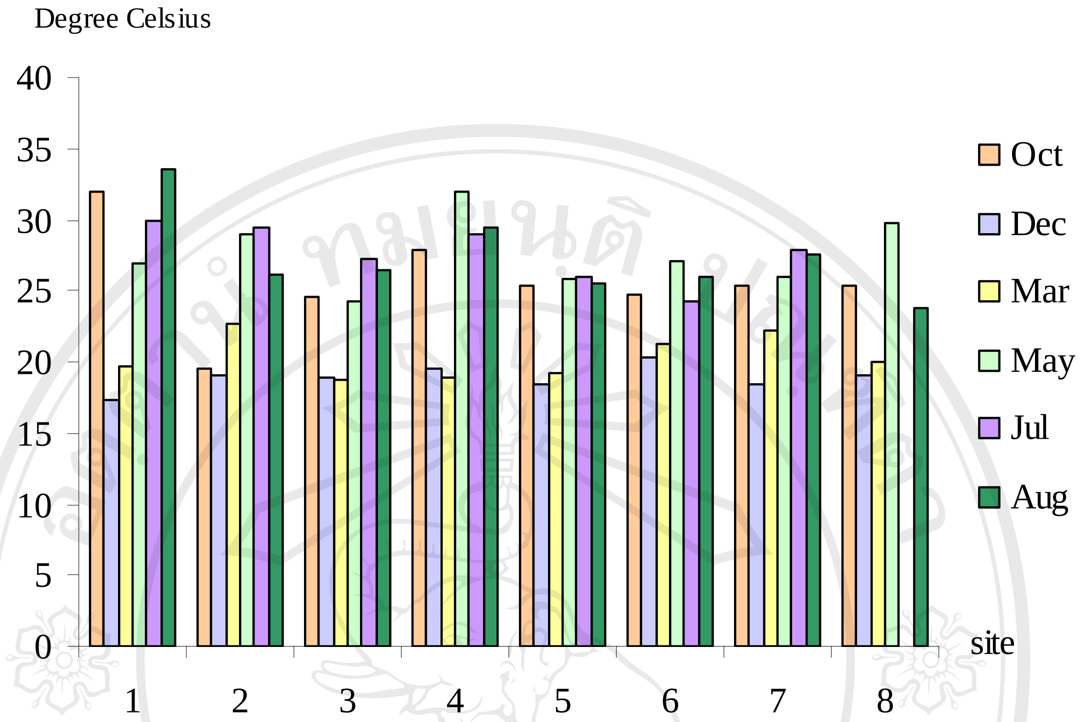

Figure 4-8 Water temperature in each sampling period of the Mae Kham Watershed from October 2003 to August 2004

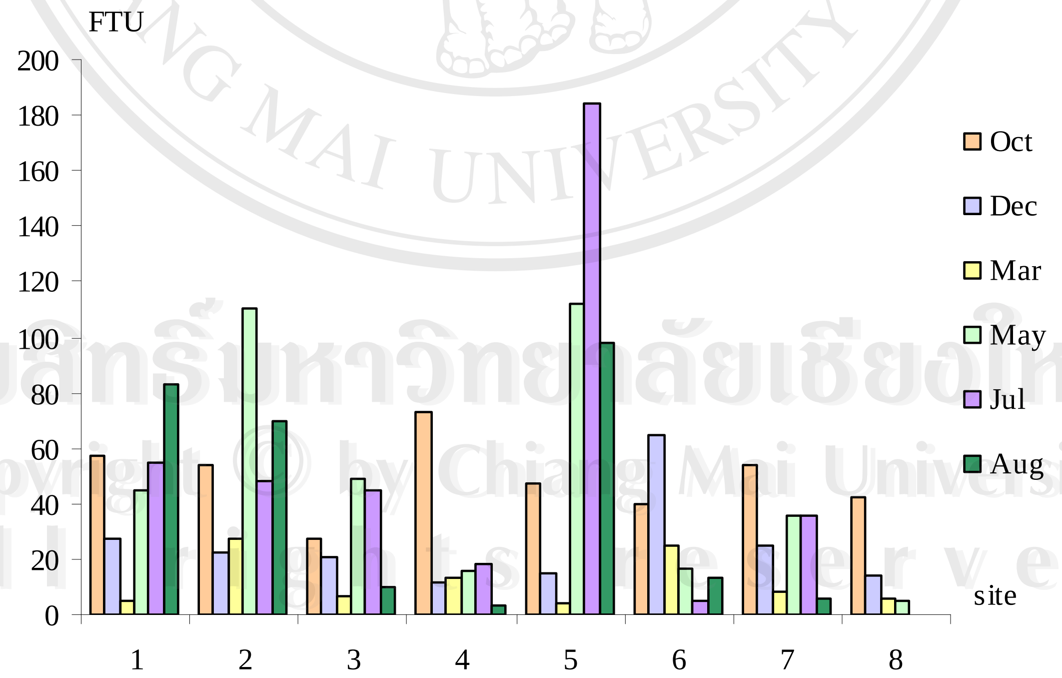

Figure 4-9 The turbidity in each sampling period of the Mae Kham Watershed from October 2003 to August 2004

Velocity

There were differences of velocity in the sampling sites and seasons ($p<0.05$). In each study site the water basin area was different. Thus the water volume was also different. The amount of rain fall in each season was absolutely different. The velocity values were found in the range of 0.1 to 3.5 m/s with the highest values in the cool dry season (October 2003) and the lowest in the hot dry season (March 2004). In October, the velocity in all sampling sites was considerably higher than other months. Because there was a high amount of rain fall due to the effect of having a monsoon climate. The number of aquatic insects in the rainy season was very low at all sampling sites. But the insects had gone with the high water velocity. It could be concluded that the current speed was a major factor in the running of water and that it controlled the occurrence and abundance of species and hence the whole structure of the animal community (Hynes, 1970). Sampling site 1 (Mae Pern) had the lowest velocity values in every month during the year. This was because this sampling site had less water volume and there was road construction beside the stream. Soil erosion drained to the sampling site and cause by water to have high turbidity. Moreover, the dominant species of aquatic insects in the site 1 was Corixidae or water-boatman in the order Hemiptera. These insects were likely to live in low water velocity, as reported by McCafferty (1983). These bugs were present in a number of habitats, including running and quiet waters, and brackish pools. The velocity in each sampling period of the Mae Kham Watershed from October 2003 to August 2004 is shown in Figure 4-10.

3. Chemical properties

pH

pH value of water samples for each sampling date was not different by much between sampling sites. However, there was a difference with a statistical significance at $p<0.05$ between the hot dry and the rainy seasons. In December 2003, pH had interestingly high values, with the highest of 9.9. The pH range of surface water quality standard of Thailand is 5 to 9. The results in December were higher than other months because high values of carbonates and bicarbonates were discharged to the water. This reason was that corroborate by alkalinity resultss in December were also high. The lowest value was 5.9 in the rainy seasons (July 2004) at site 3. The pH in each sampling period of the Mae Kham Watershed from October 2003 to August 2004 is shown in Figure 4-11.

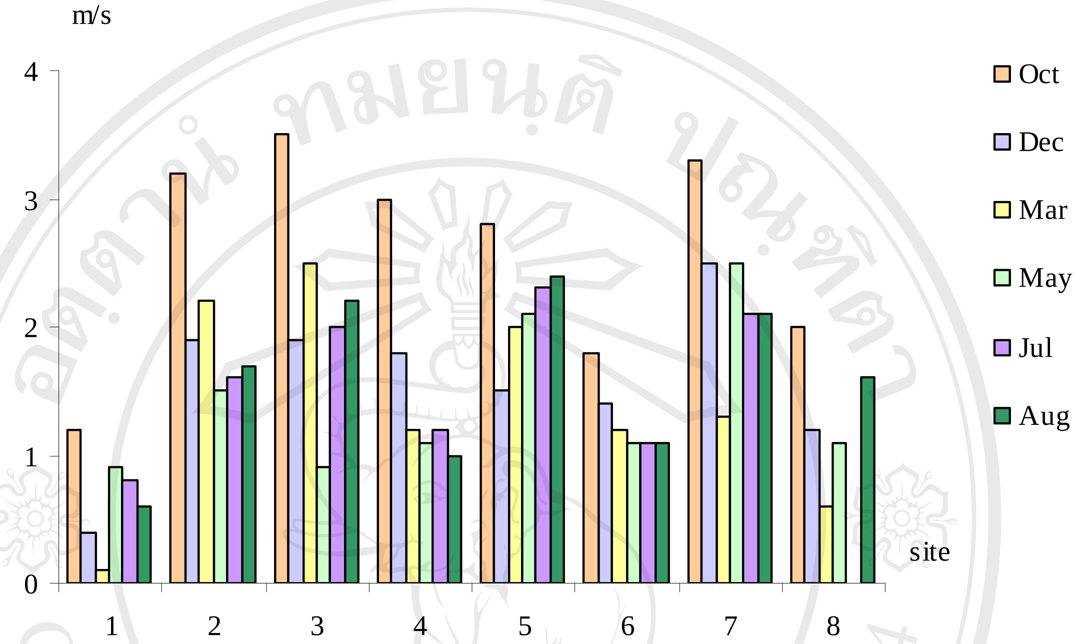

Figure 4-10 The velocity in each sampling period of the Mae Kham Watershed from October 2003 to August 2004

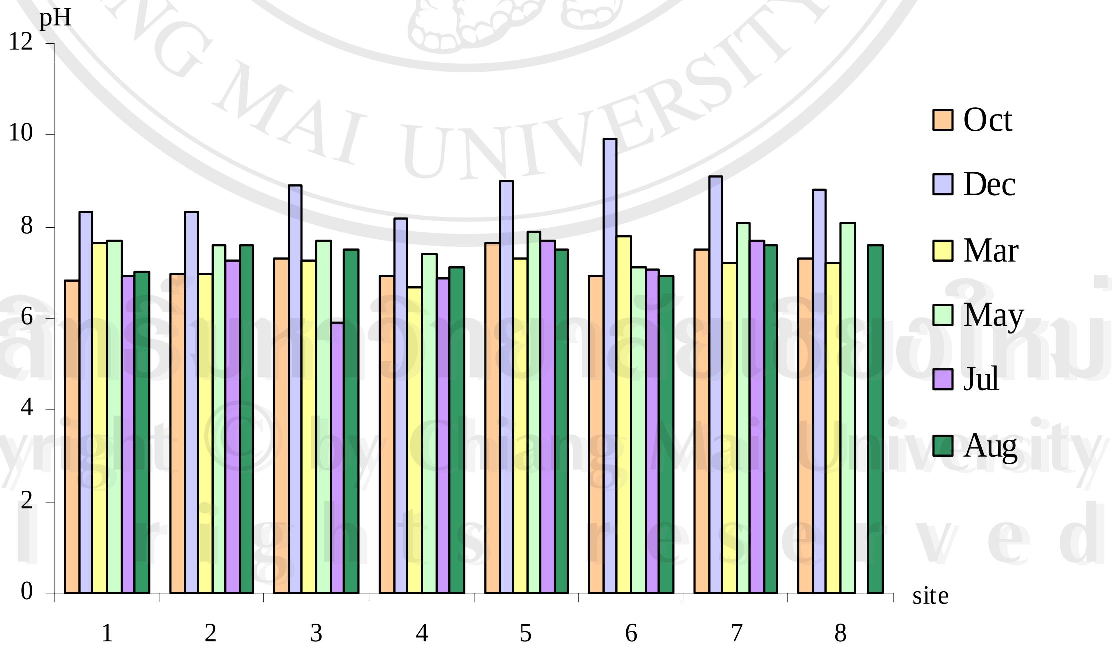

Figure 4-11 The pH in each sampling period of the Mae Kham Watershed from October 2003 to August 2004

Conductivity

The highest value of conductivity was 169.4 µs/cm at site 2 in March 2004. And the lowest value (51µs/cm) was measured at site 1 in August 2004. The highest conductivity was caused by the high rate of soil erosion and that many ions were dissolved in the water. Conductivity due to all ions dissolved in the water was related to alkalinity and velocity. The conductivity values were significantly ($p<0.05$) different in each season and sampling site. The conductivity value tended to be increasing continually during October 2003, December 2003, March 2004 and was the highest in May 2004. Then it tended to decrease in July and August 2004 at almost all sampling sites, except site 1 and site 2. The water volume changed in the different seasons. The dry season had less water volume so the ion-concentration might be higher. Moreover, the conductivity was affected by the impacts of human activities such as agriculture, the raising of livestock and the discharge of urban wastewaters (Jitmanee, 2003; Sopsop, 1995). However, this study did not have too high conductivity values. The Mae Kham Watershed was the running water ecosystem without many ions accumulating in the stream. And it was in the upstream area which was not very contaminated. The conductivity in each sampling period of the Mae Kham Watershed from October 2003 to August 2004 is show in Figure 4-12.

Alkalinity

The alkalinity values varied from 18 to 82 mg/L. Site 2 in the cool dry season (December 2003) was the highest score. While, the lowest score was in hot dry season at site 5 (March 2004) and site 4 (May 2004). Alkalinity indicated that water was contaminated with some ions, carbonate, bicarbonate and hydroxide. Two sources of carbonate and bicarbonate were rain and soil (Chapman, 1996). Phosphate, borate and silicate might also be included (Traichaiyaporn, 2000). Alkalinity was not significant in each season although it was significantly different ($p<0.05$) between sites. At Mae Salong, alkalinity tended to be higher than other sampling sites. The alkalinity depended on the geology of the watershed area and limestone which was a natural source of alkalinity. The alkalinity in each sampling period of the Mae Kham Watershed from October 2003 to August 2004 is shown in Figure 4-13.

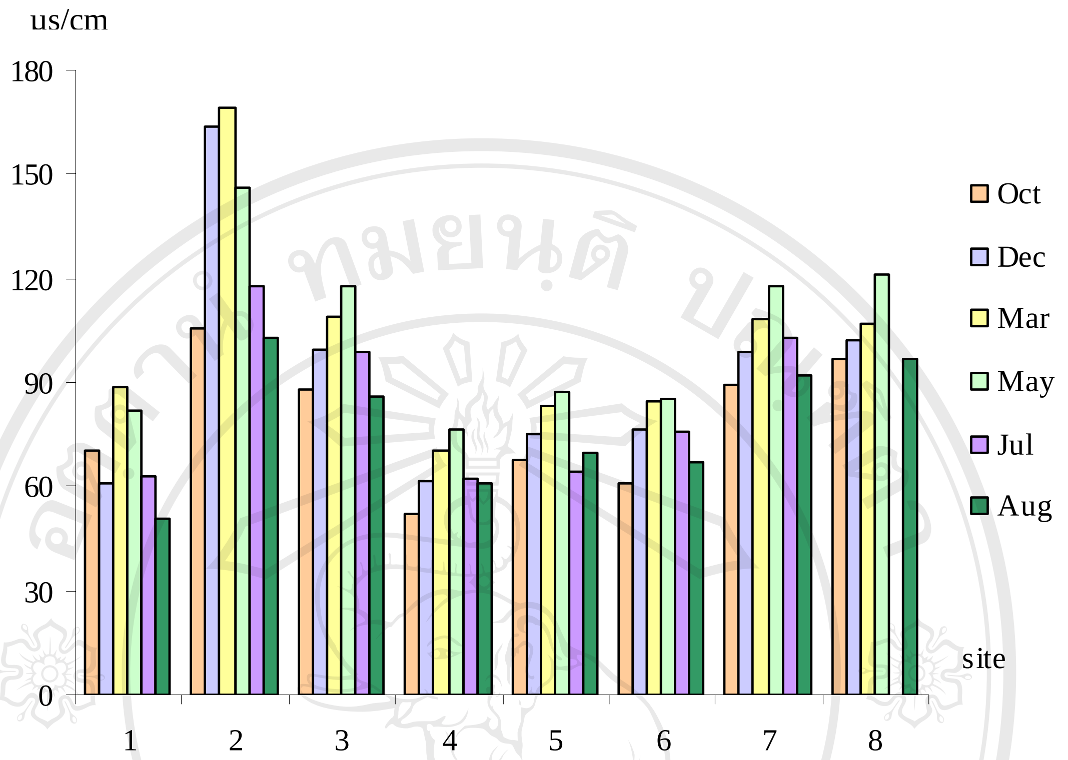

Figure 4-12 The conductivity in each sampling period of the Mae Kham Watershed from October 2003 to August 2004

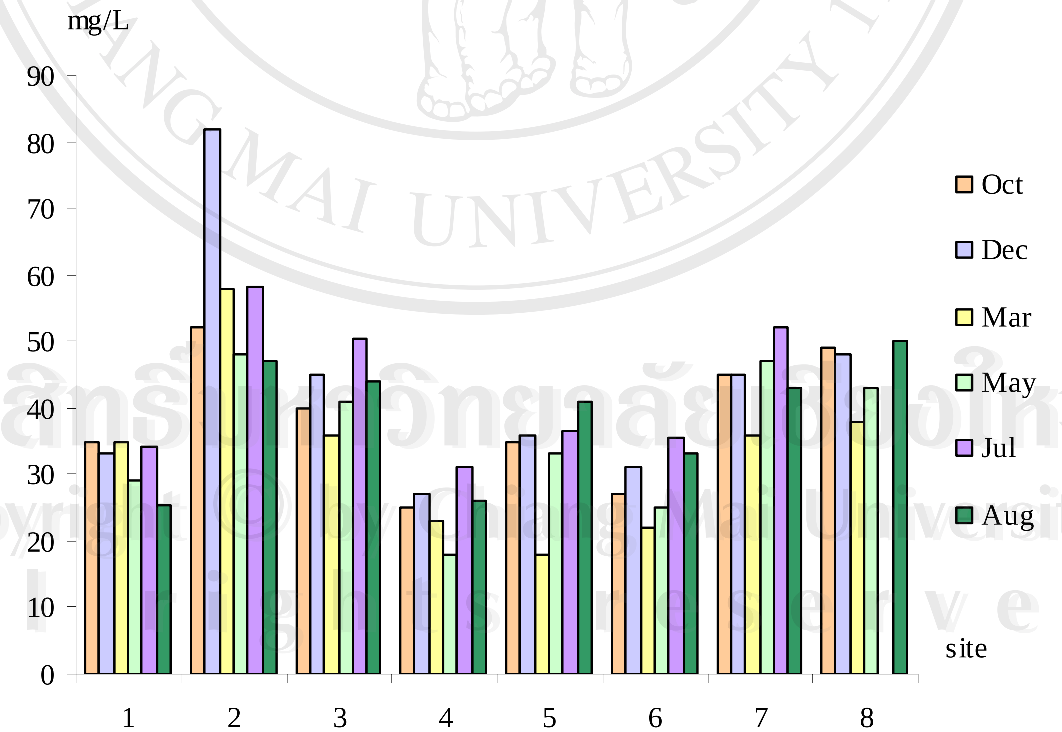

Figure 4-13 The alkalinity in each sampling period of the Mae Kham Watershed from October 2003 to August 2004

Dissolved Oxygen (DO)

DO is present in the normal level of running water as 4.6-8.6 mg/L. It was assessed from class 1 to class 3 when indicated by the surface water quality standard of Thailand. The highest score was revealed at site 7 in the cool dry season. The DO was that collected in October 2003 was higher than other months at all sampling sites. The lowest DO was measured at site 1 in the rainy season (August 2004). Site 1 might be contaminated by urban wastewater passing into the stream. In 2002, Mustow suggested that the low levels of DO at Kha Canal located in Chiang Mai may have been more heavily impacted by organic pollution. There was no considerable difference of DO in the sampling sites. However, differences were pronounced between the hot dry season and the rainy season ($p<0.05$). High oxygen level was found at all sampling sites in the rainy season as a result of velocity. The main source of oxygen was dissolved into water from the atmosphere by mixing process. It was different from standing water due to photosynthesis of microorganisms. Furthermore, the low DO was related to low velocity by less water mixing as reported of Jitmanee (2004). DO level in each sampling period of the Mae Kham Watershed from October 2003 to August 2004 is shown in Figure 4-14.

Biochemical Oxygen Demand (BOD)

This parameter was an approximate amount of oxygen with microorganisms oxidized for organic compound degradation in the water body. The highest BOD (3.4 mg/L) was measured at site 5 in December 2003 (cool dry season).The lowest values (0 mg/L) occurred at site 4 in March 2004 (hot dry season). BOD value was high when the water body contained high organic content. It could indicate bad water quality (Vijaranakorn, 2003). This study did not assess water to be bad quality when compared to the water quality standard of Thailand. The BOD level of all sampling period could be categorized in the range of class 1 to class 3. The water body of site 1 and site 5 in December 2003 and site 1 on May 2004 had high BOD, because organic matters were discharged by the community to the stream. Occurrences of BOD values were not significant ($p<0.05$) in all seasons. Nevertheless, it was significantly different ($p<0.05$) between all sampling sites. Different human activities might have affected BOD level. Wastewater from farming might have an impact on BOD levels more than wastewater from crop growing. BOD value in each sampling period of the Mae Kham Watershed from October 2003 to August 2004 is shown in Figure 4-15.

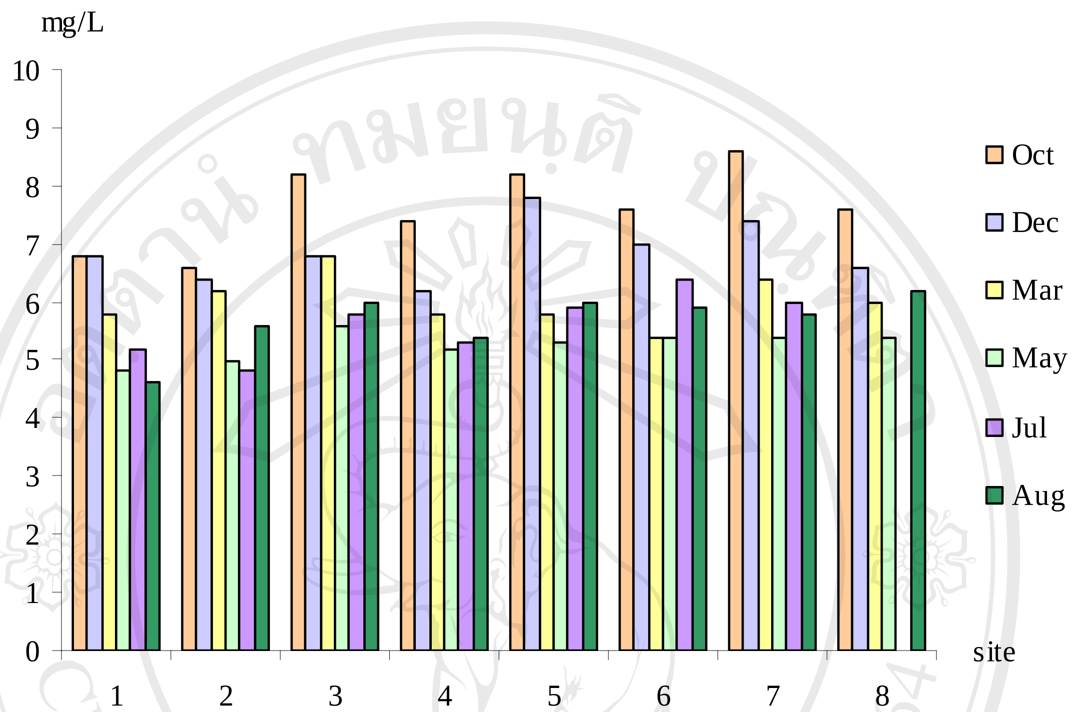

Figure 4-14 The DO values in each sampling period of the Mae Kham Watershed from October 2003 to August 2004

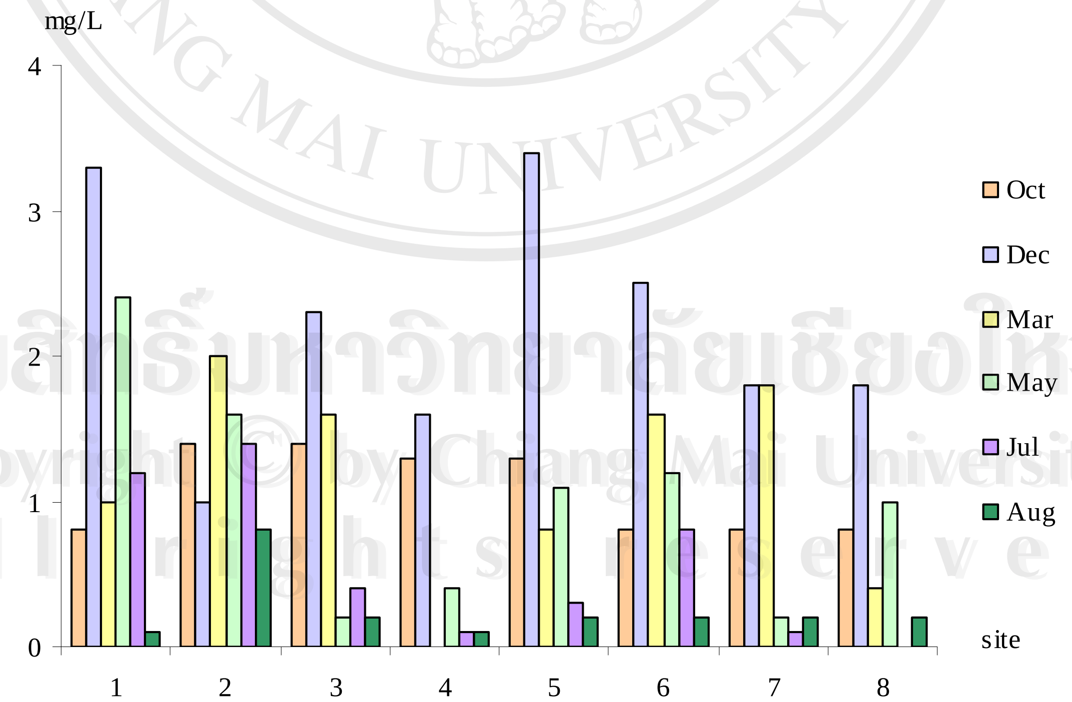

Figure 4-15 The BOD values in each sampling period of the Mae Kham Watershed from October 2003 to August 2004

Nutrients

Nitrate nitrogen (NO_3^--N)

The nitrate nitrogen values varied from 0.2 to 3.3 mg/L. The highest value was detected at site 5 in the hot dry season (March 2004). The NO_3^- did not exceed the water quality standard of Thailand (less than 5.0 mg/L). On the other hand, the lowest was found at site 5 in July and site 1 in August. The spectrophotometer was not able to detect NO_3^- in water samples from site 1 in March 2004 and site 5 in May 2004 because water samples had too many highly dissolved solids. There were two sources of nitrate. NO_3^- was from agricultural lands and domestic waste. In study by Bartram in 1996, it was concluded that NO_3^- might have come from significant sources, chemical fertilizer from cultivated land. And it may be the drainage from livestock feedlots and domestic wastewater (reference by Vijaranakorn, 2003). The results showed statistical differences ($p<0.05$) between the rainy season and the others. But there was no difference between sampling sites. There was a higher trend NO_3^- in March (hot dry season) at all sampling sites. This was opposite to a report of Traichaiyaporn in 2000. In general NO_3^- in the rainy season was higher than the dry season by soil erosion. NO_3^- level in each sampling period of the Mae Kham Watershed from October 2003 to August 2004 is shown in Figure 4-16.

Ammonia nitrogen (NH_3-N)

NH_3 was highest at site 5 in the hot dry season (May 2004) as 1.25 mg/L. It was interestingly higher than other sampling sites on the same date. At sampling site 1, site 2 and site 5 during some sampling period, NH_3 exceeded the water quality standard of Thailand (0.5 mg/L). High concentration of NH_3 was caused from urban wastewater by livestock, agricultural wastes and fertilizers. The higher level was found downstream sites as site 1, site 2 and site 5. The lowest amount (0.03 mg/L) was detected at site 6 in the rainy season (July 2004). There was considerable differences ($p<0.05$) between both the seasons and sampling sites. The difference might have been related to rainfall and water mixing. Furthermore, the amount of ammonia and nitrate could be used to assess the contamination period. High ammonia level indicated that the water had just been contaminated. Whereas, high nitrate level indicated that the water had been contaminated a long time ago. This was because of the nitrogen cycle. Ammonia could be transformed to nitrate by the nitrification procedure. And it could also be transformed back to ammonia by denitrification. Accordingly, it could be concluded that the water quality of the stream was not contaminated a long time ago. There was a comparison between nitrate and ammonia values. NH_3 level in each sampling period of the Mae Kham Watershed from October 2003 to August 2004 is shown in Figure 4-17.

Orthophosphate (O-PO_4^{3-})

Low concentration of PO_4^{3-} values were present in all sites. The highest concentration (0.45 mg/L) was presented at site 3 in March 2004. And the lowest concentration (0.01 mg/L) was showed at site 1, site 2 and site 6 in December 2003. The spectrophotometer was not able to detect PO_4^{3-} in water samples from site 1 in May 2004 and site 3 in July 2004. The PO_4^{3-} might have been contaminated from fertilizer used in agriculture and also from cleaning with detergents that are widely used. Moreover, the phosphorus compounds were converted to orthophosphate by microorganism digestion or oxidation in the natural process (Nutniyom, 2003). For this reason, the microorganism digestion was a main source of orthophosphate contamination in standing water such as reservoirs. But they were not the main source in running waters. The orthophosphate concentration was not significantly different ($p<0.05$) in the season and sampling site. There was lower concentration in December 2003 at all sampling sites. That might have been from different activities of the communities near the streams. Actually, the important nutrients as NO_3^- and PO_4^{3-} were very important to organisms in reservoirs but they had no direct impact to the organisms like aquatic insects in streams. However, they had an indirect affect to the organism as essential nutrients for growth. And they were important to the food web of running water ecosystems. PO_4^{3-} level in each sampling period of the Mae Kham Watershed from October 2003 to August 2004 is shown in Figure 4-18.

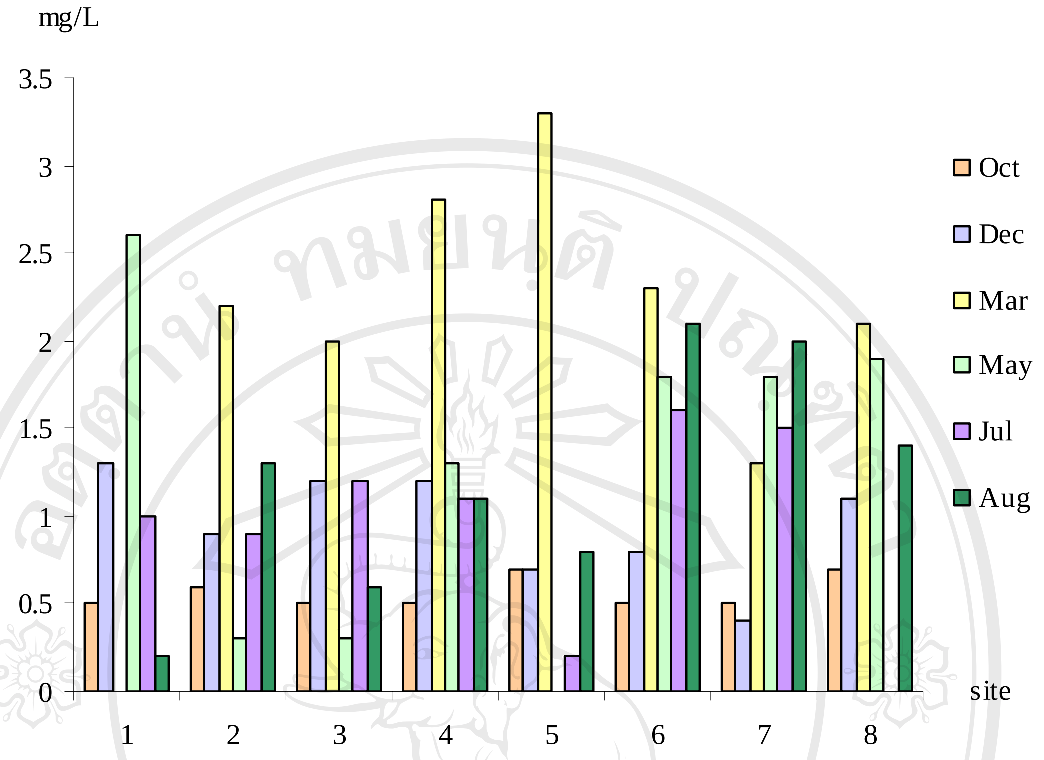

Figure 4-16 Nitrate nitrogen concentrations in each sampling period of the Mae Kham Watershed from October 2003 to August 2004

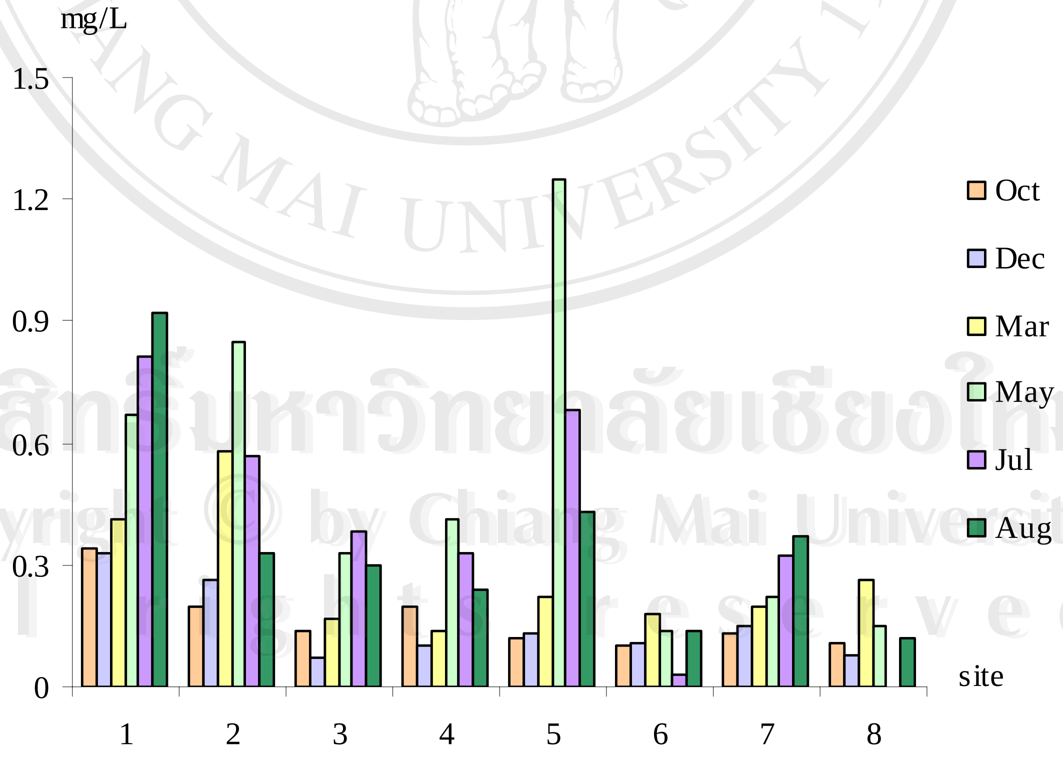

Figure 4-17 Ammonia nitrogen concentrations in each sampling period of the Mae Kham Watershed from October 2003 to August 2004

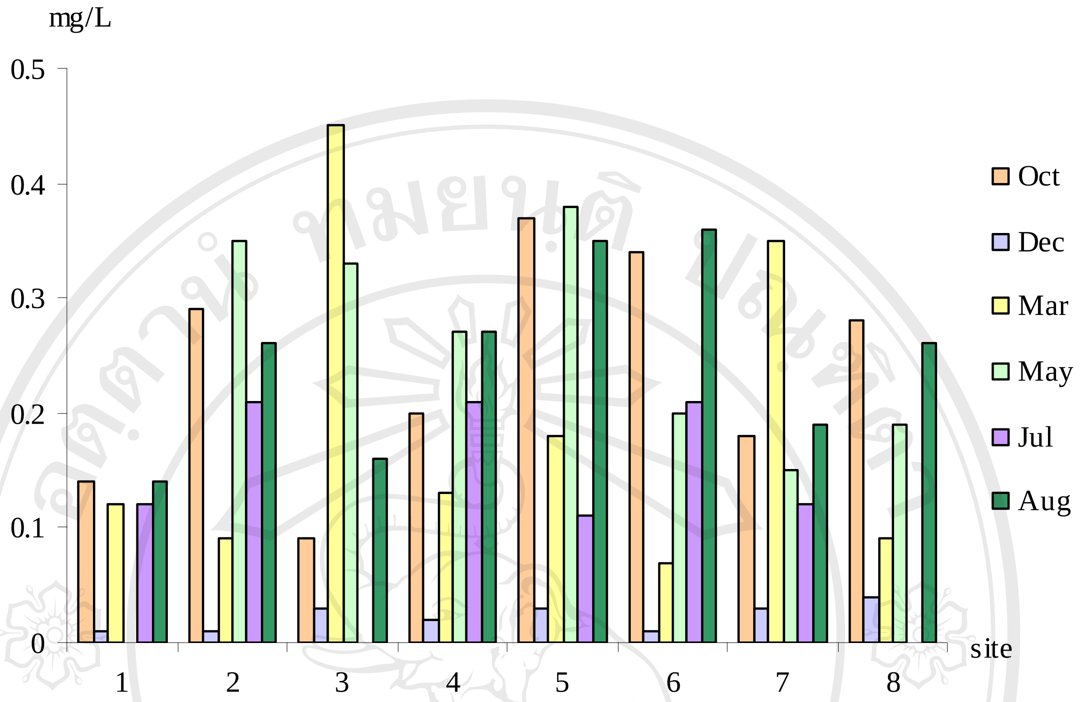

Figure 4-18 Orthophosphate concentrations in each sampling period of the Mae Kham Watershed from October 2003 to August 2004

Statistic Analysis

The Multivariate Statistical Package (MVSP) program was used to analyze the data of this research. The classification method cluster analysis (UGPMA) was used to segregate the sampling site. By using physico-chemical properties, the UPGMA showed 4 groups (Figure 4-19). The first group was at sampling site 5 Mae Kham River in the hot dry season; the second group at sampling site 1 Mae Pern in the rainy season; the third group at sampling site 5 Mae Kham River in the rainy season; and the last group at the other sampling sites and all seasons at site 2 Mae Salong, site 3 Mae Salap 1, site 4 Huai Moh Khang, site 6 Huai Jai, site 7 Mae Salap 2 and site 8 Mae Pern Pha Mieng and at site 1 in the cool dry and hot dry seasons and at site 5 in the cool dry season. In addition, they could be classified by the diversity of aquatic insects into 4 groups (Figure 4-20): the first group was at site 2 in the hot dry season; the second group was at site 4 in the hot dry season; the third group was at site 3 and site 7 in the hot dry and cool dry seasons and site 2 and site 4 in the cool dry season; and the last group was at sites 1, 5, 6 and 8 throughout the year and sites 2, 3, 4 and 7 in the rainy season. Nevertheless, there was no obvious difference between groups in both the segregation by physico-chemical properties and the diversity of aquatic insects. Principal Component Analysis (PCA) was used to analyze the correlation of all sampling times. Only site 2 in the hot dry season was clearly different from other sampling periods (Figure 4-21). As a result, the water quality in each sampling site showed not obvious difference, because the downstream sites had an impact from human and nature. The upstream sites also had humans impact, but from different sources. Therefore, the clear difference between sites was not shown. Moreover, the chosen sampling sites for this study were not of specific character.

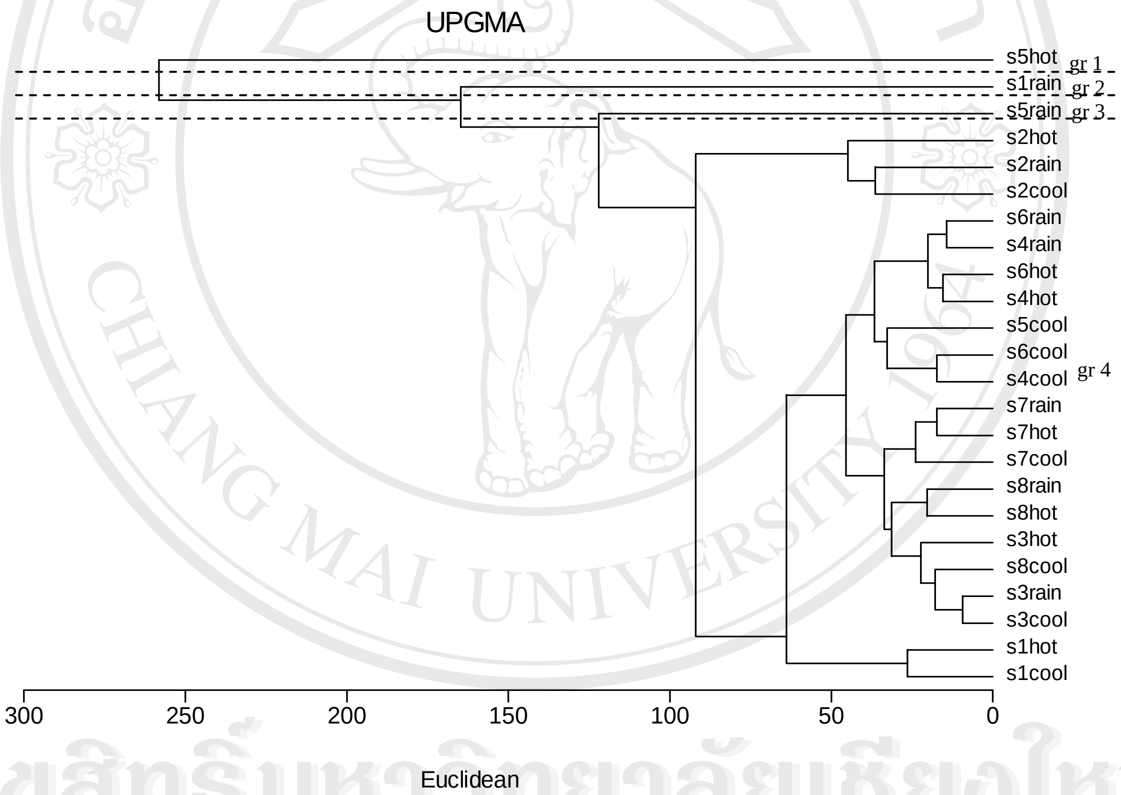

Figure 4-19 The cluster analysis of sampling period by using physico-chemical properties of the Mae Kham Watershed from October 2003 to August 2004

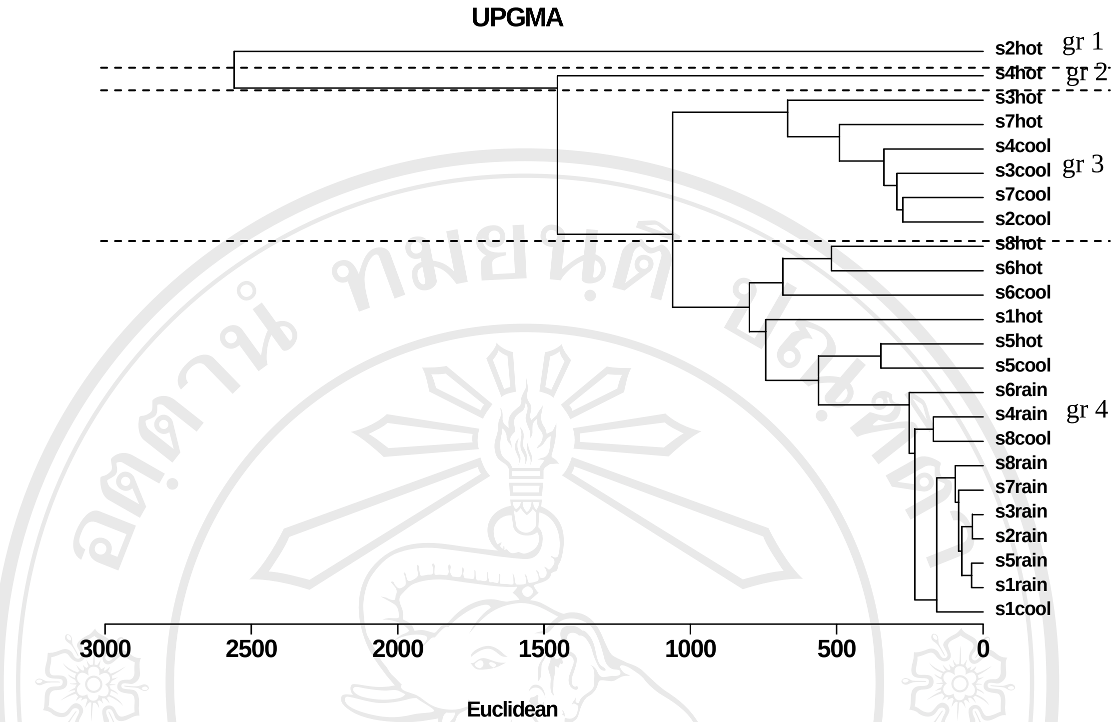

Figure 4-20 The cluster analysis of sampling period by using aquatic insects diversity of the Mae Kham Watershed from October 2003 to August 2004

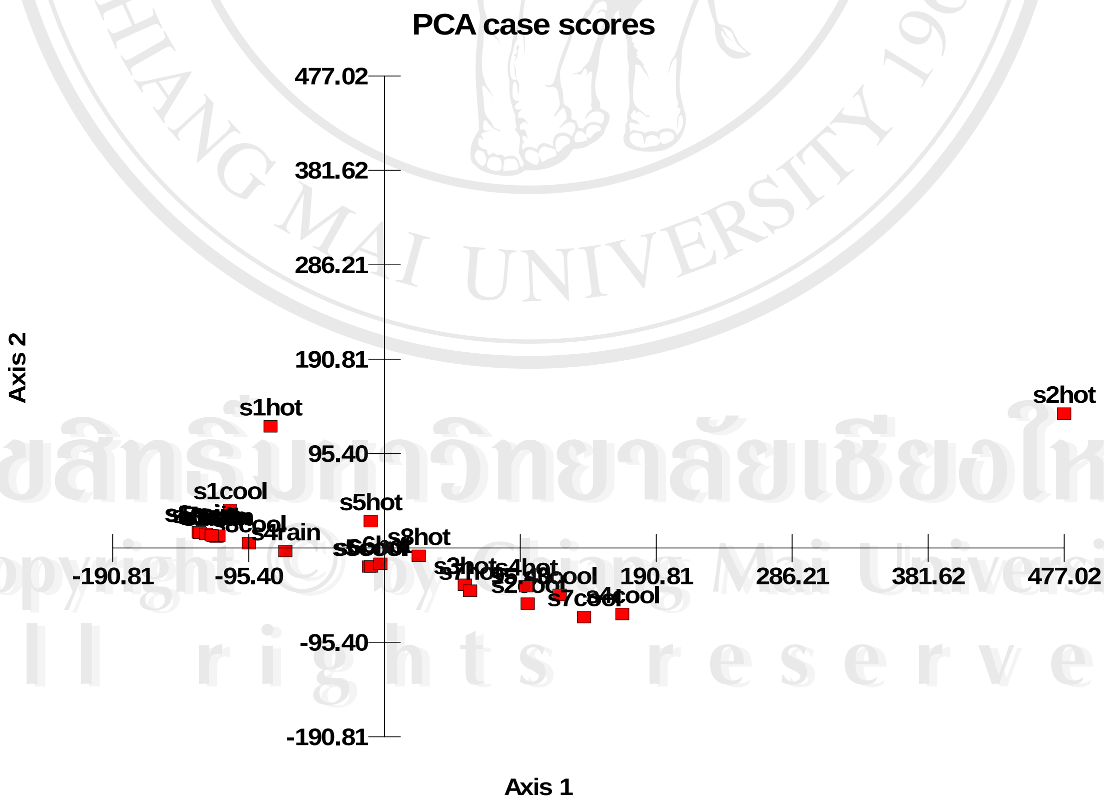

Figure 4-21 The correlation of sampling periods by using aquatic insect diversity of the Mae Kham Watershed from October 2003 to August 2004

The PCA analysis revealed the correlation between aquatic insect orders and the water quality (Figure 4-22). Insects in order Coleoptera, Diptera, Odonata, Megaloptera, Lepidoptera and Hemiptera were related to the concentration of nitrate nitrogen. And the insects in order Ephemeroptera, Plecoptera, Trichoptera and Collembora had relationships with conductivity and phosphates. Conductivity was an important property to indicate water quality. Therefore, insects in sensitive order, such as Ephemeroptera, Plecoptera and Trichoptera were affected.

Correlation between biological indices and water quality in some physico-chemical properties were evaluated (Figure 4-23). The values of ASPT, EPT ratio and diversity index were clearly related to velocity, DO, alkalinity and conductivity. From this correlation it could be concluded that the 3 indices were appropriated to be used to indicate water quality in the Mae Kham Watershed. They were related to physico-chemical parameters which were significant to specify the quality of the running water. However, HBI index was not related to any parameters.

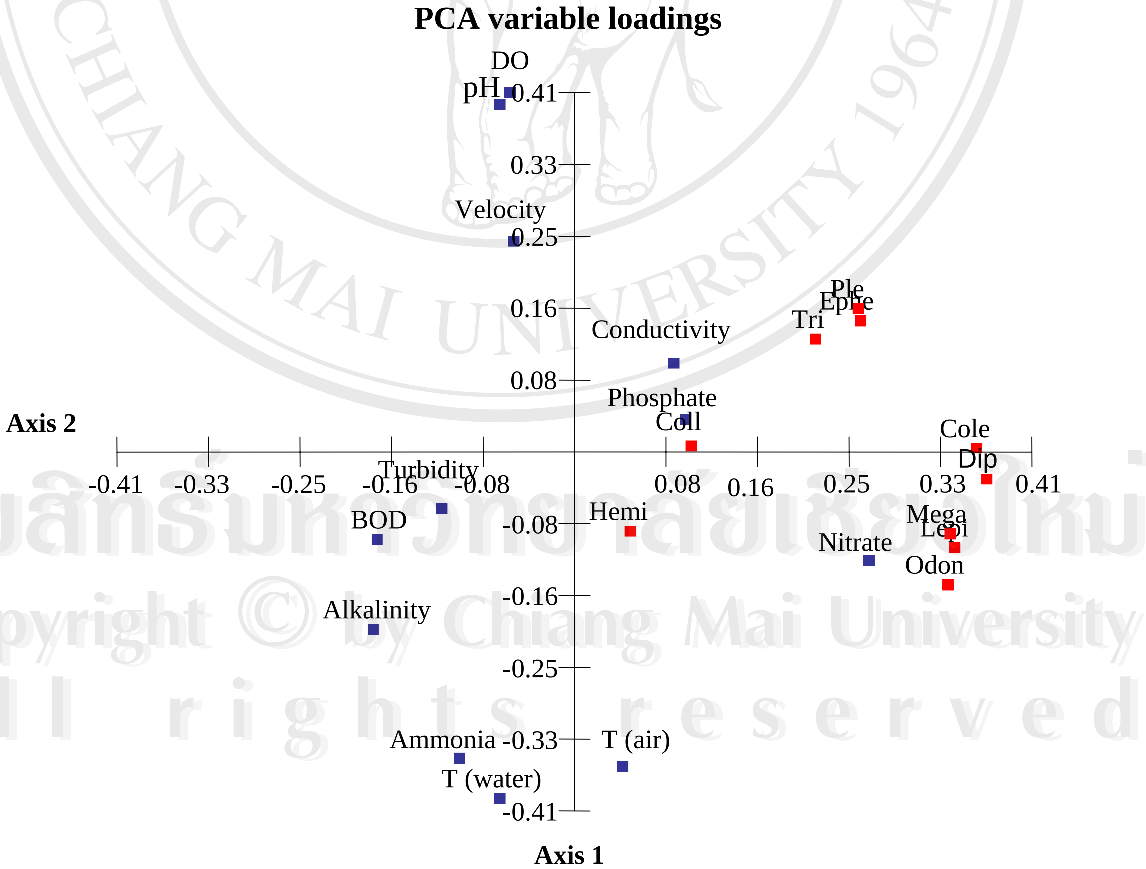

Figure 4-22 The correlation between aquatic insect orders and water quality of the Mae Kham Watershed from October 2003 to August 2004

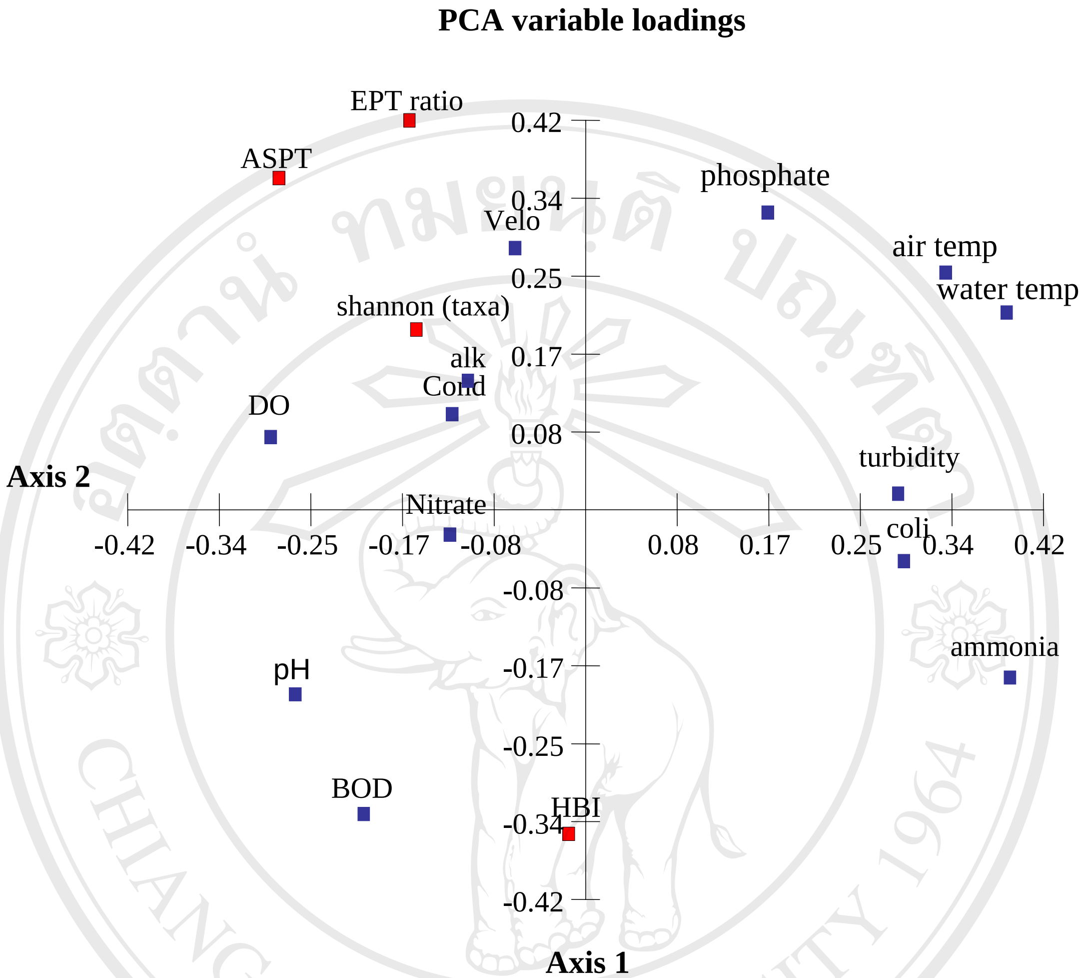

Figure 4-23 The correlation between biotic indices and water quality in some physico-chemical properties of the Mae Kham Watershed from October 2003 to August 2004