The Effect of Stream Culverts on Aquatic Insects in Monteverde, Costa Rica

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Abstract:

Aquatic insects play an important role in tropical ecosystems as food for birds and fish. Concrete tubing, called a culvert, is used to alter the natural flow of a stream to allow it to pass under a road, and this change in flow has a big impact on the aquatic insects within this aquatic ecosystem. To assess the impact of the culvert on aquatic insects, I collected aquatic insects upstream and downstream of three culverts along tributaries of the Quebrada Maquina in Monteverde. From these collections I compared the relative abundance and species richness of these insects morphospecies found upstream versus downstream. Using direct sampling of insects from different substrate sampling and collection with traps, I found a difference in the insect abundance and species richness above and below every culvert. However, sample sizes were only large enough for three morphospecies to detect a statistically significant difference. In the future a better design of the culvert would maintain higher species richness of aquatic insects.

Resumen:

Los insectos acuáticos juegan un papel importante en diversos sistemas en Monteverde, especialmente en quebradas y rios. El flujo de estos es alterado mediante alcantarillas cuando pasan debajo de las calles, teniendo un impacto sobre los insectos acuáticos en estos sistemas. Para evaluar este impacto, colecté insectos acuáticos aguas arriba y aguas abajo en tres alcantarillas de la misma quebrada, utilizando metodos de muestreo directo mediante redes y trampas con diferente sustratos. De estas colecciones, comparé la riqueza y abundancia relativa de las morfoespecies encontradas, aguas arriba y aguas abajo, encontrando diferencias en cada alcantarilla. Sin embargo, soló tres morfoespecies tuvieron un tamaño de muestras suficicutemente grande para demestrar diferencias significativas. En el futuro, un mejor diseño de alcantarillas servirá para mantener una riqueza alta de insectos acuáticos.

Introduction:

Streams change their course naturally over time and the organisms within these aquatic ecosystems have adapted to a dynamic environment. Aquatic insects are important in the ecology of streams as a food source for birds and fish, especially in the larval stage (Borror 1989). For example, the diet of the American Dipper consists of mainly aquatic insects (Abram Burkholder pers.com). In streams, the aquatic insect distribution is set by the physical and chemical tolerances of the individuals in the population to an array of environmental factors (Merrit & Cummins 1996). While many natural changes in stream flow occur gradually, humans can alter the flow very quickly resulting in a big impact on aquatic insect populations. A human water diversion can both increase and decrease the flow of the water, causing a host of chemical and physical changes in the affected river systems (Allan 1995).

Many of the streams in Monteverde run underneath the road through concrete tubing, called a culvert. The culverts are smooth and dark on the inside making it unlikely for rocks to deposit or vegetation to establish. In my study I assumed that most species of aquatic insects distribute through the water column of the stream; however, it is possible for some species to distribute by flying as adults. From my assumption I predicted that culverts are barriers for aquatic insects and I would find a difference in the aquatic insect populations upstream and downstream. To measure this impact, I looked at the relative abundance and species richness of insect morphospecies upstream and downstream of three culverts along tributaries of the Quebrada Maquina in Monteverde.

Materials and Methods:

Study Sites

The three different culverts I studied were all along the Quebrada Maquina in Monteverde, Costa Rica (Figure 1). 1) The first culvert I studied was in front of Stella's Bakery. The creek running through this culvert is the smallest of the three locations, with an average width of 0.26 meters and average depth of 0.04 meters. It is impossible to measure velocity at this location using a plastic bottle tied to a 2-meter string because the water was too shallow. The culvert at this location has a diameter of 0.62 meters. 2) The second culvert is located near the La Cascada and at this location the stream has a average width of 2.3 meters, an average depth 0.21 meters, an average surface velocity upstream of 1.324 meters per second, and an average surface velocity downstream of 1.08 meters per second. The culvert at this location is the largest of all the sites with a diameter of 1.3 meters. 3) The third location of the Quebrada Maquina is near the Hotel Belmar. This part of the stream has an average width of 2.28 meters, an average depth of 0.2 meters, an average surface velocity upstream of 2.83 meters per second, and an average surface velocity of 3.293. The culvert at this location was 0.9 meters in diameter.

Data Collection/ Sampling

First, I constructed 24 identical substrate traps for aquatic insects (Figure 2). I included four different types of substrates within the traps to collect a variety of insects. The foam and sponge layers were intended for smaller insects, while the plastic netting with and without leaf litter were intended for larger insects. The first eight traps were placed above and below of the culvert close to the Hotel Belmar on 15 November 2001. Then, the remaining 16 traps were placed upstream and downstream of the culverts near the La Cascada and Stella's Bakery on 16 November 2001. Each trap was placed either under rocks or wedged between rocks, within 5 meters of the culvert. In some cases, where the current was strong, metal wire was used to secure the traps in place. The first traps were retrieved from the Hotel Belmar location on 23 November 2001 and from the Stella's Bakery and La Cascada locations on 24 November 2001. However, the traps I placed upstream in front of Stella's Bakery were missing and the rocks that were next to them had been moved when I went to retrieve them. In all cases, I pulled each trap out and poured alcohol over the sides to preserve any of the insects within the trap. Then the traps were placed in plastic bags and carried to the Estación Biológica, Monteverde.

For the second method of collection, I took into account the different types of substrate present at each of the sites and sampled each depending on the percentage that was represented collecting rocks, roots, leaf litter and sediment. I placed the samples in a plastic bowl to sort out the insects present on each substrate. Each kind of substrate was collected in the bowl and each bowl accounted for ten percent of the area of the stream. Therefore, ten bowls were sampled at each site (Table 2). The samples were taken at Stella's Bakery and La Cascada on 20 November 2001 and at the Hotel Belmar location on 21 November 2001. The insects found through the two different methods of sampling were preserved in alcohol and identified to morphospecies with the aid of an specialist using several identification guides (Lehmkuhl 1979, Merrit & Cummins 1996, Roldán 1998).

Statistical Analysis

I used the Jaccard Index to measure the similarity in species composition between the morphospecies upstream and downstream of the three streams (Magurran 1988). To account for the abundance of each morphospecies I used the Simplified Morisita Index (Krebs 1989). In addition, I used a chi-squared test to compare the three most abundant morphospecies that I found from the direct substrate collection of the three streams above and below the culvert. Because I had only two categories to compare, I used the Yates' Correction of Continuity to correct the chi-squared value (Fowler & Cohen 1990).

Results:

From both the traps and the direct collection I found a total of 29 morphospecies from eight different families (Table 1). At the location near Stella's bakery, I found a total of 11 morphospecies, and only 1 morphospecies, larvae from the subfamily Chironomidae, was present both upstream and downstream. At the La Cascada location of the 12 morphospecies found only five were shared above and below the culvert. At the Hotel Belmar location I found 17 morphospecies, among these only five were shared. There was no trend in which side of the culvert had a greater diversity of insects. For the Stella's Bakery and Hotel Belmar locations there were more morphospecies upstream, yet at the La Cascada location it was the opposite.

With the traps I collected 12 morphospecies, and six of these were found exclusively in the traps. Chironominae larvae, *Leptonema sp.* (Hydropsychidae), *Anchytarsus sp.* (Ptilodactylidae), *Macrelmis sp.* (Elmidae), Terpides sp. (Leptophlebiidae), a morphospecies from the families Psephenidae, and a morphospecies from the order Plecoptera were present in various substrates. However, *Simulium sp.* (Simuliidae), and a morphospecies of the family Psephnidae were all restricted to the wood. Likewise, *Phylloicus sp.* (Calamoceratidae) was found only in the foam. Furthermore, morphospecies from the families Metretopodidae and Staphylinidae were only found in the plastic netting.

From the Jaccard index, I found the similarity of morphospecies composition upstream and downstream to be 0.091 (9.1%) at Stella's Bakery, 0.417 (41.7%) at La Cascada, and 0.294 (29.4%) at Hotel Belmar. To account for the abundance of each morphospecies I used the Simplified Morisita Index (Stella's Bakery C_h= 0.9194, La Cascada C_h= 0.9907, and Hotel Belmar C_h= 2.07). Of all three sites, three of the morphospecies were high in abundance: Chironominae larvae, *Simulium sp.* (Simuliidae)., and *Leptonema sp.*(Hydropsychidae) (Table 1). At the Stella's Bakery location there was a difference in the relative abundance of Chironominae larva upstream and downstream of the culvert (X^2= 5.68, p= 0.05). However, for the Hotel Belmar and La Cascada locations there was not a significant difference. In addition, there was also a difference in the relative abundance of *Simulium sp.* at the location near La Cascada (X^2= 37, p= 0.01), but there was no difference at the Hotel Belmar location. For *Leptonema* *sp.* there was no difference in relative abundance at the Hotel Belmar or the La Cascada locations.

Discussion:

By using the two different methods of insects sampling I was able to collect a variety of morphospecies. However, time was a constraint in the lack of multiple individuals for each morphospecies. The method of sampling insects from different substrates and using a plastic bowl was the most efficient for a short amount of time. On the other hand, the insect traps are better for long-term collection. Unfortunately, I only used the traps in the water for a week, which was not sufficient time. If the traps are left for a longer amount time in the water it would be clearer which insects are commonly collected in which substrate. For better results in future studies I would recommend leaving the traps in the water for a longer period of time (i.e. a month). In addition, when the traps are retrieved it would be easier to find the insects before using alcohol, while the insects are alive and moving at the site.

When I began the study I only considered the four substrates that were between the plywood; however, when I retrieved the traps from the water I noticed there were also insects on the wood. It would be likely for insects to attach to the wood, as it is similar to the logs and other wooden debris found on the water.

I expected to find a difference in the insect population upstream and downstream, and although the Jaccard index of showed less than fifty percent similarity, the index values are not conclusive. The Jaccard index does not take into account the abundance of each morphospecies. For many of the morphospecies that I collected, I only found one individual of each morphospecies, in some cases these could have been accidentals. With more collections I might have found that an unshared morphospecies are actually shared and the differences between upstream and downstream of the culverts are actually less. In addition, in the aquatic ecosystem of a stream with a culvert, the culvert is not the only thing that has an effect on the aquatic insects. First, there are some species of aquatic insects that can disperse by flying and would not be affected by the culverts. Other factors that influence aquatic insects populations include physiological, food, physical, and biotic constraints (Merrit & Cummins 1996). For example, the location in front of Stella's bakery had a terrible odor because of something in the water. The water conditions may be acting on the insects populations more than the culverts.

The three morphospecies that I found a high abundance of were *Simulium*, Chironominae larva, and *Leptonema*. Members of *Simulium* and *Leptonema* are commonly found in running water because they produce silk to attach to different substrates (Anderson & Wallace 1996, Wiggins 1996). This feature may have been a reason why I found a high abundance. In addition, the family Chironomidae is an ecologically important group of aquatic insects, and as I found in my study, they often occur in high densities and the larva stage is the most frequently encountered (Ferrington & Coffman 1996).

Although further studies are needed, I believe a better design of a culvert would lessen the barrier above and below the culvert for aquatic insects that disperse through the water column. For example, if small speed bumps were placed inside the culverts, then sediment and small pebbles could accumulate and provide a habitat for aquatic insects. By maintaining insect populations the bird populations in Monteverde that feed on aquatic insects would also be maintained.

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Tables:

Table 1

Morphospecies Found Along the Quebrada Maquina, Upstream and Downstream of Three Culverts
*** Numbers in paratheses mean trap samples**

				Location					
				Stella's		Cascada		Maquina	
Order	Family	Subfamily	*Genus*	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Coleoptera	Staphylinidae		*Genus 1*		[1]				[1]
	Psephenidae		*Genus 2*					[2]	
	Ptilodactylidae		*Anchytarsus*			[2]	[2]	1[3]	[3]
	Elmidae		*Macrelmis*					1[2]	
	Dytiscidae		*Thermonectus*	1					
Diptera	Ceratopognidae		*Serromyia*	1					
	Tabanidae		*Leucotabanus*	1					
	Simuliidae		*Simulium*	5		55	142	15[5]	24
	Unknown		*Genus 1*					1	
	Chironomidae		*Orthocladius*	5					
	Chironomidae	Chironominae	*(larvas)*	31	14[88]	3[1]	[2]	7[8]	[6]
	Chironomidae	Chironominae	*(pupas)*		1	4			
Ephemeroptera	Metretopodidae		*Genus 1*					[1]	
	Baetidae		*Baetis-1*						1
	Baetidae		*Baetis- 2*			2	12	1	
	Leptophlebiidae		*Terpides*		[1]			5	2
	Unknown		*Genus 2*				[1]		
Hemiptera	Corixidae		*Centrocorisa*						1
	Vellidae		*Rhagovelia*				4		
	Gerridae		*Brachymetra*	1					
Hymenoptera	Ichneumonidae		*Apsilops*	1					
Odonata	Coenagrionidae		*Ischnura*				6	5	
	Libellulidae		*Brechmorhoga*				2		
Plecoptera	Perlidae		*Anacroneuria*					1	
	Unknown		*Genus 2*				[1]		
Trichoptera	Glossosomatidae		*Mortoniella*			2			
	Philopotamidae		*Chimarra*						1
	Calamoceratidae		*Phylloicus*					3[1]	
	Hydropsychidae		*Leptonema*			3[1]	4[2]	7[3]	1[4]

Table 2 Number of Bowls Collected Per Substrate Type

	Stella's Bakery		La Cascada		Hotel Belmar	
	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
Sediment	4	6	4	4	3	3
Rocks	3	2	5	4	3	4
Leaf Litter	3	2	1	1	3	2
Roots	0	0	0	1	1	1

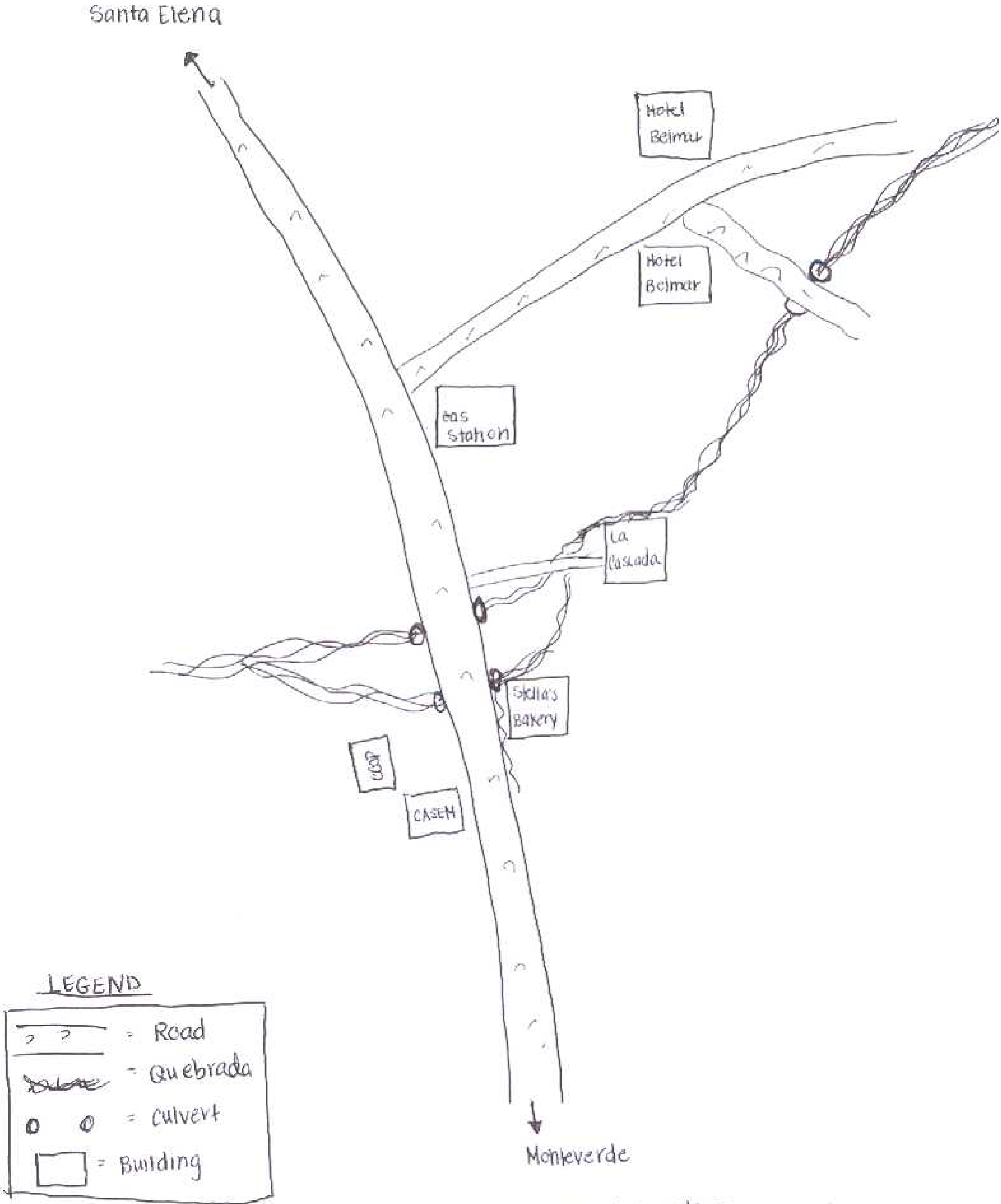

Figure 1 : Map of Culvert Locations

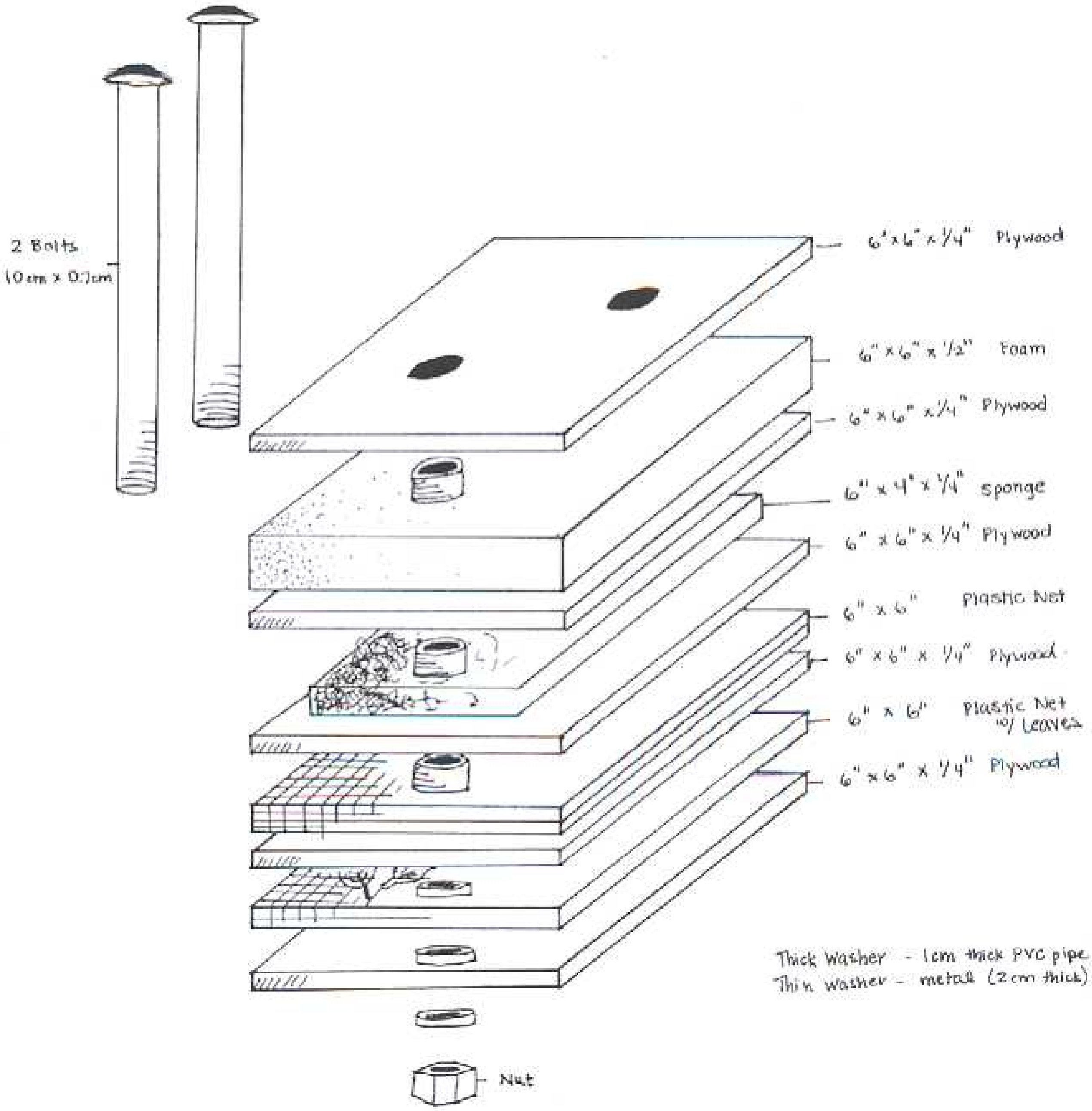

Figure 2: Diagram of Insect Trap

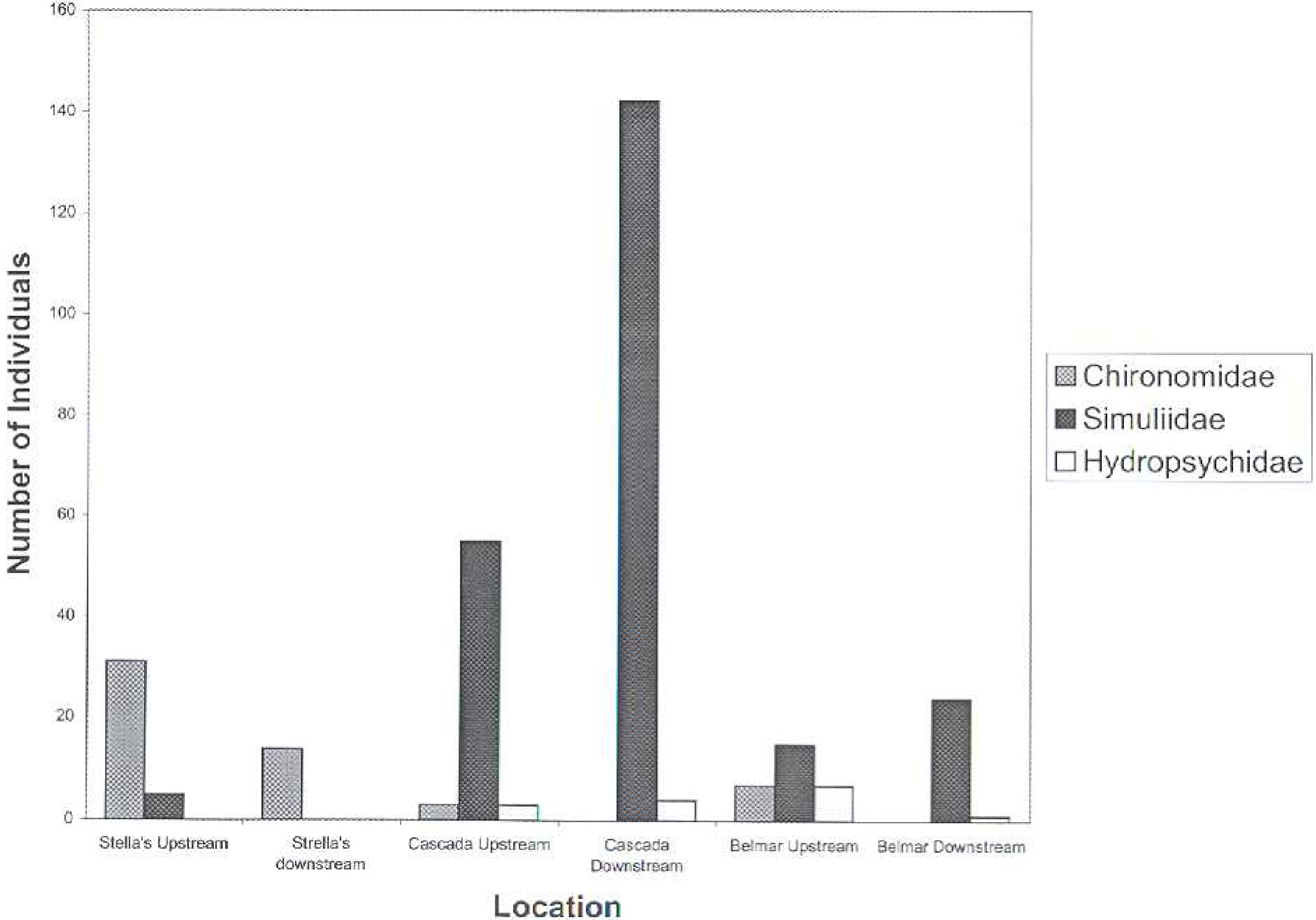

Figure 3: Relative Abundance of the Three Most Abundant Morphospecies