Effect of Human Trampling on Abundance and Composition of Stream Insect Communities

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Master of Science Thesis in Ecology

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Major Program	Ecology

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ชื่อวิทยานิพนธ์	ผลกระทบของการเหยียบย่ำต่อโครงสร้างและความหนาแน่นสังคมของแมลงน้ำ
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บทคัดย่อ

การศึกษาครั้งนี้ ได้ทำการศึกษาเกี่ยวกับผลกระทบของการเหยียบย่ำต่อ โครงสร้างและความหนาแน่นของสังคมแมลงน้ำ โดยสำรวจปริมาณการเหยียบย่ำของผู้ที่มาเที่ยวที่บริเวณน้ำตกโดนงาช้าง อ. หาดใหญ่ จ.สงขลา น้ำตกบริพัตร อ.รัตภูมิ จ. สงขลา และ น้ำตกไพรวัลย์ อ. กงหรา จ. พัทลุง

จากการสำรวจนี้ ในบริเวณที่มีผู้คนสัญจรไปมามาก มีปริมาณการเหยียบย่ำมากพบว่ามีความหนาแน่นและความหลากหลายของแมลงน้ำน้อยกว่าบริเวณที่มีผู้คนศัญจรไปมาน้อยซึ่งมีปริมาณการเหยียบย่ำน้อย หลังจากสำรวจแล้วได้ทำการทดลองจำลองการเหยียบย่ำโดยแบ่งระดับการเหยียบย่ำเป็น 4 ระดับคือ 1). ระดับสูง 2). ระดับปานกลาง 3). ระดับต่ำ และ 4). ระดับควบคุม ผลการทดลองพบว่า บริเวณที่มีการเหยียบย่ำต่ำ และบริเวณควบคุม มีความหนาแน่นและความหลากหลายของแมลงน้ำมากกว่าบริเวณที่มีความเหยียบย่ำระดับสูงและปานกลาง และหลังจากที่ได้รับผลกระทบจากการเหยียบย่ำแล้ว แมลงน้ำไม่มีการฟื้นตัวกลับมารวมกลุ่มดังเดิม (recolonization) ภายใน 7 วัน

ดังนั้น การเหยียบย่ำของมนุษย์แสดงให้เห็นถึงผลกระทบต่อความหนาแน่นและความหลากหลายของแมลงน้ำ ผลกระทบนี้ควรได้รับการพิจารณาให้มีการควบคุมเพื่ออนุรักษ์ทรัพยากรแหล่งน้ำต่อไป โดยเฉพาะอย่างยิ่งในบริเวณน้ำตกที่มีชื่อเสียงที่นักท่องเที่ยวนิยมไปเที่ยวมาก

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Abstract

This study was carried out in three waterfalls: 1). Tone Nga Chang waterfall in Muang District , Songkhla Province ; 2). Boripat waterfall in Rattapum District , Songkhla Province and ; 3). Priwal waterfall in Kongra District, Pattalung Province. The effect of trampling was observed by surveying areas with high intensity and low intensity of trampling. The result of the survey was that the areas of high intensity of trampling had lower abundances and lower diversity of insects than the areas of low intensity of trampling.

After the survey, an experimental trampling study was conducted. There were 4 treatments which were 1). high intensity of trampling; 2). intermediate intensity of trampling ; 3).low intensity of trampling ; and 4). control. The result of the experiment was that abundance and diversity of stream insects was higher in low trampling and control plots than in high and intermediate trampling plots. After trampling, recolonization was not complete after 7 days.

Trampling, therefore was shown to have effect on abundance and diversity of stream insects. The effects of human trampling should be considered in stream management and conservation plans, especially, at popular waterfall sites.

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Khanobporn Buranapanitkit

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Chapter 1

General Introduction and Literature Review

Stream ecosystems are subject to frequent natural and man-made disturbances. It is likely that all streams are disturbed to some degree, as a result communities are usually in state of recovery from the last disturbance event, for example, flood or drought (Reice, 1985; Dudgeon, 1987). Recolonization of denuded patches following small scale physical disturbances, however is rapid (Lake *et al.,* 1989). After a large scale of disturbance, the recovery of stream invertebrates was still weak after 14 months (Englund, 1991). Invertebrate community in copper polluted streams recovered about 6 weeks (Schultheis *et al.*, 1997).

Pattrick (1963) compared the relative abundance of diatom species in natural and polluted streams. She found that polluted streams supported fewer species but that a few of these were extremely abundant. Pollution creates conditions that are intolerable or even lethal for most of species in the communities, but which are extremely favorable for a few species. Such conditions are not only created by pollution. Acidic streams that flow through coniferous forests also have relatively fewer species than other natural streams, and the relative abundance of the species are disturbed less equitably (Ricklefs, 1973). This pattern probably occurs wherever conditions are marginal for life.

The continuing down hill flow of water which characterizes streams influences all aspects of the lives of lotic animals. An important process is drift, where benthic animals enter the water column and are carried downstream by the current until they settle out. Both entry to , and exit from the water column can be a passive or active process. Passive initiation of drift is especially common during spates, and involves accidental dislodgment of animals which are swept away by the current. Subsequent return to the stream bed may involve active swimming movements, entanglement in snags and other obstacles, or passive deposition in areas of slow flow or dead water (Dudgeon, 1987). Active entry into the water column induced by the animal itself may involve swimming movements from sheltered sites to those exposed to the full force of the current or merely releasing hold of the stream bed (Dudgeon, 1987). Passive or accidental entry into the water column comprises background drift; where this occurs during spates, it may be termed catastrophic drift and can lead to significant reductions in benthic population densities (Anderson and Lehmkul, 1968).

One of the most consistent effects of disturbances on the structure of communities is to increase the variation in the relative abundance of species. The high diversities observed in tropical rain forest trees and in coral reefs appear to be a consequence of disturbances intermediate in the scales of frequency and intensity (Connell, 1978). It is not clear whether a similar mechanism may explain differences in diversity among streams. Evidence from small-scale studies of grazing communities on cobbles, however , do show the importance of disturbance and succession process (Reice, 1985). Englund (1991) examined the effects of disturbance on stream moss and the effects of disturbance on stream moss and the associated invertebrate community structured by overturning stones in the stream. He concluded that such disturbance of substrate markedly reduced the distribution of stream moss and the total abundance of invertebrates as well as diversity.

Humans also add disturbances or perturbations which can effect the structure of stream communities. Channelization, damming and water transfers alter natural stream flow patterns influencing seston transport, sediment movements and also river bed characteristics. Dams also impede the breeding migrations of fish and some crustaceans. Finally, the introduction of exotic plants and animals has disrupted the integrity of many natural stream ecosystems, an affect exacerbated by the tendency for invasion of alien species to be more successful in perturbed or polluted environments (Dudgeon, 1987). Water in streams is used for consumption, irrigation, and hydropower production. Man's modification of stream valleys can also affect the lotic fauna by influencing the terrestial adult stages of amphibiotic aquatic insects (Dudgeon, 1992). Indiscriminate use of insecticides, or removal of riparian vegetation leading to destruction of mating and resting sites, may reduce breeding success and recruitment. Streams are also used for recreation.

In Thailand, waterfalls in wildlife sanctuaries and national parks are extremely popular places for recreation. People in large numbers go to streams on weekends or holidays to enjoy themselves bathing and playing in streams. People sometimes collect aquatic animals and plants, and often over-turn stones and trample habitat. The impact of these activities in streams are largely unknown.

Trampling could potentially cause changes in physical structure of the environment and associated communities. This activity could result in reduction in density of organisms. Thomas and Willson (1992) studied the effect of experimental trampling on the federally endangered plant species, *Lesquerella filliformis Rollins.* They found the highest level of trampling reduced *L. filliformis* survival by 42% compared to control plots. Trampling accounted for the greatest percentage of damage to plants in the forest (McCarthy and Facelli, 1990). Trampling disturbance do not only arise from human activities. In a study of a trampling by geese led to as much as 47% tree seeding mortality (Wurtz, 1995). Panetta and Wardle (1992) studied gap size and regeneration in a New Zealand diary pasture, they found that as a result of trampling by cattle, seeding mortality occurred most rapidly for all species in the bare plots. Trampling can lead to changes in soil structure and may cause severe problems of soil degradation. Usman (1994) studied the effects of cattle trampling and soil compaction. His study showed that cattle trampling produced dense zones of soil at a depth of 7.5 cm, which reduced infiltration, in spite of the existence of numerous macro pores.

Substrate structure is important for the micro distribution and abundance of stream fauna (Hynes, 1970). Different organisms prefer different type of substrate to live. Preference for more than one substrate type is often seasonally determined or dependent on the development stage of the species (Tolkamp, 1982). Most stream substrate consists of different particle sizes such as gravel, pebbles, cobbles or detritus. Substrate particle size was found to be a primary limiting factor in the micro distribution of some organisms such as mayfly larvae and also other benthic animals (Hynes, 1970; Minshall, 1982). Substratum characteristics seem to be the major factor that control the occurrence of animals. Trampling by visitors, therefore, could influence the distribution of stream insects, through changing the physical structure of the stream bed, as well as direct dislodgment (see Figure 1).

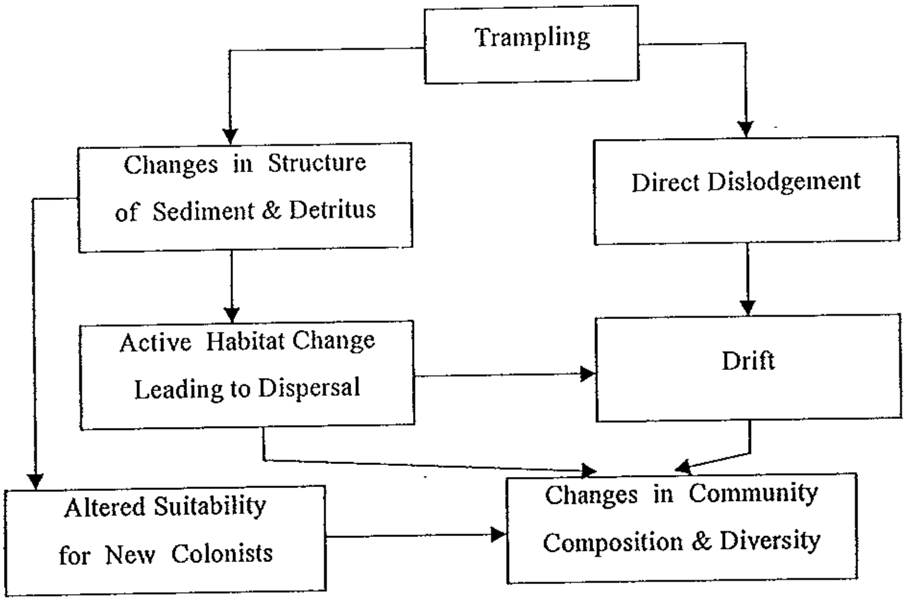


Figure 1 Conceptual framework for the potential effects of trampling on the composition of stream community

Although human activities in streams are wide spread and in some locations, intense, their effects have apparently not been studied. A search of on- line data bases failed to reveal any studies of trampling disturbance on stream communities. Intentional trampling, however, has been used as a qualitative sampling method by stream ecologists for decades, because of its effectiveness in dislodging fauna from the stream bed and into drift or hand held nets downstream (Hynes, 1975). There have however, been a few detailed examinations of the effects disturbance by trampling in terrestrial and marine environments.

Studies of trampling in terrestrial environments described above for example (Thomas and Wilson, 1992 : 101-105 ; McCarthy and Facelli, 1990; Panetta and Wardle, 1992; Usman, 1994) have often considered the impacts of herbivores and less frequently of humans, on soil and vegetation. Most habitats in terrestial environments consist of sand , soil or clay, etc. These habitats are usually covered by grass or other plant species. The organisms that are influenced directly by trampling are vegetation and some soil invertebrates.

Studies of trampling in marine environments have generally compared one area heavily used by people with another area of low use (e.g. Boalch *et al.,* 1974; Zedler, 1976). Beachamp and Gowing (1982) attributed differences between sites or between times to human influences. Trampling by visitors in some shallow marine environments has increased dramatically in recent years because of growth of tourism. Balley and Griffith (1989) examined the effects of human trampling on exposed rocky shore by marking transects across the intertidal zone of a little frequented section of the shore and subjected to trampling up to 500 times per month. They found immediate effects of pedestrain impact included the dislodgment of dead barnacles, damage to algae and the crushing of small numbers of amphipods and isopods. Long term effects, however, could not be found from this study, and after a few months, those transects subject to the most intensive pressure did not differ significantly from a control area.

Trampling by scuba drivers and snorkellers on reefs can also cause serious impacts (Hawkins and Roberts, 1993). Recreational activities including scuba and skin diving, fishing, human trampling, sediment resuspension, and other damage caused by " innocent " visitors are causing a rapid deterioration of reefs. Their destruction require years and decades for full recovery (Rinkevich, 1994).

However, conclusion based upon these previous terrestial and marine studies must be viewed with caution because of the absence of replication of experimental and control areas and the natural variability of populations (Sousa, 1985). The most convincing evidence of causal relationships between biological patterns and human activities comes from experiments in which the levels of the activity in question are modified (Underwood and Peterson, 1988; Keough and Quinn, 1991).

Experimental investigation has the advantage over field surveys because the investigator can examine species' s abundance before and after trampling and use the results to predict what will happen to a previous untrampled area. The study by Povey and Keough (1991) is an excellent example of an experimental approach to determine the effects of human trampling. In their study of the effect of disturbances caused by pedestrian traffic on a rocky shore in temperate southern Australia, they investigated the effects of three levels of sustained trampling on organisms in three different habitats (Hormorsira mat, coralline algal mat and bare rock). They also tested for the presence of such effects at different spatial and temporal scales. They found that trampling by visitors could result in replacement of its assemblage with bare rock and grazing mollusks, and thus, trampling should be considered as a disturbance capable of directly and indirectly influencing intertidal populations on rocky shores.

The study of Povey and Keough (1991) in the marine environment is relevant to an investigation of trampling effects in stream ecosystems in a number of ways. The activities of human visitors in the shallow marine environment are broadly similar to activities of visitors to the stream environment including playing in the water and walking over the substrate. The studied habits were under around 0.5 meter of water as is typical in high use areas of streams in Thailand. They adopted an experimental design with control areas to eliminate confounding factors. To apply their approach to a study in the stream ecosystem, attention must be paid to the level of trampling. Most habitats in marine environment are algal mat, bare rocks, coral reef, mussel bed, etc. Tourists usually avoid stepping on algal mat because it is slippery , avoid stepping on mussel bed, coral reef or any habitat which has sharp edge because that habitat might hurt their feet. Thus, the level of trampling that is considered high intensity in marine environment in some habitats might not be equal to the high intensity in stream environment. In stream ecosystem, most habitats consist of gravel, sand, cobbles, litter and boulder. These habitats in stream environments which hardly have sharp edge may be exposed to human trampling levels higher than those in coral reef or other marine habitats. However, stream environments do have some habitats which are covered with some vegetation that makes these habitats slippery as well.

Shallow rock platforms in the marine environments are generally larger than the upland stream areas with waterfalls popular with visitors.

Along with the potential for downstream impacts, this makes selection of sites in stream ecosystems more difficult.

In this study, a preliminary survey of human behavior was made to investigate variability in the intensity of human trampling. This data was then used to develop a classification of sites according to their exposure to trampling and so that we could manipulate the system with realistic levels of trampling.

After the descriptive survey, a trampling experiment was carried out to draw stronger conclusion about the effects of human trampling. The objectives of this research was to test 1). What are the effects of human trampling on diversity and composition of stream insect communities? 2). Are all habitats affected similarly? 3). What kinds of organisms appear to be more susceptible to human trampling? 4). At the scale of 5 m patch, how long does the effect last?

Chapter 2

Survey

Effect of Human Trampling on Abundance and Composition of Stream Insect Communities

Introduction

Waterfalls are a popular recreation destination for tourists in southern Thailand, especially on weekends. At Tone Nga Chang waterfall in Songkhla province for example, as many 10,000 visitors will come in one day(Tone Nga Chang Wildlife santury, 1996).

Trampling in terrestial environment substrate is known to have effects on soil structure, vegetation and associated micro - fauna. Experimental studies on marine rocky shores have become demonstrated clear effects of human trampling on abundance and composition of marine communities (Povey and Keough, 1991). Little is known, however, about the effects of trampling in stream communities.

Stream insects are known to have complex substrate preferences and drift behaviors suggesting that trampling could also have a substantial impact on insect communities both directly and indirectly.

Objectives

This preliminary survey was carried out to investigate levels of human activity (i.e. trampling) and the diversity and composition of stream insect communities at different sites and habitats.

Materials and Methods

1. Study sites

The study sites were located at three waterfalls (Tone Nga Chang, Boripat and Priwal) in wildlife sanctuaries in southern Thailand. Tone Nga Chang and Boripat are in the province of Songkhla, whereas Priwal is in the province of Pattalung. The three waterfalls are similar geographically and well known to tourists (see Figure 2).

These three waterfalls were chosen because although they are very popular, they also include reaches which are not so frequently visited. Their popularity is not a surprising, given their proximity to the major urban and tourists center of Had Yai. The aquatic habitats in the waterfall reaches diverse varying from sandy pools, riffles, cobble runs to vertical granite drops. In most places for most of the year, water is less than 0.5 m in depth. More over , the physical factors, the percentage cover of habitats, and the stream gradient of these three waterfalls are similar (Table 1).

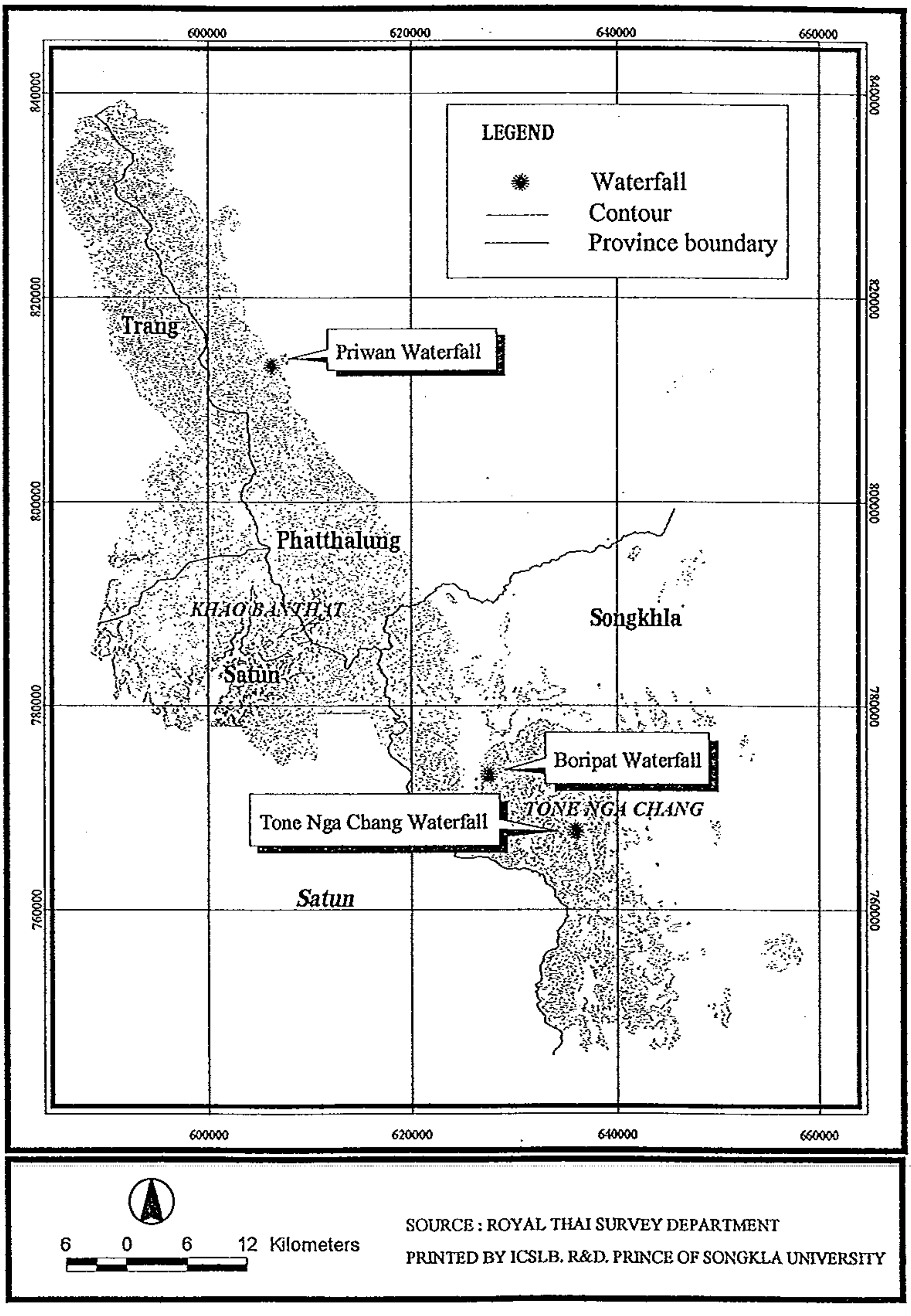


Figure 2 : Location of the three waterfalls. Shaded areas have elevation above 500 meters.

Table 1 Some physical factors in 3 sites(Tone Nga Chang, Boripat, Priwal).

Site	% cover of five habitats (n= 500 random points over 20 meter reach)	Stream gradient (1km vicinity of site)
Tone Nga Chang	Boulder = 22 Cobble = 12 Gravel = 19 Litter = 21 Sand = 26	1 : 10
Boripat	Boulder = 22 Cobble = 16 Gravel = 21 Litter = 18 Sand = 23	1 : 10
Priwal	Boulder = 25 Cobble = 17 Gravel = 15 Litter = 23 Sand = 20	1 : 10

2. Survey of natural variation in stream community composition at sites with different trampling intensity.

2.1 Observations of natural human trampling intensity in the stream

I made systematic observations of the behavior of visitors in the stream at the three waterfall sites. The purpose of these surveys was to get an idea of realistic and quantitative levels of trampling experienced by stream habitats.

Four rectangular plots (4m x6m) were selected at each waterfall. Two plots were in areas known to be frequently visited and this likely to have high levels of trampling and the other two were in areas known to be seldom visited and thus likely to have low level of trampling (see Figure 3).

Plots were inconspicuously marked out, and included some areas of each habitat type (see Table 2).

In each plot I counted the total steps of people visiting the plot in 8 hours to derive trampling levels in steps per hour per plot. The date of surveys and collections samples were Tone Nga Chang April 15 1995, Boripat May 1 1995, and Priwal May 15 1995. These days were weekends.

Table 2. Classification of each habitat type.

Habitat	Definition
Boulder	A large rounded mass of rock lying on the surface of the ground.
Cobble	A rock fragment between 64 and 256 millimeters in diameter.
Gravel	An unconsolidated mixture of rock fragments or pebbles 2 to 64 mm. in diameter.
Litter	The upper most layer of the floor in stream consisting chiefly of fallen leaves and other decaying organic matter usually overlying sand.
Sand	Small loose grains of worn or disintegrated rock or a sedimentay material with grains between 0.06-2.0 millimeters.

2.2 Collection of benthic samples

After counting the number of foot steps for 8 hours, samples were collected.

Sampling Technique

1. A specially prepared sampling device (Figure 4) was used to collect the benthic samples.
2. To take the random samples, I divided a map of the plot into 0.1 meter x 0.1 meter grid (Figure 5) and used random number tables to decide where samples should be collected. Samples were collected in blocks, taking one sample of each habitat from each block. A map was prepared first, so that

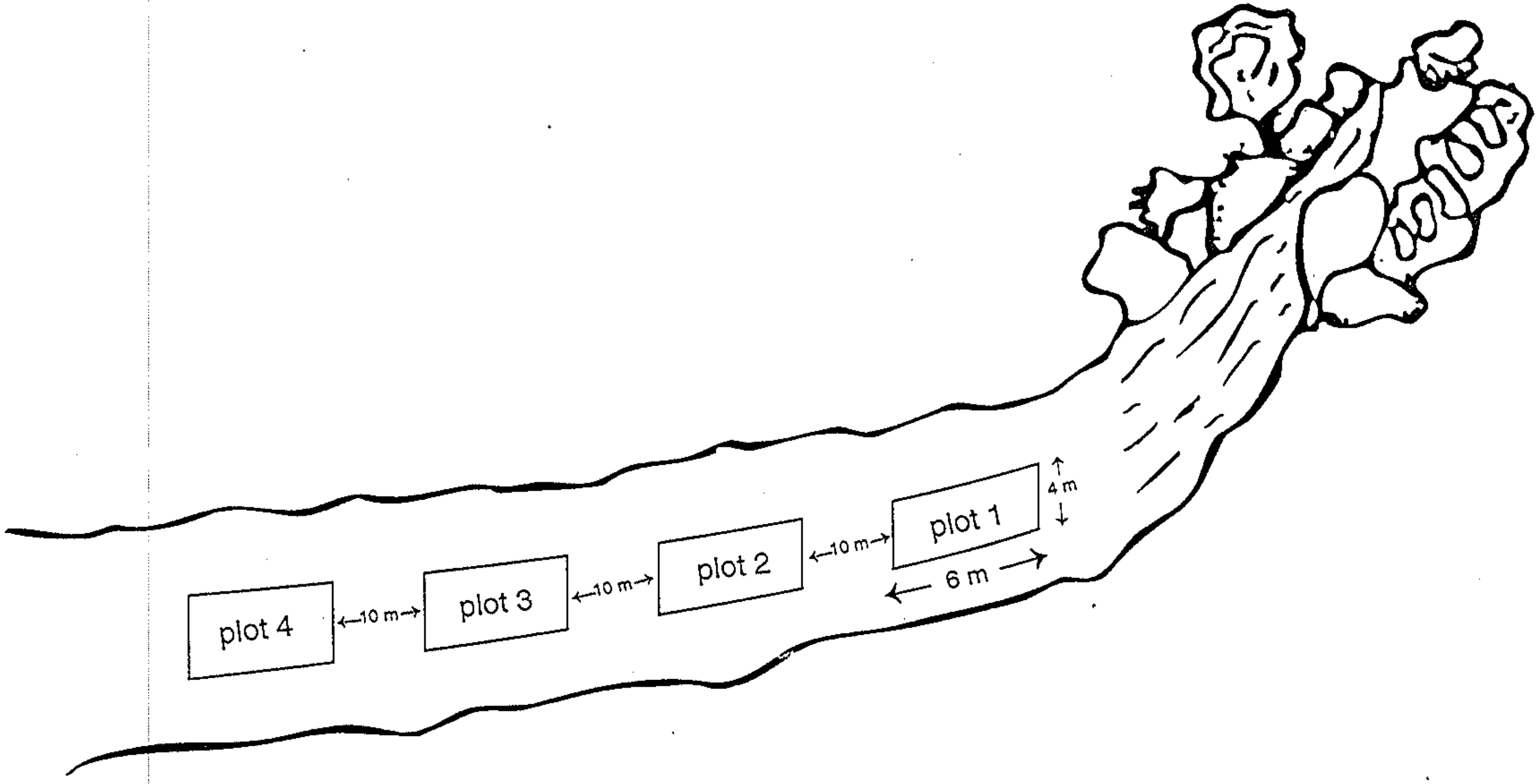


Figure 3 : Lay out of plots (4 m x 6 m) selected at each waterfall

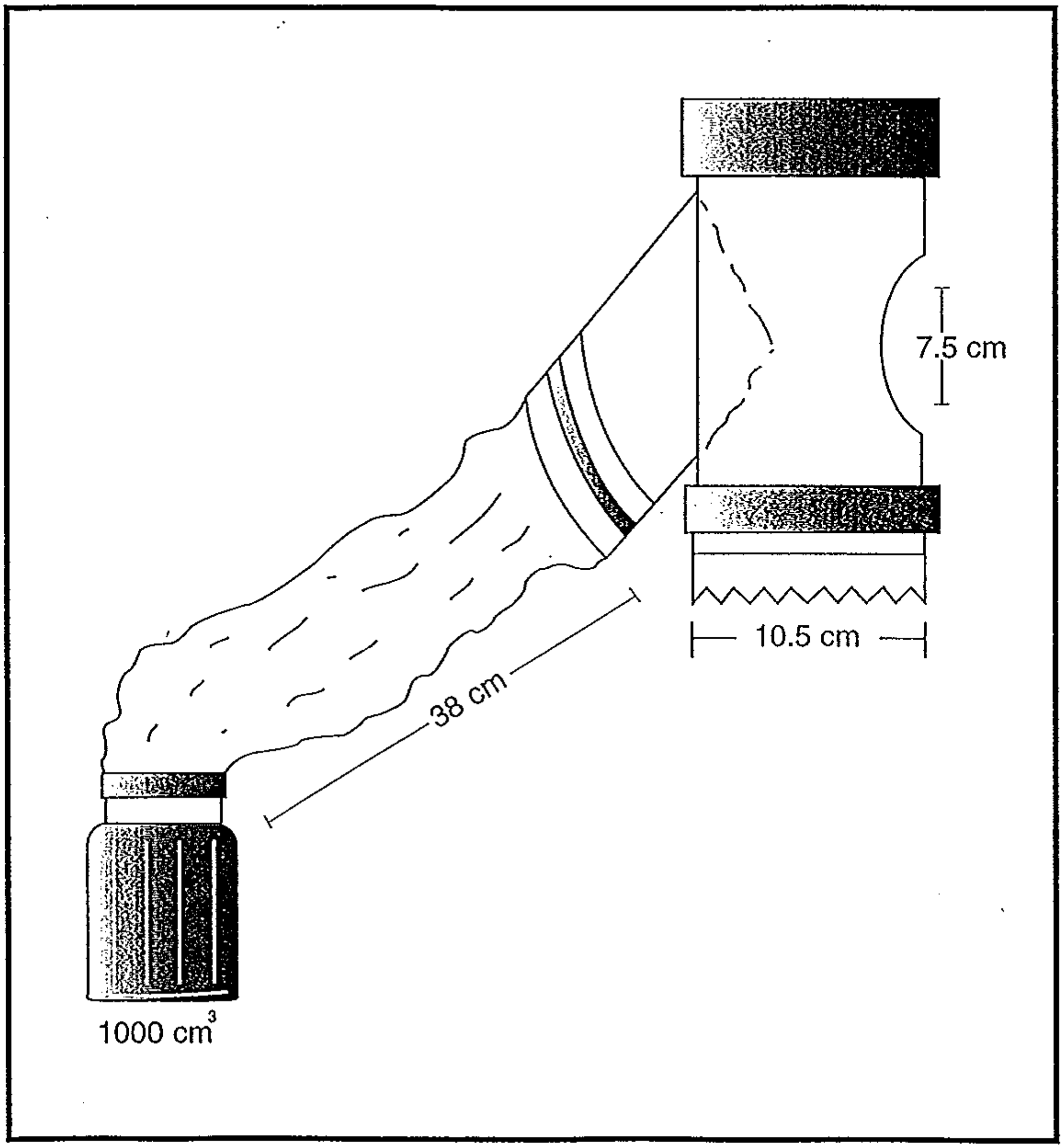


Figure 4 : Equipment used for collecting the benthic samples

Sample area = 0.01 m^2 per plot

we could plan the sequence of blocks and samples within the plot so as not to disturb other samples in the plot. Samples were collected by starting at blocks near the bottom end of the plot first and then working upstream. In this way I could minimize disturbances caused by the sampling process.

3. When the first position to collect the sample is set, the habitats will be determined by using the boulder, the cobble, the litter , the sand and the gravel habitat which are nearest to that position (Figure 5). Samples were thus collected in blocks, with one replicate of each habitat in each block.

If the next position was closer than 1 m to the previous position, then the position was discarded and another position would be chosen again by randomization. This was done because of the likelihood of disturbing nearby areas when collecting a sample, which would make the two samples non- independent.

The sample was collected immediately after the 8 hours observation period of human activity in each plot, which was around 6.00 p.m. or 1/2 to 1 hour before sun set.

Samples were immediately preserved in 70% ethanol alcohol for later sorting and identification. After sorting insects from each sample, the number of insects were counted and identified into family-level in order to investigate the effect of trampling on abundance and diversity of insects.

2.3 Sorting and Identification

The keys for identification into family-level used were Borror *et al* (1976) , Luhmkuhl (1979), Mccafferty and Provansha (1981).

In addition taxonomic experts familiar with aquatic insect groups were consulted for help with the identification.

Figure 5 An example of the spatial layout of samples and sampling technique (see description)

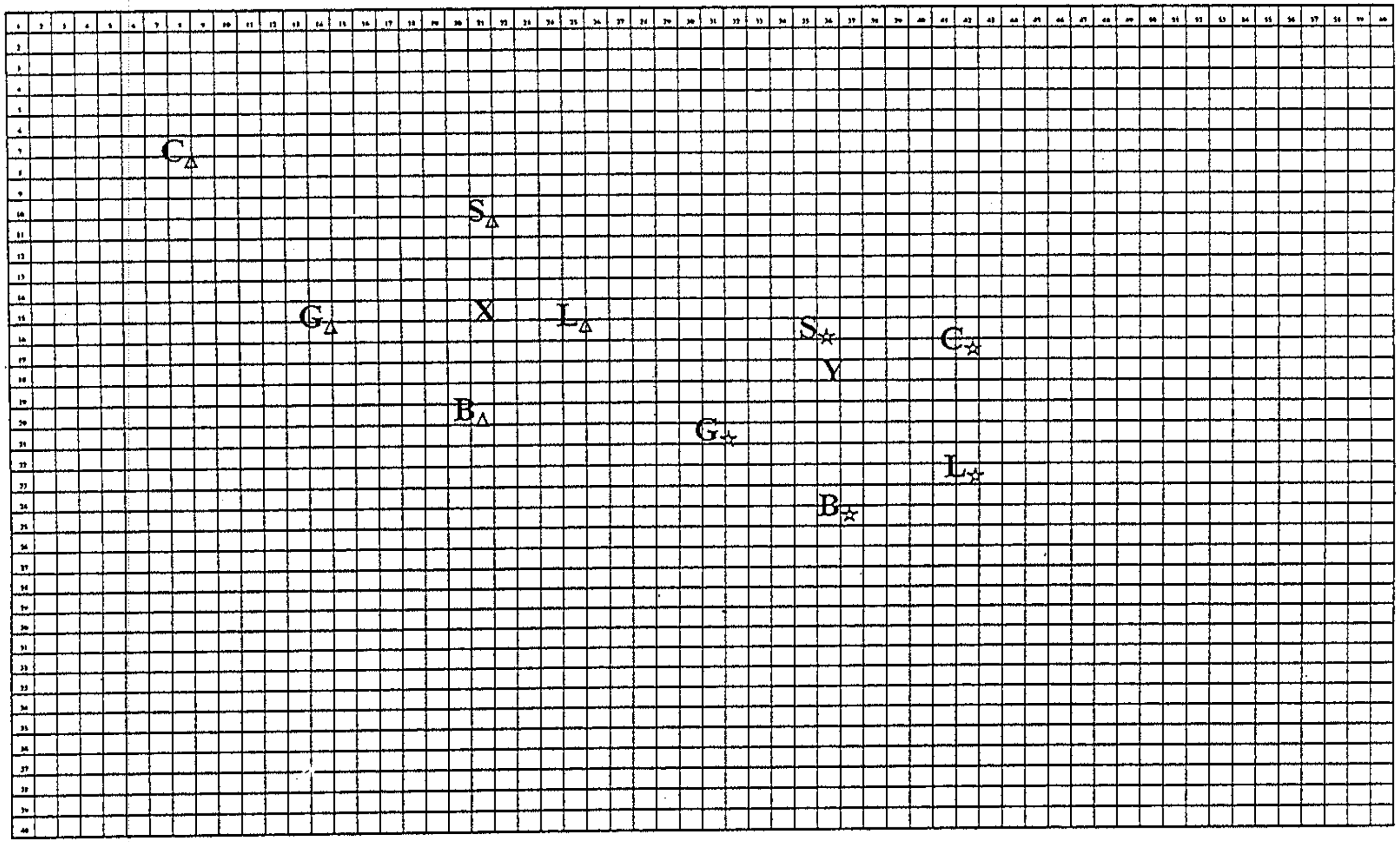
B = boulder

C = cobble

G = gravel

L = litter

S = sand



Description

1. Suppose the first position (which comes from randomization) is located in grid number x, the samples of habitats determined to be collected are the samples at boulder, cobble, litter, sand and gravel which are nearest to that x position. These will be samples from B_{Δ}, C_{Δ}, G_{Δ}, L_{Δ} and S_{Δ}
2. Then, next position will be selected by randomization again. Suppose the next position is y, the samples of habitats determined to be collected will be $B_{☆}$, $C_{☆}$, $G_{☆}$, $L_{☆}$ and $S_{☆}$
3. This process of collecting samples will be done 5 times.

2.4 Litter processing

After removing the insects from the litter habitat samples for identification, leaves and leaf fragments were placed in foil paper envelopes and dried. Leaves were dried at 60° C for 72 hours, cooled and weighed.

Analysis

Statistical analyses were performed using the General Linear Models procedure for balanced crossed effect ANOVA designs in SAS version 6.02 (SAS 1985). In all tests, the critical level of significance was $\alpha = 0.05$.

All counts of animals were transformed as $\log_{10}(n+1)$ to reduce heteroscedasticity before analysis, and the assumption of homogeneity of variance was tested using Bartlett's test.

Result

1. <u>Natural Trampling Intensities</u>

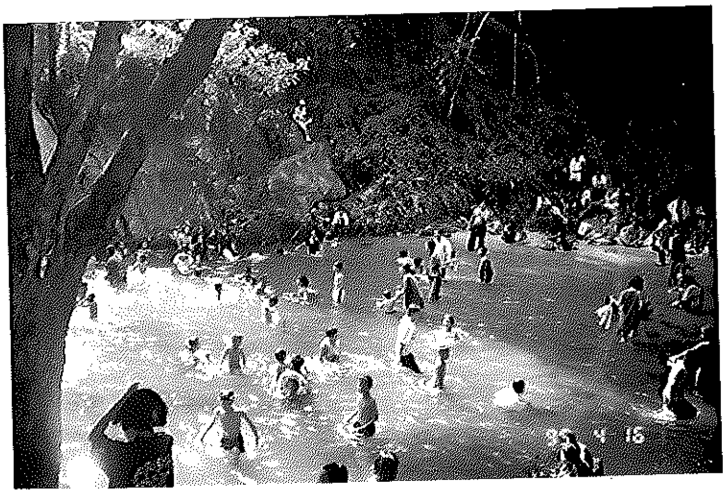
High and low- level trampling intensities were similar among the three sites (Table 3). The low trampling areas located at the areas where were difficult to reach and occasionally visited by humans. The high trampling areas were the areas that usually easily accessible from the car parks and were used by educational tours as well as visitors.

Table 3 Intensity of human trampling at 3 sites (Mean, ± SEM, number of steps per hour per 4m x 6m plot).

Site	High Trampling	Low Trampling
Tone Nga Chang	501 (± 29)	100 (±9)
Priwal	524 (± 44)	100 (± 8)
Boripat	520 (± 29)	97 (±11)

2. <u>Trampling and Abundance</u>

As expected, the abundance of aquatic insects was higher in low trampling than high trampling plots in all three waterfalls (Table4 and 5). The results also suggest that the effects of trampling may differ between habitats (Trampling x Habitat P= 0.08 ; (Table 4)), but this effect was much smaller than overall negative impact of trampling. There was also significant variation in abundance of insects among habitats and this pattern varied between waterfall sites (Habitat x Site ,P=0.001; (Table 4 and 6)).



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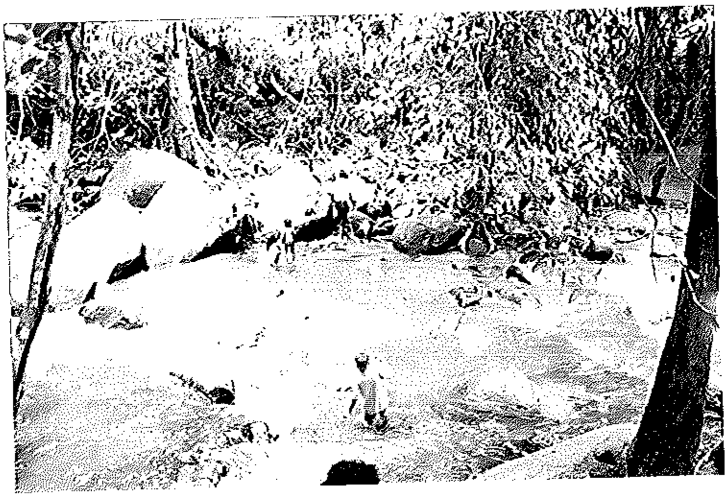

B

Figure 6 The areas of natural intensity of human trampling

A : High trampling area

B : Low trampling area

Table 4 Three - way Anova show F- values and significant number of Individuals in high trampling and low trampling areas from survey among 3 sites (Tone Nga Chang, Boripat and Priwal) in 5 habitats(boulder, cobble, gravel, litter and sand). Individual counts were transformed by log (x+1) before analysis.

Source	Df	MS	F	P
Trampling	1	18.18	50.6	0.0000
Habitat	4	9.54	26.5	0.0000
Site	2	18.08	50.4	0.0000
Trampling*Habitat	4	0.75	2.0	0.0848
Trampling*Site	2	0.59	1.6	0.1918
Habitat*Site	8	1.25	3.5	0.0012
Trampling*Habitat*Site	8	0.60	1.6	0.1079
Error	30	0.36		

Table 5 Abundance of insects in 3 sites (Tone Nga Chang, Boripat and Priwal) between high and low intensity of trampling. The table shows the count mean number of individuals per 0.01 m^2 sample.

Site	High Trampling	Low Trampling
Tone Nga Chang	1.92	3.60
Priwal	0.48	23.00
Boripat	5.24	18.34

Table 6 Mean number of insects in 5 habitats(boulder, cobble, gravel, litter and sand) between high and low intensity of trampling among 3 sites (Tone Nga Chang, Boripat and Priwal).

Habitat	High Trampling			Low Trampling		
	Tone	Boripat	Priwal	Tone	Boripat	Priwal
Boulder	0.6	0.2	0.7	1.3	0.2	1.9
Cobble	2.4	0.9	16.3	5.4	2.6	19.5
Gravel	0.6	0.2	2.1	1.6	2.1	7.6
Litter	5.5	1.1	4.7	7.8	4.0	57.8
Sand	0.4	0	2.4	1.9	2.6	4.9

3. Trampling and diversity

Family level diversity of insects differed between plots high and low trampling areas, but the effect was not consistent across habitats (Trampling x Habitat P= 0.0001 ; (Table 7)). A plot of the means (Figure 9) helps explain this interaction. Family level diversity was much lower in all habitats apart from boulders in plots in high trampling compared to low trampling areas. The difference for boulder habitats, compared to the other was relatively small but still in the same direction with diversity lower in plots in high trampling areas. Family- level diversity in boulder habitat samples was very low.

Table 7 Three- way Anova shows F- values and significant number of families in high trampling and low trampling areas from survey among 3 sites (Tone Nga Chang, Boripat and Priwal) in 5 habitats (boulder, cobble, gravel, litter and sand). All number of families counts were transformed by log(x+1) before analysis.

Source	Df	MS	F	P
Trampling	1	0.11	7.0	0.0125
Habitat	4	0.05	3.0	0.0333
Site	2	0.28	16.9	0.0001
Trampling*Habitat	4	0.17	10.4	0.0001
Trampling*Site	2	0.00	0.1	0.8244
Habitat*Site	8	0.02	1.7	0.1380
Trampling*Habitat*Site	8	0.01	0.6	0.7703
Error	30	0.02		

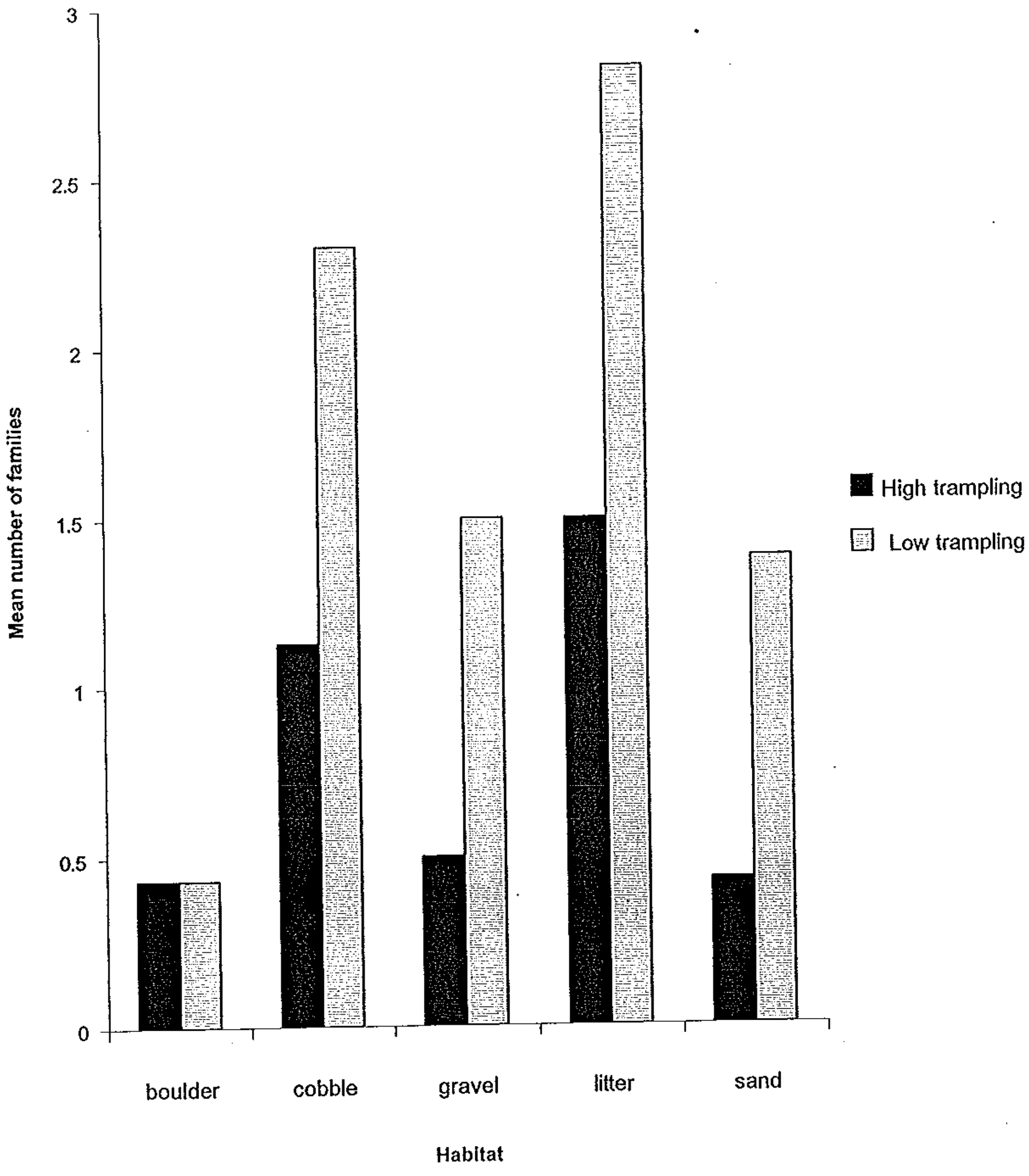

Figure 7 Mean number of families of insects per 0.01 m^2 sample in each habitat in high and low trampling areas.

4. Community Structure

All together , I found 9 orders and 49 families of aquatic insects in the survey of three waterfalls Table 8 and 9). Only Diptera differed significantly in the number of individuals between high trampling and low trampling areas (Table10). Other orders of insects had very low counts and did not differ significantly in abundance between high and low trampling areas.

5. Site and habitat differences

Of secondary interest to the study , there was also significantly variation in abundance of insect among habitats, and this pattern varied among waterfall (habitat x site (Table 4, Table 6)).

Variation in abundance of insects among samples from litter habitats could in part be explained by the amount of litter collected (Figure 8).

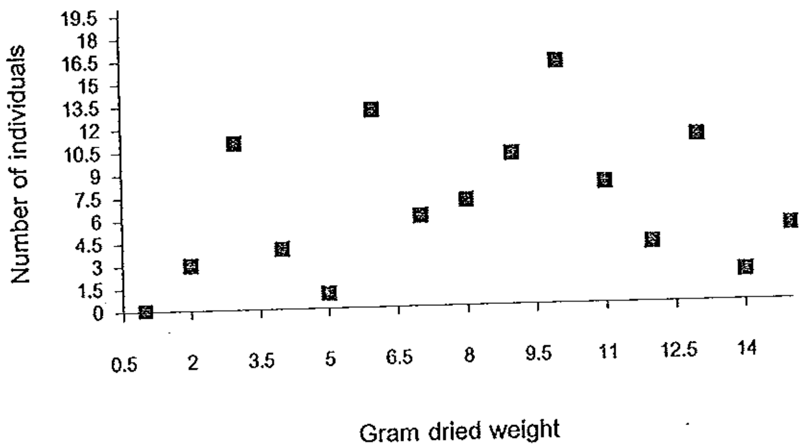

Figure 8 Association between abundance of insects and dry weight of organic material in litter habitat samples.
Coefficient of determination (R^2 =0.47)

Table 8 Community structure of stream insects of three sites.

Order	Percentage of Total Individuals		
	Tone Nga Chang (n=278)	Boripat (n=137)	Priwal (n= 1179)
Coleoptera	3.2	2.9	2.1
Diptera	88.6	92.7	90.7
Ephemeroptera	3.9	3.6	5.0
Plecoptera	2.1	0.7	0.1
Tricoptera	1.8	0	1.8
Lepidoptera	0	0	0.2
Odonata	0.4	0	0.1

Table 9 Community structure of stream insects in five habitats.

Order	Percentage of Total Individuals				
	Boulder (n=46)	Cobble (n=474)	Gravel (n=144)	Litter (n=810)	Sand (n=120)
Coleoptera	2.2	3.2	5.6	1.4	7.5
Diptera	89.1	89.7	83.3	92.7	82.5
Ehemeroptera	4.4	3.8	9.0	4.2	9.2
Plecoptera	2.2	0.6	1.4	0.3	0
Tricoptera	0	2.5	0	1.2	0.8
Lepidoptera	0	0.2	0	0.3	0
Odonata	2.2	0	0.7	0	0

Table 10 F- values for Three way analysis of vaiance of the number of individuals in each order.

*=P<0.05, ** = P<0.01, *** = P<0.0001 , degree of freedom is in parenthesis.

Comparison	Source of Variance							
	Mean number per sample(.01m^2)	Site(2)	Tramp(1)	Habitat(4)	Site*Tramp(2)	Site*Habitat (8)	Tramp*Habitat (4)	Site*Tramp*Habitat (8)
Diptera	120.17	38.83***	14.96**	17.54***	0.02	3.88	19.38***	0.93
Coleoptera	3.17	6.24*	1.58	1.27	1.99	0.98	2.71	1.34
Ephemeroptera	6.25	14.72***	3.46	1.67	0.04	1.77	1.74	0.81
Plecoptera	0.66	2.50	0.36	0.37	0.68	0.25	1.92	0.70
Tricoptera	2.42	4.77*	0.03	3.36*	1.00	1.96	0.89	0.58
Lepidoptera	0.17	1.84	0.16	0.79	0.16	0.79	1.21	1.21
Odonata	0.17	0.50	0.00	0.75	1.50	1.13	1.25	0.87

Discussion

The number of families of insects significantly differed between high trampling and low trampling areas (Table 3). The densities of insects were lower in high than low trampling areas overall and in every habitat at three waterfall sites. These results cleared that the plots in high trampling areas had different community structure than those in low trampling areas. The results of this survey however do not allow us to conclude that trampling itself was the cause of this difference. The possibility exists that the differences are confounded by some other variables. For example, it may be that high trampling areas are those with easier access which also occurs in gradients, places, etc. where abundances and diversity are lower for other reasons.

Other physical factors might have also had an effect on densities and diversities of insects. The influence of various abiotic factors on aquatic insects of the Yamuna River in Garthwal Himalaya was studied by Chopra *et al* (1993). They found that temperature and velocity had a significant positive relationship with the presence of Ephemeroptera, Tricoptera, Plecoptera and Coleoptera whereas turbidity had no effect on those aquatic insects. Different habitats have different physical compositions such as boulders are large rounded mass of rock , cobbles are rock fragment, sand is small loose grain etc. So the insects in different habitats had been influenced by human trampling differently.

The abundance of insects in litter habitat was higher than other habitats (Table 6). When leave fragments were dried and weighed after removing all insects, I found a positive relation between the number of insects and the dry weight of leaves (Figure 8). This is probably because many insects larvae are detritivores. Litter also provides shelter. Few insects were found in the flat boulder habitat. Trampling reduced densities of insects among all habitats.

Diptera was the only order of insects numerous enough for a significant effect to be detected for specific taxonomic groups.

Among three waterfalls, there was variation in benthic densities. As shown in Table 5 , the greatest number of individual insects was in Priwal, Patalung Province. The lowest abundance was in Boripat, Songkhla Province. Watanasit (1996) found much lower densities at the stream which is heavy visited by tourists. By the time I surveyed this waterfall, a lot of people had come to visit this site and did a lot of activities for example, washing their hair with shampoo, washing their clothes with detergent, throwing some food into the stream etc. These kinds of activities could result in reduction of insect number. I also found the pipes which were used to transfer water to the cultivated land near by Boripat waterfall. So this might be another factor which reduced the number of insects. Although there were variation in the number of individual insects among 3 waterfalls, these waterfalls showed the same trend of declining in number of insects in the area of high trampling.

From this survey, I could not know how long the effect lasts. Further more, the investigation from the field survey can hardly predict what will happen to a previously untrampled area because there might be some other factors influencing the densities or diversity of insects which were not measured. To conclusively establish that trampling really has an effect on diversity and densities, an experimental investigation is necessary.

Chapter 3

Experimental Analysis of the Effect of Human Trampling on Abundance and Composition of Stream Insect Communities

Introduction

In the field of ecological study, conclusions based only upon surveys will almost always be tentative. There is always many naturally varying biotic and abiotic factors which can influence the natural communities not all of which are known to the investigators. Povey and Keough (1991) did the experiment about the effect of trampling on plant and animal populations on rocky shores, and proposed that experimental investigation has the advantage over the field survey because the investigator can examine species abundance before and after trampling and use the results to predict what will happen to a previously untrampled area. To draw stronger conclusions about the effects of human activities , it is preferable to compare multiple control and impact sites before and after disturbance (Stewart- Oaten *et al.*, 1986). The most convincing evidence of causal relationships between biological patterns and human activities comes from experiments in which levels of the activities in question are modified (Underwood and Peterson, 1988; Keough and Quinn, 1991).

In this experimental study, I report an experimental design in order to find whether the differences found from the survey were in fact due to trampling or could be explained by local sites differences. The advantage of this experimental study is that we are able to control through randomization of treatments , factors which could not be taken into account in the descriptive field survey. In addition we sought to explain the rate at which stream communities recovered following a trampling disturbance.

Objectives

1. To control some potentially confound factors that could not be taken into account in the descriptive field survey.
2. To explore the rate at which stream communities recovered following a trampling disturbance.

Materials and Methods

1. Study Areas

The sites for setting the trampling experiments were located in Tone Nga Chang and Boripat . These two waterfalls were chosen for experimental study because overall geographic are quite similar, and they include some areas hardly accessed by visitors and suitable for experimental manipulation by trampling.

2. Experimental Design

2.1 Twelve rectangular plots (4 m x 6 m) were marked at each waterfall. The levels of trampling were set similarly to the range in actual trampling observed in the field. Plots were randomly assigned to 4 treatments, namely 1 high trampling (500 steps/ hour), 1 intermediate trampling (250 steps/hour) , 1 low trampling (100 steps/ hour) and 1 control (0 step/hour) (see Figure 5). Each plot was selected so as to include some areas of each habitat type, boulder, cobble, gravel, litter and sand.

2.2 The design was factorial experiment arranged in a complete randomized design with 3 replicates of each habitat. I did the trampling experiment by getting one person to site along the strip at a normal walking style with bare feet. The high, intermediate and low trampling plots were trampled for an hour. I used levels of trampling based on observational study of stream visitors which are 500 steps/hour in high intensity of trampling, 100 steps/hour in low intensity. An intermediate intensity was set at 250 steps/hour.

2.3 Samples from each habitat on the 4 m x6 m plots from each treatment were collected either immediately after trampling treatment , 3 days or 7 days later. That is, each plot was only sampled on one occasion.

3. Sampling of benthic invertebrates

The sampling technique is the same as we have done in the survey. That is a map of the plot was divided into 0.1m x 0.1m grid and the random number table was used to decide where samples should be collected. Samples were collected in blocks, taking one sample of each habitat from each block. A map was prepared first, so that we could plan the sequence of blocks and samples within the plot so as not to disturb other samples in the plots.

I collected samples by starting at blocks near the bottom end of the plot first and then working our way upstream. This is to minimize disturbances caused by the sampling process (Figure 5).

The insects collected were preserved in 70 % ethanol for later identification using the standard key.

4. Sorting and Identification

The keys for identification into families used were Borror *et al* (1976), Lehmkuhl (1979), Mccafferty and Provansha (1981).

In addition taxonomic experts familiar with aquatic insect groups were consulted for the identification.

Analysis

Analyses were done using the General Linear Models procedure for balanced crossed effect Anova designs in SAS version 6.02 (SAS 1985). The design was the experiment 3x5 factorial arranged in a completely randomized design with three factors. The effect of trampling was tested by a three – factor analysis of variance, with the factors being intensity of trampling (four levels) and time, and habitat (five levels). In all cases, the partial (Type II) sums of squares were used. In all tests, the critical level of significance was $\alpha = 0.05$. All counts of animals were $\log_{10}(n+1)$ transformed before analysis. The assumption of homogeneity of variance was tested using Bartlett's test. In a complete randomize design, the interaction between the treatments and environments are assumed to be zero. We tested this assumption using Tukey's test for nonadditivity. Size distributions of animals in control and trampled treatments were compared using the Chi-square test, because the size distributions of some taxas of insects were strongly skewed, even after a variety of transformations.

Result

1. Abundance pattern in each level of trampling

Trampling reduced the density of insects (Table12, Figure 9). Immediately after manipulations, higher densities were found in low trampling and control areas than in high and intermediate trampling areas (Table 12). On the 3 rd day and 7 th day after the experiment, the abundance of insects showed the same pattern as the first day. There was no significant different in abundance of insects among these 3 dates (Table11, Figure 9, Tukey HSD test).

2. Diversity of Organisms

The number of families differed significantly among levels of trampling (Table 14). Low trampling areas in both waterfalls, had more families of insects than high or intermediate trampling areas (Table13). The number of families did not differ significantly among these three dates (Table 14).

3. Effects of habitat and site

There were significantly differences in abundance of insects and number of families among habitats. There was no interaction between trampling and habitats which meant effect of trampling was consistent among habitats (Table14).

Litters were the habitats that contained the most and highest diversity.

4. Effects of sites

Trampling effects were not entirely consistent among sites (Trampling x Site P = 0.049, Table 11, Table 13). There were larger differences between high and intermediate VS low and control plots in Boripat (Figure 9, Table 12).

5. Recovery

There was no recovery in high and intermediate trampling areas for both Tone Nga Chang and Boripat waterfalls. But for the low trampling areas, the recovery occurred within 7 days in both waterfalls (Figure 9).

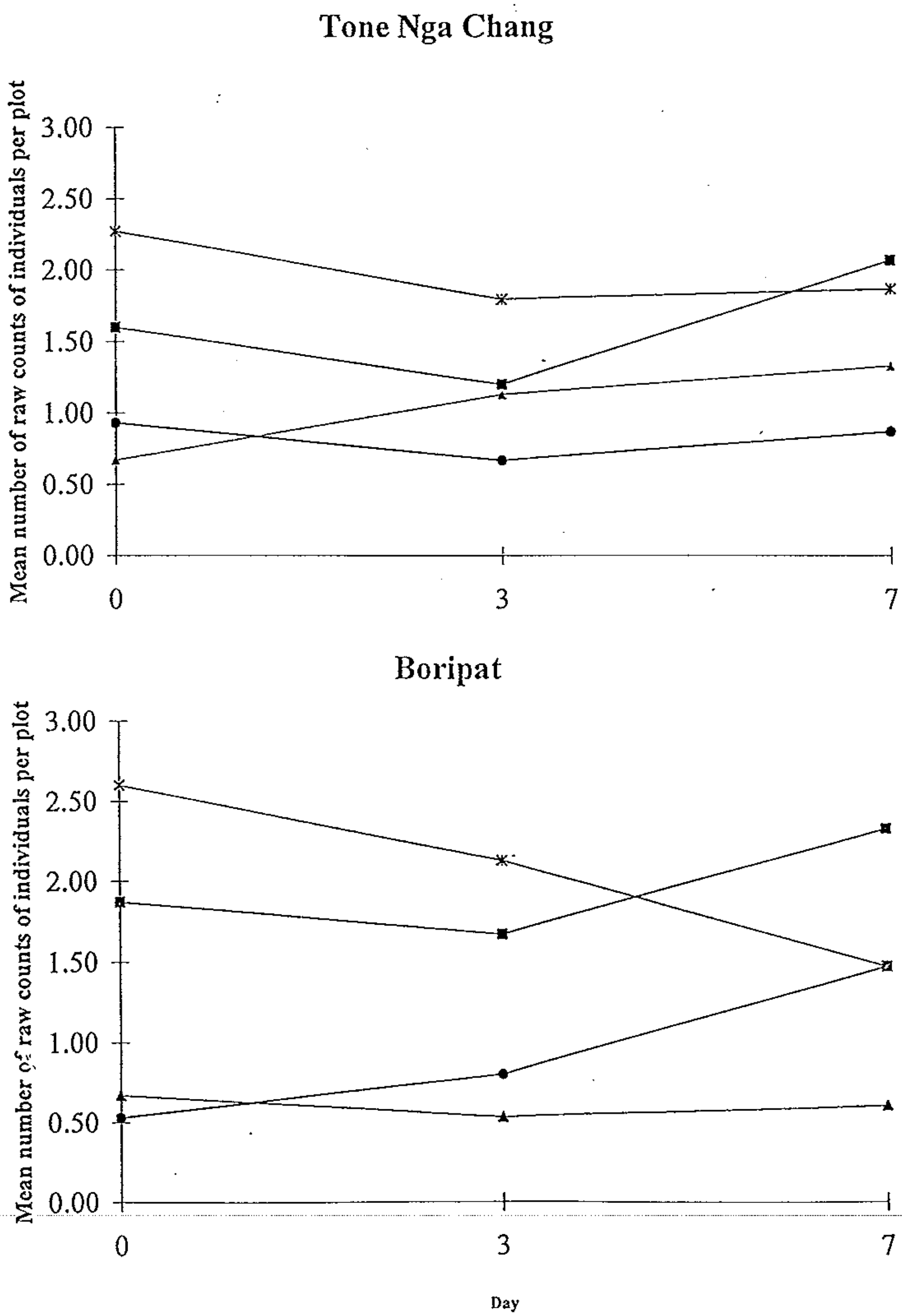

Figure 9 Changes in abundance of insects of each intensity of trampling after day 0, 3 and 7 of the experiment.

Table 11 Four way Anova shows F- Values and significant abundance of aquatic insects in five habitats(boulder, cobble, gravel, litter and sand) in 2 waterfalls (Tone Nga Chang and Boripat). Samples were collected at day 0,day 3 and day 7 after experimental trampling. All individual counts were transformed by log (x+1) before analysis.

Source	Df	MS	F	P
Day (0,3,7)	2	0.09	1.3	0.2507
Trampling	3	0.80	11.7	0.0001
Day*Trampling	6	0.05	0.8	0.5644
Habitat	4	0.64	9.4	0.0001
Day*Habitat	8	0.04	0.6	0.7153
Trampling*Habitat	12	0.05	0.7	0.7122
Day*Trampling*Habitat	24	0.06	0.9	0.5717
Site*Habitat	4	0.10	1.5	0.1905
Day*Site	2	0.29	0.4	0.6467
Tramplig*Site	3	0.18	2.6	0.0493
Day*Trampling*Site	6	0.07	1.1	0.3487
Day*Trampling*Site*Habitat	24	0.04	0.64	0.9024
Site	1	0.31	1.8	0.1782
Error	240	0.06		

Table 12 Mean number of insects per plot (0.01 m^2) in different treatments. Tukey's Studentized Range (HSD). Means with the same letter are not significantly different.

Site	Treatment			
	High	Intermediate	Low	Control
Tone Nga Chang	0.82 (0.22) a	1.04(0.21) a	1.62(0.29) b	1.98(0.45) b
Boripat	0.93(0.18) a	0.60(0.11) a	1.96(0.27) b	2.07(0.24) b

Table 13 Percentage of individuals found from each order between Tone Nga Chang and Boripat waterfall. Samples were collected at day 0, 3,and 7 after experimental trampling.

Order	Tone Nga Chang				Boripat			
	High	Intermediate	Low	Control	High	Intermediate	Low	Control
Coleoptera	14	12	5	4	9	7	16	12
Diptera	68	55	71	81	58	82	76	73
Ephemeroptera	14	27	18	14	30	11	6	10
Hemiptera	0	0	3	0	2	0	0	3
Plecoptera	3	6	0	0	0	0	1	1
Tricoptera	0	0	1	0	0	0	0	1
Lepidoptera	0	0	0	0	0	0	1	0
Odonata	3	0	1	0	0	0	0	0
Total individuals	37	51	77	90	43	28	88	93

Table 14 Four way Anova shows F- Values and significant number of families of aquatic insects in five habitats (boulder, cobble, gravel, litter and sand) in 2 waterfalls (Tone Nga Chang and Boripat). Samples were collected at day 0, day 3 and day 7 after experimental trampling. All individual counts were transformed by log (x+1) before analysis.

Source	Df	MS	F	P
Day (0,3,7)	2	0.11	2.5	0.0832
Trampling	3	0.29	6.6	0.0003
Day*Trampling	6	0.25	0.5	0.7537
Habitat	4	0.35	8.0	0.0001
Day*Habitat	8	0.01	0.3	0.9389
Trampling*Habitat	12	0.02	0.5	0.8974
Day*Trampling*Habitat	24	0.03	0.7	0.7523
Site*Habitat	4	0.04	1.0	0.3722
Day*Site	2	0.02	0.5	0.5985
Tramplig*Site	3	0.08	1.9	0.1300
Day*Trampling*Site	6	0.04	1.1	0.3444
Day*Trampling*Site*Habitat	24	0.01	0.45	0.9883
Site	1	0.10	2.4	0.1214
Error	240	0.04		

Discussion

Effect of Trampling

There was a marked decline of densities and diversity of stream insects following experimental trampling. A significant reduction compared to controls at the high and intermediate, but not low trampling levels at both sites. The effect however, was slightly more pronounced in Boripat than in Tone Nga Chang. It should be noted that these levels of trampling wee within the range observed at 3 waterfall sites. Therefore, trampling has been shown to have an effect on the diversity and density of stream insects.

Effects on diversity

The order composition of fauna was similar at the two sites. Any how, there was small difference in abundance in some orders. And this might cause the interaction but this interaction was not that huge. The experimental results here are consistent which can help explain the patterns in abundance and diversity observed with survey. Trampling reduces the abundance and diversity of insects. At the family level, the fauna was dominated by Diptera. Further sampling is necessary to determine effects of trampling on individual taxa, as the power of the test was high only for the common order, Diptera.

During the time the samples were collected in both waterfalls, there was a heavy rainfall. This may explain why observed densities in all treatments were lower than the observational study. In other words, the trampling disturbance was superimposed on a natural disturbance event effecting all experimental plots. Thus, the finding of a significant effect is even more noteworthy.

Chironomidae was the most common family of Diptera affected by trampling. In general, what I found from experiment was very similar to what I had found from my previous survey study. Other order I found from experiment which were influenced by trampling were Coleoptera and Ephemeroptera. This is one thing that is a little different from the previous survey. From survey, Tricoptera was another order which was influenced by trampling.

The effect of trampling experiment on habitats showed that there were significant differences in densities of insects among levels of trampling only in habitat cobbles, gravel, and litters. And similar to a the survey, densities in litter were most affected by trampling. Overall the results from the experiment showed similar patterns to the survey.

I could analyze changes in the abundance of only some orders of insects and in some habitats like litters, cobbles, gravel and sand. Other habitats like boulders presented small number of individuals. So the statistical test sometimes had low power. Thus, I have no information about the effects of trampling on uncommon families or orders.

Causes of diversity reduction

Measures of species diversity are commonly used in evaluating effects of stress on aquatic communities (Wihm & Dorris,1966; Sager & Haster, 1969; Bechtel & Copeland, 1970; Cairns *et al.*, 1971; Litter& Murray, 1975; Botton, 1979 and Loi & Wilson, 1979). Excessive stress generally results in decreased diversity (Beauchamp and Gowing, 1982). In my experimental study, animal diversity in the low trampling areas after 7 days of recovery was significantly greater than in high trampling and intermediate trampling areas. I cannot say that my results are in agreement with Connell's (1978) argument or not that diversity may be higher when disturbances are intermediate than in high trampling and low trampling areas. The reason for that might be because the scales I was addressing in my experiment might not relevant to this hypothesis. Connell (1978) applied his hypothesis to organisms such as plants or sessile animals that occupy most of the surface of the land or the firm substrates in aquatic habitats. He considered only two tropical communities, rain forests and coral reefs, concentrating on the organisms that determine much of the structure, in this case, trees and corals. Whether his arguments apply to the mobile species, such as insects, birds, fish, and crabs that use these structures as shelter or food, remains to be seen. Moreover, human trampling is not a natural disturbance to which community can evolve. In Connell's study (1978), the disturbance occurred more frequently. But in my study I set the trampling experiment only for 1 day. And then the samples were collected at each level of trampling in 3 days and 7 days after experiment. From my experiment, the disturbance from trampling tended to be sudden disturbance which occurred only once. This human disturbance might not have reached a sufficient intensity or duration. And although tropical community of organisms requires intermediate disturbances to maintain high species diversity, it is important to emphasize that adaptation to these natural disturbance developed over a long evolutionary period (Connell, 1978). Although disturbances that are intermediate in frequency have been said to cause highest species richness (Connell 1978), the exact shape of that relationship is not clear (Connell and Keough, 1985; Keough and Quinn, 1991). The Connell conceptual model might not fit in my results. In contrast, some perturbations caused by man are of a quantitatively new sort to which these organisms are not necessarily adapted. Some possible explanations for the reduced diversity at high and intermediate levels of trampling are : 1). sampling effects because of lower total abundance ; 2). trampling modifies micro habitat structure (i.e. reducing habitat diversity) ; 3). a different community (lower diversity) invades after disturbance. Which ,if any , of these explanations applied cannot be inferred directly from the results of this study. More detailed taxonomic level and experimental manipulations would be needed to separate these competing explanations.

Thus, long term study of effect of trampling on diversity of stream insects is needed. In my study, only a very crude measure of diversity, family level diversity, was employed limiting the ability to make any strong generalization. Future studies should consider species level analysis.

Rate of Recovery

From the experiment, trampling had effect on densities and diversity of insects. There were, however, no differences among times since disturbance. In low trampling plots of both waterfalls, the recovery occurred within 7 days but no recovery in intermediate and high trampling plots in both waterfalls, indicating that recovery form intermediate and high trampling disturbance was not complete after 7 days. This is an important result, because visitors come to the waterfalls primarily on weekends. So that a new set of disturbances can be expected every 7 days.

Chapter 4

Conclusion

I found that trampling produced marked effects on diversity and densities of stream insect community. The association patterns detected in the survey were confirmed by experimental manipulation. There was a general pattern of higher densities and higher diversity in less trampled areas.

From only survey study, however, it was very hard to predict what would happen to a previously untrampled area because there was no control areas. Experimental manipulation confirmed that trampling did have an effect on densities and diversities of stream insect community. More over, the study demonstrated that at realistic levels of human trampling, the stream fauna does not recover in 7 days. This is likely to be critical for longer impacts because peaks in visitors to waterfalls concede with weekends. The result of human trampling reduced densities and diversity of insect community.

From my study , I was unable to address the long term effects of recurrent trampling ,and my experiment was done over 1 weekend, whereas most public trampling would happen every weekend through year round. Trampling can destroy the habitats and the resting sites of insect larvae. The effect of trampling may also produce conditions suitable for invasive species.

We could apply these programs for conservation of stream ecosystem by counting the number of tourists over the years, observing their behaviors, doing some long term comparative study about how the environment changes between highly visited areas and low visited areas by comparing the abundance and diversity of organisms between these two areas. These activities will help us gather essential data how tourists affect the stream environment and stream community. In turn, this research could be used to support improving management of sanctuaries and national parks.

Human trampling in streams has been shown to have a significant local effect on insect abundance and diversity. Wildlife management has been increasingly concerned about how to control erosion of stream margins, fishing activity and waste disposal to some popular waterfall sites. Human trampling should be also considered and added to the management plans. It is very hard to control the use of waterfall effectively because waterfalls are very popular for social recreation. The highest use of waterfalls occurs in the easiest accessibility with highest facilities which means that effects may be highly localized. However, restricting access to some areas , may be worthwhile to provide a source of re-colonization for organisms after having experienced human trampling disturbances and to maintain more suitable habitats. Much more work however , is needed on the longer term impacts of human disturbances on the full range of upland streams. Such research also has tremendous potential as useful tool for planning the further development of recreational resources as well as the protection of the stream environment against over-use, in particular of waterfalls as the most population destination for tourists in national parks.

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Appendix

Table 1 **Shown total number of individual belonged to various family of aquatic insect. Samples were collected in 5 habitats(boulder, cobble, gravel, litter, and sand) in high and low trampling among 3 waterfalls (Tone Nga Chang, Boripat and Priwal).**

Taxonomic group	Tone Nga Chang		Boripat		Priwal	
	High	Low	High	Low	High	Low
Coleoptera						
F. Amphizoidae						1
F. Chrysomelidae	1					
F.Curculionidae						2
F. Dytiscidae		2		2		
F. Elmidae	1				1	12
F. Halipidae				1		1
F.Psephenidae						2
F.Shaeriidae	1					
F. Unknown	1	3		1		6
Diptera						
F. Chironomidae	62	135	14	102	207	779
F.Ceratopogoniidae	1	2	4	2		13
F.Culicidae	1				9	27
F. Ephidridae	1	1				3
F.Empididae		1				2
F.Muscidae						
F.Phychodidae		1	3		1	
F.Rhagionidae						1
F.Simulidae	9	17		2	6	5
F.Stratiomyiidae						
F.Tabanidae	1					
F.Tipulidae	1	1				2
F. Unknown	11	4	1		1	9

Table 1 (continue) Shown total number of individual belonged to various family of aquatic insect. Samples were collected in 5 habitats (boulder, cobble , gravel, litter, and sand) in high and low trampling among 3 waterfalls (Tone Nga Chang, Boripat and Priwal).

Taxonomic group	Tone Nga Chang		Boripat		Priwal	
	High	Low	High	Low	High	Low
Ephemeroptera						
F. Baetidae					6	7
F. Caenidae			1	2	1	8
F.Ephemeriidae		2				
F. Ephemerellidae					1	5
F.Heptageniidae		3		1	13	2
F.Polymitarayidae						
F.Tricorythidae	3	2				
F.Unknown	1			1	4	12
Plecoptera						
F.Chloroperlidae		2				
F.Perlidae		1		1		1
F.Perloidae		1				
F.Unknown	1					
Trocoptera						
F.Glossosomatidae						2
F.Hydroptilidae					4	
F.Hydropsychidae						3
F.Leptoceridae					1	1
F.Limnephillidae						1
F.Philopotamidae		1				
F.Polycentropodidae		2				
F. Polymitacyidae						
F.Psychomyiidae					2	
F.Rhyacophilidae	1					
F. Unknown	1					7

Table 1 (continue) Shown total number of individual belonged to various family of aquatic insect. Samples were collected in 5 habitats (boulder, cobble , gravel, litter,and sand) in high and low trampling among 3 waterfalls (Tone Nga Chang, Boripat and Priwal).

Taxonomic group	Tone Nga Chang		Boripat		Priwal	
	High	Low	High	low	High	Low
Lepidoptera						
F.Augyractini						
F. Pyralidae						2
F. Unknown						
Odonata						
F. Lebellulidae		1				
F. Unknown						1

Table 2 Shown total number of individual belonged to various family of aquatic insects. In Tone Nga Chang waterfall. Samples were collected in 5 habitats (boulder, cobble, gravel, sand, and litter) in high trampling, intermediate trampling, low trampling and control. Samples were collected on the day right after the experiment (August 13 1995).

Family	High trampling	Intermediate	Low trampling	Control
O. Coleoptera				
F. Amphizoidae				
F. Chrysomelidae				
F. Curculionidae				
F. Dytiscidae				
F. Elmidae		1		1
F. Halipidae				
F. Hydrophilidae				
F. Psephenidae				
F. Shaeriidae				
F. unknown			1	1
O. Diptera				
F. Chironomidae	6	3	18	20
F. Ceratopogoniidae				
F. Culicidae				
F. Ephidridae				
F. Empididae				
F. Muscidae	4			2
F. Psychodidae				
F. Rhagionidae				
F. Simulidae				
F. Stratiomyiidae				
F. Tabanidae				
F. Tipulidae				5
F. unknown				

Table 2 (continue) Shown total number of individual belonged to various family of aquatic insects in Tone Nga Chang waterfall. Samples were collected in 5 habitats (boulder, cobble, gravel, sand, and litter) in high trampling, intermediate trampling, low trampling and control. Samples were collected on the day right after the experiment (August 13 1995).

Family	High trampling	Intermediate	Low trampling	Control
O. Ephemeroptera				
F. Baetidae	1	1		2
F. Caenidae	1	1		3
F. Ephemeriidae				
F. Ephemerellidae				
F. Heptageniidae	1		2	
F. Leptophlebiidae				
F. Polymitarayidae				
F. Tricorythidae		2		
F. unknown		2	1	
O. Hemiptera				
F. Naucoridae				
O. Plecoptera				
F. Chloroperlidae				
F. Perlidae				
F. Perloidae				
F. unknown				
O. Tricoptera				
F. Glossosomatidae				
F. Hydroptilidae			1	
F. Hydropsychidae				
F. Leptoceridae				
F. Limnephillidae				
F. Philopotamidae				
F. Polycentropodidae				

Table 2 (continue) Shown total number of individual belonged to various family of aquatic insects. In Tone Nga Chang waterfall. Samples were collected in 5 habitats (boulder, cobble, gravel, sand, and litter) in high trampling, intermediate trampling, low trampling and control. Samples were collected on the day right after the experiment (August 13 1995).

Family	High trampling	Intermediate	Low trampling	Control
F. Polymitacyidae				
F. Rhyacophilidae				
F. unknown				
O. Lepidoptera				
F. Augyractini				
F .Pyralidae				
F. unknown				
O. Odonata				
F. Lebellulidae	1		1	

Table 3 Shown total number of individual belonged to various family of aquatic insects. In Tone Nga Chang waterfall. Samples were collected in 5 habitats (boulder, cobble, gravel, sand, and litter) in high trampling, intermediate trampling, low trampling and control. Samples were collected on the 3 th day after experiment (August 17 1995).

Family	High trampling	Intermediate	Low trampling	Control
O. Coleoptera				
F. Amphizoidae				
F. Chrysomelidae				
F. Curculionidae				
F. Dytiscidae				
F. Elmidae	1	2	1	
F. Halipidae				
F. Hydrophilidae			1	2
F. Psephenidae				
F. Shaeriidae				
F. unknown				
O. Diptera				
F. Chironomidae	6	10	11	20
F. Ceratopogoniidae	2	2		
F. Culicidae				
F. Ephidridae				
F. Empididae				
F. Muscidae				
F. Psychodidae				
F. Rhagionidae				
F. Simulidae				
F. Stratiomyiidae				1
F. Tabanidae				1
F. Tipulidae				
F. unknown				1

Table 3 (continue) Shown total number of individual belonged to various family of aquatic insects. In Tone Nga Chang waterfall. Samples were collected in 5 habitats (boulder, cobble, gravel, sand, and litter) in high trampling, intermediate trampling, low trampling and control. Samples were collected on the 3th day after the experiment (August 17 1995).

Family	High trampling	Intermediate	Low trampling	Control
O. Ephemeroptera				
F. Baetidae			2	
F. Caenidae	1	3		2
F. Ephemeriidae				
F. Ephemerellidae				
F. Heptageniidae			1	
F. Leptophlebiidae				
F. Polymitarayidae				
F. Tricorythidae				
F. unknown				
O. Hemiptera				
F. Naucoridae			1	
O. Plecoptera				
F. Chloroperlidae				
F. Perlidae				
F. Perloidae				
F. unknown				
O. Tricoptera				
F. Glossosomatidae				
F. Hydroptilidae				
F. Hydropsychidae				
F. Leptoceridae				
F. Limnephillidae				
F. Philopotamidae				
F. Polycentropodidae				

Table 3 (continue) Shown total number of individual belonged to various family of aquatic insects. In Tone Nga Chang waterfall. Samples were collected in 5 habitats (boulder, cobble, gravel, sand, and litter) in high trampling, intermediate trampling, low trampling and control. Samples were collected on the 3^{th} after the experiment (August 17 1995).

Family	High trampling	Intermediate	Low trampling	Control
F. Polymitacyidae				
F. Rhyacophilidae				
F. unknown				
O. Lepidoptera				
F. Augyractini				
F .Pyralidae				
F. unknown				
O.Odonata				
F. Lebellulidae				

Table 4 Shown total number of individual belonged to various family of aquatic insects. In Tone Nga Chang waterfall. Samples were collected in 5 habitats (boulder, cobble, gravel, sand, and litter) in high trampling, intermediate trampling, low trampling and control. Samples were collected on the 7 th day after the experiment(August 20 1995).

Family	High trampling	Intermediate	Low trampling	Control
O. Coleoptera				
F. Amphizoidae				
F. Chrysomelidae				
F. Curculionidae				
F. Dytiscidae				
F. Elmidae	1	1	1	
F. Halipidae				
F. Hydrophilidae				
F. Psephenidae				
F. Shaeriidae				
F. unknown	3	2		
O. Diptera				
F. Chironomidae	5	11	14	11
F. Ceratopogoniidae	1		2	3
F. Culicidae		1		
F. Ephidridae				
F. Empididae				
F. Muscidae				
F. Psychodidae				
F. Rhagionidae				
F. Simulidae			1	3
F. Stratiomyiidae				
F. Tabanidae		1		
F. Tipulidae			3	
F. unknown	1		1	5

Table 4 (continue) Shown total number of individual belonged to various family of aquatic insects. In Tone Nga Chang waterfall. Samples were collected in 5 habitats (boulder, cobble, gravel, sand, and litter) in high trampling, intermediate trampling, low trampling and control. Samples were collected on the 7th day after the experiment(August 20 1995).

Family	High trampling	Intermediate	Low trampling	Control
O. Ephemeroptera				
F. Baetidae	1	1		1
F. Caenidae			4	3
F. Ephemeriidae				
F. Ephemerellidae				
F. Heptageniidae			4	2
F. Leptophlebiidae				
F. Polymitarayidae				
F. Tricorythidae				
F. unknown				
O. Hemiptera				
F. Naucoridae				
F. Pleidae			1	
O. Plecoptera				
F. Chloroperlidae				
F. Perlidae				
F. Perloidae				
F. unknown	1	3		
O. Tricoptera				
F. Glossosomatidae				
F. Hydroptilidae				
F. Hydropsychidae				
F. Leptoceridae				
F. Limnephillidae				
F. Philopotamidae				

Table 4 (continue) Shown total number of individual belonged to various family of aquatic insects. In Tone Nga Chang waterfall. Samples were collected in 5 habitats (boulder, cobble, gravel, sand, and litter) in high trampling, intermediate trampling, low trampling and control. Samples were collected on the 7th after the experiment(August 20 1995).

Family	High trampling	Intermediate	Low trampling	Control
F. Polycentropodidae				
F. Polymitacyidae				
F. Rhyacophilidae				
F. unknown				
O. Lepidoptera				
F. Augyractini				
F .Pyralidae				
F. unknown				
O. Odonata				
F. Lebellulidae				

Table 5 Shown total number of individual belonged to various family of aquatic insects. In Boripat waterfall. Samples were collected in 5 habitats (boulder, cobble, gravel, sand, and litter) in high trampling, intermediate trampling, low trampling and control. Samples were collected on the day right after the experiment (August 13 1995).

Family	High trampling	Intermediate	Low trampling	Control
O. Coleoptera				
F. Amphizoidae				
F. Chrysomelidae				
F. Curculionidae				
F. Dytiscidae				
F. Elmidae	1		3	2
F. Halipidae				
F. Hydrophilidae	1			
F. Psephenidae				
F. Shaeriidae				
F. unknown				1
O. Diptera				
F. Chironomidae	4	6	23	23
F. Ceratopogoniidae	1			4
F. Culicidae				2
F. Ephidridae		1		
F. Empididae				
F. Muscidae				
F. Psychodidae				
F. Rhagionidae				
F. Simulidae		2		
F. Stratiomyiidae				
F. Tabanidae				
F. Tipulidae				
F. unknown		1		1

Table 5 (continue) Shown total number of individual belonged to various family of aquatic insects in Boripat waterfall. Samples were collected in 5 habitats (boulder, cobble, gravel, sand, and litter) in high trampling, intermediate trampling, low trampling and control. Samples were collected on the day right after the experiment(August 13 1995).

Family	High trampling	Intermediate	Low trampling	Control
O. Ephemeroptera				
F. Baetidae		1		3
F. Caenidae	1		1	1
F. Ephemeriidae				
F. Ephemerellidae				
F. Heptageniidae			1	
F. Leptophlebiidae				
F. Polymitarayidae				
F. Tricorythidae				
F. unknown		1		
O. Hemiptera				
F. Naucoridae				
F. Pleidae				1
O. Plecoptera				
F. Chloroperlidae				
F. Perlidae				
F. Perloidae				
F. unknown				
O. Tricoptera				
F. Glossosomatidae				
F. Hydroptilidae				1
F. Hydropsychidae				
F. Leptoceridae				
F. Limnephillidae				
F. Philopotamidae				

Table 5 (continue) Shown total number of individual belonged to various family of aquatic insects in Boripat waterfall. Samples were collected in 5 habitats (boulder, cobble, gravel, sand, and litter) in high trampling, intermediate trampling, low trampling and control. Samples were collected on the day right after the experiment (August 13 1995).

Family	High trampling	Intermediate	Low trampling	Control
F. Polycentropodidae				
F. Polymitacyidae				
F. Rhyacophilidae				
F. unknown				
O. Lepidoptera				
F. Augyractini				
F .Pyralidae				
F. unknown				
O.Odonata				
F. Lebellulidae				

Table 6 Shown total number of individual belonged to various family of aquatic insects. in Boripat waterfall. Samples were collected in 5 habitats (boulder, cobble, gravel, sand, and litter) in high trampling, intermediate trampling, low trampling and control. Samples were collected on the 3 th day after the experiment (August 17 1995).

Family	High trampling	Intermediate	Low trampling	Control
O. Coleoptera				
F. Amphizoidae				
F. Chrysomelidae				
F. Curculionidae				
F. Dytiscidae				
F. Elmidae	1		2	2
F. Halipidae				
F. Hydrophilidae				1
F. Psephenidae			2	
F. Shaeriidae				
F. unknown				
O. Diptera				
F. Chironomidae	6	7	16	24
F. Ceratopogoniidae	2	1		
F. Culicidae			1	
F. Ephidridae	1			
F. Empididae				
F. Muscidae				
F. Psychodidae				
F. Rhagionidae				
F. Simulidae			3	
F. Stratiomyiidae				
F. Tabanidae				
F. Tipulidae				
F. unknown				

Table 6 (continue) Shown total number of individual belonged to various family of aquatic insects in Boripat waterfall. Samples were collected in 5 habitats (boulder, cobble, gravel, sand, and litter) in high trampling, intermediate trampling, low trampling and control. Samples were collected on the 3th day after the experiment(August 17 1995).

Family	High trampling	Intermediate	Low trampling	Control
O. Ephemeroptera				
F. Baetidae				
F. Caenidae	1			
F. Ephemeriidae				
F. Ephemerellidae				
F. Heptageniidae				1
F. Leptophlebiidae				
F. Polymitarayidae				
F. Tricorythidae	1			1
F. unknown				1
O. Hemiptera				
F. Naucoridae				2
O. Plecoptera				
F. Chloroperlidae				
F. Perlidae				
F. Perloidae				
F. unknown				
O. Tricoptera				
F. Glossosomatidae				
F. Hydroptilidae				
F. Hydropsychidae				
F. Leptoceridae				
F. Limnephillidae				
F. Philopotamidae				
F. Polycentropodidae				

Table 6 (continue) Shown total number of individual belonged to various family of aquatic insects in Boripat waterfall. Samples were collected in 5 habitats (boulder, cobble, gravel, sand, and litter) in high trampling, intermediate trampling, low trampling and control. Samples were collected on the 3th after the experiment (August 17 1995).

Family	High trampling	Intermediate	Low trampling	Control
F. Polymitacyidae				
F. Rhyacophilidae				
F. unknown				
O. Lepidoptera				
F. Augyractini				
F .Pyralidae			1	
F. unknown				

Table 7 Shown total number of individual belonged to various family of aquatic insects. In Boripat waterfall. Samples were collected in habitats (boulder, cobble, gravel, sand, and litter) in high trampling, intermediate trampling, low trampling and control. Samples were collected on the 7 th day after the experiment (August 20 1995).

Family	High trampling	Intermediate	Low trampling	Control
O. Coleoptera				
F. Amphizoidae				
F. Chrysomelidae				
F. Curculionidae				
F. Dytiscidae				
F. Elmidae	1	1		3
F. Halipidae				
F. Hydrophilidae		1	4	1
F. Psephenidae			1	
F. Shaeriidae				
F. unknown			2	1
O. Diptera				
F. Chironomidae	8	4	14	13
F. Ceratopogoniidae			5	
F. Culicidae				
F. Ephidridae	1			
F. Empididae				
F. Muscidae				1
F. Psychodidae				
F. Rhagionidae				
F. Simulidae	1	1	3	
F. Stratiomyiidae				
F. Tabanidae				
F. Tipulidae		1	2	
F. unknown				

Table 7 (continue) Shown total number of individual belonged to various family of aquatic insects in Boripat waterfall. Samples were collected in 5 habitats (boulder, cobble, gravel, sand, and litter) in high trampling, intermediate trampling, low trampling and control. Samples were collected on the 7^{th} day after the experiment (August 20 1995).

Family	High trampling	Intermediate	Low trampling	Control
O. Ephemeroptera				
F. Baetidae		1	2	1
F. Caenidae	4			
F. Ephemeriidae				
F. Ephemerellidae				
F. Heptageniidae	5			
F. Leptophlebiidae				
F. Polymitarayidae				
F. Tricorythidae			1	
F. unknown	1			1
O. Hemiptera				
F. Naucoridae	1			
O. Plecoptera				
F. Chloroperlidae			1	
F. Perlidae				
F. Perloidae				1
F. unknown				
O. Tricoptera				
F. Glossosomatidae				
F. Hydroptilidae				
F. Hydropsychidae				
F. Leptoceridae				
F. Limnephillidae				
F. Philopotamidae				
F. Polycentropodidae				

Table 7 (continue) Shown total number of individual belonged to various family of aquatic insects in Boripat waterfall. Samples were collected in 5 habitats (boulder, cobble, gravel, sand, and litter) in high trampling, intermediate trampling, low trampling and control. Samples were collected on the 7thafter the experiment (August 20 1995).

Family	High trampling	Intermediate	Low trampling	Control
F. Polymitacyidae				
F. Rhyacophilidae				
F. unknown				
O. Lepidoptera				
F. Augyractini				
F .Pyralidae				
F. unknown				
O.Odonata				
F.Lebellulidae				

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