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Capstone
Final Paper

Invertebrate species richness and diversity are highest among bank habitats along Boyle River

Abstract:

Invertebrate numbers are decreasing in New Zealand and worldwide. These animals are not only important to the ecosystem, but they provide humans with ecosystem services including pollination. This study seeks to determine which part of the riparian zone should be the primary emphasis in order to protect the most species richness and diversity. Forty plots were established in two habitat areas including a rock and sand, river environment, and a grassland bank habitat. Each plot had a yellow pan trap to attract pollinator species and a pitfall trap to collect ground dwelling invertebrates. Invertebrates were collected and identified to recognizable taxonomic units (RTUs). An MDS ordination was created showing the invertebrate composition across habitats, and diversity and species richness was calculated and analyzed using an ANOVA. Overall, the bank habitat had higher species diversity and richness than the river habitat, therefore, protection of bank habitats would cover the most richness and diversity of invertebrate species. The river and bank habitats had different compositions despite being neighboring habitats. There was also a larger diversity and richness among aerial organisms over ground dwelling organisms in both habitats. Unless specific species are under threat, the general conservation focus in riparian areas should be on bank habitats.

Key words: Diversity, Richness, Invertebrates

Introduction:

In recent studies, many scientists have discovered overwhelming numbers of declining species and extinctions (Sigwart et al., 2018; Thomas. 2004). Whether this is directly caused by humans by way of habitat destruction and pollution or indirectly, like climate change, the organisms are disappearing (Sigwart et al., 2018; Weinzettel, Vačkář, & Medková, 2018).

Invertebrates are incredibly important and diverse. It is expected that there are 5-10 million species of arthropods globally (Ødegaard, 2000). These organisms occupy almost every niche. Since there is such a vast array of invertebrates, it is not surprising that scientists still struggle to understand the global dimensions of the Arthrododa phylum despite that over a million species of arthropods have been described (Stork, 1988). Invertebrates offer a wide variety of ecosystem services. Ecosystem services are ecological processes of benefit to humans and other animals. Insects are one of the most important players due to their services such as pollination, the spreading of seeds, and control of pests, (Stewart, New, & Lewis, 2007; Allsopp., De Lange, & Veldtman, 2008) as well as wildlife nutrition, and the burial of dung," (Losey &Vaughan, 2006; Stringer & Hitchmough, 2012). The yearly value of the services provided by arthropods in just the United States equates to at least $57 billion, (Losey &Vaughan, 2006) emphasizing the significance of invertebrates to humans.

Entomologists in New Zealand ranked the conservation of the diversity of indigenous invertebrates as one of the top eight most crucial issues (Lester et al., 2014). This is due to the high numbers of invertebrates under conservation status. In a study in 2012, there were 193 Threatened taxa, 106 Nationally Critical, while 30 were Nationally Endangered, and 57 Nationally Vulnerable, while many more were at risk, declining, or data deficient, (Stringer & Hitchmough, 2012). Since these endemic invertebrates are on the decline, efforts need to be made to protect them.

Braided rivers are rivers that are made up of multiple channels which are separated from each other forming small islands. They are commonly studied for the conservation of New Zealand's endemic birds, however, there is much less information present on invertebrates. Such habitats are poorly studied for their invertebrates. Braided riverbeds are uncommon around the world and, as habitats, are in the endangered class (Holdaway, Wiser &Williams, 2012). Large scale floods are common among the rivers, which dramatically move the sediment and gravel making them unstable (Sagar, 1986).

This study focuses on the combination of the conservation of invertebrates with the particularly unique braided rivers, to determine which part of the riparian zone should be the primary emphasis of conservation efforts. Two habitat types were examined, rocky river areas and grassy bank areas near Boyle River, to compare their invertebrate species richness and diversity. The idea behind this study is to determine more about the invertebrates themselves, as well as where conservation efforts should be undertaken to maximize the number of protected species.

We expect to see more organisms in the bank areas over the river areas due to the cover provided by flowering plants. A more multifaceted ecosystem has more species, this is termed the theory of spatial heterogeneity (Simpson, 1964; Connell & Orias, 1964). The rocky/sandy areas are more open and pose a greater risk of predation and will also provide little habitat for pollinator species (Quammen, 1984).

Methods:

Study area:

The study was completed at Boyle River Outdoor Education Centre along the Boyle river as seen in Figures 1, 2 and 3 (coordinates -42.532190, 172.366400). Traps were set out on Feb. 5th, 2019 (the end of NZ summer), and checked on Feb. 5th, 6th, and 7th, before being removed. The weather on the Feb. 5th was hot and sunny. The pitfall trap roofs were placed over the pitfalls in the evening due to expected rainfall. There was only light rain for a short period of time in the evening before clearing up. On Feb. 6th it was overcast and windy. On Feb. 7th the weather was again warm and calm.

Boyle River lays in Poplars Range which "lies in a climate zone characterized by cool wet weather, strongly influenced by the rain shadow effect of the Southern Alps. Annual rainfall is approximately 1150 mm and predominant winds are from the northwest and are frequently strong," (DoC, 2016). The flats along the river are modified, "with scattered low matagouri shrubland over pasture and the terrace scarp supports denser mixed scrub" (DoC, 2016). The soil along the riverbanks is sandy loam and along the far ends of the plots "the scrub is dominated by matagouri, with *Coprosma propinqua*, korokio, pohuehue, bush lawyer and occasional emergent mountain ribbonwood" (DoC, 2016).

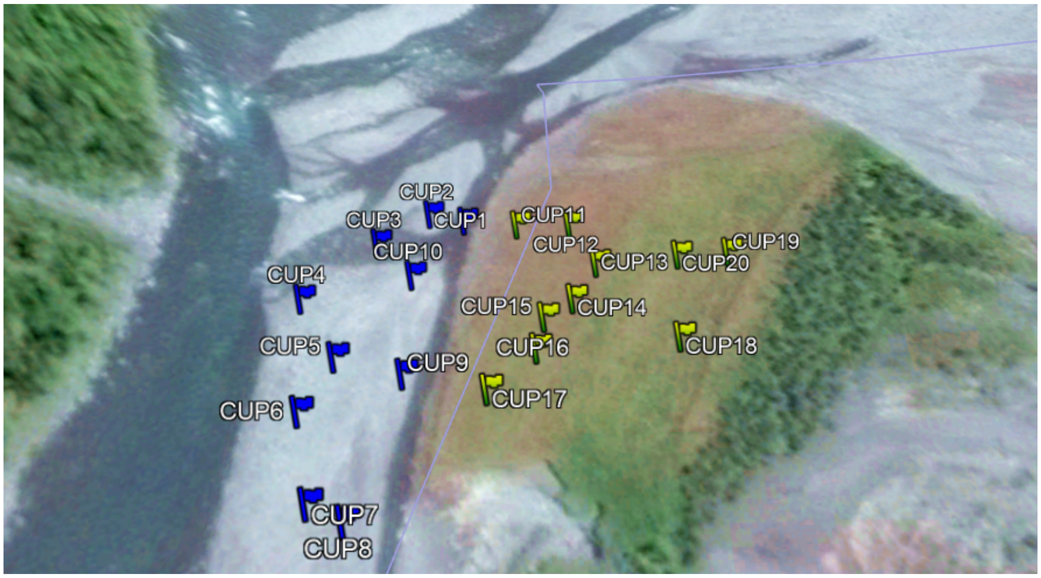

Figure 1: Collection sites 1-20. Each plot has 2 traps, a pitfall trap and a yellow pan trap. The blue plots represent the rocky/sandy habitats and the yellow plots represent the grassy/weedy areas.

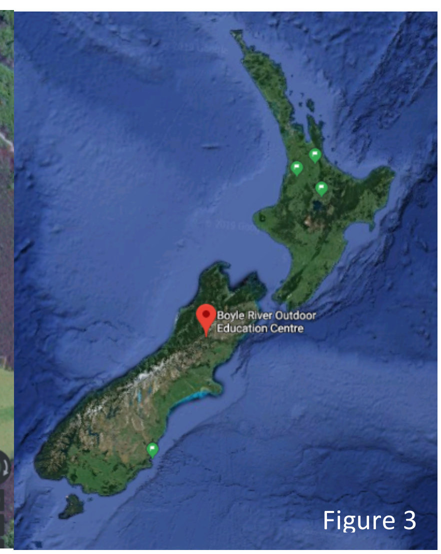

Figure 2: View of collection sites (circled in red) in relation to the Boyle River Outdoor Education Centre (pinned in red).

Figure 3: View of Boyle River Outdoor Education Centre (pinned in red) in relation to New Zealand.

Methods and materials:

The study was completed using 40 traps in 20 plots. These plots were divided into 2 habitat areas including a rock and sand environment and a grassland and weed area. The 10 plots were randomly selected by allowing the wind to take a container. The spot where this container landed became a plot. The plots were a 7 x 7 m square, oriented approximately the same direction for all plots. Each plot had a pitfall trap with water and dish soap, as well as, a yellow ice cream tub (15 x 15 cm) with water and dish soap (Figure 4). The pitfall traps are designed to collect the terrestrial invertebrates, which fall into the traps. The pitfall traps were covered by small metal roofs to prevent rainfall from displacing the specimens. The yellow tubs are designed to collect aerial pollinators attracted to the yellow color. This allows for a wider range of collection per site to further expand the diversity and species richness of each habitat. Each plot and trap had its own vial for collection of captured specimens throughout the 3-day period.

Figure 4: A pitfall trap (left) and yellow pan trap (right) are set in a river habitat plot.

In each plot, many factors were measured. These included: the general habitat, the distance from water, distance from rocks, distance from grass/weeds, and the distance from shrubs. The coordinates and elevations were collected for each of the plots using a Garmin GPSMAP 64 Handheld Navigator and are seen plotted in Figure 1. An estimation of ground cover was also collected including the categories: sand, small rocks (approx. smaller than 15 x 15 cm), large rocks (approx. larger than 15 x 15cm), vegetation, and soil. Other factors that might also influence the diversity were collected including the number of goose droppings, the number and type of flowering plants, and the abundance of each color of the flowering plants.

Once back in the lab, each specimen was examined, and the diversity and species richness were calculated using Simpson's Diversity Index as seen below (DeJong 1975). Each specimen was identified using Recognizable Taxonomic Units (RTUs).

$$D = 1 - \left(\frac{\Sigma n(n-1)}{N(N-1)}\right)$$

Statistical analysis:

To compare the species composition of habitats an MDS ordination was carried out using trap type, site, and habitats as factors. Each point represented an individual trap with 40 traps total. After calculating the species richness and diversity for each of the plots an analysis of variance was conducted to determine whether there were significant effects of trap type and habitat on richness and diversity.

Results:

Compiling the data into an ordination shows the differences in invertebrate compositions in the two different habitats. Two of the dimensions are similar, as you can see that the Habitat and Site are pointing in similar directions due to the sites being nested in the habitats (Figure 5). The Trap Type points perpendicular to the other variables because this is independent of them. In the ordination all vectors were significant: Site p = 0.001, Trap Type p = of 0.002, and Habitat p = 0.002 (Table 1).

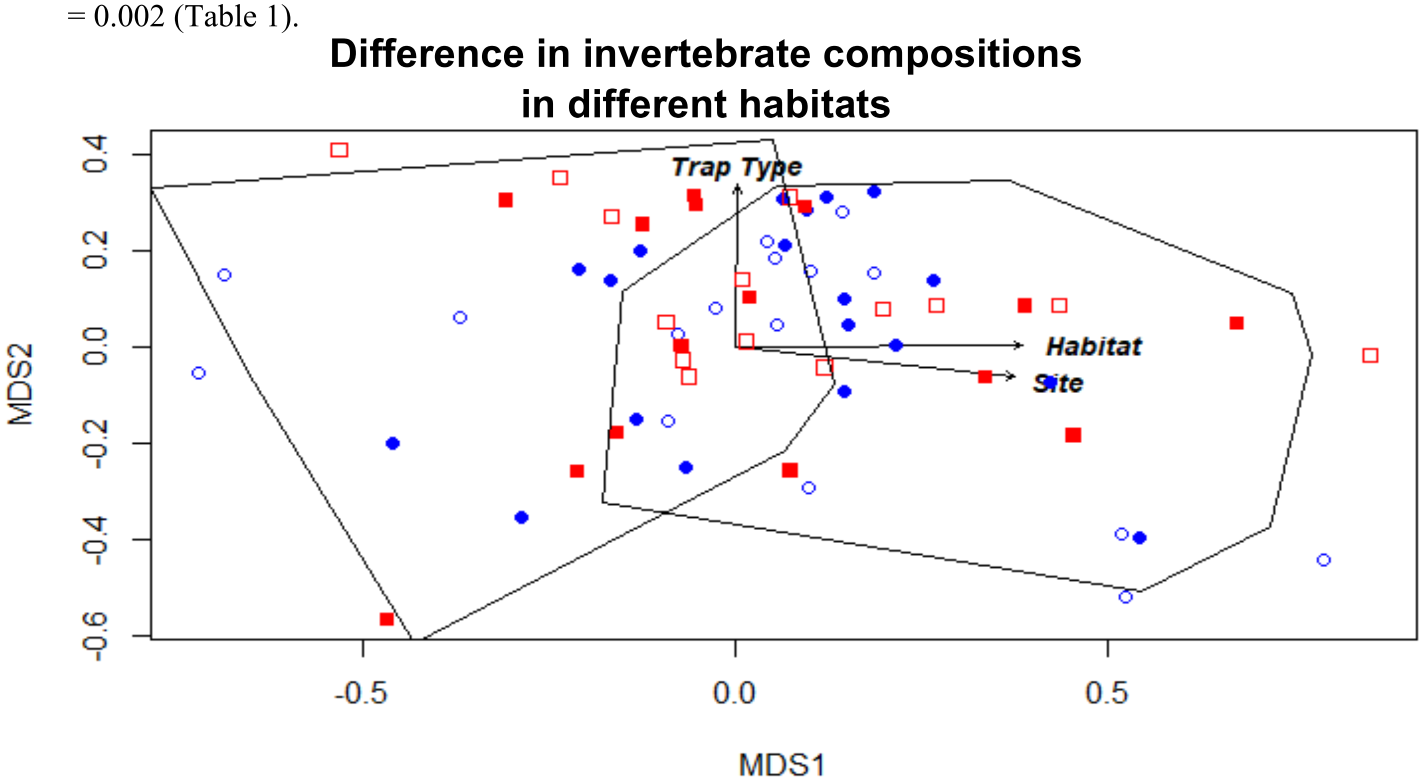

Figure 5: MDS ordination compiling factors of Site, Habitat, and Trap Type. In the graph the filled red squares are pitfall traps located in the bank habitat, the red unfilled squares are pan traps located in thebank habitat, the blue filled in circles are the pitfall traps located in the river habitat, and the blue unfilled circles are the pan traps located in the river habitat.

Table 1: MDS ordination statistics for Site, Habitat, and Trap Type.

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***VECTORS

              NMDS1    NMDS2     r2 Pr(>r)
Site        0.96529 -0.26117 0.4284  0.001 ***
Trap Type   0.07225  0.99739 0.3582  0.002 **
Habitat     0.99685 -0.07936 0.4218  0.002 **
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Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Permutation: free
Number of permutations: 999
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Species richness and diversity were calculated for each of the 40 traps. Habitat and trap type had a significant effect on species richness, but there was also a significant interaction between Habitat and Trap Type (Table 2; Figure 6). For species diversity there was a significance in Habitat p = <0.01 and Trap Type p = < 0.01, and not significant in the interaction between Habitat and Trap Type p = 0.104 (Table 3; Figure 7).

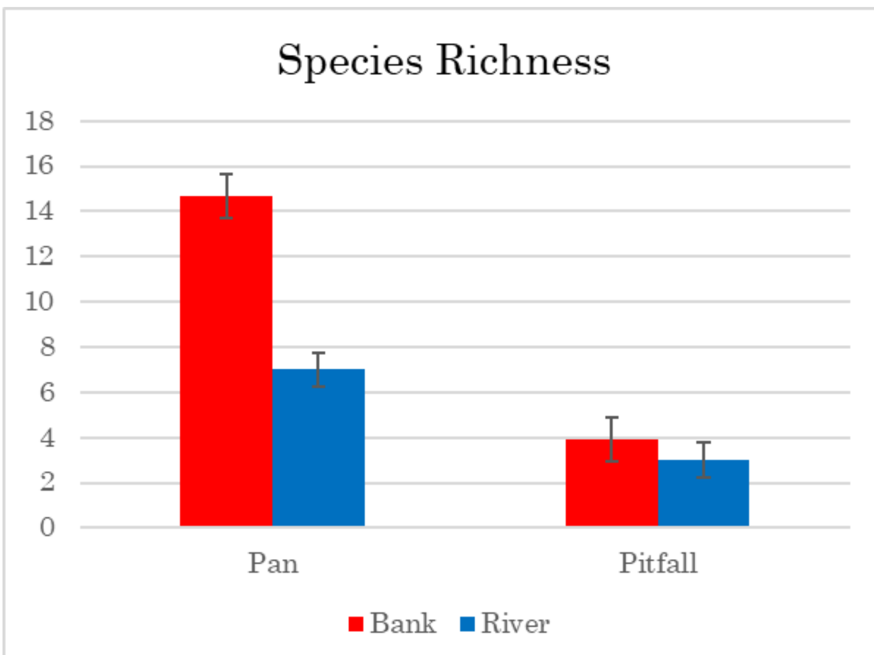

Figure 6: Species richness was determined by counting the total number of organisms for each trap. The red bars are from the bank habitat and the blue bars are from the river habitat.

Table 2: Analysis of variance statistics for the species richness for Habitat, Trap Type and the interaction between Habitat and Trap Type.

Variate: Richness

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Habitat	1	184.900	184.900	29.32	<.001
Trap_Type	1	547.600	547.600	86.84	<.001
Habitat.Trap_Type	1	115.600	115.600	18.33	<.001
Residual	36	227.000	6.306		
Total	39	1075.100			

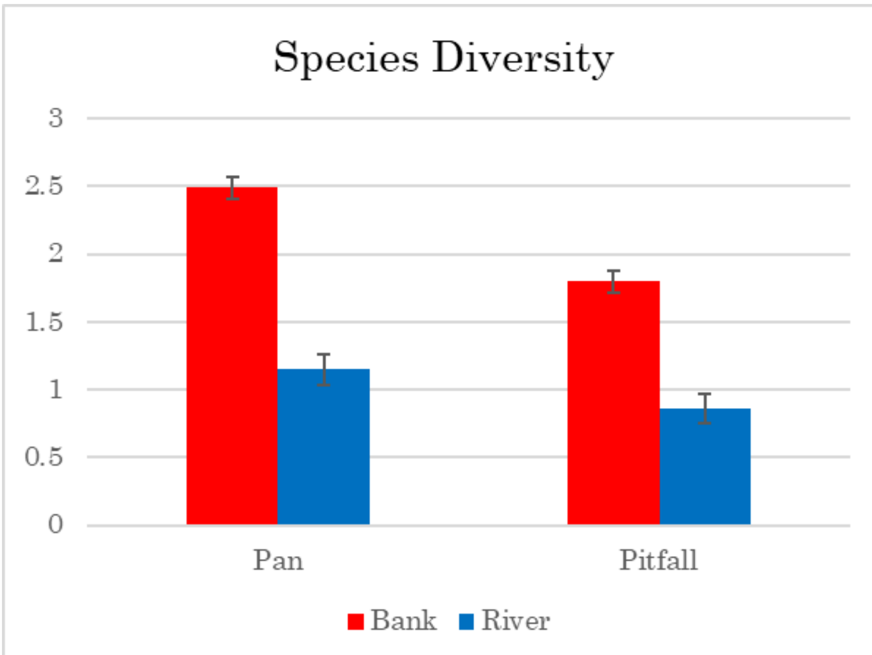

Figure 7: Species diversity was determined using the richness for each RTU and the eveness across the RTUs. The red bars are from the bank habitat and the blue bars are from the river habitat.

Table 3: Analysis of variance statistics for the species diversity for Habitat, Trap Type and the interaction between Habitat and Trap Type.

Variate: Diversity

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Habitat	1	2.7375	2.7375	18.06	<.001
Trap_Type	1	13.1761	13.1761	86.93	<.001
Habitat.Trap_Type	1	0.4206	0.4206	2.77	0.104
Residual	36	5.4563	0.1516		
Total	39	21.7905			

Discussion:

Overall the bank habitat had higher species diversity and richness than river habitats. This was as expected because of the grass present on the bank that can be used for food and shelter for many different species (Simpson, 1964; Connell & Orias, 1964). There were also a range of flowering plants which attracted many different pollinator species. An exception to this was the richness in pitfall traps, which showed to have no significant difference. This could, however, prove to be different if there was a larger sample size over a longer period.

As seen in the ordination model, the river and bank habitats had mainly different compositions, with little overlap despite the habitat's close proximity to each other. This is expected among the ground dwelling organisms because living on the rocky river would require completely different adaptations than living in a grassy bank (Den Boer, 1990). This was surprising among the aerial species though, because they can move much further, and it would be expected that the same pollinators would be drawn to both the pans on the river or the bank. The pan traps tended to attract more flies in the river areas, and this could have been due to the increased number of geese droppings compared to the bank habitat. However, this increase in number of geese droppings could have been due to being able to see them more easily on the rocks of the river habitat. Some of the flies were phorids, which are known to be found around decaying material and feces, (Disney, 2012). Other flies in the area including asilids, which are predatory, (Shelly, 1978) may have used the open river to find easy prey. Much of the pan traps in the bank area had more lepidoptera which was most likely due to the flowering plants. Higher abundance of tettigoniids was likely due to their need to stay in the grasses to remain camouflaged with the grasses (Tiwari & Diwakar, 2018). Both pan traps had similar amounts of hymenopterans which was unexpected due mainly to their reliance on either flowering plants (Stewart, New, & Lewis, 2007) or insects to parasitize (Jervis & Kidd, 1986) which would have both had higher densities on the bank.

There was a larger diversity and richness among aerial organisms over ground dwelling organisms, which is noticeable because of the higher numbers of invertebrates caught in the pan traps over the pitfall traps. Most of what was caught in the pitfall traps seemed to be carabids which we expect might lay a pheromone because whenever one beetle was captured there were usually at least 2 others of the same species. This could be comparable to carabids that follow the trail of a host ants back to their nest, (Cammaerts, Detrain & Cammaerts, 1990). The pan traps, however, had a much greater richness and diversity.

Knowing which habitats have the most diversity is crucial in order to make decisions on what areas to protect. Conservation areas with the most diversity and richness will be crucial to protect the most species successfully. For invertebrates along Boyle River this means protecting the bank habitat. Unless specific species are under threat, the general focus should be on bank habitats.

Limitations:

The time at Boyle River was limited to only a few days. More time would have allowed more days of sunny weather and most likely more invertebrates caught, however there were still 438 invertebrates captured in the study over the few days. There was also limited time to identify these samples. RTUs were used in identification instead of identifying each species due to these time constraints. This is a limitation because RTUs do not signify which species are native or non-native which is important when regarding conservation.

Due to a collection error there was a possible loss of part of sample 16. The plots were also not completely random because they were determined using the wind and the wind was primarily in the same direction. Efforts were taken to try and make these plots as random as possible. The yellow pans were also more visible on the river than the bank which could have drawn more pollinator species to those traps.

Future Research:

Including more habitats to the invertebrate study would be beneficial to continue the understanding of where the highest diversity of insects are in riparian zones. This study only featured two main habitats, but there were slight differences in the bank habitats as they moved further from the river. Some of the bank habitats had more grasses while others had more flowering plant species that drew in pollinators. This could be a distinction in future studies with more time.

Identifying each species would also be beneficial. This allows for the identification of nativeness. Most conservation efforts focus largely on endemic species and this study most likely included many different non-native species. Focusing on identification could completely change the results of this study. This would add a needed dimension to the study and should be highly considered in future work.

Conclusions:

Overall the bank habitat had higher species diversity and richness than the river habitat, therefore, protection of bank habitats would cover the most richness and diversity of invertebrate species. The river and bank habitats had different compositions despite being neighboring habitats. There was also a larger diversity and richness among aerial organisms over ground dwelling organisms in both habitats. Unless specific species are under threat, the general focus in riparian areas should be on bank habitats.

Acknowledgements:

I would like to thank Boonyanuj Yukate (TK) with helping set the traps in the field, as well as, Mike Bowie, Mike Fake, and Boonyanuj Yukate (TK) for helping collect invertebrates from the traps. I would also like to thank Timothy Curran, Mike Bowie, and Jodanne Aitken for assisting in the plot land surveys. For analysis, I would like to thank Akika Takada, Timothy Curran, and Jon Sullivan for help with the program R and the Analysis for Regressions. This experiment was funded by Lincoln University and the DOC permit 28815-FAU written to John Marris was utilized.

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