Aquatic Insect Drift and Water Quality of the River in Kubah National Park

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AQUATIC INSECT DRIFT AND WATER QUALITY OF THE RIVER IN KUBAH NATIONAL PARK

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I hereby declare that this thesis is based on my original work except for quotation and citation, which have been duty acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UNIMAS or other institutions.

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List of Abbreviations

ANOVA	Analysis of Variance
D	Diptera
DO	Dissolved oxygen
EPT	Ephemeroptera, Plecoptera and Trichoptera
TSS	Total suspended solid

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ABSTRACT

A study on the aquatic insects drift and water quality was conducted in the river of Kubah National Park. Samplings were conducted five times which were once in December 2014, thrice in February 2015 and once in March 2015. Drift samples and water quality measurements were taken at every three hours interval for a period of 24 hours during each sampling session. Drift samples were taken by using a Surber sampler. There were five water quality parameters measured *in-situ* which are pH, dissolved oxygen, temperature, turbidity and velocity and two water quality parameters measured *ex-situ* which are total suspended solids and also volume of water discharge by the sampler. A total of 313 individuals collected consisting of six orders of aquatic insects. Diptera was the most dominant group of aquatic insects in the drift sample followed by Plecoptera, Trichoptera, Ephemeroptera, Coleoptera and lastly Hemiptera. The total drift densities for the whole sampling period was 79.72 individuals per 100 m^3 of volume filtered by the sampler and the highest drift density recorded was at 12.30 pm with 19.86 individuals per 100 m^3 of volume filtered by the sampler. Analysis of Variance (ANOVA) showed no significant differences within each hour for each of the water quality parameters. Correlation Analysis by using Pearson Correlation showed that dissolved oxygen (r = -0.54) and velocity (r = -0.50) have a strong correlation with drift densities. The drift pattern of these aquatic insects does not show a distinct diurnal pattern. Analysis by using paired t-test showed no significant difference between day and night drift samples (p = 0.839). The data gathered in this study is hoped to be useful for monitoring and managing the rivers of Kubah National Park in the future.

Keywords: aquatic insects, drift, water quality, Kubah National Park

ABSTRAK

Satu kajian mengenai hanyutan serangga akuatik and kualiti air telah dijalankan di salah satu sungai di dalam Taman Negara Kubah. Penyampelan telah dilakukan sebanyak lima kali iaitu satu kali pada bulan Disember 2014, tiga kali pada bulan Febuari 2015 dan satu kali lagi pada bulan Mac 2015. Sampel hanyut dan bacaan kualiti air telah diambil pada setiap tiga jam dalam jangka masa 24 jam untuk setiap sesi penyampelan. Penyampel "Surber" telah digunakan untuk mengambil sampel hanyut. Terdapat lima parameter kualiti air yang diambil secara in-situ iaitu pH, oksigen larut, suhu, kekeruhan serta halaju air dan dua parameter kualiti air yang diambil secara ex-situ iaitu jumlah pepejal terampai dan jumlah air yang ditapis oleh penyampel. Sebanyak 313 individu merangkumi enam order serangga akuatik berjaya dikumpul. Diptera merupakan kumpulan serangga yang paling dominan di dalam sampel hanyut tersebut diikuti oleh Plecoptera Trichoptera, Ephemeroptera, Coleoptera dan Hemiptera. Jumlah keseluruhan kepadatan hanyut ialah 79.72 individu bagi setiap 100 m^3 air yang ditapis oleh penyampel dan kepadatan hanyut tertinggi ialah pada pukul 12.30 dengan 19.86 individu bagi setiap 100 m^3 air yang ditapis oleh penyampel. Analisi Varians (ANOVA) menunjukkan tiada perbezaan yang signifikan bagi setiap jam untuk kesemua parameter kualiti air. Analisis korelasi menggunakan Korelasi Pearson menunjukkan oksigen larut (r = -0.54) dan halaju air (r = -0.50) mempunyai korelasi yang kuat dengan kepadatan hanyut. Corak hanyutan bagi serangga akuatik ini tidak menunjukkan corak hanyutan diurnal yang jelas. Analysis menggunakan t-test berpasangan menunjukkan tiada perbezaan signifikan bagi sampel hanyutan siang dan malam (p = 0.839). Data yang dikumpul di dalam kajian ini diharap berguna bagi kerja-kerja pemantauan dan pengurusan sungai-sungai di dalam Taman Negara Kubah di masa hadapan.

Kata kunci: serangga akuatik, hanyut, kualiti air, Taman Negara Kubah

1.0 INTRODUCTION

Drift can be interpreted as the downstream transport of an aquatic organism in the current and was first observed in the early twentieth century (Matzinger and Bass, 1995). It is known to be one of the significant medium of dispersal and colonization of the downstream habitats by the stream invertebrates (Hauer and Lamberti, 2006). Drift has intrigued vast amount of stream ecologists for decades with its distinctive diel periodicity and changes of number of individuals drifting in the 24-hour period. Moon (1940) proposed that drift activity exhibits a nocturnal rhythm. This is due to the rapid colonization of substrate set on the bottom of the lake at night than during the day (Moon, 1940).

There are varieties of reasons that cause these invertebrates to drift. Factors such as in search for food and substratum and avoidance of predators and unfavorable conditions are among the things that can be associated to drifts (Hauer and Lamberti, 2006). Waters (1965) suggested that drift can be classified into three different patterns which are, (1) constant, the continuous frequency of low numbers of most species, (2) behavioral, a consistent diel periodicity usually at night (nocturnal drift) and (3) catastrophic, drifts that which are triggered by physical disturbance such as floods, high temperatures and pollutants.

According to Wahizatul *et al*. (2011), studies on the relationship between the aquatic insect species in freshwater rivers ecosystem and its habitat can also help in analyzing the water quality of the aquatic ecosystem. There are species known to possess a certain requirements of nutrients, water quality, substrate components and also the structure of vegetation. When these requirements are defined, the existence of a particular species in a habitat can indicate the given parameters are within the tolerance limits of that particular species which in turn shows that the species really belongs to that habitat (Hellawell, 1986).

Indicator species are those from the taxa that are known to be very sensitive to any specific environmental factors meaning that the changes in their abundance and incidence may directly portray the changes that occurred in the environment (New, 1984). The concept of using aquatic insects as biological indicators is actually based on their abundance, diversity and also distribution in relation to the chemical and physical conditions of the habitats. Biological monitoring, which used living organism to estimate the water quality and also its chemical contents is significant to determine the health of an aquatic ecosystem because physicochemical monitoring alone is inadequate to fully describe the status of the water body (Wahizatul *et al*., 2011).

Although the study on aquatic insect drift is not new in Malaysia, there is still no documented research on aquatic insect drift in the rivers of Kubah National Park. The objectives of this study are, (1) to document the pattern of drift of aquatic insects in the river of Kubah National Park, (2) to investigate the composition of aquatic insects occurring in the drift in the river of Kubah National Park and (3) to investigate the relationship between water quality and the drift of aquatic insects in the river of Kubah National Park.

2.0 LITERATURE REVIEW

2.1 Aquatic insect

Aquatic insects are classified under the subphylum Hexapoda under the Phylum Arthropoda (Thorp and Rogers, 2011). As described in Thorp and Rogers (2011), there are three main characteristic of an aquatic insects which are three pairs of leg, three major body regions (head, thorax and abdomen) and also single pair of antennae (Figure 2.1).

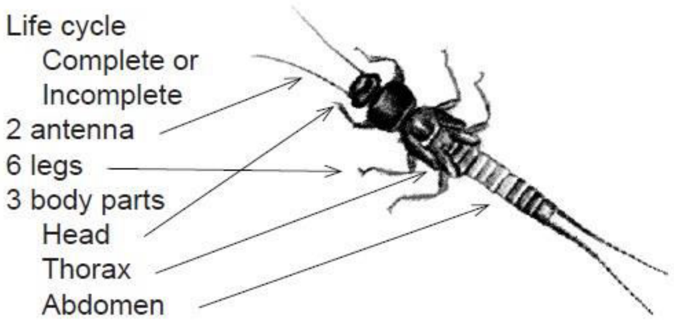

Figure 2.1: Major morphology of an aquatic insect (Voshell, 2009)

Aquatic insects have a very diverse taxonomic composition which consists of orders Odonata (damselflies, dragonflies), Plecoptera (stoneflies), Ephemeroptera (mayflies), Coleoptera (aquatic beetles), some Blattodea (cockroaches), Megaloptera (alderflies, fishflies, dobsonflies), some Hemiptera (water bugs), some Neuroptera (spongillaflies, owlflies), some Trichoptera (caddisflies), some Diptera (midges), and some Lepidoptera (moths) (Yule and Yong, 2004).

Five of these orders (Ephemeroptera, Odonata, Plecoptera, Megaloptera and Trichoptera) possess aquatic stages in all of their species while the remaining orders (Coleoptera, Blattodea, Hemiptera, Neuroptera and Lepidoptera) contain terrestrial, semiaquatic and aquatic stages in their species. Aquatic stages of these insects can be found in hot and cold springs, ponds, intertidal pools, intermittent streams and also less severe running and standing water habitats. The semiaquatic species usually live in damp marginal habitats such as the upper surface of the air-water interface or above the water surface by submerging themselves temporarily (Ward, 1992).

Some of these groups such as the mayflies, stoneflies and caddisflies are known to be associated with clean waters while others like the midges can survive in organically polluted ecosystem which made all these four groups as important indicators of water quality (Thorp and Rogers, 2011).

2.2 Drift

Drift can be defined as the phenomenon where stream-dwelling organisms which possess a limited swimming ability are being swept downstream in the water column (Allan, 1995). Among the insects, Ephemeroptera, Plecoptera, Trichoptera and Diptera (especially the Simuliidae) are known to be the most common drifters (Allan, 1995). Waters (1972) stated that drift are more common in the later rather than the earlier life stages of an organism as there is more energy demands when the organism reached the absolute growth. This energy demands will then lead a greater intraspecific competition, foraging activity and of course, drift (Waters, 1972).

Waters (1965) also suggested that drift diel periodicity can be classify into three different types which are first, behavioral drift that shows a consistent pattern, commonly a distinct nocturnal increase. Second, the constant drift which refers to the perpetual background of low numbers that is mostly detected during the day and lastly the catastrophic drift that refers to the effects of adverse events such as floods, high temperatures, drought and anchor ice which can help in providing a useful index of human disturbance. Allan (1995) stated that the number of animals drifting at night is usually greater than the day. Most stream-dwelling taxa are nocturnal drift as they show a nocturnal peak in numbers but for some, such as Chironomidae was reported to be a periodic while some trichopterans and water mites are day-active (Allan, 1995). Nocturnal drift usually reaches a major peak after dusk and then decrease through the night then rise again to a small peak before dawn (Allan, 1995). According to the study conducted by Elliot (1968), nocturnal drift is encoded genetically in the organisms. This is because even when these organisms are being put in a predator-free environment, they did not response to an immediate shift in activity.

These invertebrates are able to travel up to hundreds of meters during high flow period but generally, they can travel in relatively narrow distances during low flow conditions (Lancaster *et al*., 1996). Size and swimming ability of these insects can also affect the distance that they can travel during drifting events. Chironomidae for example, drift to similar distances when they are alive and also dead showing that they are carried passively by the water flow (Daheny *et al*., 2011). Daheny *et al*., (2011) also mentioned that the genus *Baetis*, from the order Ephemeroptera are capable to swim back to the substrate after drifting for less than five meters. Rader (1997) suggested that drift is common in the early instars of these insects rather than the later instars. This is because the smaller individuals are more vulnerable to be swept downstream in longer distances while they are drifting.

The most common factor that can affect drift is light level (Allan, 1995). In behavioral drift for example, light serves as its time signal. In a study conducted by Muller (1965), he manipulated the light-dark (LD) cycle in the field by using lamps and opaque plastics on the drift of two species of *Baetis*. The results showed an extreme LD cycles which is 23:1 as all the drift concentrated into one hour. Continuous light can leads to virtually no drift and no rhythm while natural drift patterns can be tenacious for 8 days in an artificial darkness (Allan, 1995). Anderson (1966) also suggests that moonlight may also suppress drift.

There are a lot of reasons why drift occur and the most common reason is to avoid predators which are mostly relying on their vision to capture prey (Allan, 1995). Mayflies nymph for example are commonly active at night as they drift downstream to avoid predators (Thorp and Rogers, 2011). There are strong evidences that show predation risks can govern the nocturnal periodicity for macroinvertebrates (Allan, 1995). Comparisons can be made in locations with different fish populations as drifts are diurnal or aperiodic in streams lacking drift-feeding fish (Turcotte and Harper, 1982).

2.3 Water quality

Insects have been frequently used to measure and detect any kinds of environmental disturbance that occurs from pollution by pesticides, sewage, nutrient enrichment, fertilizers and chemical waste (Heliövaara and Väisaänen, 1993). They are very useful especially in stream monitoring studies as they possess a lot of readily measurable biological characteristic. In a study of the influence of water physicochemical characteristic on Simuliidae (Diptera) prevalence which was conducted by Rabha *et al.* (2013), they stated that each simuliid species actually prefers different sets of physicochemical variables in their habitat. pH, water flow and turbidity were found to be very important water parameters for simuliid density and prevalence in the freshwater rivers. Thorp and Rogers (2011) stated that mayflies have different oxygen requirements making them a very useful indicator for organic pollution. They are usually absent in a severely polluted water but they can be commonly found in running waters where the oxygen concentration is high (Yule and Yong, 2004). They are also known to be very sensitive towards acidification thus; they may reduce in diversity, density and richness at places with a low pH (Heliövaara and Väisaänen, 1993). They are often having a higher drift rate than other benthic invertebrates when pH decreases (Heliövaara and Väisaänen, 1993). Other than that, turbidity may also affect the drift of mayflies. Based on the study by Matzinger and Bass (1995) in the Blue River Oklahoma, the nymphs of the genus *Baetis*, had an increase in its drift rate as turbidity increased. They suggested that this may happened as the insects drifted to find a better habitat as turbidity can decrease light penetration.

The EPT (Ephemeroptera, Plecoptera and Trichoptera) groups are well-known for being suitable bioindicators of water quality as they are highly sensitive towards pollution while the Chironomidae (Diptera) is the group of aquatic insects that is tolerant towards pollution (Triplehorn and Borror, 2005). In a study conducted by Wahizatul *et al.* (2011) in Sungai Peres and Sungai Bubu in Hulu Terengganu, the individuals from the EPT groups were more abundant in the upstream, where better water quality was recorded while the pollution tolerant group Chironomidae, was more abundant in the downstream where the water quality was quite low compared to the upstream. Although EPT are known to be intolerant towards pollution, a study on the distribution of aquatic insects in urban headwater streams which was conducted by Hepp *et al.* (2013) showed several genera of EPT can still be present in a stream where the concentrations of nitrate and phosphorus exceeded the normal level. However, they suggest that there might be two interpretations that can be concluded from the findings which are first, although the studied streams were located in an urban area, it might have not experienced any particular chemical change that can affect the EPT compositions and second, some of the genera might be more tolerant than reported in the literature.

Temperature also has a positive correlation towards the density of aquatic insect. Pearson and Franklin (1968) suggest that drift rates may increase when the temperature rises. In a study by Matzinger and Bass (1994), they discovered that there was a significant correlation between temperature and density of the aquatic insects. This may happen due to the association between growth and activity for the immature insects (Merritt and Cummins, 1984). As the size of an insects increase with temperature, it will be more active searching for food. When they become more active, they also become more vulnerable to being washed into current inducing behavioral drift (Waters, 1965).

2.4 Kubah National Park

Kubah National Park is located 33 kilometers from Kota Samarahan. The forest in Kubah is a mixed dipterocarp and it covers an area of 2,230 hectares which mainly comprises of ridges and heavily forested slope. It is also known for having crystal clear streams, bathing pools and small waterfalls. There are basically three rivers that flow around the national park which are Sungai Amok, Sungai Rayu and Sungai China ("Kubah National Park," 2006). A study that was done by Long and Kasim (2013) on the freshwater nematodes in Kubah National Park concluded that the water quality in the rivers of Kubah National Park is clean. This is due to the nematode composition during the study which shows a positive correlation towards the water quality of the rivers.

3.0 Methodology

3.1 Study Area

The samples were taken at a small stream that flows from one of the main rivers in Kubah National Park which is Sungai Rayu. The coordinate of the sampling station is N 01˚ 36' 42.9" E 110˚ 11' 44.9". The stream is sheltered and possesses a mix of sandy and rocky substrate. The water that flows along the stream is clear and well oxygenated.

Figure 3.1: Map of Kubah National Park (Google Maps)

3.2 Field Sampling

Samplings were conducted for five times which are once in December 2014, thrice in February 2015 and once in March 2015.

3.2.1 Samples collection

The coordinate of the selected sampling station was taken by using GPS (GARMIN 62s). A WILDCO 12-C32 Surber stream bottom sampler (frame size of 0.31 x 0.31 m^2) with 363-micron mesh size was set up in the small stream for a duration of 24 hours in such a way that the open end facing the current (Figure 3.2). The drift samples were collected for every three hours (starting at 1530, 1830, 2130, 0030, 0330, 0630, 0930, 1230 hour) by emptying the sampler into an enamel tray. The samples were then sieve with 300 μm mesh size sieve and transferred into plastics, labeled, stained with Rose Bengal and preserved with 10% formalin.

3.2.2 Physicochemical measurement

The depth river was measured by using a ruler. Triplicate readings of water temperature (EXTECH SDL100), pH (EXTECH SDL100), turbidity (LT LUTRON TU2016) and dissolved oxygen (EXTECH SDL150) were recorded by using the respective instruments. The velocity of the river was also taken in triplicate readings by using a flowmeter (G.O. ENVIRONMENTAL 22807). One liter of water sample was taken for every sampling session for total suspended solid (TSS) analysis. Depth of the river, water sample and all of the water quality readings were also taken at every three hours interval in the 24 hour duration.

3.3 Laboratory Analyses

3.3.1 Total suspended solid (TSS) analysis

The total suspended solid of the water sample was measured by filtering the water sample using a millipore (SWINNEX-47), with a pre-weighted GF/C glass microfiber filter paper (WHATMAN GF/C 47 mm). The glass fiber filters were soaked in distilled water, oven dried at 103 ˚C and weighed. The weighed glass fiber filter papers were then put on the filtering flask before turning on the pump and filter the water samples. After the filtration, the filter papers were oven dried again at 103 to 105 ˚C and weighed. The TSS were calculated by using the formula;

TSS (mg/L) = (A-B) / C

Where A = Final weight of the filter paper (mg)

B = Initial weight of the filter paper (mg)

C = Volume of water filtered (L)

3.3.2 Sorting and identification

The insects collected were identified up to order level by using taxonomic keys in Yule and Yong (2004). Large insects were sorted by naked eyes while the smaller ones were sorted under the stereo microscope (OLYMPUS SZ61). The sorted samples were then preserved in vials containing 70% ethanol. The hourly data of the drift collected were recorded for statistical analysis.

3.4 Data analysis

3.4.1 Drift Density

Drift density of the insects were standardized to number per 100 m^3 of volume of water filtered by the surber sampler by using the formula;

$$\frac{\boldsymbol{n} \times \mathbf{100}}{\boldsymbol{t} \times \boldsymbol{w} \times \boldsymbol{h} \times \boldsymbol{v} \times \mathbf{3600}\,(\boldsymbol{sec/hour})}$$

Where n = Number of individuals

t = Exposition period (in hour)

w = Width of the sampler

h = Depth of the water

v = Mean velocity of the river

3.4.2 Water Quality and Water Discharge

The mean and the standard deviation of the data for the water quality parameters were also calculated. Volume of water discharge by the sampler for each sampling session was calculated by using the formula;

Volume of Water Discharge by Surber Sampler (m^3/hour) = A x V

Where A = Area of the mouth of the sampler (depth of the water x width of the sampler)

V = Velocity of the water current (m/hour)

3.4.3 Statistical Analysis

One- way analyses of variance (ANOVA) was used to determine the significant differences within each hour for each of the water quality parameters. Pearson Correlation was used to determine the correlation between the selected water quality parameters and drift densities. Paired t-test was used to analyze the significant difference between day and night drift densities.

4.0 RESULTS

4.1 Aquatic Insect Composition

A total of 313 individuals of aquatic insects were captured during the whole sampling period. Six orders were identified consisting of Ephemeroptera, Plecoptera, Trichoptera, Diptera, Coleoptera and Hemiptera.

From the five sampling activities conducted between 13/12/14 and 12/3/15, order Diptera is the most dominant group of insects with 164 individuals (Figure 4.1) comprising 52% of the total number of insects (Figure 4.2), followed by Plecoptera with 75 individuals (24%), Trichoptera with 34 individuals (11%), Ephemeroptera with 23 (7%), Coleoptera with 14 individuals (5%) and finally the least dominant group of insects which is Hemiptera with only 3 individuals (1%).

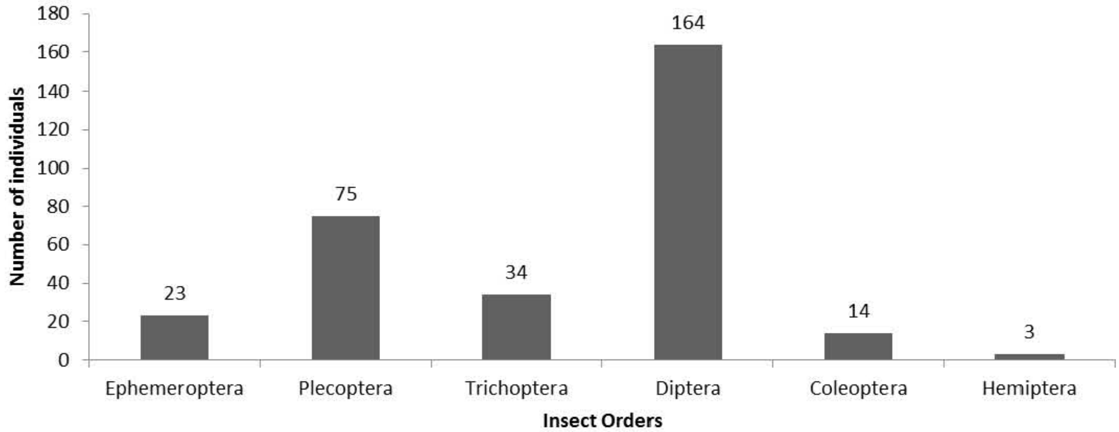

Figure 4.1: Number of individuals of aquatic insects collected

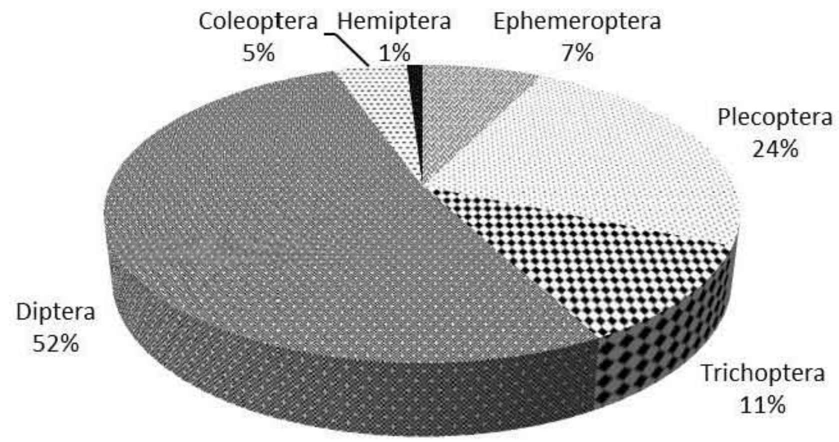

Figure 4.2: Percentage of the total number of aquatic insects captured

In the samples taken on 13-14/12/14 (Appendix I), only 16 individuals of insects were captured in the drift samples, representing only five from six orders identified in the overall samples. Trichoptera and Diptera showed the highest number of insects while Ephemeroptera, Plecoptera and Coleoptera showed the lowest number of insects. The highest number of insects recorded hourly was at 2130 hours and 0630 hours with 4 individuals and the lowest number of insects recorded was at 1830 hours and 0330 hours with zero individuals of insects.

A higher number of insects were recorded in the 9-10/2/15 samples (Appendix II) which are 77 individuals consisting all 6 orders. Diptera showed the highest number of insects while Ephemeroptera, Coleoptera and Hemiptera showed the lowest number of insects. The highest number of insects recorded hourly was at 1230 hours with 38 individuals and the lowest number of insects recorded was at 0630 hours with 2 individuals of insects.

A total of 83 individuals of insects representing only five of the orders were collected in the 16-17/2/15 sample (Appendix III) with Diptera showing the highest number of insects and Hemiptera showing the lowest number of insects. The highest number of insects recorded was at 0030 hours with 25 individuals and the lowest number of insects recorded was at 1530 hours and 1830 hours with 3 individuals of insects for each hours.

In the 25-26/2/15 sample (Appendix IV), 45 individuals of insects were collected consisting five orders of insects. Diptera also showed the highest number of insects while Trichoptera showed the lowest number of insects. The highest number of individuals of insect was recorded at 1530 hours with 14 individuals and the lowest number of insects recorded was at 0030, 0630 and 0930 hours with 2 individuals respectively.

In the 11-12/3/15 sample (Appendix V) 92 individuals of insects were collected representing all six orders and Plecoptera showed the highest number of insects collected. Hemiptera showed the lowest number of insects collected for that sample. The highest number of individuals of insects was recorded at 2130 hours with 24 individuals and the lowest number of insects recorded was at 1230 hours with 5 individuals.

4.2 Drift Pattern

The numbers of insects occurring in all the drift samples were standardized to number per 100 m^3 of volume of water filtered by the sampler in order to obtain the drift densities of the insects for each subsequent hour. Figure 4.3 below shows the drift pattern of the insects occurring in the river of Kubah National Park. The total drift density for the whole sampling period is 79.72 individuals per 100 m^3 of volume filtered by the sampler. The highest number of drift densities recorded was at 12.30 pm with 19.86 individuals per 100 m^3 of volume filtered by the sampler (Figure 4.3) while the lowest number of drift densities recorded was at 9.30 am with 4.24 individuals per 100 m^3 of volume filtered by the sampler.