PROJECT FSP: Y091155

DESIGN OF RIPARIAN ZONES: RESPONSE OF SECONDARY PRODUCTIVITY TO STREAM GEOMORPHOLOGY AND CLASSIFICATION.

FINAL REPORT

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BY

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1 EXECUTIVE SUMMARY

Riparian forests make up a significant component of the productive forest in B.C. that is protected at some level from harvesting. Given that these areas are known for their unusually high levels of biodiversity, such protection likely serves a crucial role to retain biodiversity. This project examined the site-level biodiversity of riparian reserves as affected by geomorphic characteristics of streams. Specifically, we wished to determine whether buffers in alluvial systems appear to retain greater wildlife values/secondary productivity than non-alluvial systems, and if so, whether this would suggest that riparian reserve zones should be increased for the more valuable, sensitive systems. Wildlife value was assessed using carabid beetles, an invertebrate indicator species that has been used in numerous studies of forest biodiversity.

Pitfall trapping was used to examine the epigaeic (ground-dwelling) carabid fauna in 20 riparian sites associated with 15 different streams (3 non-alluvial, 7 alluvial, 3 semi-alluvial and 2 old-growth) between June and September 2008. All 15 streams are located in coastal western hemlock forests in TFL 54 and 57, in the hyper-maritime CWH zone, and vh subzone. These sites were all in the Kennedy Lake Flats region and several were located within the park boundary of the Pacific Rim National Park.

Carabid beetles were trapped using pitfall traps placed at 10 m intervals along transects that ran perpendicular to the stream course, starting at the stream edge, and extending through the riparian buffer and a further 75 m into the adjoining forest or adjoining clearcut. On the 7 alluvial streams, a total of 9 sites were set up (3 sites with transects extending into old growth, 5 into 2nd growth and one into a recent clearcut). Six semi alluvial riparian sites were set up, with transects from riparian areas extending into 4 adjoining clearcuts and two 2nd growth sites. Three non-alluvial sites were set up, with transects from riparian areas extending into the adjoining 2nd growth forest. Thus, a total of 18 sites were set up and a total of 347 traps were sampled monthly between June and September.

Carabid beetles were identified to family or genus, and the by-catch was identified only to order. 14 carabid beetle species with a total of 3906 individuals were collected in the alluvial sites, 14 species with a total of 1542 individuals were collected in the semi-alluvial sites, 13 species with a

total of 3230 individuals were collected in the non-alluvial sites, and 10 species with a total of 3785 individuals were collected in the old-growth sites. A total of 8258 carabids were trapped overall, from a total of 20 species.

In the alluvial sites, the most abundant species captured was a forest specialist, *Pterostichus crenicollis* Le Conte, while in the semi-alluvial sites both *P. crenicollis* and another forest specialist, *Scaphinotus angusticollis* (Fischer von Waldheim) were similarly common. In the non-alluvial sites, the most common species caught was also *P. crenicollis*, but there were also high numbers of *Pterostichus lama* (Menetries) and relatively high catches of *P. algidus* caught. These latter species have been identified as generalists in previous studies. In the old-growth sites, *P. crenicollis* was most abundant. *Zacotus matthewsii* Le Conte, identified as an old-growth specialist, was only found associated with the old-growth control sites and one of the alluvial sites. Other species were also found restricted to one or two site "types": *Agonum affine* Kirby and *A. ferruginosum* Dejean are both very hygrophilous species and were found only in alluvial sites; additionally *Leistus ferruginosus* Mannerheim, another species associated with moist ground, was also found only in alluvial sites; *Amara littoralis* Mannherheim, a more open country or meadow species was found only in semi-alluvial sites; while *Agonum piceolum* LeConte and *Harpalus cordifer* Notman were both found only in non-alluvial sites. The former species is often found on bare soil or under leaves.

Using non-metric multidimensional scaling, I examined how the sites differed in terms of "species-space". There appeared to be a clear separation of the alluvial, semi-alluvial, and non-alluvial communities. Indicator species analysis showed that four species: *Pterostichus lama, P. algidus* LeConte*, P. crenicollis and Z. matthewsii* have high indicator value. The first two species are most commonly associated with the non-alluvial site type, while *P. crenicollis* is most commonly associated with the alluvial riparian strips, and *Zacotus matthewsii* has a high indicator value for old-growth sites.

Differences in biomass amongst site types were examined. Larger carabids such as *Cychrus tuberculatus*, *Omus dejeani*, *Pterostichus lama*, and the *Scaphinotus* genus had the highest biomass, and thus abundance of these species affected overall biomass in any one location. Highest biomass was noted in the non-alluvial sites, then the alluvial sites, and lowest average biomass for the season was seen in the semi-alluvial sites. Biomass for the adjoining clearcuts or immature sites was always much lower than that found in the adjacent riparian buffers. In alluvial sites, approximately 70% of the biomass was made up of *P. crenicollis*, while in the semi-alluvial sites, *P. crenicollis*, and *S. angusticollis* made similar contributions (42 and 38%, respectively). In non alluvial sites, approximately 46% of the biomass was made up by *P. lama*, while in the old-growth sites most of the biomass (54%) was made up by *P. crenicollis*.

The invertebrate communities of the riparian sites sampled in this study showed differences to the communities of many of the sites that have been sampled on Vancouver Island in previous studies (Pearsall, 2002-2007). For most Vancouver Island forests, whether in dry or wet variants, the dominant species has always been *Scaphinotus angusticollis*, which is a forest specialist and makes up a very high abundance in most forested blocks. Although this species was the second most commonly captured species in the Kennedy Flats, catches of *P, crenicollis* far surpassed the catches, with almost 5000 *P. crenicollis* versus 1500 *S. angusticollis* caught for all sites overall. Additionally, there did appear to be some hygrophilous species associated with the riparian buffers that we have not captured in previous communities. Finally, abundance of *P. lama* was much higher in the non-alluvial sites of this study than we have seen in sites at any other location on the island.

Diversity was highest in the non-alluvial sites, then the semi-alluvial sites, and then the alluvial sites. Both diversity and evenness were particularly low in the alluvial sites A2, A3 and A4 and the old-growth site R2. Diversity of the clearcuts adjacent to the alluvial and semi-alluvial riparian strips was much higher than within the adjoining buffers. This is in accord with results from previous work that has shown that older communities generally have lower species richness and diversity than younger communities. This is often the result of the dominance of the forest specialist, *S. angusticollis* in control sites, while clearcuts and younger sites tend to receive an influx of small, winged species that are open-habitat specialists, such as *Harpalus* and *Amara* species. In the Kennedy flats region, the loss of evenness and diversity was more associated with the dominance of *P. crenicollis* rather than *S. angusticollis* in the riparian buffers of the alluvial and old-growth sites, however.

In summary, there appear to be relatively distinct communities found in the different types of buffers, and associated with the geomorphology of the streams. Riparian buffers appear to be able to retain distinct communities of carabids which are not lost or degraded when the adjoining forest blocks are harvested. Although clearcuts and immature sites adjacent to the buffers do lose biomass, species and diversity, this did appear to recover in time, and forest species were not entirely lost from these blocks.

However, placing values on these distinct communities is somewhat a subjective decision. All the communities in the different site types were dominated by the forest specialist, *P. crenicollis*, but in the non-alluvial sites, there was also a particularly high abundance of forest generalists, *P. lama*, and *P. algidus*. Thus we may suggest that there is a greater "richness" associated with alluvial areas as compared to non-alluvial areas given the differences in species composition. However, this did not result in higher biomass values in the alluvial sites, since the common generalist found in the non-alluvial sites, *P. lama*, is also one of the largest species that we collect.

Future monitoring will be vital, to examine how the carabid assemblages change over time in the riparian buffers and the adjoining blocks. At this time, the direction of carabid species succession is uncertain, since we do not know the possible extent of competitive interactions and whether the size of buffers is adequate for long-term survival of beetles at any of the sites. Although we did find *Zacotus matthewsii*, an old-growth species, and somewhat of a "flagship" species, in the old-growth and one of the alluvial sites, we did not find it in any of the alluvial riparian buffers that were adjacent to areas that had been cut since 1995, when the Forest Practices Code came into effect and was augmented by recommendations from the Clayoquot Sound Scientific Panel (CSSP). It would be very interesting to examine alluvial riparian buffers that had retained *Zacotus* prior to harvest, and assess the changes post-harvest in this species. In addition, we chose only to examine buffers on S3 streams during 2008: future studies aim to extend this to S1 and S2 streams so that we can compare the impacts of buffer size.

Keywords: riparian strategy, reserve zone width, stream geomorphology, stream classification, biodiversity indicator, carabid beetles, invertebrate response

2 INTRODUCTION

One of the premises of EBM is to ensure maintenance of primary and secondary productivity, where primary productivity is defined as the rate at which biomass is produced per unit area by plants, and secondary productivity is defined as the rate at which biomass is produced per unit area by heterotrophic organisms (Begon et al. 1981).

One method of trying to attain this is to ensure that there is representation of all ecosystem types (represented by the site series surrogate model for the Central Coast EBM). Another method would be to retain representative habitat (through a structural analysis). The availability of habitat (in which ecosystem classification may or may not be representative) is agreeably one of the primary factors that influences distribution and abundance of species.

However, not all "habitat" is created equal, and it is widely recognized that riparian areas facilitate a much higher density of species. If riparian areas provide a disproportional representation of habitat use (and types) and populations are generally not proportional to habitat area, and then a 1:1 ratio is not appropriate. If we are to accept this logic, then it should also be correct to assume that secondary productivity is not consistent among all riparian areas. Given consistent steam size, one of the variables may be the geomorphic characteristics of the stream (alluvial vs. semi-alluvial vs. non-alluvial).

The objectives of riparian management include protecting aquatic habitats, water quality, and riparian habitat. Current management approaches in British Columbia include delineation of management zones in which timber harvest is not allowed (riparian reserve zone) or where harvest is allowed with limitations of equipment use or levels of tree removal (riparian management zone). Widths of reserves depend on stream size, presence of fish, and the downstream use of water for domestic supply (BC FPC 1995, FPPR 2004). Streams lacking fish and not used for drinking water, and very small streams with fish (<1.5 m bankfull width) have no required reserve. However these streams do get a management zone intended to keep heavy machinery out and away from the streambank during harvest operations. Fish-bearing streams > 1.5 m get a reserve width that increases from 20 to 30 and then to 50 m based on increasing channel widths. A 50 m reserve is intended to serve more than the immediate objectives of LWD supply, and the large alluvial rivers with this reserve size may have more riparian dependent wildlife species than smaller streams.

One of the major questions is how wide should a buffer strip be? Clearly, fixed buffer sizes are simple to administer and to implement. However, variable width buffer strips have the potential to improve stream protection based on individual stream reach characteristics. Washington and California currently implement variable width buffer strips under their respective forest practice act regulations. Use of variable widths would allow buffer strip layout to more closely mimic natural ecosystem disturbance, in keeping with "new forestry" concepts. However, very few studies appear to have been carried out to determine the advantages or disadvantages of variable width over minimum fixed width buffers.

Interfor (and some other licensees) has an alternate riparian strategy where they can vary widths based on site level information. Prescribing foresters need to make a decision based on an “ecological rationale that is supported by riparian factors”. Riparian factors include the need to buffer the system from deleterious materials that affect water quality and fish habitat, channel and bank integrity, as well as the role of trees and understory vegetation in conserving water quality, fish habitat, wildlife habitat and biodiversity. Interfor takes into consideration the stream bank (slope, soil type, stability), wind firmness (current stand and future rotations), channel type (e.g. less sensitive entrenched to least sensitive seasonally confined) and the steam type. Currently Interfor is using the guidelines to vary Riparian Reserve Zone (RRZ) width based primarily upon the relative sensitivity of streams (alluvial, semi-alluvial, non alluvial, with the latter being the least sensitive) (Figure 1). The general interpretation is that RRZ will be less than Forest Practices and Planning Regulation (FPPR) s.47 defaults on non-sensitive stream sections (e.g. confined, low energy, non-alluvial, moderately sloping banks) and greater than FPPR widths on sensitive sections (e.g. frequently confined, moderate energy, semi or fully alluvial, steep banks, high wildlife usage areas), but we are aware of no studies that justify these decisions for the management of secondary productivity. By using insects as an indicator of secondary productivity we could develop a better understanding of where Interfor should be adding RRZ, and where they have leeway to reduce RRZ.

Previous work done in coastal B.C. by I. Pearsall since 2001 has clearly identified that carabid beetles are a highly sensitive indicator, with significantly different communities in clearcut, immature and mature forests. Our work has shown that the responses by carabids are sensitive at small enough spatial and temporal scales such that they may be used to examine edge-responses, and to assess how quickly sites recover and re-establish typical old-growth communities.

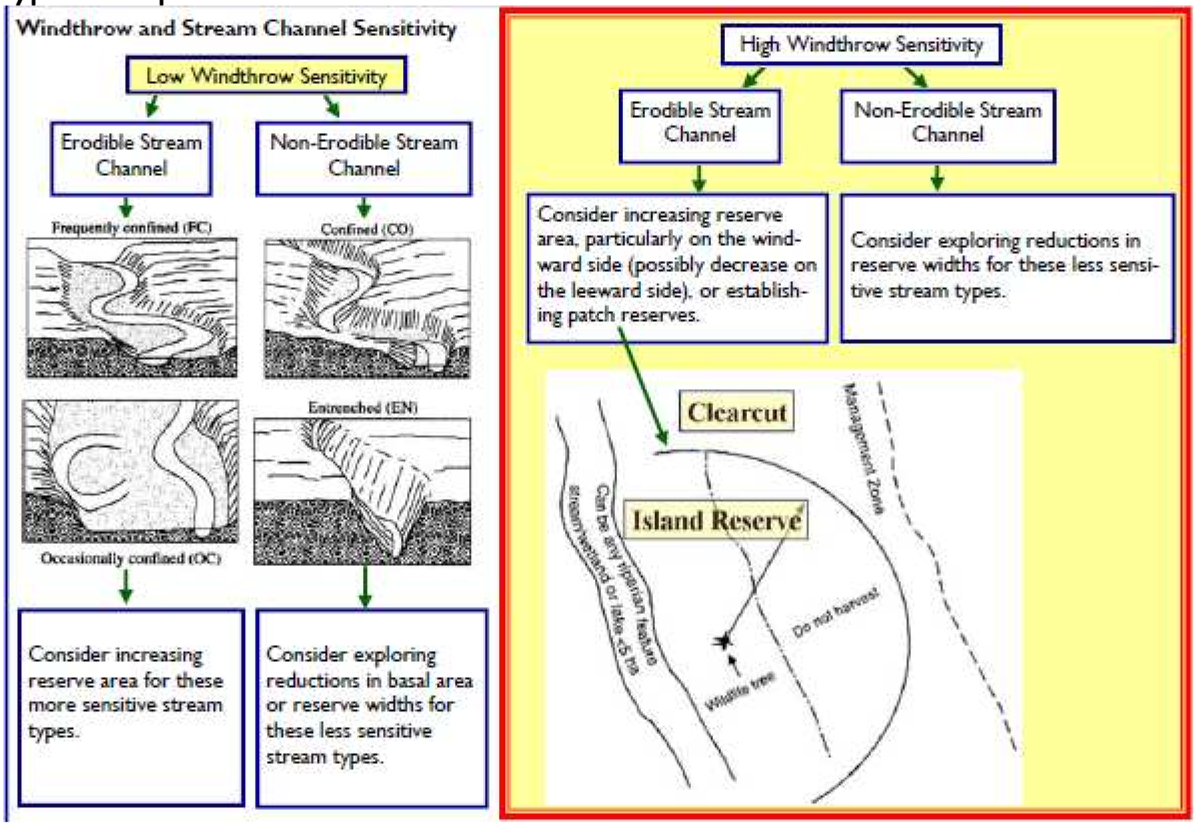
Carabid beetles have been used as an indicator of soil diversity after disturbance caused by forest fire (Holliday 1991a, b), clear cutting (Sustek 1981, 1984, Lenski 1982, Jennings *et al.* 1986, Langor *et al.* 1991), scarification (Parry and Rodger 1986), pollutants (Stubbe and Tietze 1982, Kolbe 1988), land reclamation (Day and Carthy 1988), management of primeval or old growth forests (Niemela *et al.* 1988, Terrel-Nield 1990) and climate change (Elias 1991). As primary and secondary predators, carabids integrate a substantial amount of ecological information about the biological communities to which they belong (Day and Carthy 1988). Also, they make up a large fraction of the soil arthropod biomass, forming the basis of the food chain for higher level predators such as gastropods, birds, small mammals, and bears. They are also efficient natural pest control agents (Edwards *et al.* 1979, Jennings *et al.* 1986, Sustek 1981, Weseloh 1985).

This project compared carabid biodiversity and biomass in riparian buffers on replicated alluvial, semi-alluvial and non-alluvial streams for S3 streams with matched stream characteristics for recently logged, immature, and mature 2nd growth systems. We chose to examine buffers on S3 streams during 2008: future studies aim to extend this to S1 and S2 streams so that we can compare the impacts of buffer size. We wished to determine whether wildlife value (secondary productivity), as assessed by carabid biodiversity and biomass, was greater in alluvial than in semi-alluvial or non-alluvial systems. We decided to examine the response of carabids at the stream edge, within the buffer zone, and extending out into the adjoining forest so that we could determine whether riparian protection results in source populations of carabids that are able to repopulate the adjoining harvested areas, how this is affected by geomorphology, and how this varies over time.

Evaluation of these data will assist managers in determining the most appropriate strategies for varying RRZ width to conserve biodiversity, and possibly challenge or support some of the assumptions used within the Clayoquot Sound Scientific Panel Recommendations (2005) and the

South Central Coast Government Order (2007) for the determination of extensive reserve widths. The results from this study will be made available to forest managers of both Interfor and Western Forest Products. This study will also make a significant contribution to a growing body of literature that examines invertebrate responses to forest fragmentation (Newbold 1980, Davies and Margules 1998), and how these responses can affect ecosystem processes (Klein 1989).

Figure 1. Interfor recommendations for variance of buffer width with sensitivity of channel types for riparian areas.



Consider increasing reserve area for these more sensitive stream types.

Consider exploring reductions in basal area or reserve widths for these less sensitive stream types.

Consider increasing reserve area, particularly on the wind-ward side (possibly decrease on the leeward side), or establishing patch reserves.

Consider exploring reductions in reserve widths for these less sensitive stream types.

2.1 Objectives

Riparian reserves maintain special ecosystem types, provide habitat and structural elements, and contribute to ecosystem representation, and thus this project aims to help establish priorities as to the allocation of riparian reserves.

We aimed to make a temporal assessment of site-level biodiversity of riparian reserves as affected by geomorphic characteristics of streams. We wished to determine whether buffers in alluvial systems appear to retain greater wildlife values/secondary productivity than non-alluvial systems, and if so, does this suggest that riparian reserve zones should be increased for the more valuable, sensitive systems? Since retention of riparian habitats makes a significant contribution to protection of the overall forested landbase, and since these areas are known for their unusually high levels of biodiversity, we also wish to compare the lifeboating potential of the riparian buffers in terms of repopulation of the adjacent cut forest over time.

We decided to work on S3 stream classifications of 3 different geomorphic types (alluvial vs. semi-alluvial vs. non-alluvial) in the Kennedy Flats region, West Vancouver Island, and to examine the responses of carabids and vegetation in both the riparian strips and the adjoining forest. We looked for riparian buffers that were surrounded by different age classes: recently cut, immature and mature 2^{nd} growth. The streams used were closely matched in terms of stream characteristics (gradient, aspect and parent material). Future studies aim to expand this study to address differences with buffer size and stream classification. This year, focus was on small, fish-bearing S3 streams.

Main questions included:

- Is wildlife value and secondary productivity, as assessed by carabid biodiversity and biomass, greater in alluvial than in semi-alluvial or non-alluvial systems?
- How does the above impact the usage of the adjacent forest by carabids, and how does this vary with distance from the stream, and with age of adjoining forest?
- Do riparian reserves of S3 streams adequately conserve terrestrial invertebrates, and do they result in repopulation of the surrounding forest? How does this vary with geomorphological characteristics of the stream?

Evaluation of these data will assist managers in determining the most appropriate strategies for varying RRZ width to conserve biodiversity.

3 MATERIALS AND METHODS

3.1 Study sites

A total of 13 S3 streams were used: 6 alluvial, 4 semi-alluvial and 3 non-alluvial. Each group of streams and associated riparian forest were chosen to be similar in terms of site series, elevation, aspect, soil type, and stream parent material. All 13 streams are located in the Coastal Western Hemlock biogeoclimatic zone of BC and within the very wet maritime to very wet hypermaritime (CWHvh1-CWHvm1) variants in TFL 54 and 57. Sitka spruce, western red cedar, western hemlock, amabilis fir and red alder are the dominant native riparian trees. Several of the sites were located within the park boundary of the Pacific Rim National Park. These sites were all in the Kennedy Lake Flats region, and at particularly low elevations in general (10-40m above sea level), and generally between 40-60 years of age (Figure 2).

Streams were classified based on features shown in Figure 3 on the next page. Alluvial streams have channels with at least one unconfined erodible bank in alluvial desposits, and the bank is made up of the same material as the the substrate (Figure 4a). These streams have gravel/sand substrates, and an identifiable floodplain and channel migration zone. The most sensitive channels are those that are low gradient (<4%) and greater than 3m wide. In alluvial sites, the value of large woody debris (LWD) as a functional element is high.

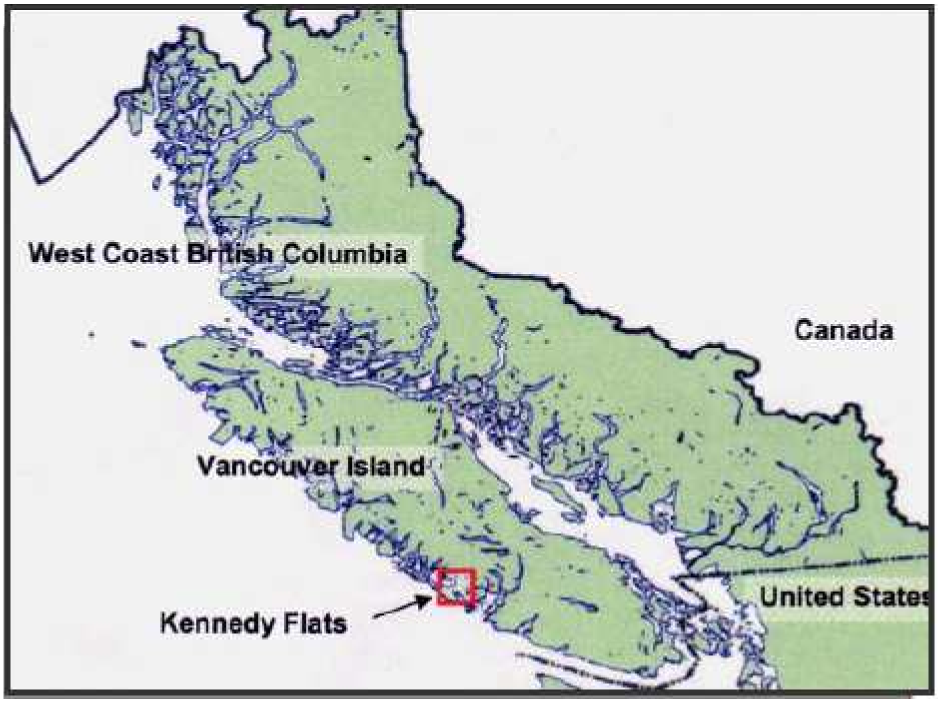
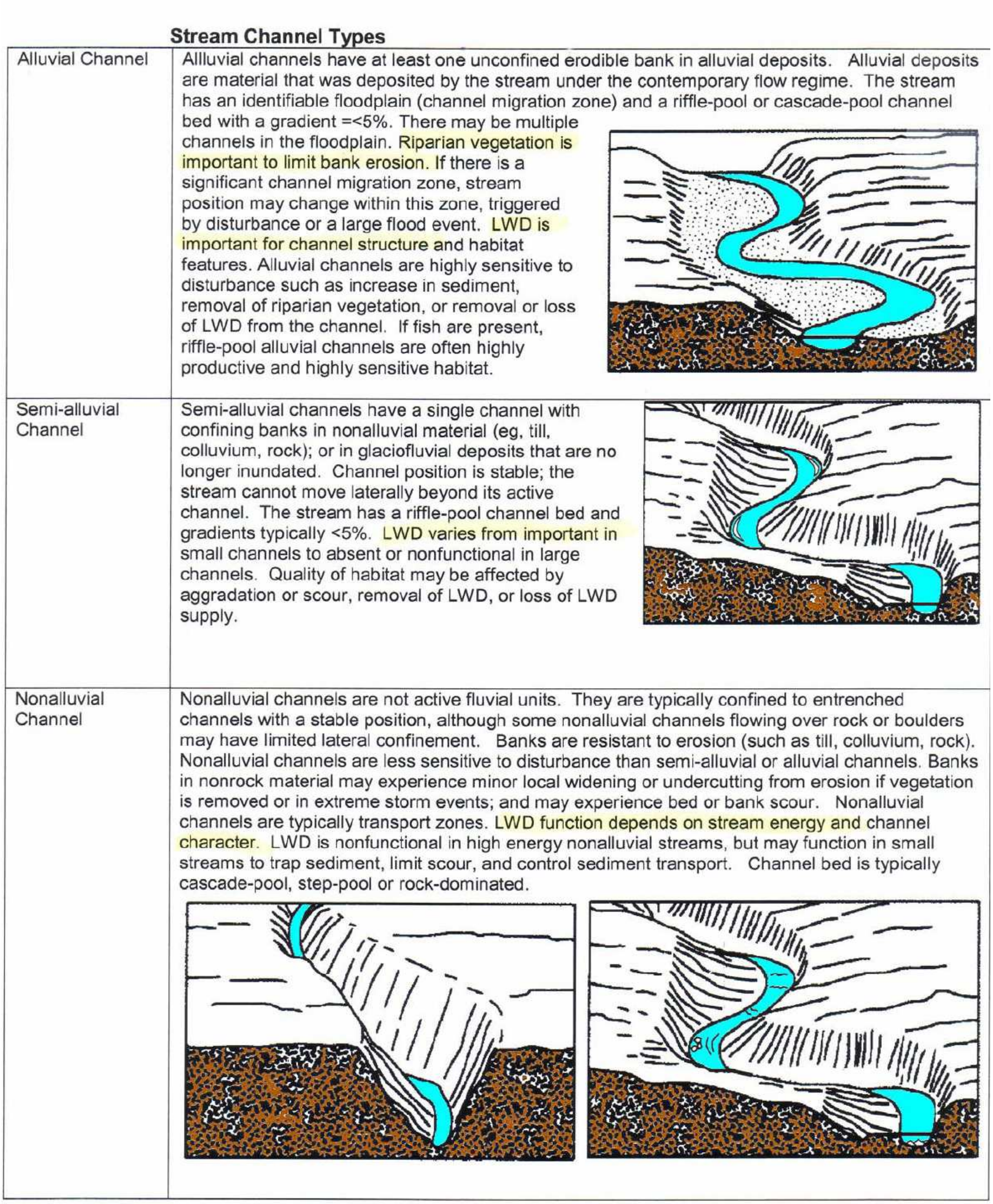


Figure 2. Location of Kennedy Flats, West Vancouver Island (from Hutchinson et al. 2008).

Figure 4a. Typical alluvial stream.

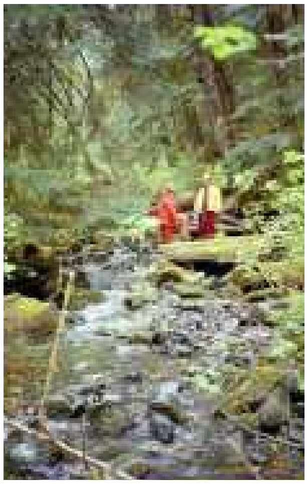


Stream Channel Types

Alluvial Channel	Allluvial channels have at least one unconfined erodible bank in alluvial deposits. Alluvial deposits are material that was deposited by the stream under the contemporary flow regime. The stream has an identifiable floodplain (channel migration zone) and a riffle-pool or cascade-pool channel bed with a gradient =<5%. There may be multiple channels in the floodplain. Riparian vegetation is important to limit bank erosion. If there is a significant channel migration zone, stream position may change within this zone, triggered by disturbance or a large flood event. LWD is important for channel structure and habitat features. Alluvial channels are highly sensitive to disturbance such as increase in sediment, removal of riparian vegetation, or removal or loss of LWD from the channel. If fish are present, riffle-pool alluvial channels are often highly productive and highly sensitive habitat.
Semi-alluvial Channel	Semi-alluvial channels have a single channel with confining banks in nonalluvial material (eg, till, colluvium, rock); or in glaciofluvial deposits that are no longer inundated. Channel position is stable; the stream cannot move laterally beyond its active channel. The stream has a riffle-pool channel bed and gradients typically <5%. LWD varies from important in small channels to absent or nonfunctional in large channels. Quality of habitat may be affected by aggradation or scour, removal of LWD, or loss of LWD supply.
Nonalluvial Channel	Nonalluvial channels are not active fluvial units. They are typically confined to entrenched channels with a stable position, although some nonalluvial channels flowing over rock or boulders may have limited lateral confinement. Banks are resistant to erosion (such as till, colluvium, rock). Nonalluvial channels are less sensitive to disturbance than semi-alluvial or alluvial channels. Banks in nonrock material may experience minor local widening or undercutting from erosion if vegetation is removed or in extreme storm events; and may experience bed or bank scour. Nonalluvial channels are typically transport zones. LWD function depends on stream energy and channel character. LWD is nonfunctional in high energy nonalluvial streams, but may function in small streams to trap sediment, limit scour, and control sediment transport. Channel bed is typically cascade-pool, step-pool or rock-dominated.

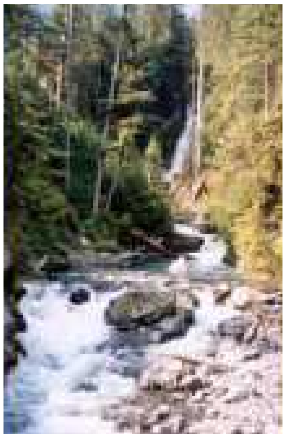
Figure 3. Description of stream channel types: alluvial, semi-alluvial and non-alluvial (from Interfor).

Figure 4b. Typical semi-alluvial stream



Semi-alluvial stream channels do have confining banks and a stable position, such that the stream cannot move laterally beyond its' active channel. The channels are typically less than 6% gradient, and have a gravel/cobble substrate. These streams are a priority for retaining LWD, which is variable as a functional element (Figure 4b).

Figure 4c. Typical non-alluvial stream.



Non-alluvial streams have a completely confined or entrenched channel, and the banks are highly resistant to erosion (Figure 4c). The LWD as a functional element is generally low.

3.2 Method of trapping

Our methodology was similar to that used in other studies, in that we used pitfall trapping to capture beetles and other invertebrates. This is standard methodology for trapping ground-dwelling invertebrates and we followed the guidelines in the Inventory Methods for Terrestrial Arthropods (Resources Inventory Branch 1998). Pitfall traps have been widely used to sample ground-dwelling arthropods (Southwood 1978), especially carabid beetles (e.g. Waage 1985, Niemela et al. 1990). Data from pitfall traps have been used to describe annual activity patterns (e.g. Niemela et al. 1992a), spatial distributions (Hengeveld 1987), habitat associations (Niemela et al. 1992a), and relative abundances of species (Kharboutli and Mack 1991).

Pitfall trapping was used in this study to characterize species composition, diversity, and relative abundance of the various invertebrate taxa along transects which extended from the stream edge, through the riparian zone, and into the adjacent forest upslope. The pitfall catches in this study can be used to compare "relative activity-density" within species across riparian treatments (Thiele 1977).

The trap design is found in Pearsall (2002). The contents of each pitfall trap were placed into labelled collecting vials which were filled with isopropyl alcohol back at the lab. The vial contents were analysed prior to the following field trip.

3.3 Sampling design utilized

Streams were chosen such that was surrounded by cutblocks of varying ages. The initial aim was to work on 3 alluvial, 3 semi-alluvial and 3 non-alluvial streams, and to located three sites along each of the streams where the riparian buffer borders a) clearcut forest (age 0-5 years), b) immature forest (age 20-40 years) and c) mature 2nd growth (age 60+ years). The aim was to set up 2 transects in each of the 3 replicates for 3 geomorphology types for 3 age class treatments, giving a total of 27 sites.

Field scouting for sites was done in early May. At that time, we located 3 non-alluvial streams, 7 alluvial, and 3 semi-alluvial streams. There were no recent cut blocks adjacent to any non alluvial streams so the set up of transects in riparian areas adjacent to the 3 non-alluvial streams extends into 2nd growth only. Within each of the sites, we set up transects perpendicular to the stream course, starting at the stream edge, and extending through the riparian buffer and a further 75 m into the adjoining forest or adjoining clearcut. On the 7 alluvial streams, a total of 9 sites were set up (3 sites with transects extending into old growth, 5 into 2nd growth and one into a recent clearcut). Six semi alluvial riparian sites were set up, with transects from riparian areas extending into 4 adjoining clearcuts and two 2nd growth sites. Thus, a total of 18 sites were set up. The original idea of 27 sites could not be realized due to the lack of cut sites adjacent to non-alluvial and alluvial systems (for the latter, many of these streams are within the park boundary so recent harvesting has not taken place). Overall however, more traps were sampled from these sites than in the original proposal since we added a third transect into each site to sample the riparian area more thoroughly, and we decided to trap for 4 successive months rather than 3 successive months, so that a greater seasonal period could be evaluated.

The 3 transects were placed at least 10 m apart. This was to avoid depletion of more mobile species which could result in potential alteration of community structure (Digweed et al. 1995). Transects were set perpendicular to the streams and pitfall traps were placed at the stream edge, 5 m from the stream edge, and at 10 m intervals along the transect. 7 traps were placed along each of two of the transects, and a further 4 traps were placed along the third transect, for a total of 18 traps per site. On each of the three transects, (T1-T3), the first trap at the stream edge was trap 1. In those sites in which the riparian buffers were located adjacent to a cut block or a block of different age, traps 1-3 were placed in the riparian buffer ("in" traps), 4 at the buffer edge ("edge" traps), and 5-7 were located in the adjacent forest block ("out" traps).

Field sites were set up in May 2008 and were sampled 4 times over the field season (between June-September).

3.4 Data collection

Pitfall trap collections were done monthly from June until September 2008. Abundance of each species of carabid in each pitfall trap was assessed. Carabid and other beetles were pinned where necessary and taken to the George J. Spencer Entomological museum for aid with identification. Bycatch species were determined largely to family or order.

Elevation was noted for each site, and moisture readings were done using a Hydrosense soil moisture meter (Campbell Scientific). Vegetation analysis was carried out in all sites. We examined percent cover of herbaceous vegetation, moss, bare soil, and leaf litter in 1*1 m plots adjacent to each pitfall trap. We also examined shrub cover within one 3*8m plot set up at each sampling distance. Soil moisture readings and vegetation analysis were done in July 2008. Photography of sites was done in August and September 2008.

4 DATA ANALYSIS

4.1 Ground vegetation and description of stands

Ground cover was assessed in all treatments over the summer to try to assess similarity of sample blocks.

4.2 Trap catches

All carabid data were subjected to the following analyses:

4.2.1 Description of carabid species

The abundance and types of species collected in each block were listed. In addition, we used published length-mass regression equations to determine biomass of carabids (Rogers et al. 1976, 1977; Schoener 1980; Sample et al. 1993, Jarosik, 1989). Using these relationships we were able to estimate biomass in buffers for the different stream types, and in varying ages of forest. Biomass was used to give an indication of the overall amount of secondary productivity in these buffers.

4.2.2 Description of temporal trends

Temporal trends, comparisons of patterns in catches among treatments/locations were examined graphically.

4.2.3 Analyses

Species captures were stored as Excel spreadsheets and then the data were imported into MS Access. Analyses done included the following:

- Abundance of carabids were compared among treatments using nested ANOVA with site type as the main factor (e.g. alluvial, non-alluvial or semi-alluvial) and trap locations nested within sites (e.g. In, Out). In this way we could examine if statistical differences existed, for example in the abundance of any one species among the various site types, given the variability among the different sites, and also among locations nested within sites, given that some riparian buffers were located adjacent to cut blocks of different ages (old-growth, 2nd growth or clearcut).
- Multivariate community analysis (using PC-ORD software, McCune & Mefford 1999) was used to examine patterns of association across the stream-riparian buffer-edge-forest gradients for the riparian sites for the three different geomorphology types ((e.g. alluvial, non-alluvial or semi-alluvial). Non-metric multidimensional scaling (NMS) was used to quantitatively summarize the overall distribution of species assemblages across the various gradients and to show how the treatments compare to one another in terms of "species space". NMS has been widely used in ecological gradient studies (Clarke 1993).
- Using PC ORD 4, we also performed indicator species analysis (Dufrene & Legendre 1997) to examine the associations of individual taxa with predefined groups (ie. distance from the stream and geomorphology type).
- Whittaker plots (Krebs 1989) were produced for each trap location (in, edge or out) whereby the log of % abundance for each species was plotted against the species rank for each treatment type. These plots allow for a simple visual comparison of the dominance or equality of species within the community. Total numbers of carabids caught in each

particular treatment were summed for the whole season and the sum catches of each species were then expressed as a percentage of this yearly total.

- Several nonparametric diversity indices were calculated for the different treatments (Southwood 1978). These measures take into account both species richness and species evenness and are thus referred to as heterogeneous measures (Magurran 1988, Krebs 1989). They are valuable in that they allow for comparison across all treatments, despite differences in sample size and number of individuals caught, and are useful as they assume no statistical distribution. The Simpson index, 1-D and the Shannon Wiener index, H' are useful values in studies of this kind. These indices combine the effects of species richness and dominance within a community and allow for comparison across treatments. The Simpson index highlights the changes that occur in the most common species and the Shannon-Wiener index, a measure of entropy within the system, highlights the more rare species in the assemblage (Magurran 1988). I also examined evenness (or equitability), by calculating the inverse of Simpson's Index. These indices were calculated for the carabid beetle data only. Heterogeneity values were calculated using PC ORD 4.
- Cluster analysis was used to assess how the assemblages of the different treatments compare to one another. We used the cluster analysis function in Systat, using Ward's linkage method and Euclidean distance measure. This allows us to visualize the similarity of the different communities sampled from the treatments and locations.

4.3 By-Catch data

By-catch information is given in Appendix 1. Bycatch species were determined largely to family or order. These data were not analyzed for this report.

5 RESULTS

5.1 Ground vegetation and stand differences among sites

The main tree species and understory vegetation was assessed during the summer in each site. Photographs of sites are given in Appendix 2. Overall, alluvial sites had higher shrub and herb cover than non-aluvial sites, there were more species of moss in the old-growth forests, and simpler communities overall in the non-alluvial sites. The different sites were similar in terms of age and elevation. Location of sites is shown in Figure 5.

Alluvial Sites

A1: This site is a 2nd growth site between 41-60 years of age, adjacent to Lost Shoe Creek close to its' entrance to the ocean. This site is within the Pacific Rim National Park. This creek was heavily logged in the 1960s at a time when approximately 90% of the watershed in the Park was logged. This site is made up primarily of Coastal Western hemlock, Douglas-fr, Sitka spruce, with a strong component of red alder at the traps located closest to the creek. The main shrubs in this site were salmonberry and stinkberry close to the stream, and salmonberry, salal, and red huckleberry throughout the rest of the site. There were many species of herbs, including sword fern, lady fern, spiny oak fern, and deer fern throughout the site. Within the first 15 m of the stream were also tule, hellebore, bracken fern and shunk cabbage. Figure 6 shows the average canopy, shrub, herb, moss, bare soil and leaf litter cover as one moves from the stream edge (trap 1) out for 75-80 m perpendicular to the stream. It is apparent that the % shrubs declined as one moved away from the stream edge. Canopy closure increased away from the water's edge, and leaf litter increased, while the % herbs, mosses, shrubs and bare soil were all variable but showed no clear changes with distance from the stream.

A2: This site is a 2nd growth site alluvial site adjacent to Kootowis Creek between 41-60 years of age. Here the predominant conifer is "offsite" (ecologically inappropriate) Douglas fir, planted following logging in the 1970s. This site also has a small component of red alder, Sitka spruce, Western red-cedar and Coastal Western hemlock. The main shrubs in the site were salal, salmonberry, false azalea, red huckleberry and Alaskan blueberry, while the main herb species was deer fern. There was also some lady fern and sword fern adjacent to the creek. Main mosses throughout the site were large leafy moss, Oregon beaked moss, step moss, and wavy-leaved cotton moss . Figure 7 shows the average canopy, shrub, herb, moss, bare soil and leaf litter cover as one moves from the stream edge (trap 1) out for 75-80 m perpendicular to the stream. It is apparent that the % shrubs, bare soil and leaf litter declined as one moves away from the stream edge, while the percentage of moss increased. Canopy closure and % herbs did not vary significantly with distance from the stream.

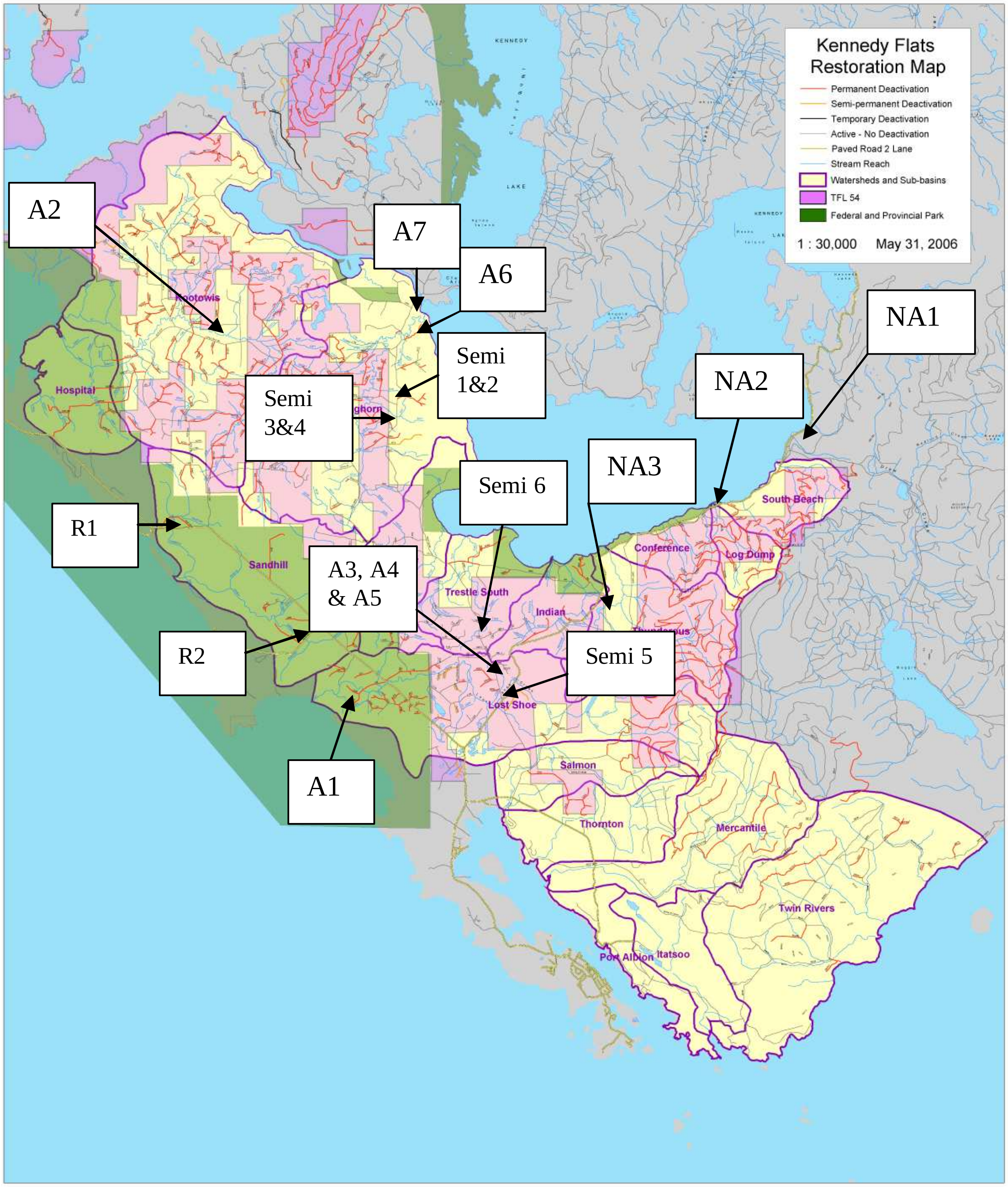


Figure 5. Kennedy Flats Watersheds and Study Sites. A1-A7 are alluvial sites, Semi 1-6 are semi-alluvial sites, NA1-3 are non-alluvial sites, and R1 and R2 are old-growth sites.

A3: This site is at Lost Shoe Creek at its intersection with Highway 4, and is a riparian buffer adjacent to a clearcut is on the opposite side of the creek from site A4. Within the riparian buffer, the main tree species were Douglas-fir, Western red-cedar and Coastal Western hemlock, with some red alder. Main shrub species were red huckleberry, salal, hardhack, false azalea and salmonberry, and herbs in this area were lady fern and sword fern. The ground cover in this riparian strip was relatively sparse, and there was a large component of bare ground. There was some moss cover of large leafy moss, true moss, and slender beaked moss. In the clearcut site adjacent to the buffer, the main tree species were crab apple, stunted Western Red-cedar, and Sitka alder. Main shrubs were hardhack, false azalea, red huckleberry, evergreen huckleberry, Alaskan blueberry, salmonberry and sitka willow. Herbs included skunk cabbage, clasping twisted stalk, false lily, lady fern, tule, round-leaved sundew, some fireweed and timothy grass. Main mosses recorded were sphagnum and Juniper haircap moss. Figure 8 shows the average canopy, shrub, herb, moss, bare soil and leaf litter cover as one moves from the stream edge (trap 1) out for 75-80 m perpendicular to the stream. It is apparent that the canopy cover declined as one moved out of the riparian strip into the clearcut block adjacent. At the same time, % shrubs, herbs and mosses increased with distance from the stream edge and out of the riparian buffer, while the leaf litter and % bare soil declined.

A4: This site was adjacent to Lost Shoe Creek along Highway 4 (opposite from site A4), and was a riparian buffer adjacent to a young swampy site (less than 20 years of age). The riparian strip of this site was very similar in composition to that of A3. The main tree species were Western red-cedar, Douglas-fir, Coastal Western hemlock, Sitka spruce and some red alder. The main shrubs were evergreen huckleberry, red huckleberry, salal and salmonberry, herbs included lady fern, tule, skunk cabbage, deer fern and sword fern, and the main mosses were large leafy moss, cotton moss, rough moss, slender beaked moss, tree moss, and Oregon beaked moss. Moving along the transects out into the younger site, there were small amounts of shore pine, sitka alder, crab apple sitka spruce as well as Western red-cedar, Douglas-fir and Coastal Western hemlock. The main herbs were hardhack, salal and salmonberry as well as some false azalea, red and evergreen huckleberry. The only mosses in the immature stand, which was also particularly swampy, were small red peat moss and flat bog moss. Figure 9 shows the average canopy, shrub, herb, moss, bare soil and leaf litter cover as one moves from the stream edge (trap 1) out for 75-80 m perpendicular to the stream. It is apparent that the canopy cover and % leaf litter both declined as one moved out of the riparian strip into the swampy immature block adjacent. The % bare soil and herbs both peaked at the edge while the % shrubs did not vary either in or out of the riparian block.

A5: This site was an interpretation trail, a riparian buffer that was a mixture of old growth and second growth forest located along the highway adjacent to Lost Shoe Creek. The site was relatively homogenous, and was made up of Western Red-cedar and Coastal Western hemlock, as well as a small component of red alder. Throughout the site, the main shrub species were evergreen huckleberry, salal, red huckleberry, and false azalea, and the main herb species was deer fern. Clasping twisted stalk lily was also a minor component of the herbs. Moss species included cat-tail moss, Oregon beaked moss, cotton moss, step moss, lanky moss, flat bog moss, large leafy moss and slender beaked moss. Figure 10 shows the average canopy, shrub, herb, moss, bare soil and leaf litter cover as one moves from the stream edge (trap 1) out for 75-80 m perpendicular to the stream. It is apparent that the canopy cover and % bare soil were similar at all locations along the transects, while the % shrubs and herbs both increased as one moved away from the riparian strip (after trap 3). There was a greater % of leaf litter within the riparian strip, close to the water's edge.

A6: This site was 2nd growth forest located adjacent to Staghorn Creek, at the end of West Main. This site was aged between 41-60 years. Moving along the transects from the stream edge (trap1) to approximately 75m out from the stream brought us to a second creek, so a final site, A7, was set up with traps located only at the water's edge and 10 m from the water's edge (trap locations 1 and 2) to assess the immediate riparian species. Site A6 was comprised of red alder, Sitika spruce, Western Red-cedar and Coastal Western hemlock. The main shrubs in this site were salmonberry, red huckleberry, salal, evergreen huckleberry and Alaskan blueberry. The main herbts were sword fern, false lily and deer fern. Close to the stream edge, additional shrub species included stinkcurrant, and additional herb species included 3-leaved foamflower, skunk cabbage, tule, lady fern and horsetail. Mosses in the site included tree moss, Oregon beaked moss, slender beaked moss, large leafy moss, small flat moss, clear moss and golden short cap. Figure 11 shows the average canopy, shrub, herb, moss, bare soil and leaf litter cover as one moves from the stream edge (trap 1) out for 75-80 m perpendicular to the stream. It is apparent that the %

shrubs and % herbs both declined as one moved from the stream's edge into the forest, while the % of moss increased. The canopy cover did not vary along the transects.

Semi-Alluvial Sites

All the semi alluvial sites were located along a logging road called West Main.

Semi1 and Semi 2 were located adjacent to the same creek. Semi 1 was a riparian buffer (2nd growth) adjacent to a clearcut, while Semi 2 was the same 2nd growth riparian buffer adjacent to an intact 2nd growth site of the same age.

Semi 3 and 4 were also located on either side of another semi-alluvial creek along West Main. Semi 3 was a riparian buffer (2nd growth) adjacent to a clearcut, while Semi 4 was the same 2nd growth riparian buffer adjacent to an intact 2nd growth site of the same age. Both Semi 5 and Semi 6 were 2nd growth riparian buffers adjacent to clearcuts. All the 2nd growth forests were aged 41-60 and at elevations between 20-40m.

Semi 1: The buffer strip at this site was made up of Coastal Western hemlock, Balsam fir, Douglas-fir, and some red alder. Main shrubs were salmonberry, red huckleberry, salal and thimbleberry. Main herb species were deer fern, spiny oak fern, 3-leaved foamflower, sword fern, and horsetail. Mosses in the buffer strip were large leafy moss, lanky moss, slender beaked moss, coastal leafy moss, flat bog moss, step moss, Oregon beaked moss, cat-tail moss, and cotton moss. The shrubs of the clearcut were Alaskan blueberry, salmonberry and red huckleberry, and the main herbs in the cut area were deer fern and 3-leaved foamflower and sword fern. Mosses in the clearcut were large leafy moss, Oregon beaked moss and cotton moss. Figure 12 shows the average canopy, shrub, herb, moss, bare soil and leaf litter cover as one moves from the stream edge (trap 1) out for 75-80 m perpendicular to the stream. It is apparent that the % leaf litter increased, while the canopy and moss cover declined as one moved out of the riparian buffer into the adjoining clearcut. The amount of bare soil and shrub cover did not vary among the buffer and clearcut.

Semi 2: The buffer strip of Semi 2 is on the opposite side of the creek to Semi 1 and extends into 2nd growth forest of the same age as the buffer. The main tree species in the site were Coastal Western hemlock, Balsam fir, Sitka spruce, and some red alder. Main shrubs were salmonberry, red huckleberry, salal and Alaskan blueberry, and the main herbs were deer fern, sword fern and spiny oak fern and some 3-leaved foam flower. The main mosses were slender beaked moss, coastal leafy moss, Oregon beaked moss, large leafy moss, big red stem moss, golden capsule, Menzie's red mnium and clear moss. Figure 13 shows the average canopy, shrub, herb, moss, bare soil and leaf litter cover as one moves from the stream edge (trap 1) out for 75-80 m perpendicular to the stream. Canopy cover did not vary along the transects, while the % herbs declined, and % moss increased.

Semi 3: The buffer strip at this 2nd growth site was made up of Coastal Western hemlock, Balsam fir, Douglas-fir, and Sitka spruce. Main shrubs were salmonberry, red huckleberry, salal and Alaskan blueberry. Main herb species were deer fern, sword fern, lady fern, 3-leaved foamflower and skunk cabbage. Mosses in the buffer strip were step moss, hairy-cap moss, large leafy moss, slender beaked moss, Oregon beaked moss, and cat-tail moss. This buffer was located adjacent to a clearcut, in which there was some regenerating Coastal Western hemlock, salmonberry, small amounts of deer fern and Oregon beaked moss only. Figure 14 shows the average canopy, shrub, herb, moss, bare soil and leaf litter cover as one moves from the stream edge (trap 1) out for 75-80 m perpendicular to the stream. It is apparent that the % leaf litter increased, while the canopy, shrub, herb and moss cover declined as one moved out of the riparian buffer into the adjoining clearcut.

Semi 4: The buffer strip of Semi 4 is on the opposite side of the creek to Semi 3 and extends into 2nd growth forest of the same age as the buffer. The main tree species in the site were Coastal Western hemlock, Balsam fir, and Western red-cedar. Main shrubs were red huckleberry, salal, salmonberry, and false azalea, and the main herbs were deer fern and sword fern. Skunk cabbage and 3-leaved foamflower were also present close to the creek edge. The main mosses were Oregon beaked moss, cotton moss, step moss, large leafy moss, slender beaked moss and there were some liverworts such as *Porella* sp. (tree-ruffle liverwort). Figure 15 shows the average canopy, shrub, herb, moss, bare soil and leaf litter cover as one moves from the stream edge (trap 1) out for 75-80 m perpendicular to the stream. Canopy cover did not vary along the transects. Declines in % shrubs, herbs and leaf litter were seen at the edge (trap location 4), while the % bare soil increased at the edge.

Semi 5: This site was a riparian buffer adjacent to a clearcut. The species of the buffer were red alder, Western red-cedar and Coastal Western hemlock, and the main shrubs were salmonberry, salal, red huckleberry, Alaskan blueberry and false azalea. The main herb species in the buffer were false lily, lady fern, skunk cabbage, deer fern, hellebore, sedge, and spiny oak fern. There were several mosses including Oregeon beaked moss, cotton moss, large leafy moss, lanky moss, tree moss, curly tailed moss, and slender beaked moss. In the clearcut, there was no canopy. There was some salal and salmonberry, sword fern and deer fern, and a small amount of spiny oak fern. Figure 16 shows the average canopy, shrub, herb, moss, bare soil and leaf litter cover as one moves from the stream edge (trap 1) out for 75-80 m perpendicular to the stream. It is apparent that the % leaf litter and bare soil increased, while the canopy, shrub, herb and moss cover declined as one moved out of the riparian buffer into the adjoining clearcut.

Semi 6: This site was a riparian buffer adjacent to a clearcut. The species of the buffer were Coastal Western hemlock, Western red-cedar and red alder. The main shrubs were salmonberry, salal, red huckleberry, Alaskan blueberry, oval leaved blueberry, evergreen huckleberry and false azalea. The main herb species in the buffer were sword fern and deer fern only. There were several mosses including Oregeon beaked moss, cotton moss, large leafy moss, step moss, and several liverworts. In the clearcut, there was no canopy. There was some salal, Alaskan blueberry red huckleberry, evergreen huckleberry and false azalea. Herbs included false lily, bunchberry, twinflower and deer fern. Small amounts of moss were present including step moss, Oregon beaked moss, cotton moss and broom moss. Figure 17 shows the average canopy, shrub, herb, moss, bare soil and leaf litter cover as one moves from the stream edge (trap 1) out for 75-80 m perpendicular to the stream. It is apparent that again, the % leaf litter and bare soil increased, while the canopy, shrub, herb and moss cover declined as one moved out of the riparian buffer into the adjoining clearcut.

Non-Alluvial Sites

NA1: This site was located adjacent to Draw Creek, and slopes on either side of the creek were particularly steep. This site was between 41-60 years of age and at an elevation varying between 40-60 m above sea level. Red alder dominated at the creek edge, and was replaced by Douglas-fir, Western red-cedar and Western Hemlock as one moved along the transects away from the stream. The vegetation at this site was very simple, the main shrub species were salmonberry, red huckleberry, salal, and Alaskan blueberry, the main herb species were false lily, deer fern and sword fern, and the main mosses were large leafy moss, cotton moss, step moss, and Oregon beaked moss. Figure 18 shows the average canopy, shrub, herb, moss, bare soil and leaf litter cover as one moves from the stream edge (trap 1) out for 75-80 m perpendicular to the stream. Canopy cover was relatively similar along the transects, while % shrubs increased somewhat at 75 m away from the stream edge, and bare soil also increased as one moved along the transects away from the stream edge. There was generally a higher cover of herbs close to the water edge.

NA2: This site was located adjacent to Log Dump Creek, and approximately 40 years of age. The elevation varied between 0-40m above sea level. A steep cliff face adjoined the valley bottom. Again, red alder dominated at the creek edge, and was replaced by Douglas-fir, Western Hemlock and Balsam fir as one moved along the transects away from the stream. Again, the vegetation at this site was very simple, the main shrub species were salmonberry, red huckleberry, thimbleberry, some false azalea, salal and evergreen huckleberry, the main herb species was deer fern throughout the sites, but with sword fern, grasses and sweet-scented bedstraw and 3-leaved foamflower dominating at the water's edge. The main mosses were large leafy moss, coastal leafy moss, step moss, Oregon beaked moss, cat-tail moss and wavy-leaved cotton moss. Figure 19 shows the average canopy, shrub, herb, moss, bare soil and leaf litter cover as one moves from the stream edge (trap 1) out for 75-80 m perpendicular to the stream. Canopy increased and leaf litter and herb cover increased, while moss and shrub cover showed slight declines as one moved from the stream edge up the hill into the 2nd growth forest.

NA3: This site was a large, flat block of forest located alongside Thunderous creek. This site is aged between 21-40 years of age and at an elevation of 40-70m. Again, the riparian strip was dominated by red alder, wich was replaced by Western Hemlock and Western Red-cedar at about trap 5 along the transect, approximately 45m from the stream bank. Within the riparian strip, the main vegetation was comprised of thimbleberry, stinkcurrant, salmonberry, Souler's willow and salal, as well as seedlings of Western Hemlock. Main herb species in this region were sweet-scented bedstraw, piggyback, sword fern, maidenhair fern, 3-leaved foamflower and sword fern. Moving from the red-alder strip into the forest, which was made up of Western Hemlock, Western Red-cedar, and some Balsam fir, the ground vegetation was almost entirely made up of sword fern, with some salmonberry and red huckleberry, and with increasing abundance of mosses, such as Oregon beaked moss, large leafy moss and Menzie's tree moss. Figure 20 shows the average canopy, shrub, herb, moss, bare soil and leaf litter cover as one moves from the stream edge (trap 1) out for 75-80 m perpendicular to the stream. Canopy and herb cover both increased, while the shrub cover and percentage of leaf litter declined as one moved from the stream edge into the 2nd growth forest.

Old-growth Sites:

R1: This site was located adjacent to Staghorn Creek, within the Pacific Rim National Park, adjacent to Highway 4. The creek is bound on either side by steep banks of old-growth forest. Main tree species in this site were Coastal Western hemlock, Western red-cedar and a small amount of Sitka spruce. The site was relatively homogenous. The main shrub species were evergreen huckleberry, salal, red huckleberry, false azalea, salmonberry, and Alaskan blueberry, while the main herb species recorded were 3-leaved foamflower, horsetail, sword fern, skunk cabbage, deer fern, false lily and bunchberry. Main moss species were Oregon beaked moss, lanky moss, flat bog moss, slender beaked moss, step moss, large leafy moss, coatal leafy moss, sphagnum moss, and tree moss. Figure 21 shows the average canopy, shrub, herb, moss, bare soil and leaf litter cover as one moves from the stream edge (trap 1) out for 75-80 m perpendicular to the stream. Leaf litter increased, and moss cover decreased as one moved from the stream edge up the steep back into the old- growth forest. The other vegetation showed variable patterns.

R2: This site was located along the turn-off to the Wickanninish. It was comprised of Western Red-cedar, Coastal western hemlock and Yellow Cedar. There was also some Sitka spruce close to the water's edge. The main shrub species in this site were red huckleberry, salal, salmonberry, Alaskan blueberry, evergreen huckleberry and false azalea. Main herb species were skunk cabbage at the water's edge, and deer fern and horsetail throughout the block. Mosses included green sphagnum, cotton moss, step moss, large leafy moss, clear moss, lanky moss, and Oregon beaked moss. There were also various liverworts including Cedar shake liverwort. Figure 22 shows the average canopy, shrub, herb, moss, bare soil and leaf litter cover as one moves from the stream edge (trap 1) out for 75-80 m perpendicular to the stream. Canopy and vegetation cover appeared to be relatively homogenous within this site, regardless of distance from the stream bank.

Other data collected included moisture readings which were taken at each trap location along transects within the sites (Tables 1-4). Thus, 5-8 readings were taken at the edge of the stream, and out along the transect through the riparian buffer into the adjoining intact forest or clearcut, depending on the site. Moisture readings in alluvial sites did not show clear patterns. In sites A3 and A4, we might have expected some changes with distance from the buffer, since the riparian buffers in these sites adjoined a clearcut (A3) and a 20-year old immature site (A4). Patterns were too variable to discern any major trends in the alluvial or old-growth sites (Figure 23). This was also the case in the semi alluvial sites and non-alluvial sites (Figures 24-25). In the semi-alluvial sites, there was a particularly high moisture reading in Semi 4 at the stream bank, and also in the clearcut of Semi 6.

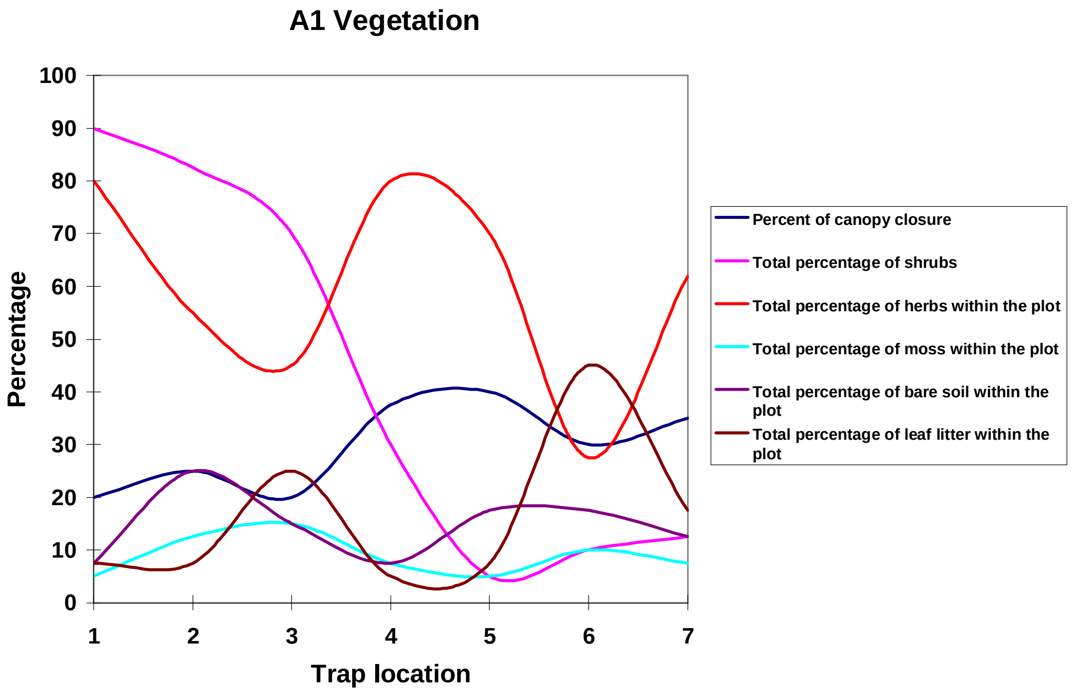


Figure 6. Canopy closure, shrub, herb, moss and soil cover in A1.

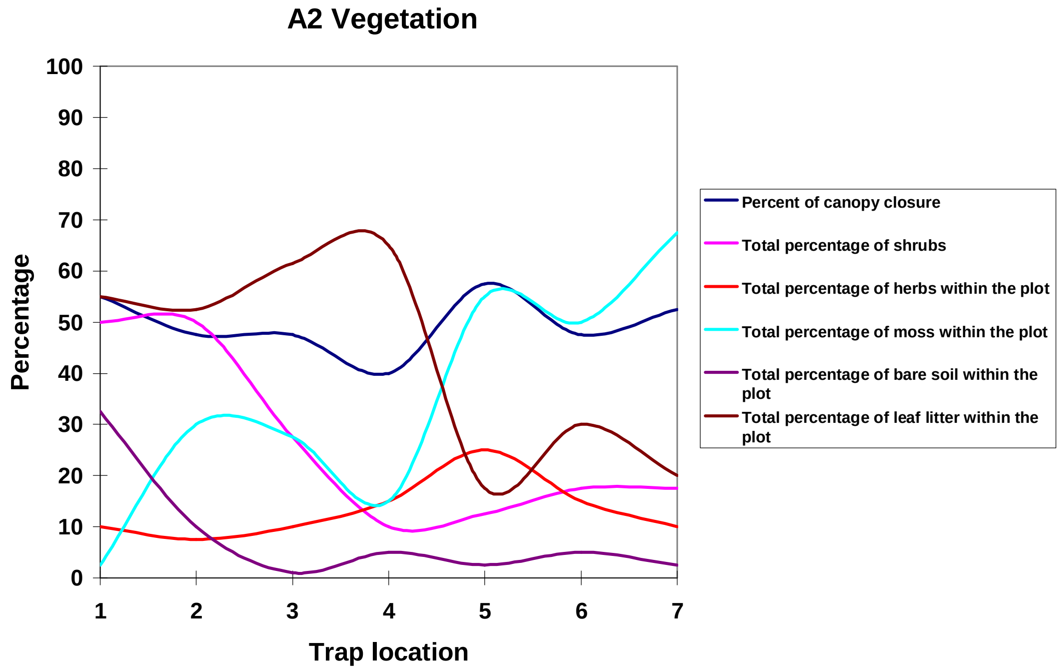


Figure 7. Canopy closure, shrub, herb, moss and soil cover in A2.

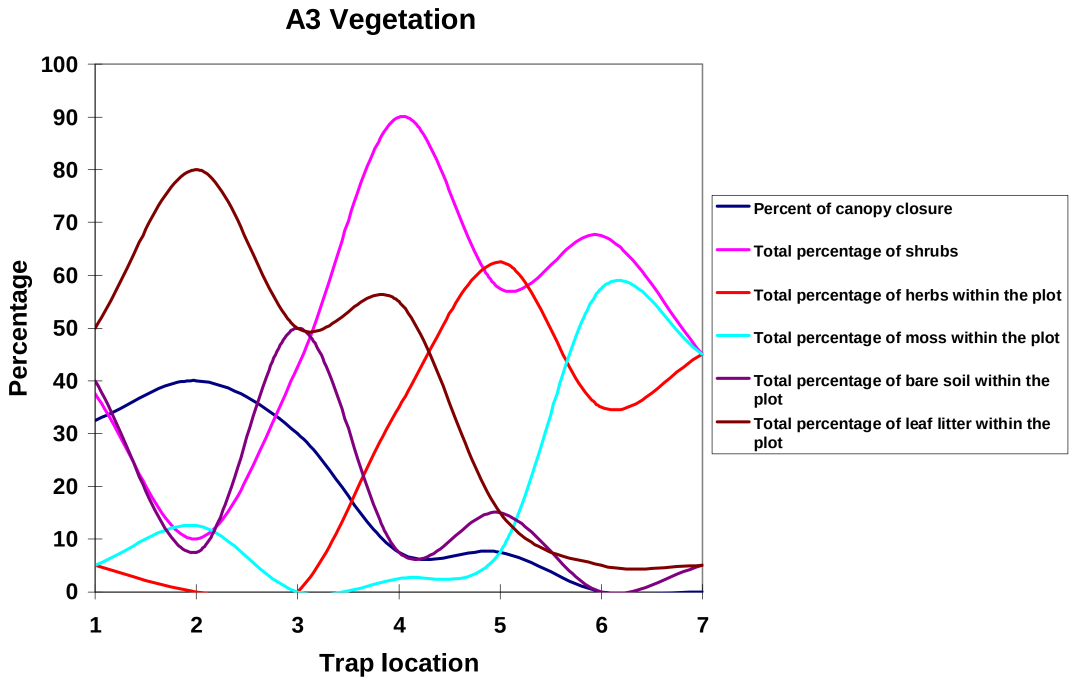


Figure 8. Canopy closure, shrub, herb, moss and soil cover in A3.

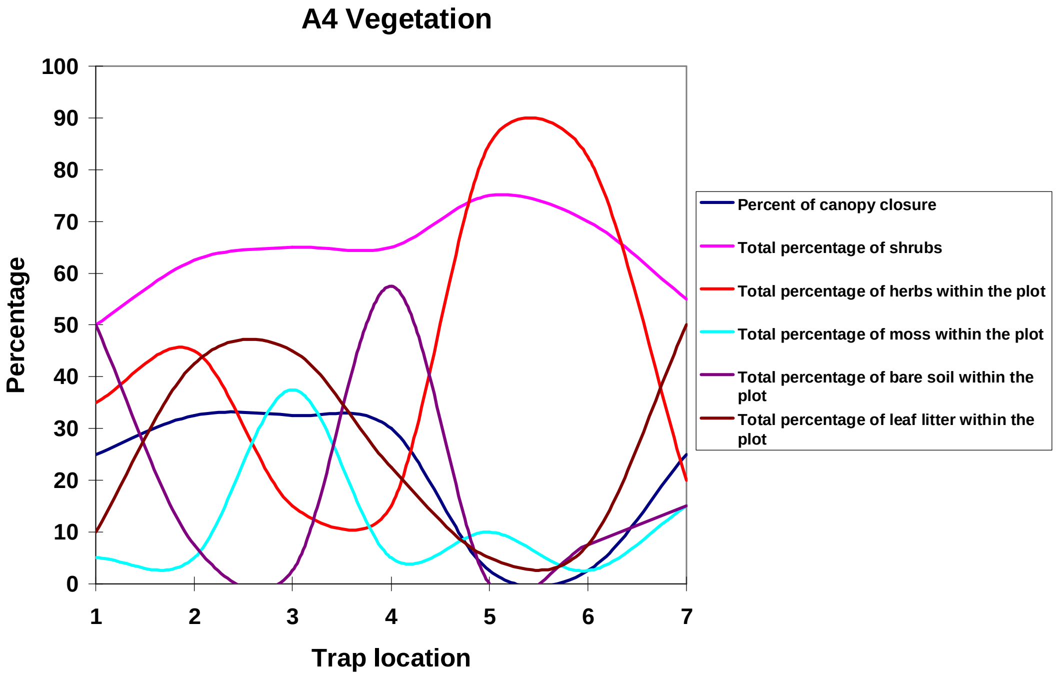


Figure 9. Canopy closure, shrub, herb, moss and soil cover in A4.

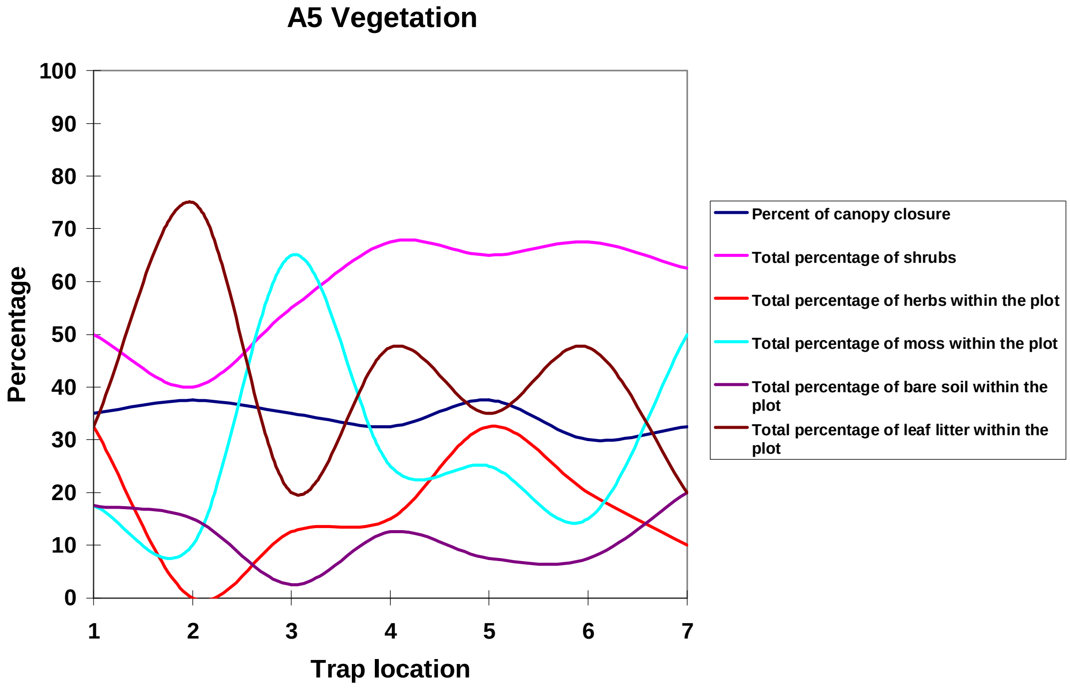


Figure 10. Canopy closure, shrub, herb, moss and soil cover in A5.

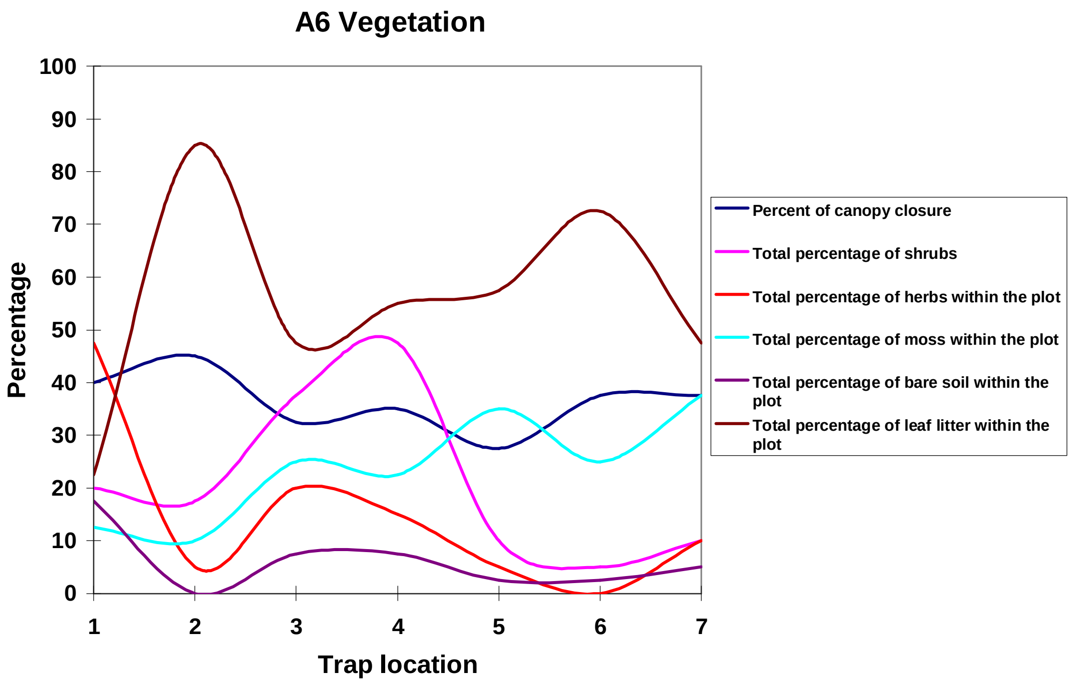


Figure 11. Canopy closure, shrub, herb, moss and soil cover in A6.

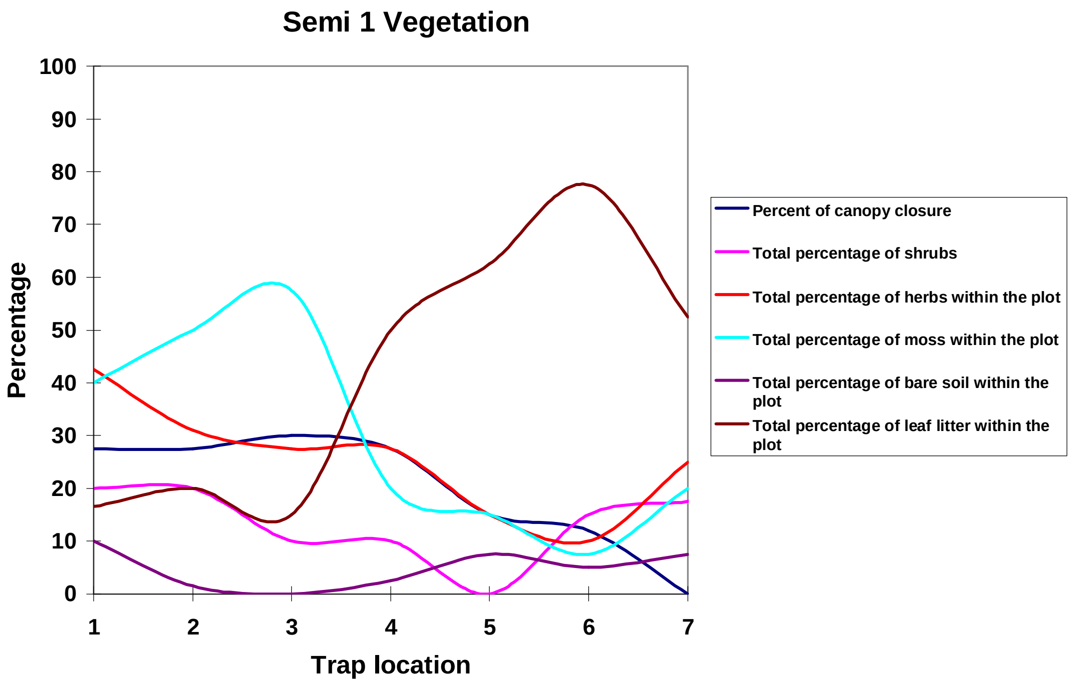


Figure 12. Canopy closure, shrub, herb, moss and soil cover in Semi 1.

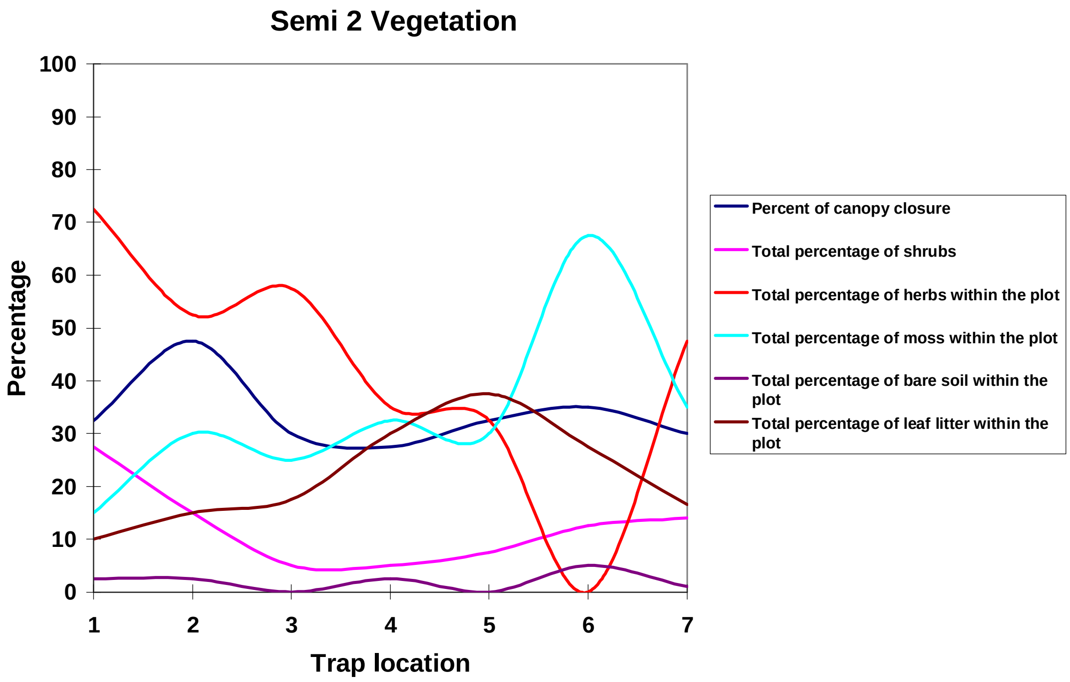


Figure 13. Canopy closure, shrub, herb, moss and soil cover in Semi 2.

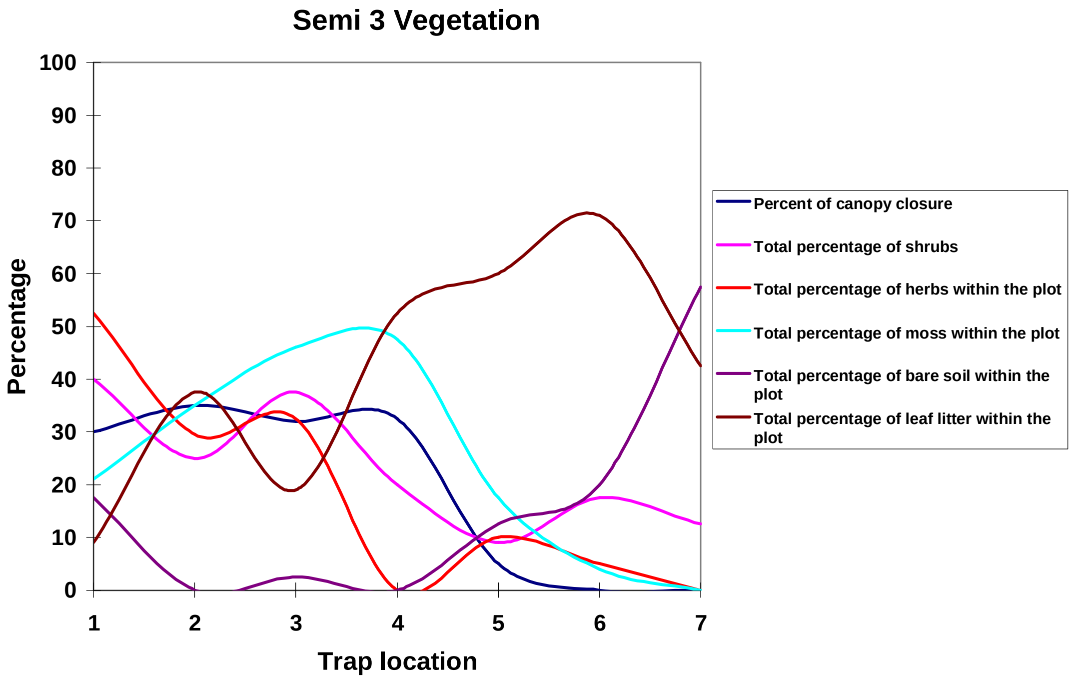


Figure 14. Canopy closure, shrub, herb, moss and soil cover in Semi 3.

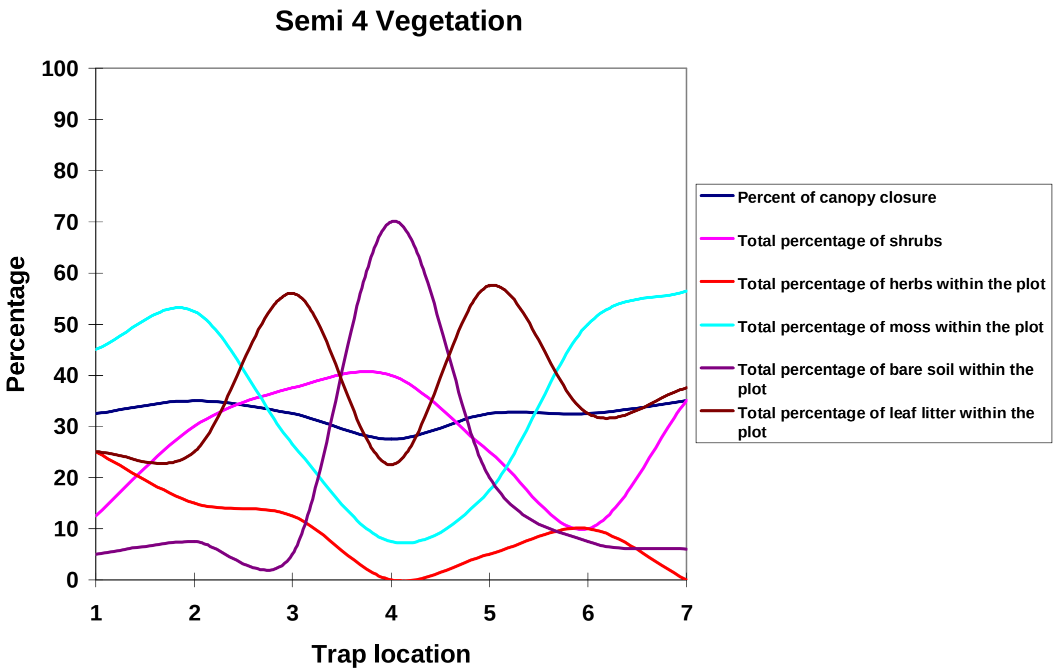


Figure 15. Canopy closure, shrub, herb, moss and soil cover in Semi 4.

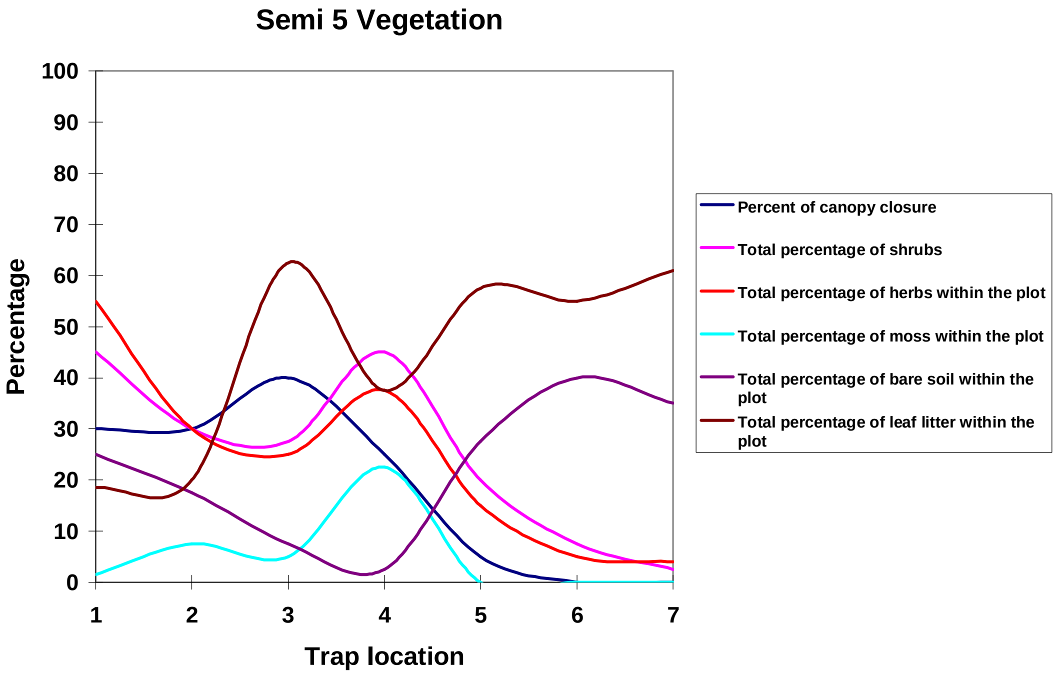


Figure 16. Canopy closure, shrub, herb, moss and soil cover in Semi 5.

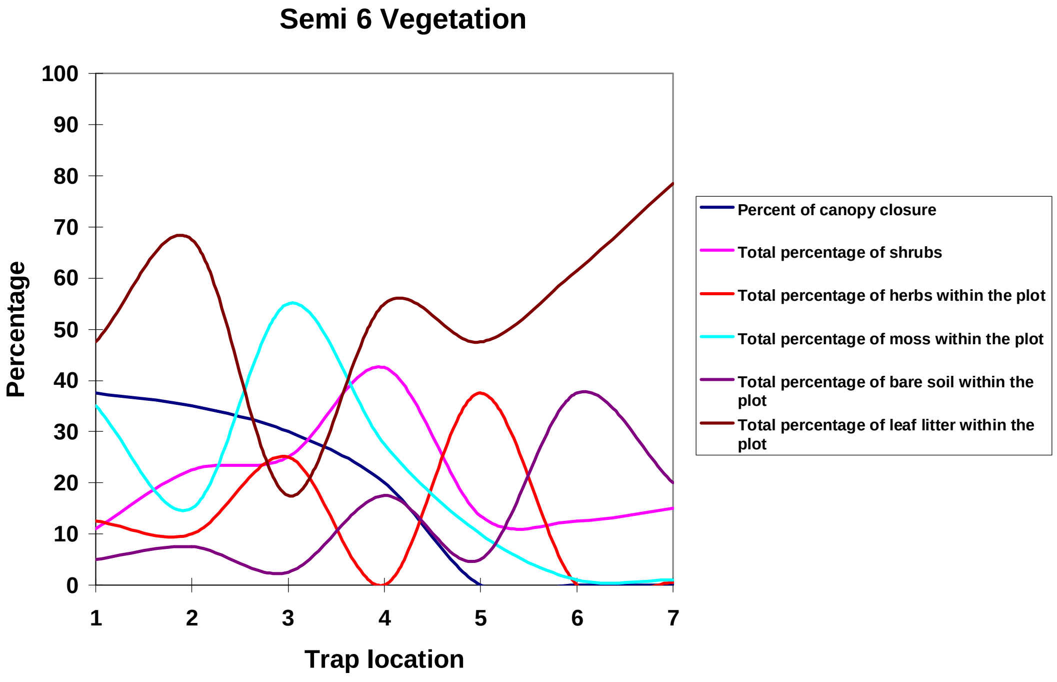


Figure 17. Canopy closure, shrub, herb, moss and soil cover in Semi 6.

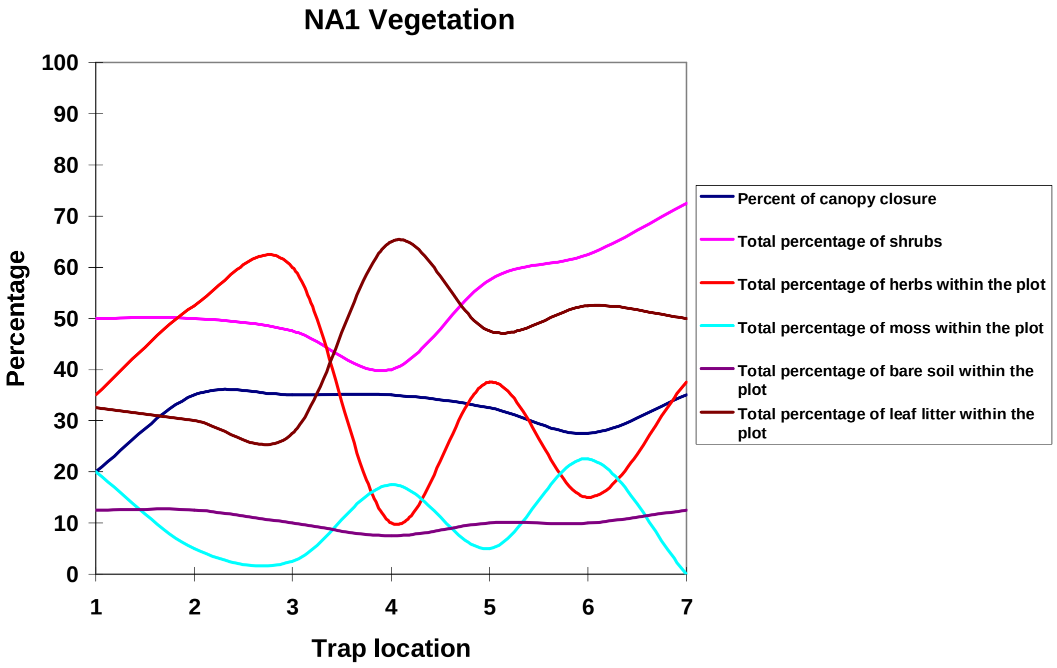


Figure 18. Canopy closure, shrub, herb, moss and soil cover in NA1.

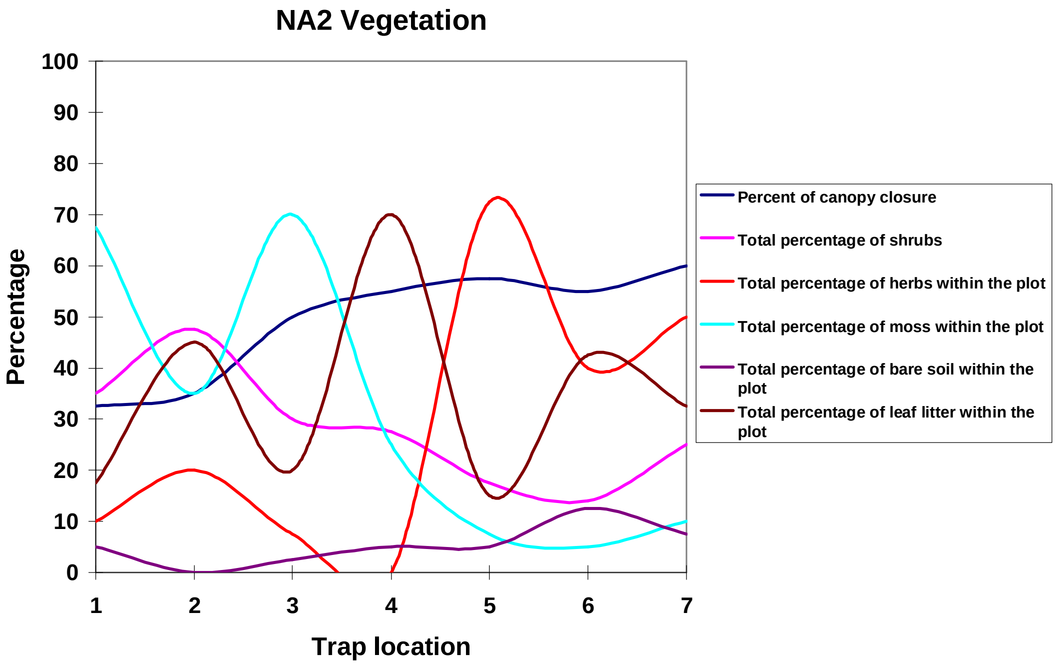


Figure 19. Canopy closure, shrub, herb, moss and soil cover in NA2.

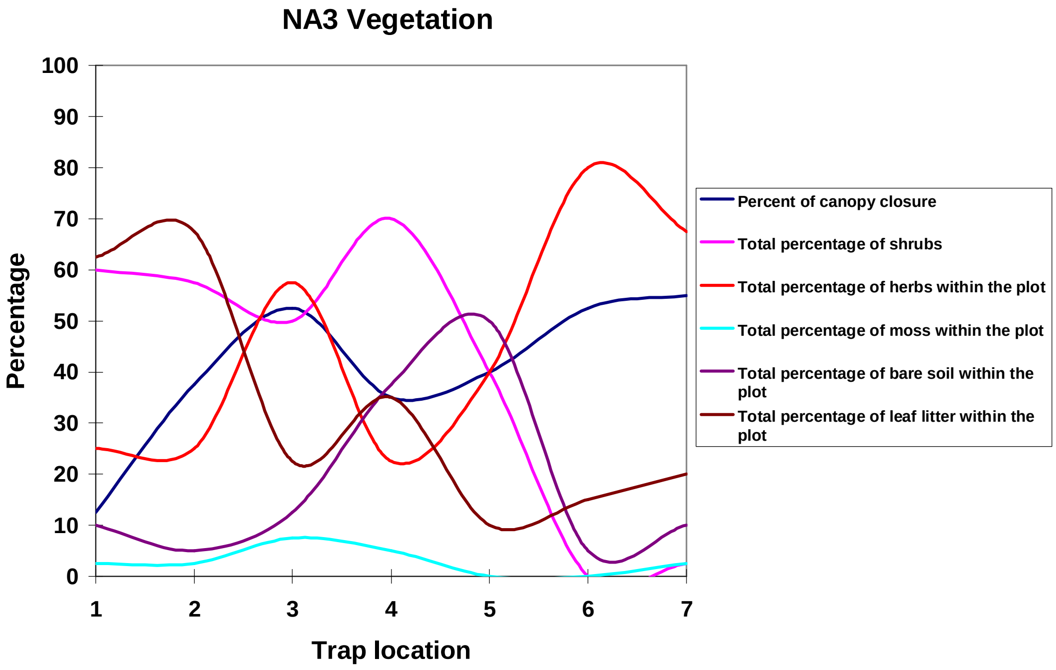


Figure 20. Canopy closure, shrub, herb, moss and soil cover in NA3.

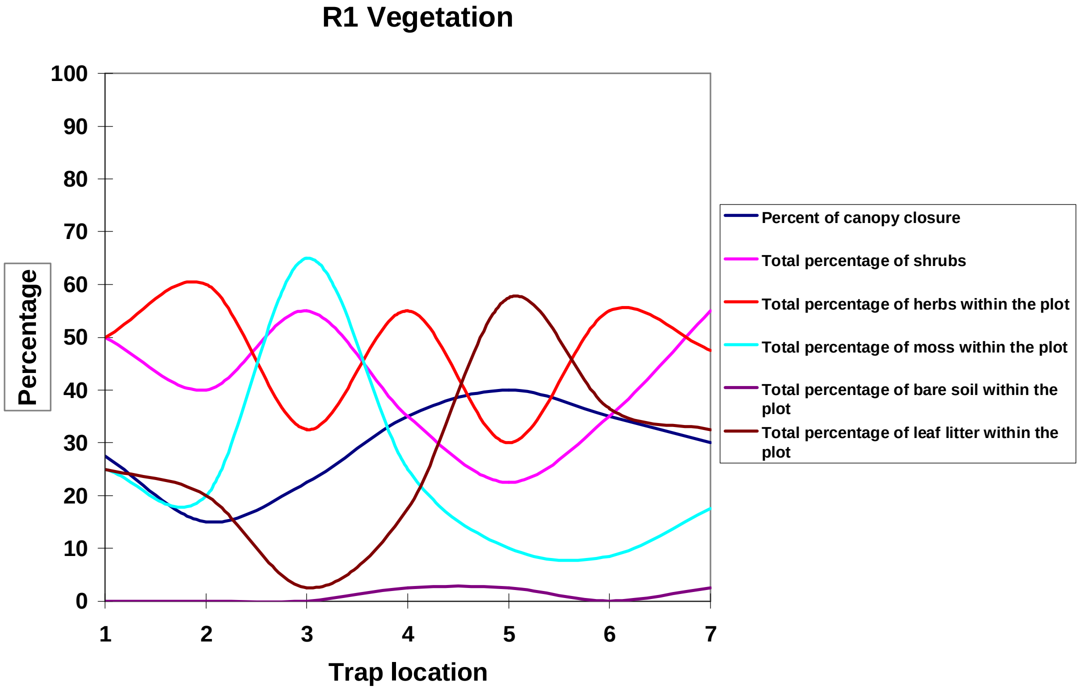


Figure 21. Canopy closure, shrub, herb, moss and soil cover in R1.

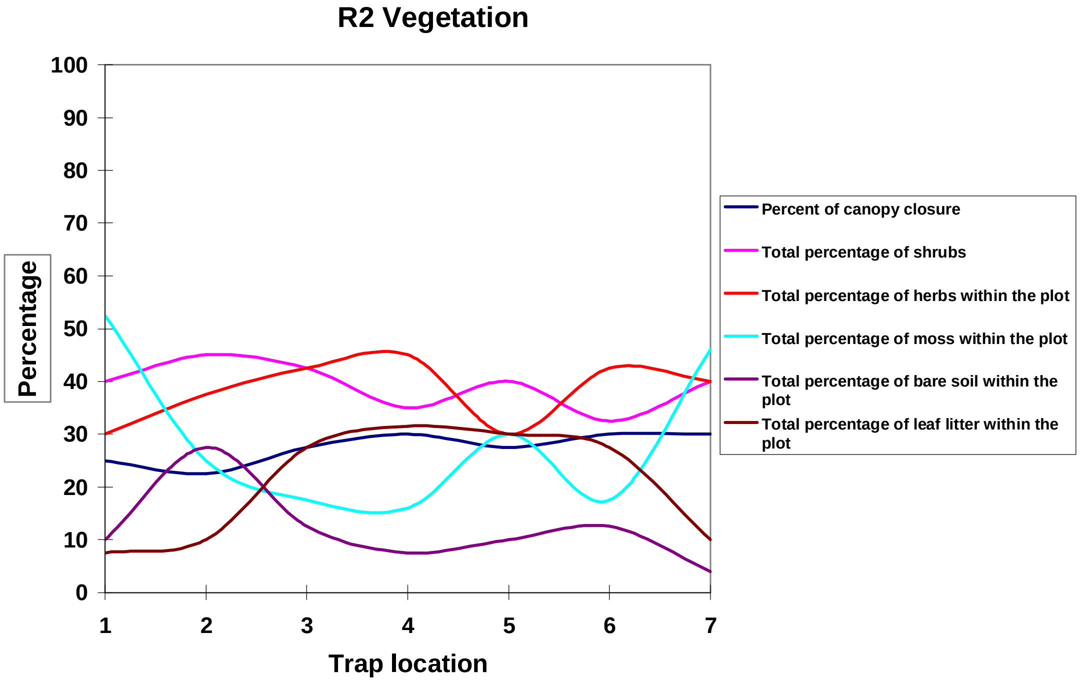


Figure 22. Canopy closure, shrub, herb, moss and soil cover in R2.

Table 1. Mean moisture readings(%) for alluvial sites with standard errors. Readings taken July 2008.

Trap Location	A1		A2		A3		A4		A5		A7	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	17.43	4.07	25.57	3.76	9.50	1.18	8.00	0.45	20.25	1.43	31.67	6.55
2	34.86	4.47	32.67	5.08	5.67	0.26	9.00	0.77	22.75	3.49	16.33	2.70
3	31.57	2.54	32.00	6.03	27.50	2.44	18.25	5.33	22.00	2.68	21.67	5.56
4	30.00	4.07	28.00	0.63	25.00	4.24	35.67	2.73	9.00	1.83	15.00	0.37
5	24.20	7.94	26.50	4.11	27.60	5.24	10.00	4.77	7.40	0.68	12.00	2.90
6	30.25	3.71	31.00	1.90	5.33	0.93	40.67	0.26	18.75	3.55	11.75	0.92
7	32.60	1.81	33.00	1.90	20.25	4.62	16.33	7.02	16.67	0.68	25.75	2.40

Table 2. Mean moisture readings(%) for semi-alluvial sites with standard errors. Readings taken July 2008.

Trap Location	Semi 1		Semi 2		Semi 3		Semi 4		Semi 5		Semi 6	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	26.67	7.10			11.67	0.68	50.25	4.26	32.67	4.06	16.00	2.72
2	11.00	1.95	7.67	1.37	9.00	0.45	10.00	1.21	25.75	7.62	13.50	3.40
3	13.67	1.37	7.67	1.69	8.75	1.88	13.33	0.26	12.25	1.73	22.00	5.04
4	7.50	0.77	17.33	4.93	8.67	0.68	12.00	0.77	11.25	1.61	14.33	0.93
5	14.33	4.13	15.50	3.53	17.00	0.45	9.67	0.68	14.50	1.84	19.67	3.64
6	14.00	0.89	9.33	0.68	27.67	12.17	10.25	1.84	13.00	0.00	32.00	10.66
7	12.00	2.37	5.33	0.68	9.00	2.79	5.00	0.45	11.20	2.48	38.67	4.13

Table 3. Mean moisture readings(%) for non- alluvial sites with standard errors. Readings taken July 2008.

Trap Location	NA1		NA2		NA3	
	Mean	SE	Mean	SE	Mean	SE
1	5.00	0.00	9.25	1.28	8.67	1.44
2	5.67	0.26	12.50	0.86	26.00	3.22
3	18.00	3.66	33.00	6.17	20.50	1.18
4	7.75	1.38	11.80	1.07	39.50	2.46
5	11.33	1.57	22.00	2.74	44.00	2.37
6	8.00	0.37	23.00	2.28	10.00	1.76
7	7.33	1.37	26.40	6.94	30.25	10.77

Table 4. Mean moisture readings(%) for old-growth sites with standard errors. Readings taken July 2008.

Transect	R1		R2	
	Mean	SE	Mean	SE
1	15.75	5.16	7.67	0.26
2	34.75	10.34	18.33	1.13
3	29.83	5.36	15.67	2.11
4	24.50	4.32	18.67	2.88
5	39.00	2.50	11.00	0.89
6	32.40	5.84	15.25	0.99
7	31.83	5.73	27.50	2.21

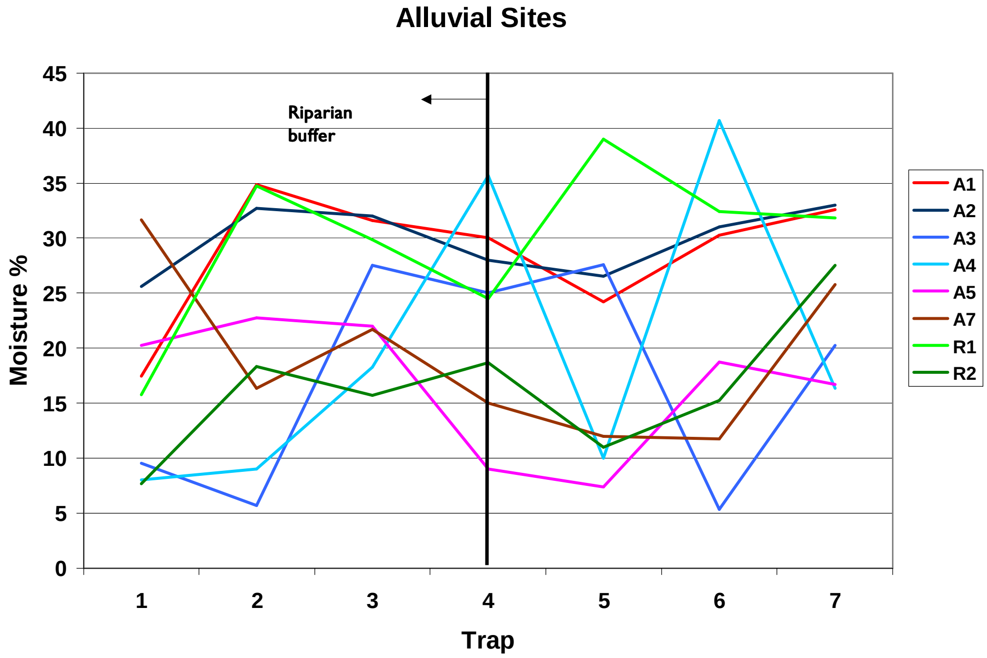


Figure 23. Moisture readings in Alluvial sites (A1-A7) and Old-growth sites (R1, R2) along transects, where 1= stream edge.

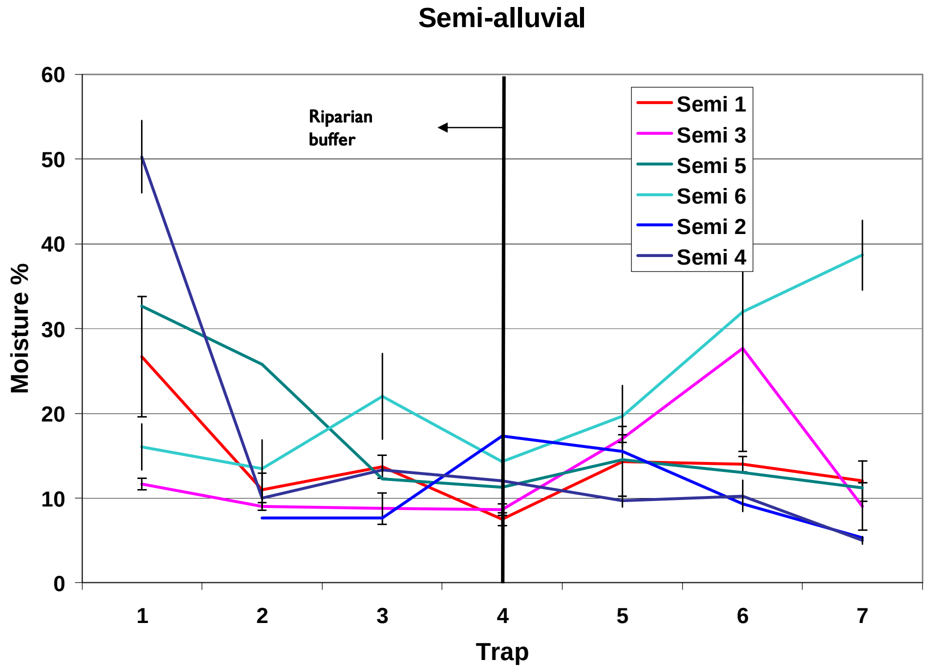


Figure 24. Moisture readings in Semi-Alluvial sites (Semi1-Semi6) along transects, where 1= stream edge.

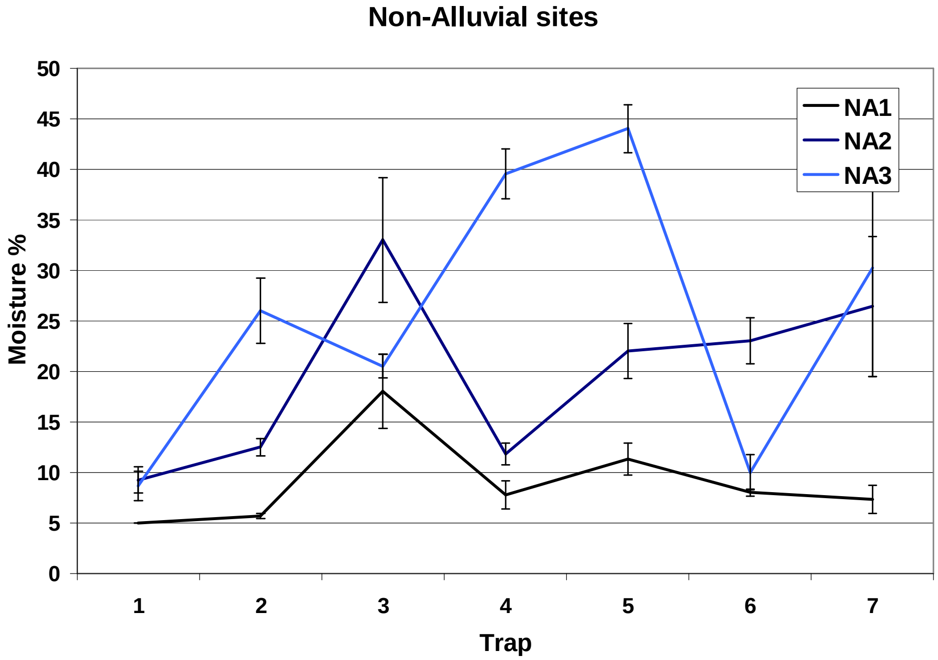


Figure 25. Moisture readings in Non-Alluvial (NA1-NA3) sites along transects, where 1= stream edge.

5.2 Trap catches

Catch data for all animals caught in pitfall traps was placed into a MS Access Database. A synoptic collection of carabid beetles has been given to the George J. Spencer Entomological Museum and one remains with me. The latter collection includes pinned examples of the non-carabid beetles captured. Beetles are identified by site, location and pitfall trap, date of collection, and species/genus name.

5.2.1 Description of carabid species

All carabid beetles were identified at the species level. Details regarding ecology, distribution and habits of the species caught during this study are given in Appendix 3.

14 carabid beetle species with a total of 3906 individuals were collected in the alluvial sites (A1-A7, from a total of 113 traps collected each month), 14 species with a total of 1542 individuals were collected in the semi-alluvial sites (Semi 1-Semi 6, from a total of 108 traps collected each month) , 13 species with a total of 2088 individuals were collected in the non-alluvial sites (NA1-NA3 from a total of 54 traps collected monthly ,and 10 species with a total of 722 individuals were collected in the old-growth sites (R1 & R2, from a total of 36 traps sampled monthly) (Tables 2-4). A total of 8258 carabids were trapped overall from 20 different species.

In the alluvial sites, the most abundant species captured was *Pterostichus crenicollis* Le Conte with a total of 2046 individuals caught overall (Table 2). The next most dominant species were *Scaphinotus angusticollis* (Fischer von Waldheim), with 520 individuals, *Pterostichus algidus* Le Conte with 222 individuals and *P.lama,* with 117 individuals. Thus, *P. crenicollis* was particularly dominant in these sites. The other species were fairly uncommon. In the semi-alluvial sites, the most commonly captured species were similar: *P. crenicollis* was most abundant, with a total of 782 individuals, followed by *S. angusticollis,* with a total of 510 individuals. The next abundant was *P. lama*, with 71 individuals, then *Cychrus tuberculatus* Harris, with 65 individuals, then *P. algidus* with 42 individuals and then *Scaphinotus marginatus*, with 36 individuals. The other species were fairly uncommon.

In the non-alluvial sites, the most common species caught was *P. crenicollis* with 930 individuals, followed by *P. lama*, with 490 individuals, then *P. algidus*, with 284 individuals, *S. angusticollis* with 251 individuals, and then *Cychrus tuberculatus* with 55 individuals. The other species were fairly uncommon. In the old-growth sites, *P. crenicollis* was most abundant, with 431 individuals, followed by *S. angusticollis* with 176 individuals, *P. lama* with 41 individuals and *Zacotus matthewsii*, with 30 individuals.

The largest carabids captured were *Cychrus tuberculatus*, *Omus dejeani* Reiche, and *Scaphinotus angusticollis*, whereas the smallest carabid beetles captured were *Amara littoralis* Mannerheim*, Harpalus cordifer* Dejean*, Agonum affine* Kirby*, Agonum ferruginosum* Dejean*, Harpalus cordifer* Notman *and Agonum piceolum* LeConte*.*

5.2.1.1 Specific differences among the sites

The presence/absence and abundance data for the species of carabids for each separate site, as well as the proportional contribution that the different species make to the catch in each site, are shown in Tables 5 -9. The species *P. crenicollis, S, angusticollis*, and *C. tuberculatus* were found in all the sites. *P. algidus* was common to most sites, but absent from A2, A3, A5 and Semi 6. *S. marginatus* was also found in all sites except one, Semi 6. *Zacotus matthewsii* was only found in the two old-growth sites, and the one alluvial site, A1, which was the riparian area adjacent to Lost Shoe Creek. This species has been noted as an old-growth specialist in previous studies (Pearsall, 2002-2007) as well as from studies carried out at the HJ Andrews Experimental Forest in Oregon and by Craig (1995) for southern Vancouver Island. Most of the other species were found in only a few sites*. Leistus ferruginosus* was found only in 2 non-alluvial sites and also in one alluvial site (A1), and this species is known to have strong associations with riparian areas (Larochelle and Lariviere 2003).

When we compare the catches of the different species in those sites where the riparian buffer was found adjacent to a younger stand (A4) or a clearcut (A3, Semi 1, Semi 3, Semi 5, Semi 6), it was apparent that catches of all species are generally much lower in the cut areas than in the riparian buffers (Tables 10-11). *S. angusticollis* was not found at all in the clearcut adjacent to the buffer of A3, and there were also very few *P. crenicollis* (Table 10). There were increased catches of

Agonum affine in the clearcut however. In site A4, there were far more *P. crenicollis* and *S. angusticollis* in the riparian buffer than found in the immature stand adjacent to the buffer (Table 10). The clearcut adjacent to Semi 1 had fewer catches of *P. crenicollis, S. angusticollis,* and *P. lama*, and higher catches of *P. algidus* than found in the buffer (Table 11). A similar pattern was found at Semi 3, where lower catches of the same species as well as *S. marginatus* were recorded in the clearcut than in the buffer (Table 11). *P. crenicollis* also declined in the clearcut adjacent to the buffer at Semi 5, and no *S. angusticollis* or *S. marginatus* were found in the clearcut. Finally, declines of *P. crenicollis, S. angusticollis, C. tuberculatus* were noted in the clearcut adjacent to Semi 6, although more *P. lama* were found in the cut area of this site than in the buffer.

The proportional contribution to the overall catch of the different species at each site differed at times, and some of the rarer species were only found in one or two locations (Tables 12-15). On a proportional basis, *P. crenicollis* made up the bulk of the catch in the alluvial sites. In the semi-alluvial sites, and the old growth sites, this species together with *Scaphinotus angusticollis* made up the bulk of the catch. In the non-alluvial sites, *P. crenicollis* also made up the bulk of the catch, but *P. lama* made up a much greater proportion of the catch than in the other site types. *P. algidus* was also more important on a proportional basis in the non-alluvial sites.

Tables 16-19 show the means and standard errors of catches of each carabid species in each of the sites. This allows us to compare among sites which have had different trapping intensity. It is apparent that the mean carabid catches overall were higher in the alluvial and non-alluvial sites than in the semi-alluvial sites. Within the alluvial sites, catches were higher in sites Al, A6, and A7 than in A2, and were lowest in A4, A5 and A3. In the semi-alluvial sites, catches were highest in Semi 5, then Semi 1 then Semi 4, then Semi 2, then Semi 3 and lowest in Semi 6. In the non-alluvial sites, overall average catches of carabids were not as high as in A1, A6 or A7. There were generally low catches in the old growth sites.

Table 20 shows that there were much higher catches in the riparian buffers of A3 and A4 than the younger stands adjacent to these buffers, and that overall average catch was higher in A4 (immature site) than in A3 (clearcut). Similar patterns were seen in the semi-alluvial buffers, where catches were also much higher than in the adjoining clearcuts of Semi 1, 3, 5 and 6 (Table 21).

Table 5. Total number of carabids caught during 2008 in alluvial Sites (all locations pooled). Species are listed in order of abundance.

Species Name	Sum Of Count	A1	A2	A3	A4	A5	A6	A7
Pterostichus crenicollis	2844	351	427	348	444	289	699	286
Scaphinotus angusticollis	520	208	6	46	27	67	104	62
Pterostichus algidus	222	68			2		147	5
Pterostichus lama	117	7	8	6	7	34	43	12
Cychrus tuberculatus	80	33	11	4	1	11	11	9
Scaphinotus marginatus	49	4	5	3	9	5	11	12
Zacotus matthewsii	38	38						
Agonum affine	12			12				
Pterostichus amethystinus	9	4	1			3	1	
Scaphinotus angulatus	6		4	1	1			
Pterostichus herculaneus	3	2	1					
Leistus ferruginosus	2	2						
Pterostichus pumilus pumilus	2		2					
Agonum ferruginosum	1				1			
Scaphinotus larvae	1						1	
TOTAL	**3906**	**717**	**465**	**420**	**492**	**409**	**1017**	**386**

Table 6. Total number of carabids caught during 2008 in semi-alluvial Sites (all locations pooled). Species are listed in order of abundance.

Species Name	Sum Of Count	Semi 1	Semi 2	Semi 3	Semi 4	Semi 5	Semi 6
Pterostichus crenicollis	782	137	98	55	38	410	44
Scaphinotus angusticollis	510	67	91	96	147	56	53
Pterostichus lama	71	20	24	6	5	2	14
Cychrus tuberculatus	65	8	15	7	13	13	9
Pterostichus algidus	42	19	1	6	15	1	
Scaphinotus marginatus	36	3	2	13	7	11	
Pterostichus amethystinus	13	4		3	3	2	1
Scaphinotus angulatus	7	1		3	2		1
Pterostichus pumilus pumilus	4			1			3
Omus dejeani	3		3				
Pterostichus protractus	3	3					
Scaphinotus larvae	3	2	1				

Amara littoralis	1	1					
Broscoderus insignus	1		1				
Pterostichus herculaneus	1					1	
TOTAL	**1542**	**265**	**236**	**190**	**230**	**496**	**125**

Table 7. Total number of carabids caught during 2008 in non-alluvial sites. Species are listed in order of abundance.

Species Name	Sum Of Count	NA1	NA2	NA3
Pterostichus crenicollis	930	308	215	407
Pterostichus lama	490	230	62	198
Pterostichus algidus	284	8	149	127
Scaphinotus angusticollis	251	136	55	60
Cychrus tuberculatus	55	27	5	23
Agonum piceolum	25			25
Pterostichus amethystinus	11	3	5	3
Pterostichus herculaneus	11	1	10	
Leistus ferruginosus	9		3	6
Omus dejeani	8			8
Scaphinotus marginatus	8	2	3	3
Harpalus cordifer	2			2
Scaphinotus angulatus	2	2		
Scaphinotus larvae	2			2
TOTAL	**2088**	**717**	**507**	**864**

Table 8. Total number of carabids caught during 2008 in old-growth sites. Species are listed in order of abundance.

Species Name	Sum Of Count	R1	R2
Pterostichus crenicollis	431	215	216
Scaphinotus angusticollis	176	145	31
Pterostichus lama	41	37	4
Zacotus matthewsii	30	24	6
Cychrus tuberculatus	21	13	8
Pterostichus algidus	8	6	2
Pterostichus amethystinus	5	3	2
Scaphinotus marginatus	5	4	1

Pterostichus pumilus pumilus	3	3	
Pterostichus herculaneus	2	1	1
TOTAL	**722**	**451**	**271**

Table 9. Abundance Data for carabid species at all sites (species are listed in order of abundance). Alluvial sites are A1-A7, semi-alluvial sites are Semi 1-6, non-alluvial sites are NA1-NA3. Old growth control riparian sites are R1 and R2.

Species Name	Sum	A1	A2	A3	A4	A5	A6	A7	Semi 1	Semi 2	Semi 3	Semi 4	Semi 5	Semi 6	NA1	NA2	NA3	R1	R2
Pterostichus crenicollis	4987	351	427	348	444	289	699	286	137	98	55	38	410	44	308	215	407	215	216
Scaphinotus angusticollis	1457	208	6	46	27	67	104	62	67	91	96	147	56	53	136	55	60	145	31
Pterostichus lama	719	7	8	6	7	34	43	12	20	24	6	5	2	14	230	62	198	37	4
Pterostichus algidus	556	68			2		147	5	19	1	6	15	1		8	149	127	6	2
Cychrus tuberculatus	221	33	11	4	1	11	11	9	8	15	7	13	13	9	27	5	23	13	8
Scaphinotus marginatus	98	4	5	3	9	5	11	12	3	2	13	7	11		2	3	3	4	1
Zacotus matthewsii	68	38																24	6
Pterostichus amethystinus	38	4	1			3	1		4		3	3	2	1	3	5	3	3	2
Agonum piceolum	25																25		
Pterostichus herculaneus	17	2	1										1		1	10		1	1
Scaphinotus angulatus	15		4	1	1				1		3	2		1	2				
Agonum affine	12			12															
Leistus ferruginosus	11	2														3	6		
Omus dejeani	11									3							8		
Pterostichus pumilus pumilus	9		2								1			3				3	
Scaphinotus larvae	6						1		2	1							2		
Pterostichus protractus	3								3										
Harpalus cordifer	2																2		
Agonum ferruginosum	1				1														

Amara littoralis	1								1										
Broscoderus insignus	1									1									
TOTAL	**8258**	**717**	**465**	**420**	**492**	**409**	**1017**	**386**	**265**	**236**	**190**	**230**	**496**	**125**	**717**	**507**	**864**	**451**	**271**

Table 10. Abundance Data for carabid species in alluvial sites with adjacent clearcuts. "In" catches are from riparian buffers, while "Out" catches are from the younger forest (A3) or clearcut (A4) adjacent to buffers. (Species are listed in order of abundance).

Species Name	Sum	A3In	A3Out	A4In	A4Out
Pterostichus crenicollis	792	334	14	360	84
Scaphinotus angusticollis	73	46	0	26	1
Pterostichus lama	13	4	2	3	4
Agonum affine	12	2	10	0	0
Scaphinotus marginatus	12	3	0	8	1
Cychrus tuberculatus	5	4	0	0	1
Pterostichus algidus	2	0	0	2	0
Scaphinotus angulatus	2	1	0	1	0
Agonum ferruginosum	1	0	0	0	1
TOTAL	**912**	**394**	**26**	**400**	**92**

Table 11. Abundance Data for carabid species in semi-alluvial sites with adjacent clearcuts. "In" catches are from riparian buffers, while "Out" catches are from the cut area adjacent to buffers. (Species are listed in order of abundance).

Species Name	Sum	Semi 1 In	Semi 1 Out	Semi 3 In	Semi 3 Out	Semi 5 In	Semi 5 Out	Semi 6 In	Semi 6 Out
Pterostichus crenicollis	646	103	34	44	11	394	16	39	5
Scaphinotus angusticollis	272	55	12	84	12	56	0	51	2
Pterostichus lama	42	15	5	6	0	2	0	0	14
Cychrus tuberculatus	37	6	2	2	5	9	4	8	1
Scaphinotus marginatus	27	3	0	13	0	11	0	0	0
Pterostichus algidus	26	2	17	1	5	0	1	0	0
Pterostichus amethystinus	10	1	3	0	3	2	0	1	0
Scaphinotus angulatus	5	1	0	3	0	0	0	1	0
Pterostichus pumilus pumilus	4	0	0	0	1	0	0	0	3

Pterostichus protractus	3	1	2	0	0	0	0	0	0
Scaphinotus larvae	2	1	1	0	0	0	0	0	0
Amara littoralis	1	0	1	0	0	0	0	0	0
Pterostichus herculaneus	1	0	0	0	0	0	1	0	0
TOTAL	**1076**	**188**	**77**	**153**	**37**	**474**	**22**	**100**	**25**

Table 12. Proportion of each species of carabid caught during 2008 in alluvial Sites (all locations pooled). Species are listed in order of abundance.

Species Name	A1	A2	A3	A4	A5	A6	A7
Pterostichus crenicollis	**0.490**	**0.918**	**0.829**	**0.902**	**0.707**	**0.687**	**0.741**
Scaphinotus angusticollis	**0.290**	0.013	**0.110**	0.055	**0.164**	**0.102**	**0.161**
Pterostichus algidus	0.095	0.000	0.000	0.004	0.000	**0.145**	0.013
Pterostichus lama	0.010	0.017	0.014	0.014	0.083	0.042	0.031
Cychrus tuberculatus	0.046	0.024	0.010	0.002	0.027	0.011	0.023
Scaphinotus marginatus	0.006	0.011	0.007	0.018	0.012	0.011	0.031
Zacotus matthewsii	0.053	0.000	0.000	0.000	0.000	0.000	0.000
Agonum affine	0.000	0.000	0.029	0.000	0.000	0.000	0.000
Pterostichus amethystinus	0.006	0.002	0.000	0.000	0.007	0.001	0.000
Scaphinotus angulatus	0.000	0.009	0.002	0.002	0.000	0.000	0.000
Pterostichus herculaneus	0.003	0.002	0.000	0.000	0.000	0.000	0.000
Leistus ferruginosus	0.003	0.000	0.000	0.000	0.000	0.000	0.000
Pterostichus pumilus pumilus	0.000	0.004	0.000	0.000	0.000	0.000	0.000
Agonum ferruginosum	0.000	0.000	0.000	0.002	0.000	0.000	0.000
Scaphinotus larvae	0.000	0.000	0.000	0.000	0.000	0.001	0.000

Table 13. Proportion of each species of carabid caught during 2008 in semi-alluvial Sites (all locations pooled). Species are listed in order of abundance.

Species Name	Semi 1	Semi 2	Semi 3	Semi 4	Semi 5	Semi 6
Pterostichus crenicollis	**0.517**	**0.415**	**0.289**	**0.165**	**0.827**	**0.352**
Scaphinotus angusticollis	**0.253**	**0.386**	**0.505**	**0.639**	**0.113**	**0.424**
Pterostichus lama	0.075	0.102	0.032	0.022	0.004	0.112
Cychrus tuberculatus	0.030	0.064	0.037	0.057	0.026	0.072
Pterostichus algidus	0.072	0.004	0.032	0.065	0.002	0.000

Scaphinotus marginatus	0.011	0.008	0.068	0.030	0.022	0.000
Pterostichus amethystinus	0.015	0.000	0.016	0.013	0.004	0.008
Scaphinotus angulatus	0.004	0.000	0.016	0.009	0.000	0.008
Pterostichus pumilus pumilus	0.000	0.000	0.005	0.000	0.000	0.024
Omus dejeani	0.000	0.013	0.000	0.000	0.000	0.000
Pterostichus protractus	0.011	0.000	0.000	0.000	0.000	0.000
Scaphinotus larvae	0.008	0.004	0.000	0.000	0.000	0.000
Amara littoralis	0.004	0.000	0.000	0.000	0.000	0.000
Broscoderus insignus	0.000	0.004	0.000	0.000	0.000	0.000
Pterostichus herculaneus	0.000	0.000	0.000	0.000	0.002	0.000

Table 14. Proportion of each species of carabid caught during 2008 in non-alluvial sites. Species are listed in order of abundance.

Species Name	NA1	NA2	NA3
Pterostichus crenicollis	**0.430**	**0.424**	**0.471**
Pterostichus lama	**0.321**	**0.122**	**0.229**
Pterostichus algidus	0.011	**0.294**	**0.147**
Scaphinotus angusticollis	**0.190**	**0.108**	0.069
Cychrus tuberculatus	0.038	0.010	0.027
Agonum piceolum	0.000	0.000	0.029
Pterostichus amethystinus	0.004	0.010	0.003
Pterostichus herculaneus	0.001	0.020	0.000
Leistus ferruginosus	0.000	0.006	0.007
Omus dejeani	0.000	0.000	0.009
Scaphinotus marginatus	0.003	0.006	0.003
Harpalus cordifer	0.000	0.000	0.002
Scaphinotus angulatus	0.003	0.000	0.000
Scaphinotus larvae	0.000	0.000	0.002

Table 15. Proportion of each species of carabid caught during 2008 in old-growth sites. Species are listed in order of abundance.

Species Name	R1	R2
Pterostichus crenicollis	**0.477**	**0.797**
Scaphinotus angusticollis	**0.202**	**0.114**
Pterostichus lama	0.052	0.015

Zacotus matthewsii	0.033	0.022
Cychrus tuberculatus	0.018	0.030
Pterostichus algidus	0.008	0.007
Pterostichus amethystinus	0.004	0.007
Scaphinotus marginatus	0.006	0.004
Pterostichus pumilus pumilus	0.004	0.000
Pterostichus herculaneus	0.001	0.004

Table 16. Mean monthly abundance (with standard errors) for each carabid species caught in alluvial sites.

Species Name	A1		A2		A3		A4		A5		A6		A7	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Agonum affine	0.000	0.000	0.000	0.000	0.231	0.099	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Agonum ferruginosum	0.000	0.000	0.000	0.000	0.000	0.000	0.021	0.014	0.000	0.000	0.000	0.000	0.000	0.000
Cychrus tuberculatus	0.472	0.210	0.207	0.097	0.043	0.039	0.021	0.015	0.158	0.047	0.158	0.066	0.375	0.080
Leistus ferruginosus	0.042	0.042	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pterostichus algidus	**1.250**	0.810	0.000	0.000	0.000	0.000	0.028	0.036	0.000	0.000	**2.059**	0.971	0.208	0.208
Pterostichus amethystinus	0.056	0.039	0.019	0.019	0.000	0.000	0.000	0.000	0.044	0.044	0.014	0.014	0.000	0.000
Pterostichus crenicollis	**5.493**	1.351	**8.060**	0.759	**3.938**	0.459	**6.117**	1.120	**4.198**	1.152	**9.898**	1.356	**11.917**	0.843
Pterostichus herculaneus	0.028	0.028	0.020	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pterostichus lama	0.104	0.024	0.153	0.052	0.090	0.040	0.127	0.028	0.491	0.087	0.610	0.230	0.500	0.000
Pterostichus pumilus pumilus	0.000	0.000	0.037	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Scaphinotus angulatus	0.000	0.000	0.074	0.074	0.010	0.014	0.014	0.018	0.000	0.000	0.000	0.000	0.000	0.000
Scaphinotus angusticollis	**3.625**	1.743	0.111	0.111	0.479	0.639	0.369	0.370	0.984	0.626	**1.448**	1.221	**2.583**	1.709
Scaphinotus larvae	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.014	0.014	0.000	0.000
Scaphinotus marginatus	0.076	0.059	0.094	0.037	0.031	0.042	0.136	0.139	0.073	0.015	0.154	0.061	0.500	0.354
Zacotus matthewsii	0.688	0.414	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	11.833		**8.773**		**4.823**		**6.833**		**5.947**		**14.355**		**16.083**	

Table 17. Mean monthly abundance (with standard errors) for each carabid species caught in semi-alluvial sites.

Species Name	Semi 1		Semi 2		Semi 3		Semi 4		Semi 5		Semi 6	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Amara littoralis	0.025	0.016	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Broscoderus insignus	0.000	0.000	0.014	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cychrus tuberculatus	0.109	0.045	0.208	0.114	0.125	0.039	0.193	0.108	0.198	0.118	0.110	0.030
Omus dejeani	0.000	0.000	0.042	0.042	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pterostichus algidus	0.375	0.175	0.014	0.014	0.138	0.038	0.209	0.138	0.021	0.016	0.000	0.000
Pterostichus amethystinus	0.073	0.032	0.000	0.000	0.075	0.044	0.042	0.042	0.023	0.029	0.010	0.014
Pterostichus crenicollis	**1.811**	0.310	**1.361**	0.296	0.728	0.081	0.554	0.109	**4.777**	1.552	0.521	0.144
Pterostichus herculaneus	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.021	0.015	0.000	0.000
Pterostichus lama	0.274	0.049	0.333	0.173	0.065	0.070	0.070	0.026	0.022	0.018	0.292	0.080
Pterostichus protractus	0.052	0.042	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Pterostichus pumilus pumilus	0.000	0.000	0.000	0.000	0.031	0.016	0.000	0.000	0.000	0.000	0.063	0.047
Scaphinotus angulatus	0.011	0.016	0.000	0.000	0.031	0.044	0.033	0.020	0.000	0.000	0.013	0.016
Scaphinotus angusticollis	0.828	0.595	**1.264**	0.580	**1.203**	0.938	**2.178**	0.808	0.688	0.670	**0.654**	0.585
Scaphinotus larvae	0.031	0.028	0.014	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Scaphinotus marginatus	0.031	0.042	0.028	0.028	0.135	0.191	0.097	0.097	0.138	0.172	0.000	0.000
	3.620		**3.278**		**2.532**		**3.376**		**5.886**		**1.663**	

Table 18. Mean monthly abundance (with standard errors) for each carabid species caught in non-alluvial sites.

Species Name	NA1		NA2		NA3	
	Mean	SE	Mean	SE	Mean	SE
Agonum piceolum	0.000	0.000	0.000	0.000	0.391	0.174
Cychrus tuberculatus	0.431	0.189	0.075	0.046	0.344	0.090
Harpalus cordifer	0.000	0.000	0.000	0.000	0.029	0.017
Leistus ferruginosus	0.000	0.000	0.042	0.042	0.100	0.100
Omus dejeani	0.000	0.000	0.000	0.000	0.122	0.083
Pterostichus algidus	0.111	0.075	**2.104**	1.256	**1.873**	0.877
Pterostichus amethystinus	0.049	0.029	0.075	0.034	0.042	0.042
Pterostichus crenicollis	**4.674**	1.016	**3.235**	0.136	**5.906**	1.530
Pterostichus herculaneus	0.014	0.014	0.141	0.065	0.000	0.000
Pterostichus lama	**3.535**	0.728	0.902	0.290	**2.869**	0.786
Scaphinotus angulatus	0.028	0.028	0.000	0.000	0.000	0.000
Scaphinotus angusticollis	1.958	0.722	0.792	0.560	0.878	0.788
Scaphinotus larvae	0.000	0.000	0.000	0.000	0.029	0.029
Scaphinotus marginatus	0.028	0.016	0.042	0.042	0.044	0.044
	10.826		**7.406**		**12.626**	

Table 19. Mean monthly abundance (with standard errors) for each carabid species caught in old-growth sites.

Species Name	R1		R2	
	Mean	SE	Mean	SE
Cychrus tuberculatus	0.194	0.081	0.111	0.051
Pterostichus algidus	0.089	0.038	0.028	0.028

Pterostichus amethystinus	0.044	0.027	0.031	0.031
Pterostichus crenicollis	**3.228**	0.782	**3.108**	0.753
Pterostichus herculaneus	0.017	0.017	0.016	0.016
Pterostichus lama	0.558	0.253	0.057	0.023
Pterostichus pumilus pumilus	0.044	0.015	0.000	0.000
Scaphinotus angusticollis	**2.042**	1.653	0.443	0.314
Scaphinotus marginatus	0.056	0.056	0.014	0.014
Zacotus matthewsii	0.344	0.185	0.090	0.055
	6.617		**3.898**	

Table 20. Mean monthly abundance (with standard errors) for each carabid species caught in riparian buffers of sites A3 and A4 (A3In and A4In) and for clearcut of site A3 (A3out) and immature stand of site A4 (A4Out).

Species Name	A3In		A3Out		A4In		A4Out	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Agonum affine	0.045	0.045	0.417	0.250	0.000	0.000	0.000	0.000
Agonum ferruginosum	0.000	0.000	0.000	0.000	0.000	0.000	0.042	0.042
Cychrus tuberculatus	0.085	0.059	0.000	0.000	0.000	0.000	0.042	0.042
Pterostichus algidus	0.000	0.000	0.000	0.000	0.056	0.056	0.000	0.000
Pterostichus crenicollis	**7.242**	0.645	0.633	0.193	**8.325**	1.869	**3.908**	1.602
Pterostichus lama	0.089	0.037	0.092	0.053	0.071	0.024	0.183	0.069
Scaphinotus angulatus	0.021	0.021	0.000	0.000	0.028	0.028	0.000	0.000
Scaphinotus angusticollis	0.958	0.958	0.000	0.000	0.696	0.585	0.042	0.042
Scaphinotus marginatus	0.063	0.063	0.000	0.000	0.222	0.222	0.050	0.050
TOTAL	**8.504**		**1.142**		**9.398**		**4.267**	

Table 21. Mean monthly abundance (with standard errors) for each carabid species caught in riparian buffers of sites Semi 1 Semi 3, Semi 5 and Semi 6 (Semi1In, Semi3In, Semi5In, Semi6In) and for adjacent clearcuts (Semi1Out, Semi3Out, Semi5Out, Semi6Out).

Species Name	Semi 1 In		Semi 1 Out		Semi 3 In		Semi 3 Out		Semi 5 In		Semi 5 Out		Semi 6 In		Semi 6 Out	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Amara littoralis	0.000	0.000	0.050	0.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cychrus	0.127	0.053	0.092	0.053	0.042	0.042	0.208	0.125	0.195	0.113	0.200	0.141	0.179	0.045	0.042	0.042

tuberculatus																
Pterostichus algidus	0.042	0.024	0.708	0.497	0.021	0.021	0.254	0.126	0.000	0.000	0.042	0.042	0.000	0.000	0.000	0.000
Pterostichus amethystinus	0.021	0.021	0.125	0.080	0.000	0.000	0.150	0.150	0.045	0.045	0.000	0.000	0.021	0.021	0.000	0.000
Pterostichus crenicollis	2.180	0.447	1.442	0.443	0.969	0.153	0.488	0.183	8.771	2.091	0.783	0.356	0.833	0.226	0.208	0.105
Pterostichus herculaneus	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.042	0.042	0.000	0.000	0.000	0.000
Pterostichus lama	0.314	0.091	0.233	0.145	0.129	0.099	0.000	0.000	0.044	0.025	0.000	0.000	0.000	0.000	0.583	0.220
Pterostichus protractus	0.021	0.021	0.083	0.083	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pterostichus pumilus pumilus	0.000	0.000	0.000	0.000	0.000	0.000	0.063	0.063	0.000	0.000	0.000	0.000	0.000	0.000	0.125	0.125
Scaphinotus angulatus	0.023	0.023	0.000	0.000	0.063	0.063	0.000	0.000	0.000	0.000	0.000	0.000	0.025	0.025	0.000	0.000
Scaphinotus angusticollis	1.155	0.643	0.500	0.500	1.807	1.069	0.600	0.600	1.375	1.078	0.000	0.000	1.225	0.892	0.083	0.083
Scaphinotus larvae	0.021	0.021	0.042	0.042	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Scaphinotus marginatus	0.063	0.063	0.000	0.000	0.271	0.271	0.000	0.000	0.275	0.275	0.000	0.000	0.000	0.000	0.000	0.000
Total	**3.966**		**3.275**		**3.301**		**1.763**		**10.706**		**1.067**		**2.283**		**1.042**	

5.2.1.2 Biomass Data

The body lengths of all the carabids were measured to estimate biomass (mg dry weight) using regression equations given in the literature (Jarosik, 1989). Using yearly average catches, the average biomass in mg collected in each site by treatment (Table 22) and for each treatment/location combination within sites (Table 23) could be estimated. Larger carabids such as *Cychrus tuberculatus*, *Omus dejeani*, *Pterostichus lama*, and the *Scaphinotus* genus had the highest biomass, and thus abundance of these species would affect overall biomass in any one location.

Highest biomass was noted in the non-alluvial sites, then the alluvial sites, and lowest average biomass for the season was seen in the semi-alluvial sites (Table 22). Biomass of the "out" locations, which are the clearcuts or immature sites was always much lower than that for the "in" traps, which are the riparian buffers (Table 23).

Tables 24-27 show the proportion of the biomass made up by the species within any one site. Each of these tables is accompanied by a pie chart where *P. crenicollis* is coded as turquoise, *S. angusticollis* as dark green, and *P. lama* as brown. For the alluvial sites, it is apparent that the bulk of the biomass can be attributed to *P. crenicollis*, followed by *S. angusticollis*, and then *P. lama* except for in site A1, where *S. angusticollis* and then *P. crenicollis*, then *Zacotus matthewsii*, and then *P. lama*, made up the highest proportion of biomass. O verall, for all alluvial sites, an average of 70% of the biomass was made up of *P. crenicollis*, 18% by *S. angusticollis*, and 7% by *P. lama*.

Patterns in the the semi-alluvial sites differed somewhat: In Semi 1, most biomass was made up by *P. crenicollis*, *S. angusticollis*, *P algidus* and then *P. lama*, in Semi 2, most was made up of *P. crenicollis, S. angusticollis*, and then *P. lama*; in Semi 3 and Semi 4, most was made up of *S. angusticollis* and then *P. crenicollis*, while in Semi 5 the order was *S. angusticollis*, then *P. crenicollis* then *P. lama*; finally the biomass in Semi 6 was made up of similar proportions of both *S. angusticollis* and *P. crenicollis* and then *P. lama*. Overall in the semi alluvial sites, an average of 42% of the biomass was made up by *P. crenicollis*, and 38% by *S. angusticollis*.

In the non-alluvial sites, most of the biomass in sites NA1 and NA3 was made up by *P. lama*, followed by *P. crenicollis*, and *S. angusticollis*, while in NA2 the order was *P. crenicollis, P. lama, S. angusticollis* and then *P. algidus*. Overall in the non-alluvial sites, an average of 46% of the biomass was made up by *P. lama*, 34% by *P. crenciollis*, and 15% by *S. angusticollis*.

The patterns in the two old-growth sites differed somewhat, but overall, an average of 54% of the biomass was made up by *P. crenicollis*, 28% by *S. angusticollis*, and 11% by *P. lama*.

Table 22. Average Biomass by Treatment for each of the alluvial, semi-alluvial and non-alluvial sites.

Site	A1	A3	A4	A5	A2	A6	A7	AVERAGE BIOMASS FOR ALL ALLUVIAL SITES (mg)
Average Biomass(mg)	886.939	321.636	454.845	475.746	578.499	968.65	1177.35	**694.809**
Site	Semi 1	Semi 2	Semi 3	Semi 4	Semi 5	Semi 6		
Average Biomass(mg)	278.88	307.07	214.67	316.89	405.05	169.06		**281.937**
Site	NA1	NA2	NA3					
Average Biomass(mg)	1179.87	526.474	1075.29					**927.214**
Site	R1	R2						
Average Biomass(mg)	568.676	272.142						**420.409**

Table 23. Average Biomass by Treatment/Location for semi-alluvial and alluvial sites.

Site	Semi 1 In	Semi 1 Out	Semi 3 In	Semi 3 Out	Semi 5 In	Semi 5 Out	Semi 6 In	Semi 6 Out
Average Biomass(mg)	336.78	220.99	299.80	129.54	737.15	72.95	206.53	131.59
Site	A3 In	A3 Out	A4 In	A4 Out				
Average Biomass(mg)	586.44	56.84	621.82	287.87				

Table 24. Proportion of the average monthly biomass made up by each species caught in the alluvial sites.

Species Name	A 1	A 2	A 3	A 4	A 5	A 6	Average
Agonum affine	0.00	0.18	0.00	0.00	0.00	0.00	0.03
Agonum ferruginosum	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Cychrus tuberculatus	5.63	1.40	0.48	3.50	3.78	1.72	2.75
Leistus ferruginosus	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Pterostichus algidus	4.27	0.00	0.19	0.00	0.00	6.44	1.82
Pterostichus amethystinus	0.13	0.00	0.00	0.19	0.07	0.03	0.07
Pterostichus crenicollis	**38.80**	**76.70**	**84.25**	**55.28**	**87.29**	**64.02**	**67.72**
Pterostichus herculaneus	0.11	0.00	0.00	0.00	0.12	0.00	0.04
Pterostichus lama	**2.06**	**4.94**	**4.92**	**18.14**	**4.63**	**11.07**	**7.63**
Pterostichus pumilus pumilus	0.00	0.00	0.00	0.00	0.13	0.00	0.02
Scaphinotus angulatus	0.00	0.34	0.32	0.00	1.32	0.00	0.33
Scaphinotus angusticollis	**44.16**	**16.10**	**8.77**	**22.34**	**2.08**	**16.15**	**18.26**
Scaphinotus marginatus	0.31	0.35	1.07	0.54	0.58	0.57	0.57
Zacotus matthewsii	**4.51**	0.00	0.00	0.00	0.00	0.00	0.75

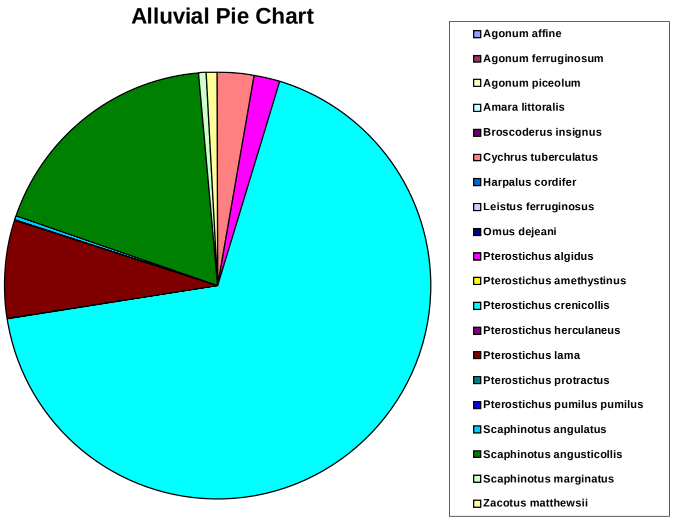


Table 25. Proportion of the average monthly biomass made up by each species caught in the semi-alluvial sites.

Species Name	Semi 1	Semi 2	Semi 3	Semi 4	Semi 5	Semi 6	Average
Amara littoralis	0.70	0.00	0.00	0.00	0.00	0.00	0.12
Broscoderus insignus	0.00	0.43	0.00	0.00	0.00	0.00	0.07
Cychrus tuberculatus	3.04	6.38	4.94	5.71	3.36	6.64	5.01
Omus dejeani	0.00	1.28	0.00	0.00	0.00	0.00	0.21
Pterostichus algidus	**10.45**	0.43	5.43	6.19	0.35	0.00	3.81
Pterostichus amethystinus	2.03	0.00	2.96	1.23	0.39	0.63	1.21
Pterostichus crenicollis	**50.45**	**41.70**	**28.77**	**16.40**	**81.16**	**31.33**	**41.63**
Pterostichus herculaneus	0.00	0.00	0.00	0.00	0.35	0.00	0.06
Pterostichus lama	**7.63**	**10.21**	2.55	2.08	0.37	**17.54**	6.73
Pterostichus protractus	1.45	0.00	0.00	0.00	0.00	0.00	0.24
Pterostichus pumilus pumilus	0.00	0.00	1.23	0.00	0.00	3.76	0.83
Scaphinotus angulatus	0.32	0.00	1.23	0.98	0.00	0.75	0.55
Scaphinotus angusticollis	**23.06**	**38.72**	**47.53**	**64.52**	**11.68**	**39.35**	**37.48**
Scaphinotus marginatus	0.87	0.85	5.35	2.88	2.34	0.00	2.05

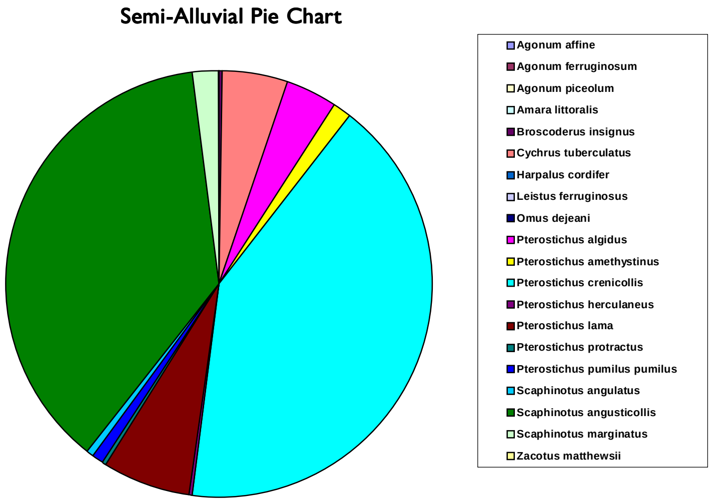


Table 26. Proportion of the average monthly biomass made up by each species caught in the non-alluvial sites.

Species Name	NA1	NA2	NA3	Average
Agonum piceolum	0.00	0.00	0.11	0.04
Cychrus tuberculatus	3.86	1.50	3.92	3.09
Harpalus cordifer Notman	0.00	0.00	0.01	0.00
Leistus ferruginosus	0.00	0.02	0.03	0.02
Omus dejeani	0.00	0.00	1.00	0.33
Pterostichus algidus	0.29	**12.11**	6.12	6.17
Pterostichus amethystinus	0.09	0.30	0.09	0.16
Pterostichus crenicollis	**24.82**	**38.50**	**39.90**	**34.41**
Pterostichus herculaneus	0.04	0.94	0.00	0.33
Pterostichus lama	**52.65**	**30.10**	**54.39**	**45.71**
Scaphinotus angulatus	0.24	0.00	0.00	0.08
Scaphinotus angusticollis	**17.93**	**16.25**	**10.23**	**14.80**
Scaphinotus marginatus	0.08	0.28	0.17	0.18

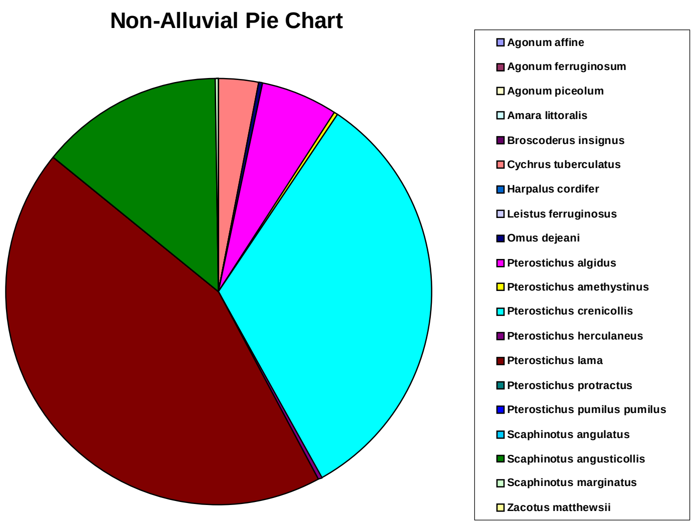
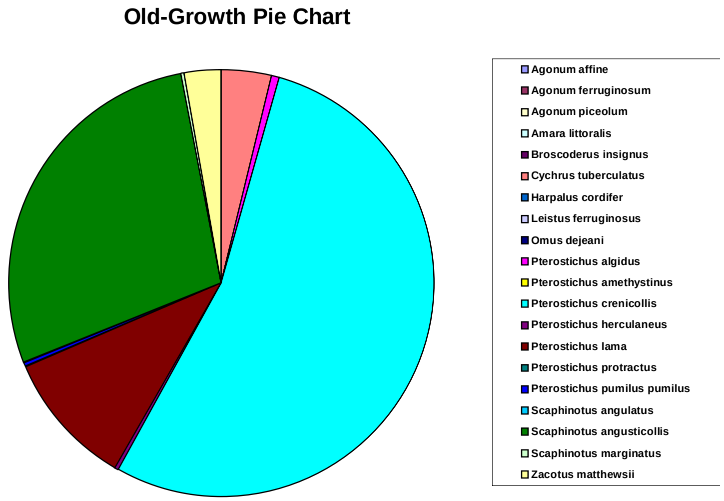


Table 27. Proportion of the average monthly biomass made up by each species caught in the old-growth sites.

Species Name	R1	R2	Average
Cychrus tuberculatus	3.62	4.32	3.97
Pterostichus algidus	0.47	0.31	0.39
Pterostichus amethystinus	0.16	0.24	0.20
Pterostichus crenicollis	**35.56**	**71.54**	**53.55**
Pterostichus herculaneus	0.10	0.20	0.15
Pterostichus lama	**17.26**	**3.70**	**10.48**
Pterostichus pumilus pumilus	0.16	0.00	0.08
Scaphinotus angusticollis	**38.79**	**17.58**	**28.18**
Scaphinotus marginatus	0.35	0.18	0.26
Zacotus matthewsii	3.53	1.93	2.73



5.2.2 Analysis of temporal trends

Overall catches of carabids cannot be compared among sites due to different trapping intensity, but can be compared over the summer within any one treatment or treatment/location, since trapping intensity did not differ over the course of the season.

Patterns in monthly catches varied among sites. In the alluvial sites A1, A4, A6, catches increased each month between June and September, with peak catches in the fall (Table 28). In A2, catches were highest in July, and in A3 were highest in July and September, and in A5 were highest in August. The sites with peaks in September had generally higher proportions of *S. angusticollis*, which is usually most abundant in the fall. In the semi-alluvial sites, highest catches were recorded in Semi 1, Semi 2, Semi 3 and Semi 6 in September, and highest in sites Semi 4 and Semi 5 were in July (Table 29). In the non-alluvial sites NA2 and NA3, highest catches were in September, while they were in July in NA1 (Table 30). In both old growth sites, highest catches were in September. High July catches were due in part to peak catches of *P. crenicollis* in many of the sites during that month (Table 31).

When we compare the catches by treatment/location combinations (Tables 32-33), peaks in sites were generally in September for most locations

Table 28. Total carabids caught by month in each alluvial sites (all locations pooled).

Month	A1	A2	A3	A4	A5	A6	A7
6	114		82	64	78	151	81
7	125	177	123	132	83	281	86
8	208	149	88	145	146	199	91
9	270	139	127	151	102	386	128

Table 29. Total carabids caught by month in each semi-alluvial site (all locations pooled).

Month	Semi 1	Semi 2	Semi 3	Semi 4	Semi 5	Semi 6
6	34	40	22	29	72	20
7	67	59	27	59	187	28
8	44	46	24	33	117	15
9	120	91	117	109	120	62

Table 30. Total carabids caught by month in each non-alluvial site.

Month	NA1	NA2	NA3
6	125	59	81
7	261	75	197
8	165	133	292
9	166	240	294

Table 31. Total carabids caught by month in each old-growth site.

Month	R1	R2
6	40	18
7	113	85
8	87	77
9	211	91

Table 32. Total carabids caught by month in each site/location combination for alluvial sites with adjoining cut blocks.

Month	A3 In	A3 Out	A4 In	A4 Out
6	75	7	38	26
7	113	10	118	14
8	81	7	101	44
9	125	2	143	8

Table 33. Total carabids caught by month in each site/location combination for semi-alluvial sites with adjoining cut blocks.

Month	Semi 1 In	Semi 1 Out	Semi 3 In	Semi 3 Out	Semi 5 In	Semi 5 Out	Semi 6 In	Semi 6 Out
6	26	8	19	3	64	8	14	6
7	56	11	20	7	177	10	24	4
8	29	15	16	8	115	2	14	1
9	77	43	98	19	118	2	48	14

Next, temporal patterns of abundance of the most commonly captured carabid species at each site were examined. For all sites, catches of *Scaphinotus angusticollis*, *Z. matthewsii* (for alluvial and old-growth only), *P. algidus, P. lama, P. crenicollis* and *Cychrus tuberculatus* were examined (Figures 26-35). Colour coding is used such that "out" locations (clearcuts and immature sites) are coded in reds and pinks. Alluvial sites are blue, semi-alluvial purple and grey, non-alluvial are red and pinks and old-growth sites are green.

For all site types, patterns for *Scaphinotus angusticollis* were very similar, showing peaks in September for this species (Figures 26a-d). This species has been noted as a forest specialist in my previous studies (Pearsall, 2002-2007). In both the alluvial and semi-alluvial sites, it was apparent that this species was rarely caught in clearcut blocks. Abundance of this species was generally much higher in alluvial sites than in the semi-alluvial and non-alluvial sites. Highest catches of *S. angusticollis* in the semi-alluvial sites was seen in Semi 4, an intact 2nd growth site. Highest catches in the non-alluvial sites were noted in NA1. Catches were much lower in R2 than in R1, of the two old-growth sites. This former site had generally low catches of carabids overall.

Zacotus matthewsii was only caught in one of the alluvial sites, A1, where it was particularly abundant in September, and also in the two old-growth sites (Figure 27). This species also appeared to peak in September. As mentioned, this species has been identified as an old-growth specialist in previous studies.

P. algidus also peaked in September in most of the sites. Catches were generally higher in the alluvial and non-alluvial sites than in the semi-alluvial sites (Figures 28a-c). Highest catches in the alluvial sites were seen in sites A6 and A7, while in the semi-alluvial sites, peak catches were recorded in the clearcuts of Semi 1 and Semi 3. Within the non-alluvial sites, most *P. algidus* were caught in NA2 and NA3, and far fewer in NA1. Abundance of this species was low in both old-growth sites (Figure 28d). This species has exhibited a generalist habit in previous studies.

Abundance of *P. lama* was variable among sites and months of capture (Figures 29a-d). Particularly low numbers were found in the alluvial sites, semi-alluvial sites and old-growth sites. In the alluvial sites, numbers were highest in A5, A6 and A7, while in the semi-alluvial sites, peak catches were recorded in the clearcuts of Semi 1 and Semi 5. Much higher catches of *P. lama* were apparent in the non-alluvial sites, and this species was much more abundant in NA1 and NA3 than in NA2.

Catches of *P. crenicollis* were much higher in the alluvial sites than in the non-alluvial sites, except for the riparian buffer of Semi 5, where they were high, and except for in the clearcut adjacent to the alluvial riparian strips of A3., where they were particularly low (Figures 30a-d). Catches of *P. crenicollis* appeared to peak in many sites during July.

Finally, catches of *Cychrus tuberculatus* were generally low, peaking in July in most sites (Figures 31a-d).

Figures 32-35 were also produced to examine the changes in catches of *C. tuberculatus, P. lama, P, crenicollis* and *S. angusticollis* along transects as one moves out from the stream edge out of the riparian buffer into the adjoining forest.

Catches of *C. tuberculatus* showed no particular patterns across transects in any sites (Figures 32a-d). Catches of *P. lama* appeared to increase in numbers as one moved away from the stream edge in sites Semi1, Semi 2, Semi 6, NA1, NA3 and both old-growth sites (Figures 33a-d).

P. crenicollis (Figures 34a-d) showed declines in catches along transects in A3 and A4, which was not surprising, since this is a forest species and was found at low abundance in the clearcut of A3 and the immature site of A4. In both these sites, declines are seen at the edge trap 4. *P. crenicollis* was particularly abundant at the stream edge in site Semi 5, but apart from this one anomaly, abundance of this species was low in all semi-alluvial sites. Patterns are variable in the non-alluvial sites: most are found close to the stream in NA1 and NA2, but the numbers increased in NA3 with distance into the forest. In NA3, there was a strong alder component adjacent to the stream bank, which was replaced by Western Hemlock and Western Red-cedar at about trap 5. Given that *P. crenicollis* is identified as a forest species, this increase at the alder/forest boundary is not surprising. Catches of this species did not vary particularly along transects in the old-growth sites.

Finally, catches of *S. angusticollis* (Figures 35a-d) were high at the stream edge and at the end of the transect within the 2nd growth forest of A1, but catches in most other alluvial sites did not vary greatly along the transects. In all the semi-alluvial sites except for Semi 2, catches of this species generally declined with distance as one moved from the riparian buffer into the adjoining stand or clearcut. Patterns were variable in the non-alluvial and old-growth sites, except there were particularly high catches close to the stream in site NA1.

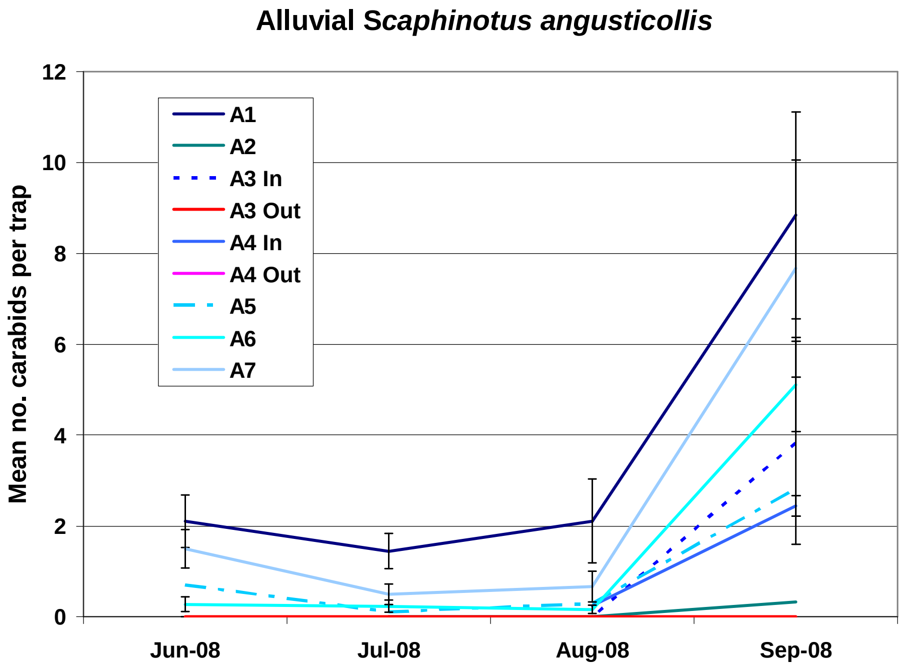


Figure 26a. Catches of *Scaphinotus angusticollis* by date in all treatments in alluvial sites.

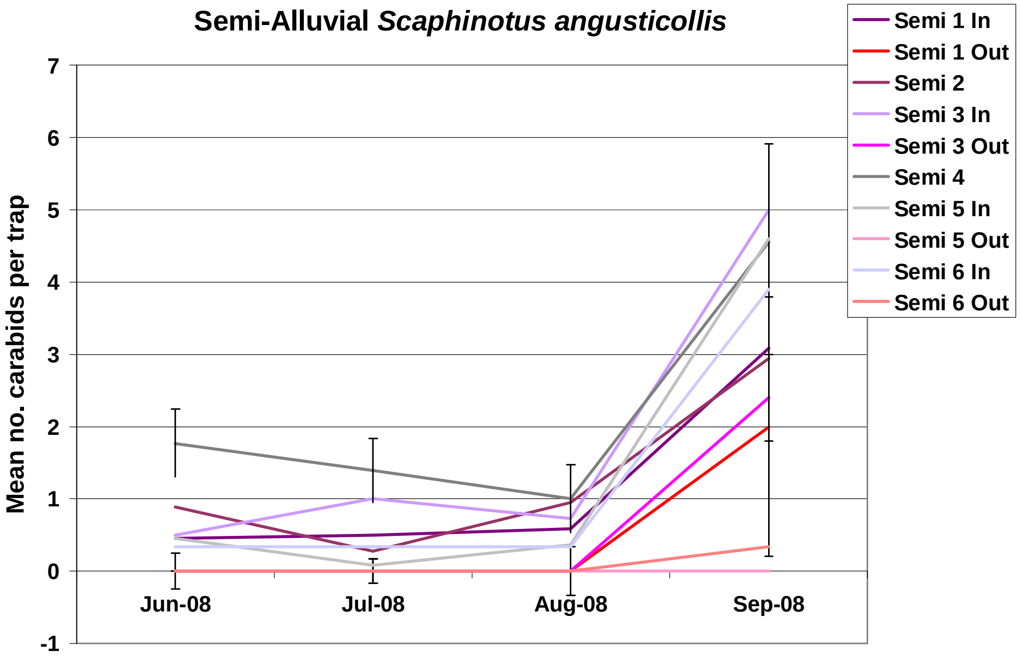


Figure 26b. Catches of *Scaphinotus angusticollis* by date in all in all treatments in semi-alluvial sites.

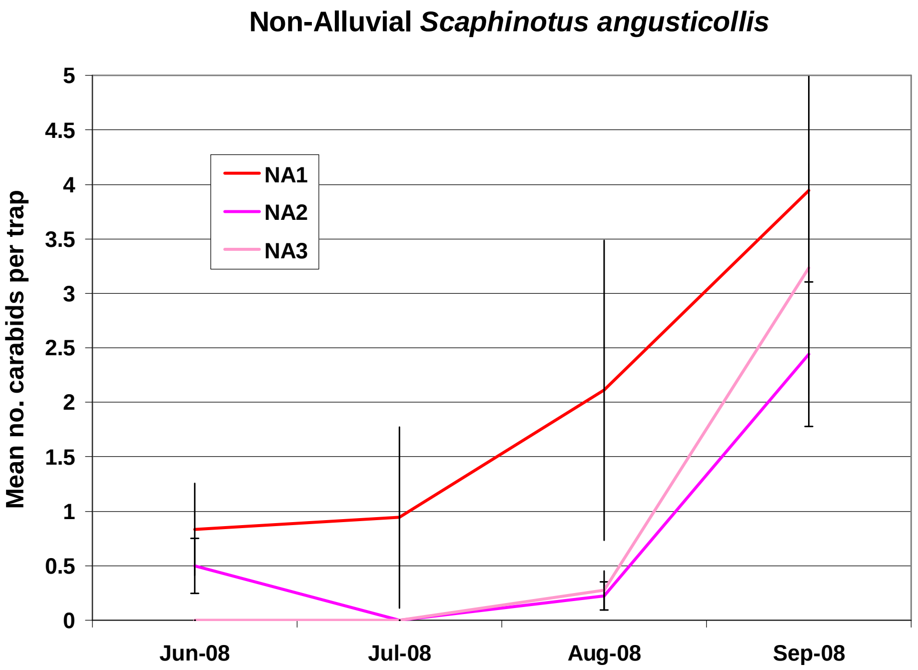


Figure 26c. Catches of *Scaphinotus angusticollis* by date in non-alluvial sites.

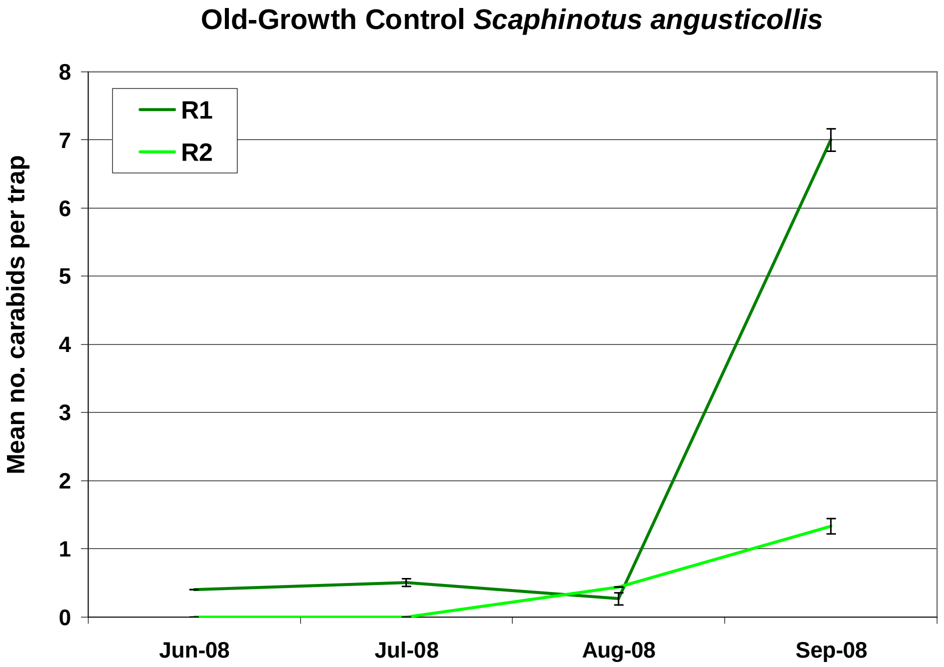


Figure 26d. Catches of *Scaphinotus angusticollis* by date in old-growth sites.

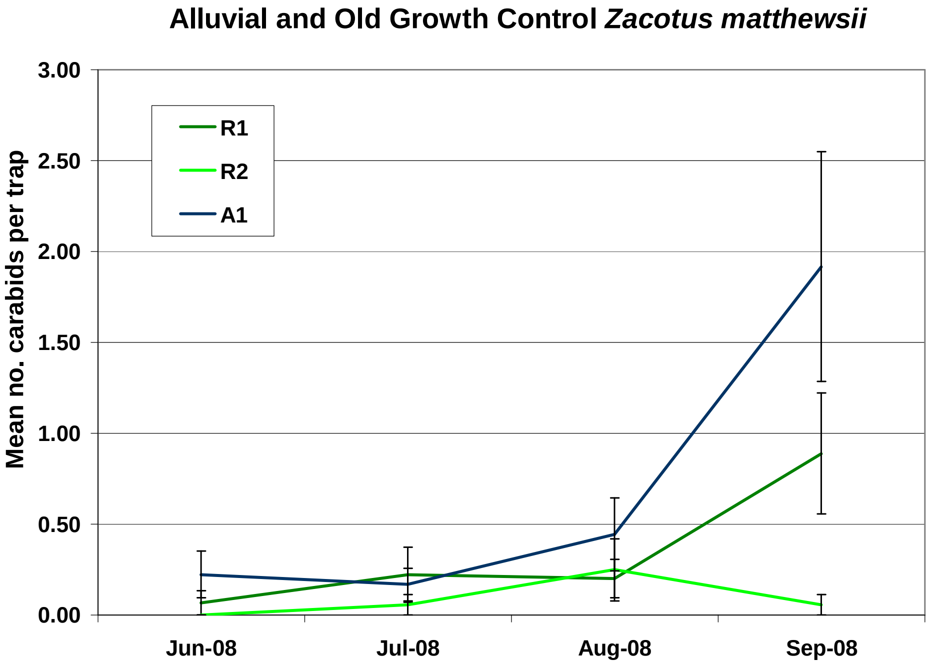


Figure 27. Catches of *Zacotus matthewsii* by date in alluvial sites A1 and both old-growth sites.

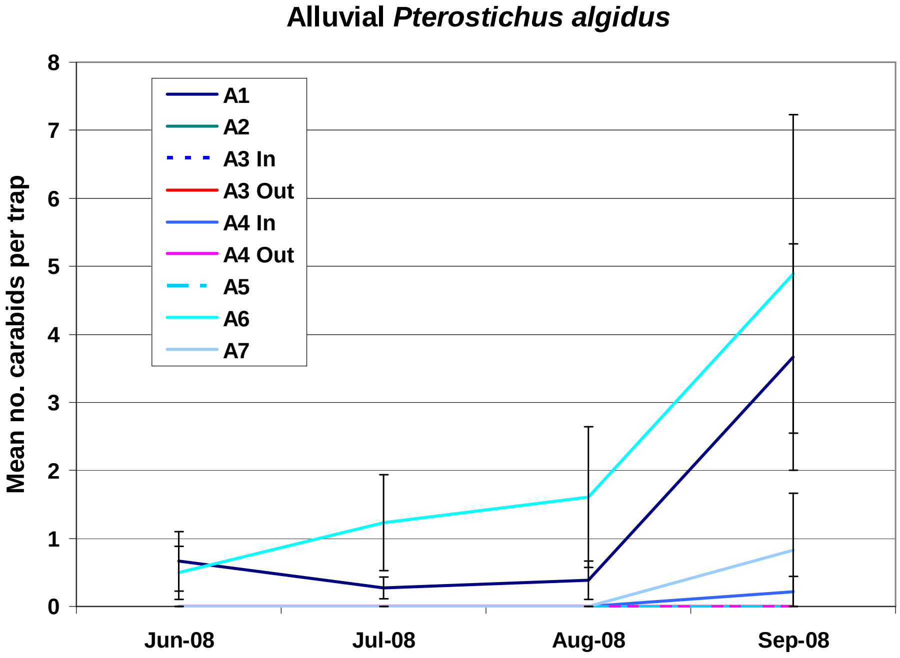


Figure 28a. Catches of *Pterostichus algidus* by date in all treatments in alluvial sites.

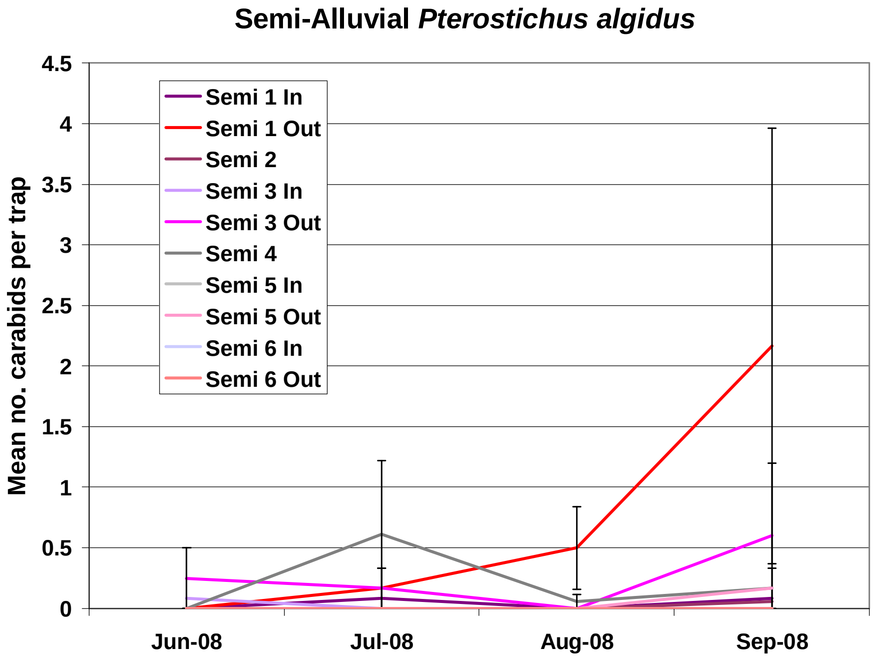


Figure 28b. Catches of *Pterostichus algidus* by date in all treatments in semi-alluvial sites.

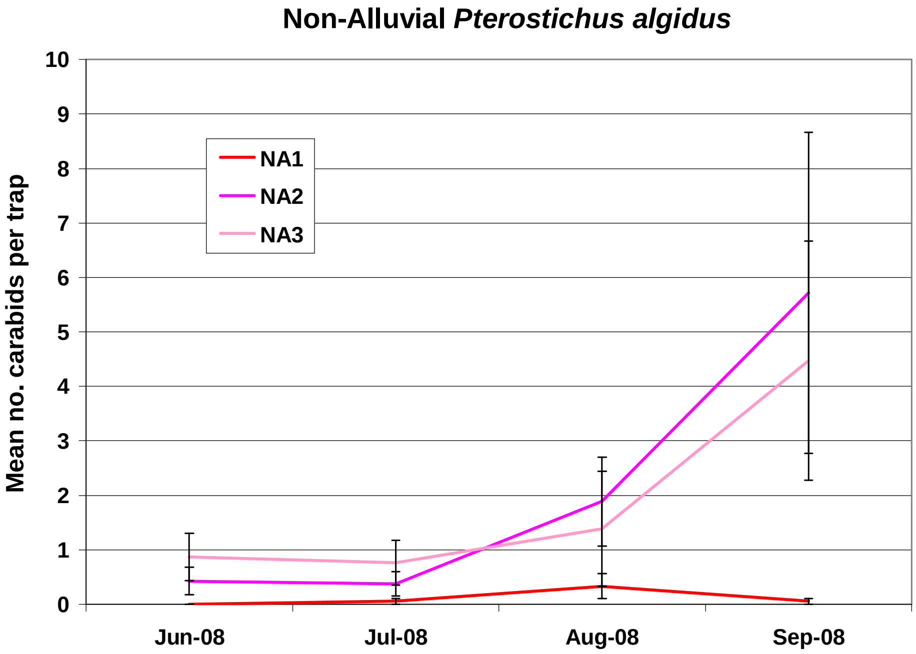


Figure 28c. Catches of *Pterostichus algidus* by date in non-alluvial sites.

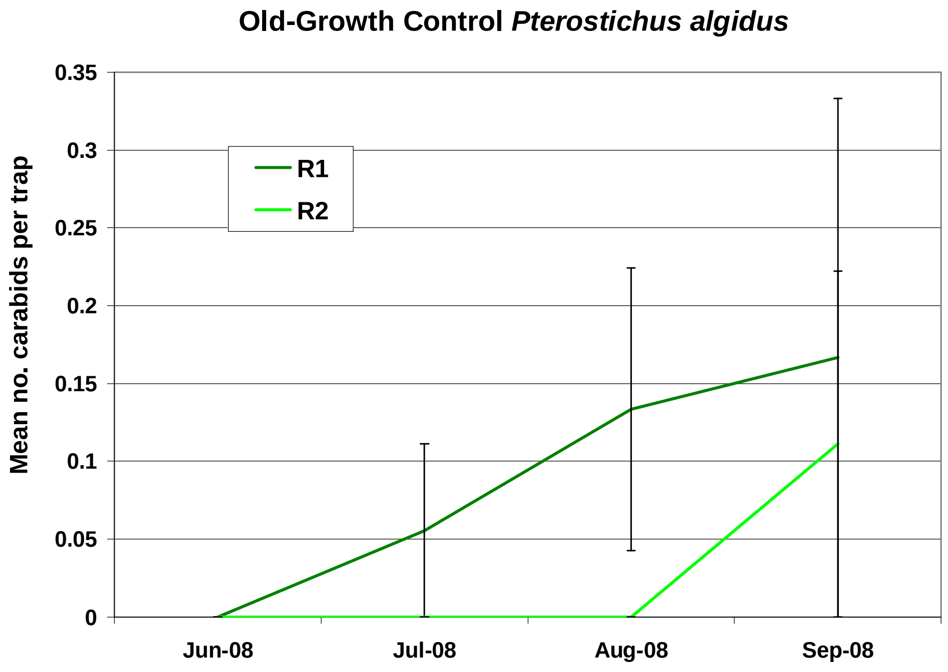


Figure 28d. Catches of *Pterostichus algidus* by date in old-growth sites.

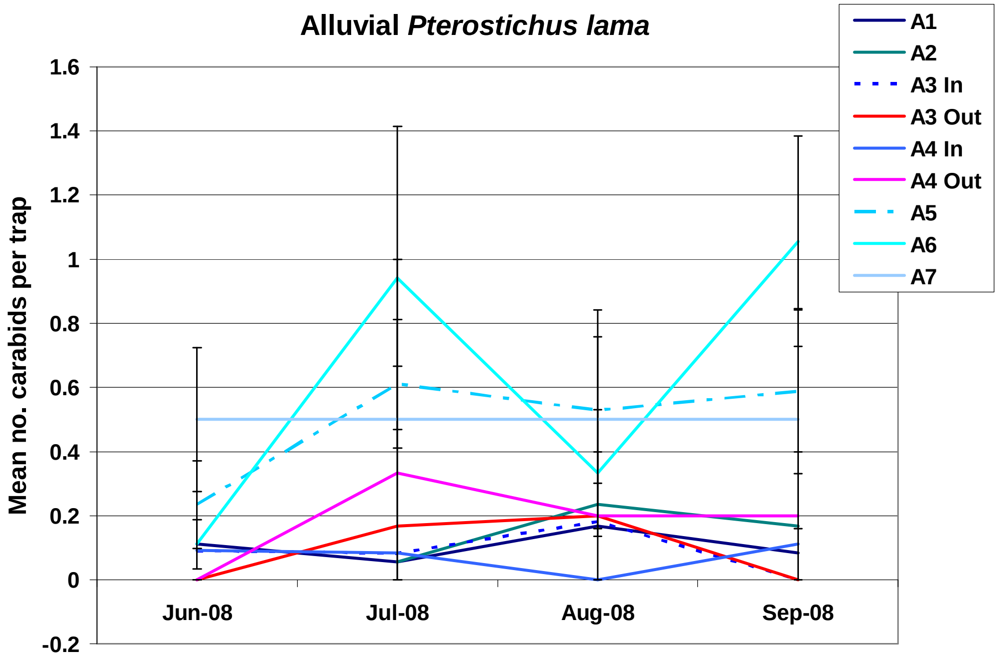


Figure 29a. Catches of *Pterostichus lama* by date at all treatments in alluvial sites.

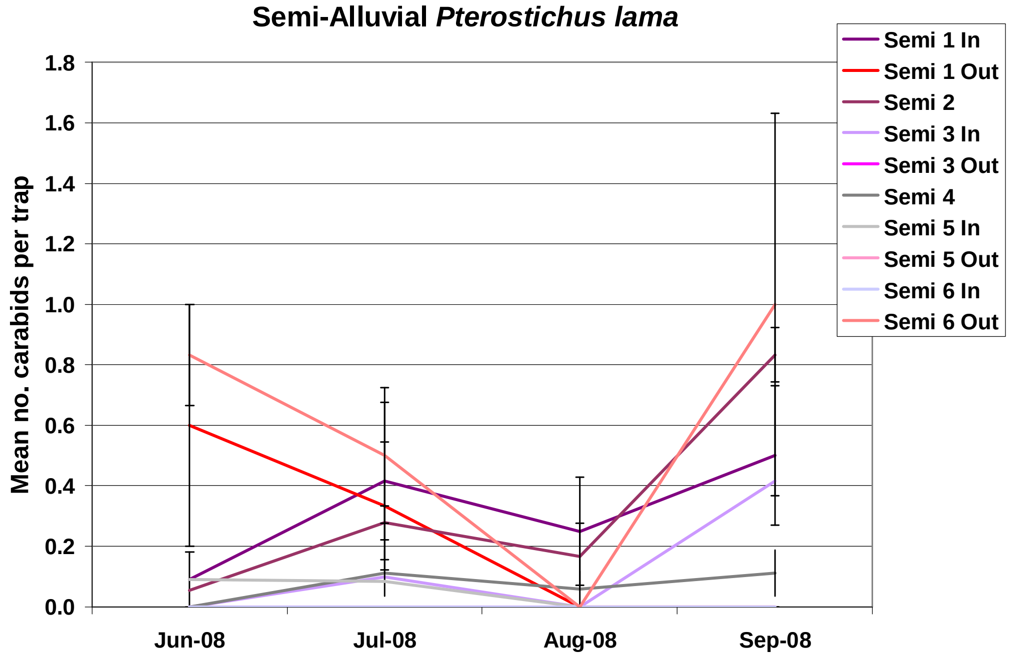


Figure 29b. Catches of *Pterostichus lama* by date at all treatments in semi-alluvial sites.

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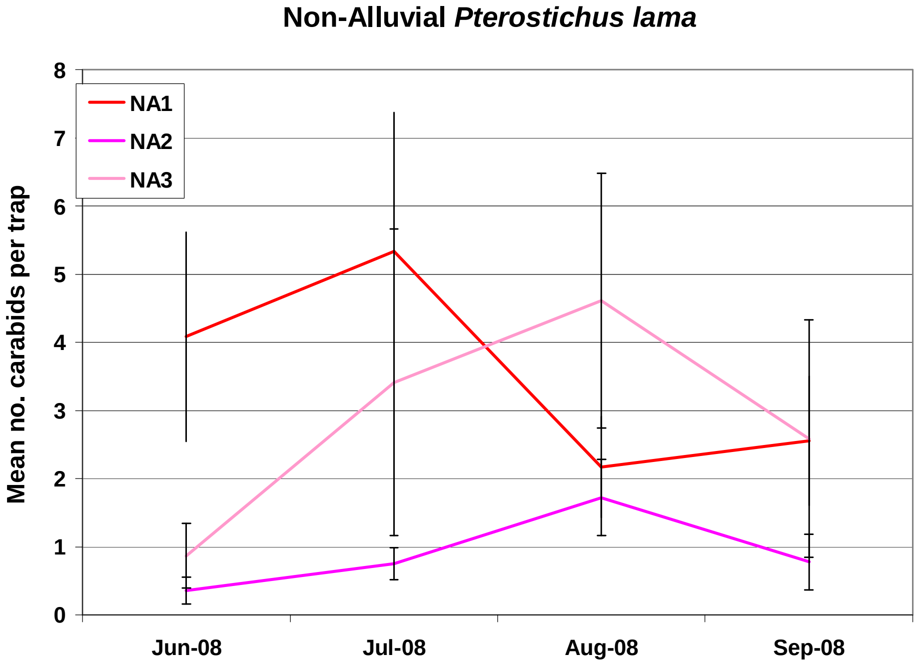

Figure 29c. Catches of *Pterostichus lama* by date in non-alluvial sites.

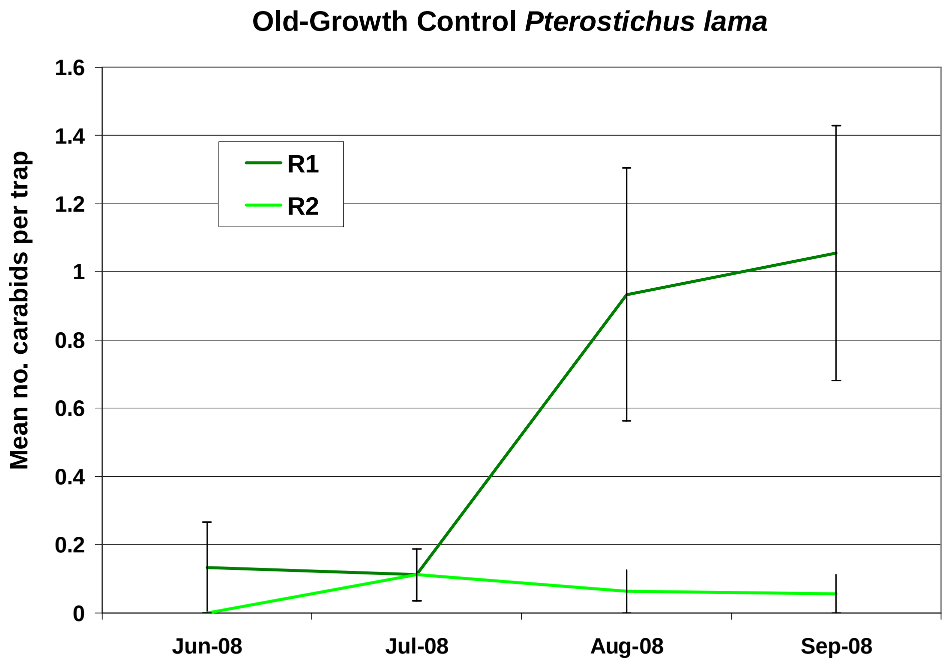

Figure 29d. Catches of *Pterostichus lama* by date in old-growth sites.

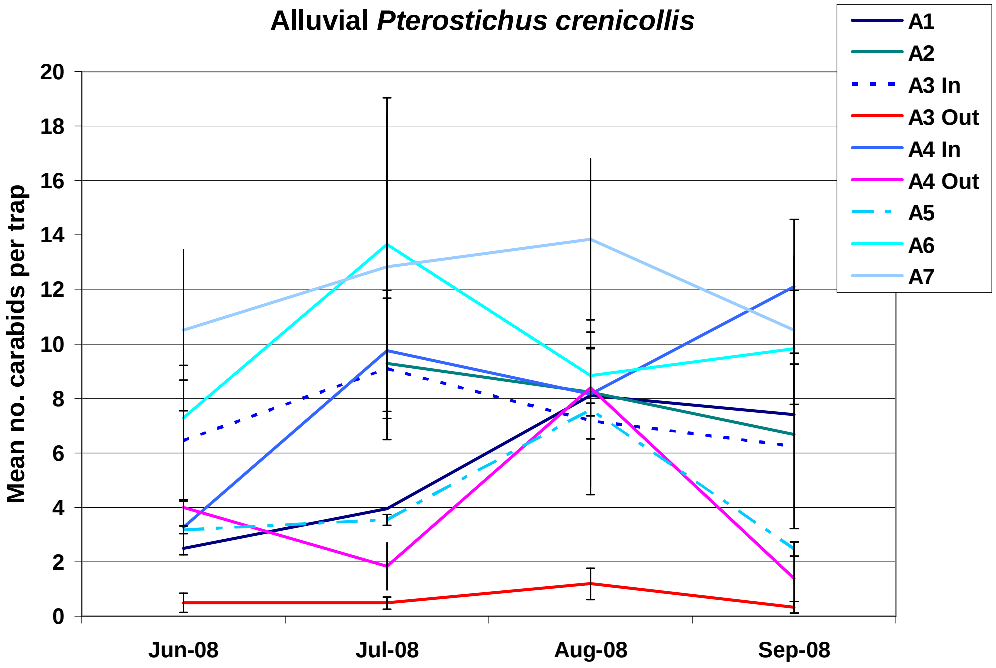

Figure 30a. Catches of *Pterostichus crenicollis* by date at all treatments in alluvial sites.

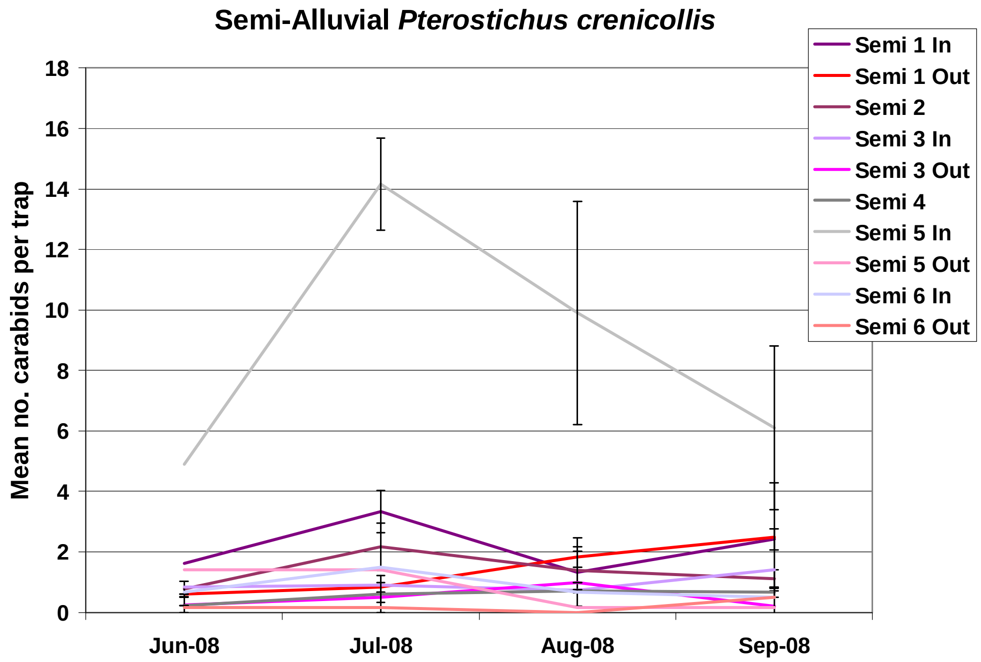

Figure 30b. Catches of *Pterostichus crenicollis* by date at all treatments in semi-alluvial sites.

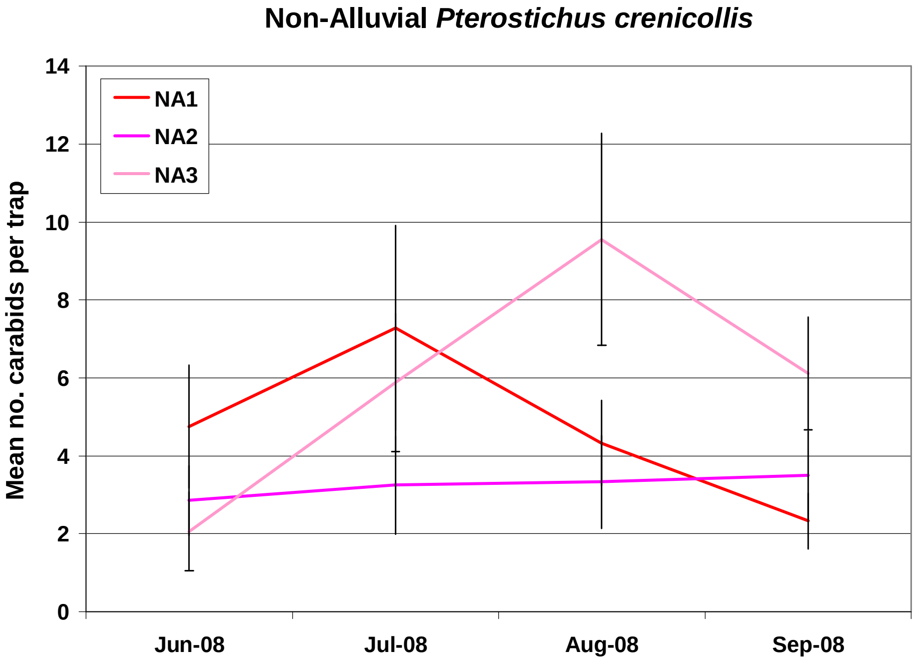

Figure 30c. Catches of *Pterostichus crenicollis* by date in non-alluvial sites.

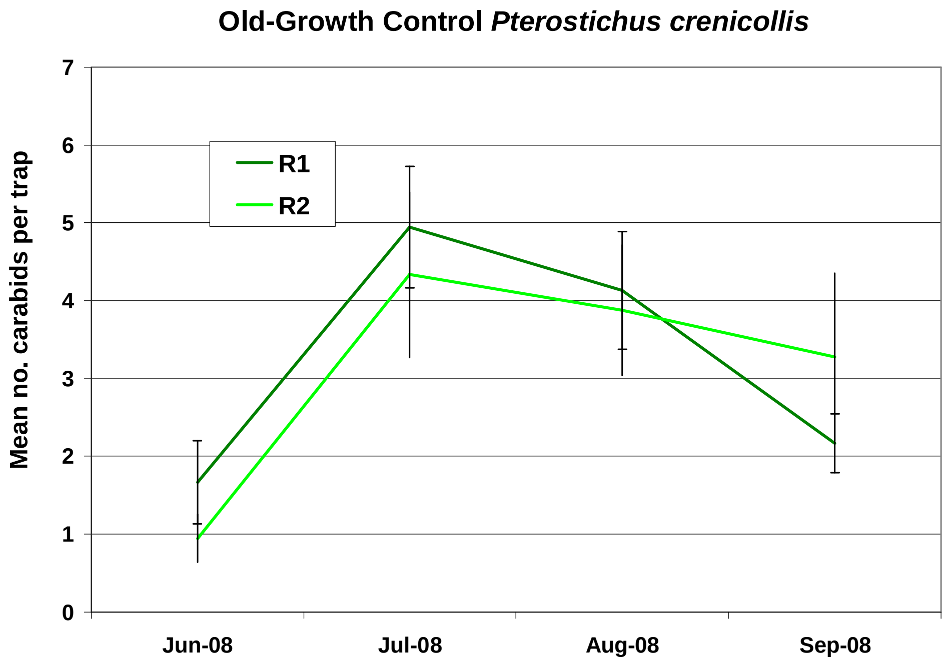

Figure 30d. Catches of *Pterostichus crenicollis* by date in old-growth sites.

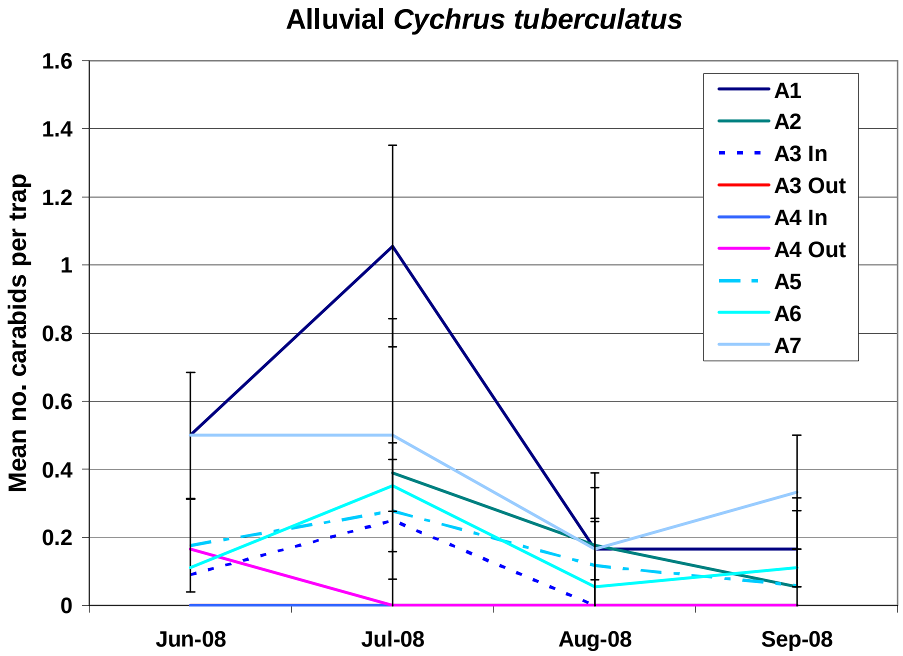

Figure 31a. Catches of *Cychrus tuberculatus* by date at all treatments in alluvial sites.

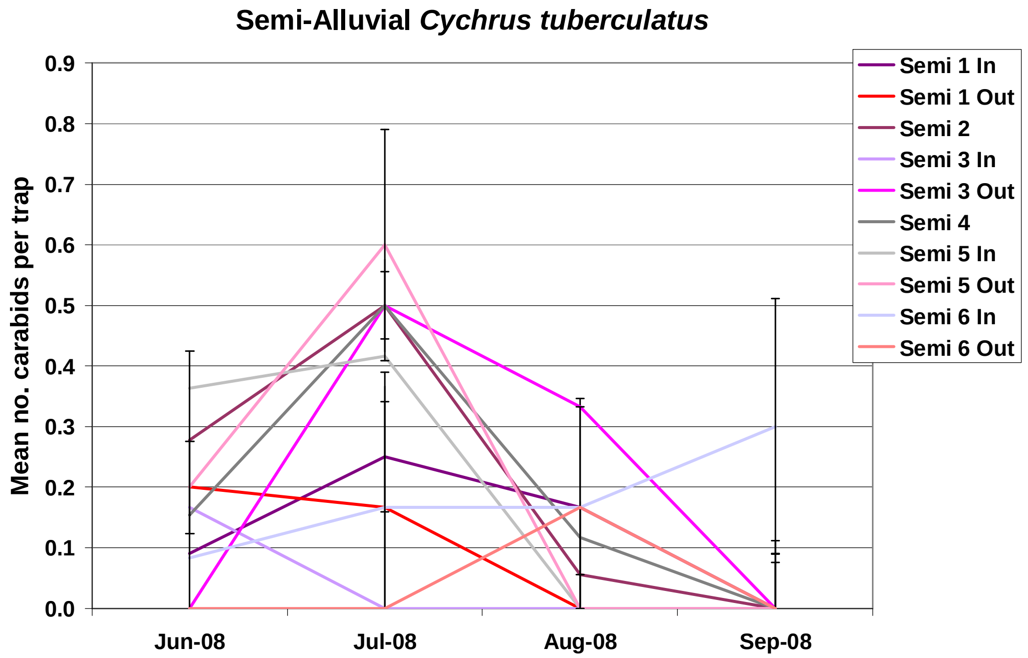

Figure 31b. Catches of *Cychrus tuberculatus* by date at all treatments in semi-alluvial sites.

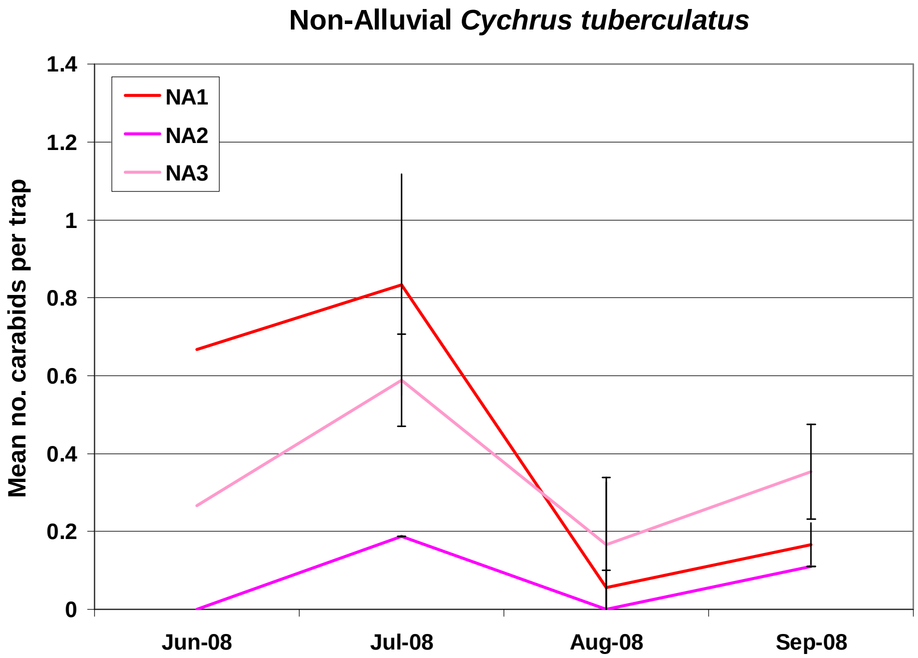

Figure 31c. Catches of *Cychrus tuberculatus* by in non-alluvial sites.

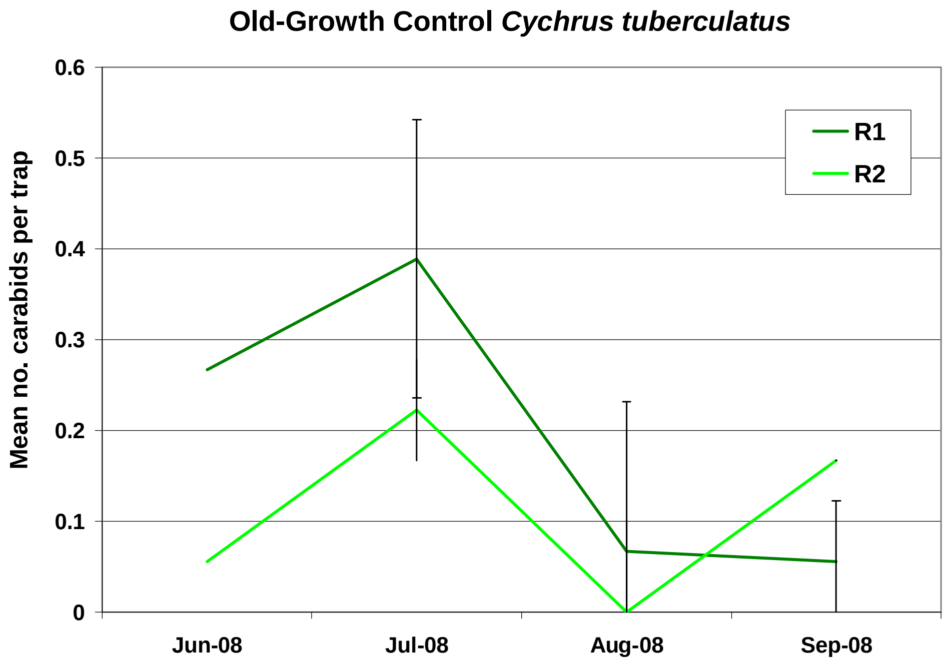

Figure 31d. Catches of *Cychrus tuberculatus* by date in old-growth sites.

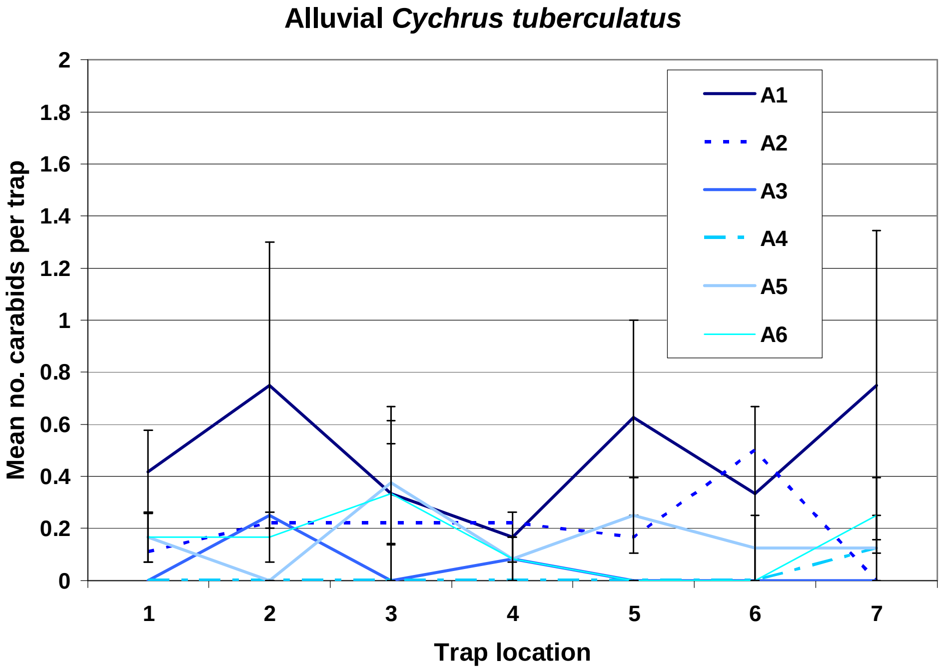

Figure 32a. Catches of *Cychrus tuberculatus* along transects where trap location 1= stream edge in alluvial sites.

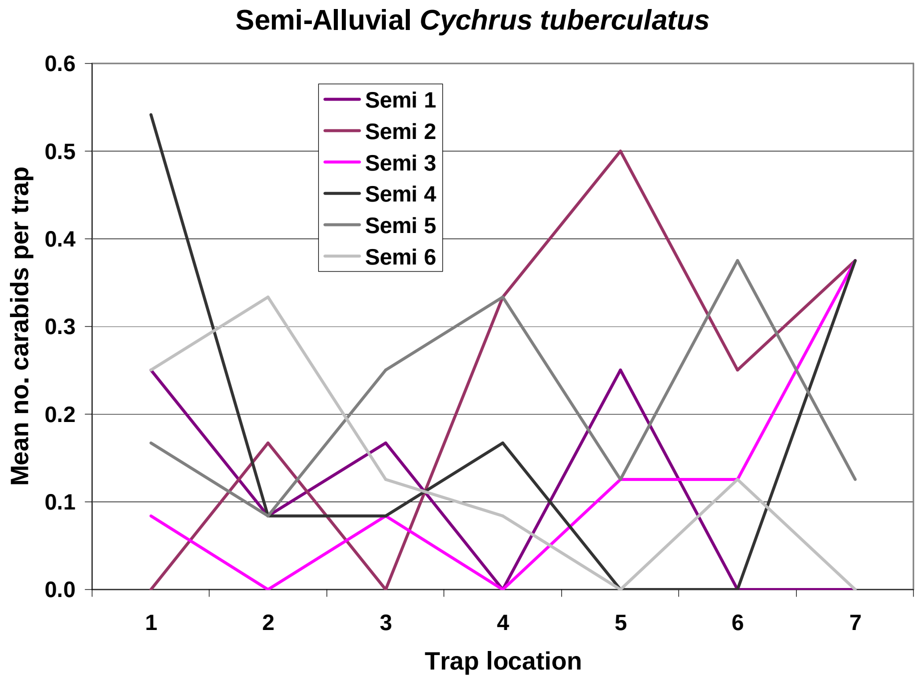

Figure 32b. Catches of *Cychrus tuberculatus* along transects where trap location 1= stream edge in semi-alluvial sites.

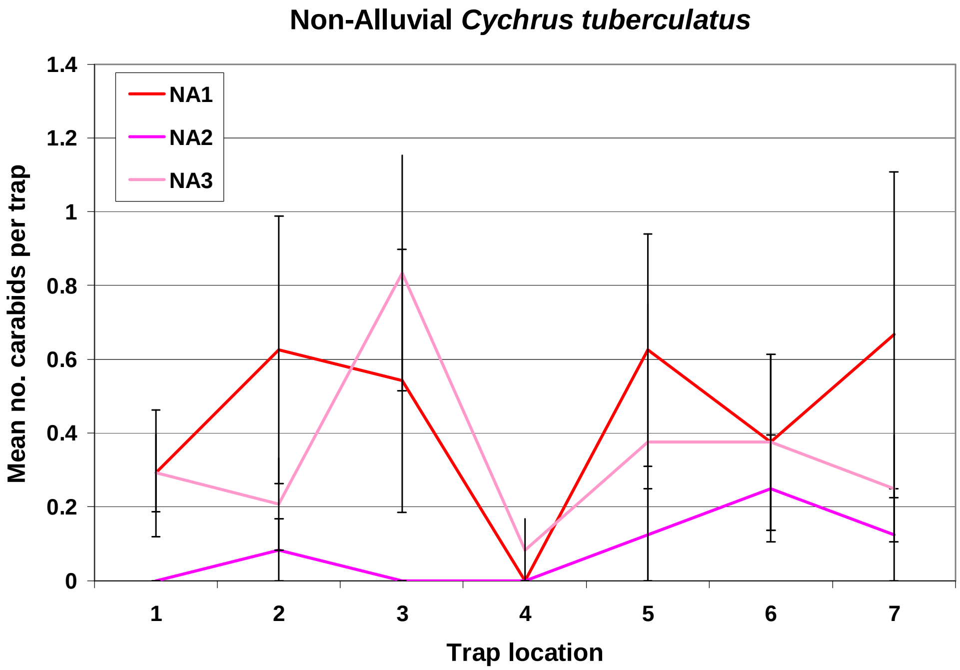

Figure 32c. Catches of *Cychrus tuberculatus* along transects where trap location 1= stream edge in non-alluvial sites.

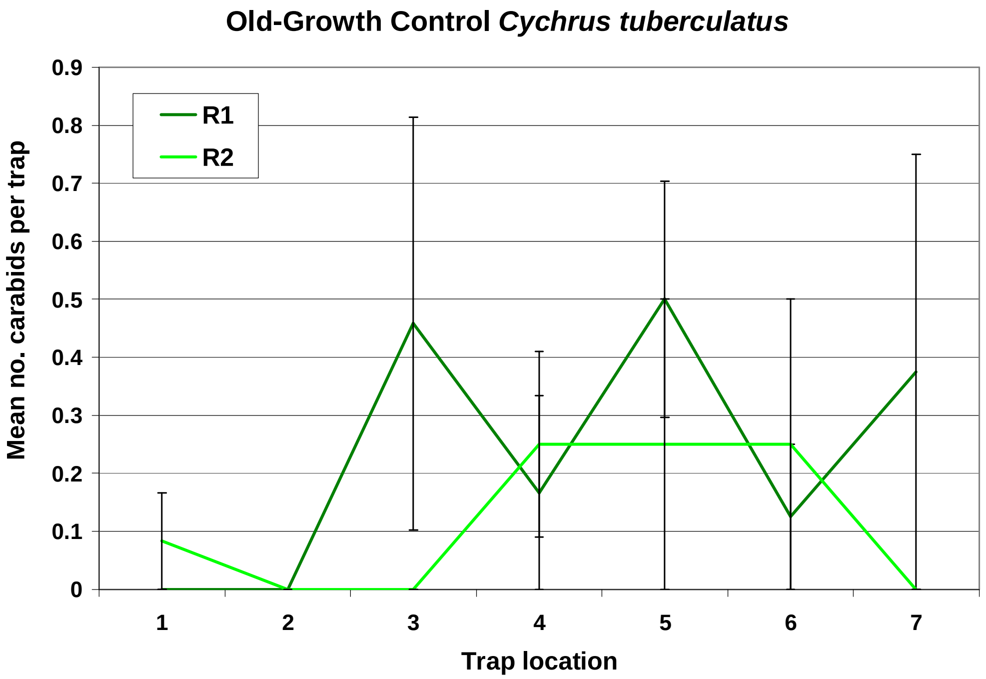

Figure 32d. Catches of *Cychrus tuberculatus* along transects where trap location 1= stream edge in old-growth sites.

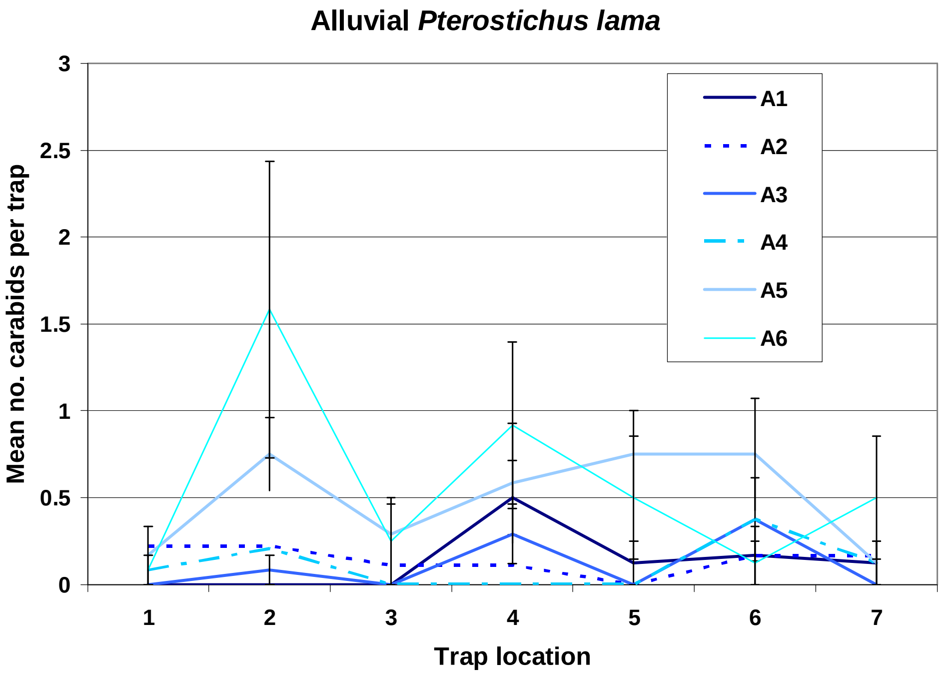

Figure 33a. Catches of *P. lama* along transects where trap location 1= stream edge in alluvial sites.

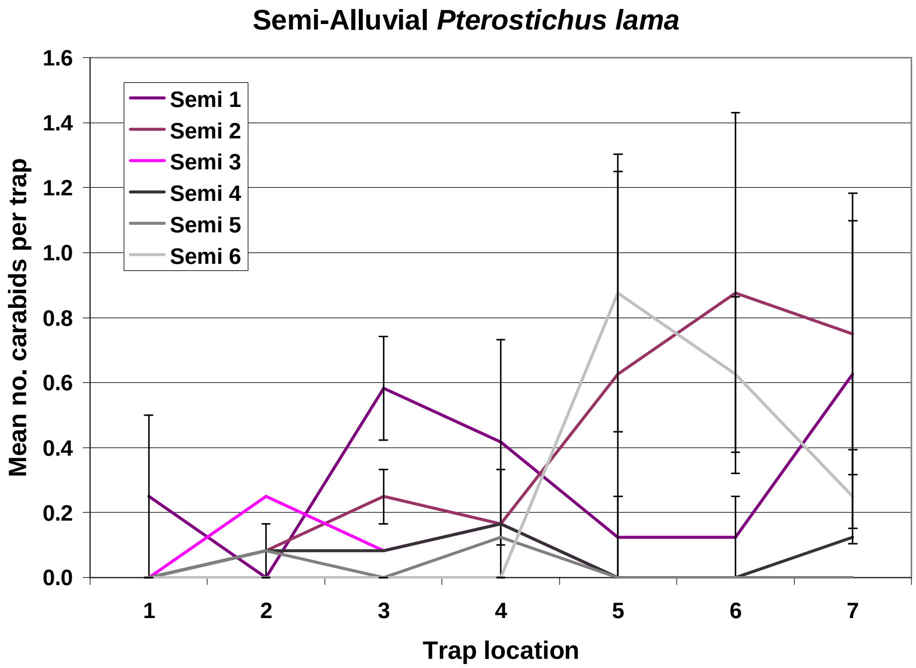

Figure 33b. Catches of *P. lama* along transects where trap location 1= stream edge in semi-alluvial sites.

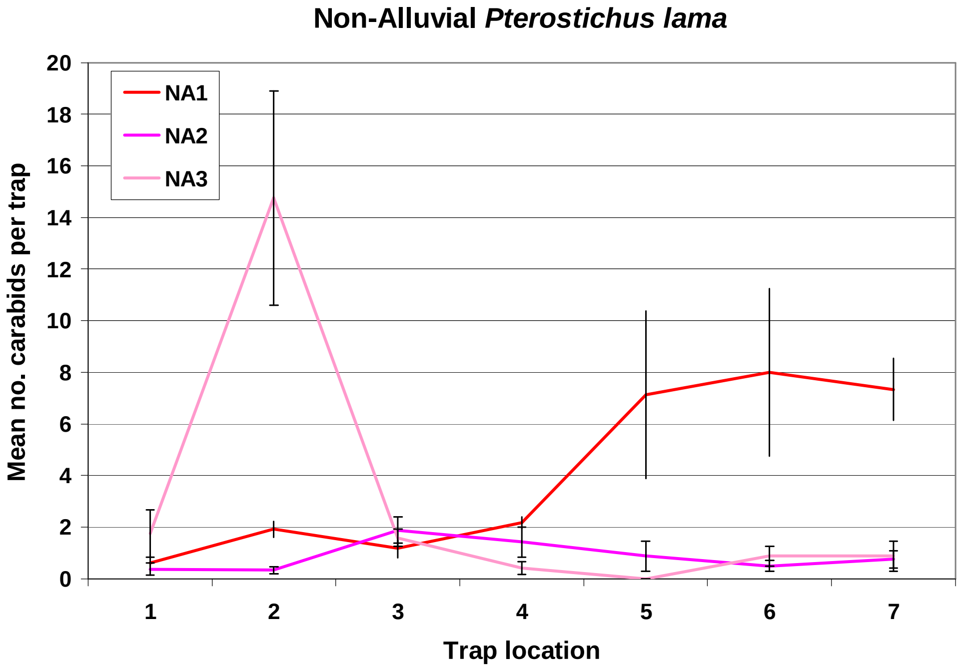

Figure 33c. Catches of *P. lama* along transects where trap location 1= stream edge in non-alluvial sites.

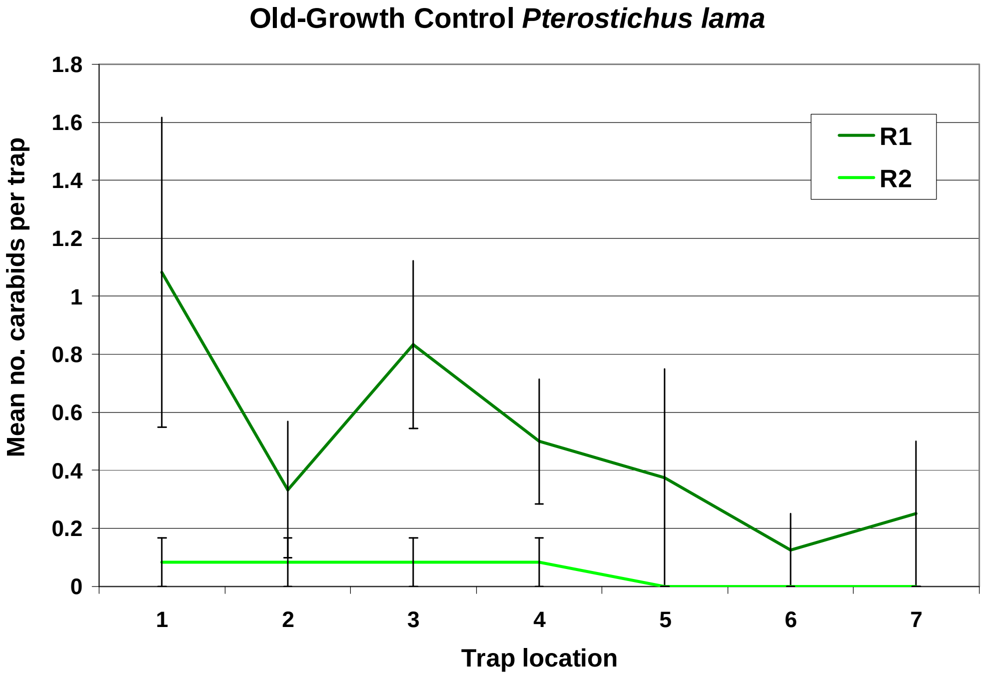

Figure 33d. Catches of *P. lama* along transects where trap location 1= stream edge in old-growth sites.

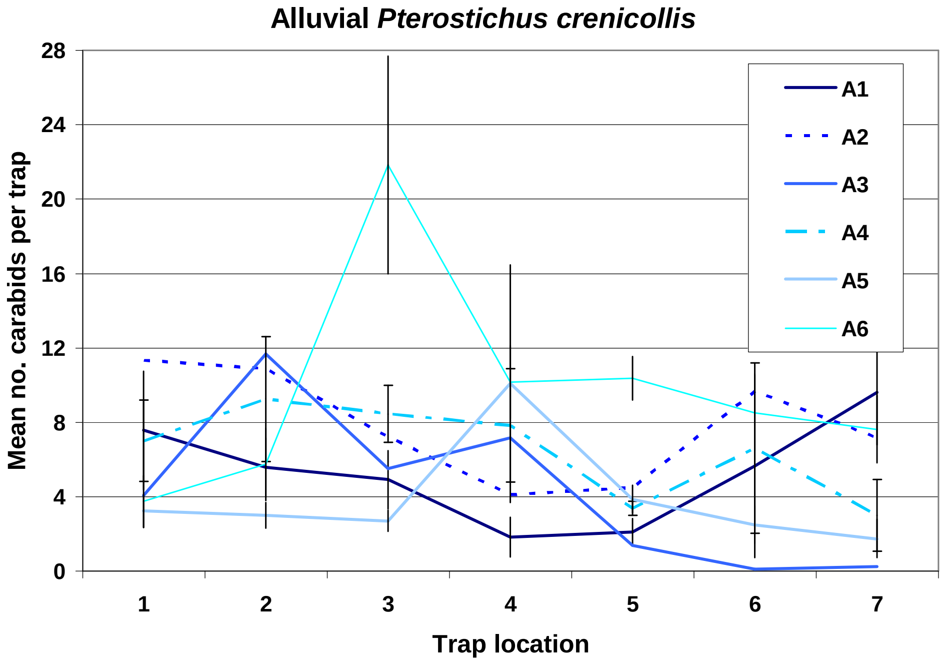

Figure 34a. Catches of *Pterostichus crenicollis* along transects where trap location 1= stream edge in alluvial sites.

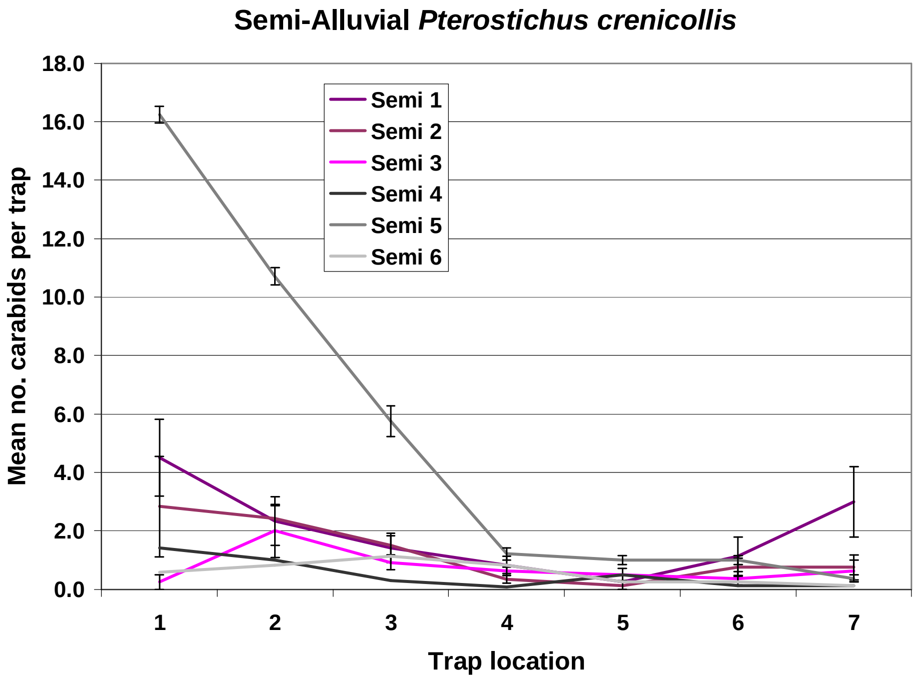

Figure 34b. Catches of *Pterostichus crenicollis* along transects where trap location 1= stream edge in semi-alluvial sites

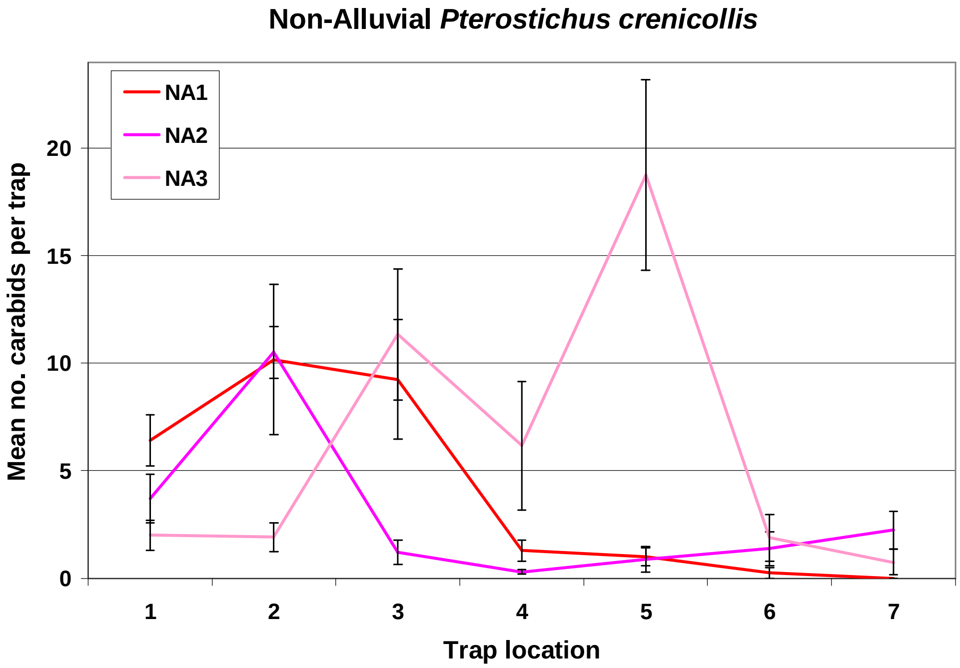

Figure 34c. Catches of *Pterostichus crenicollis* along transects where trap location 1= stream edge in non-alluvial sites

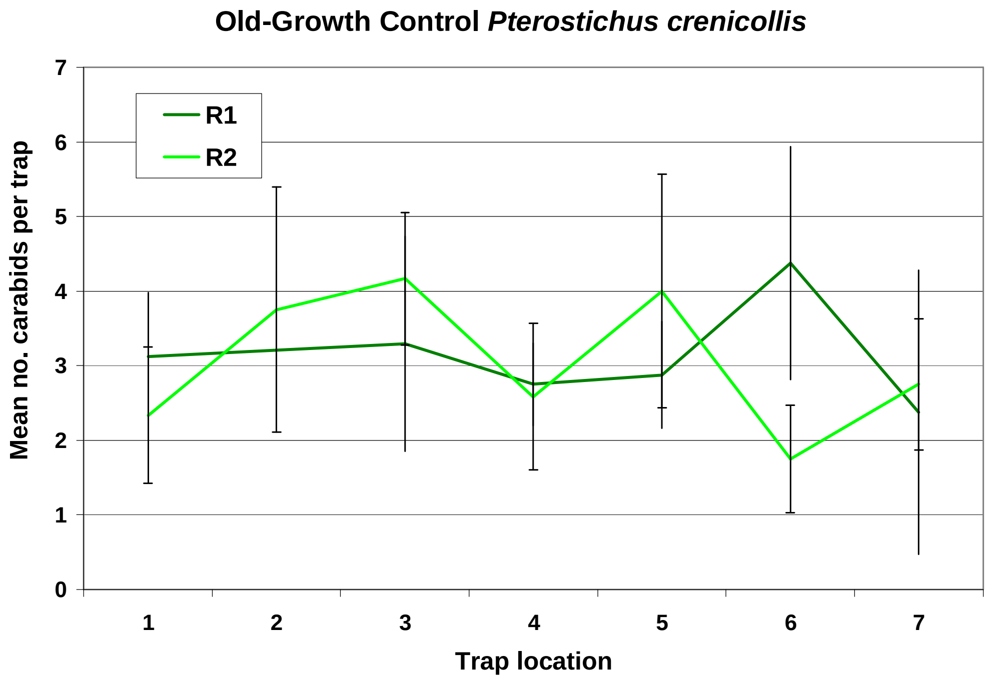

Figure 34d. Catches of *Pterostichus crenicollis* along transects where trap location 1= stream edge in old-growth sites

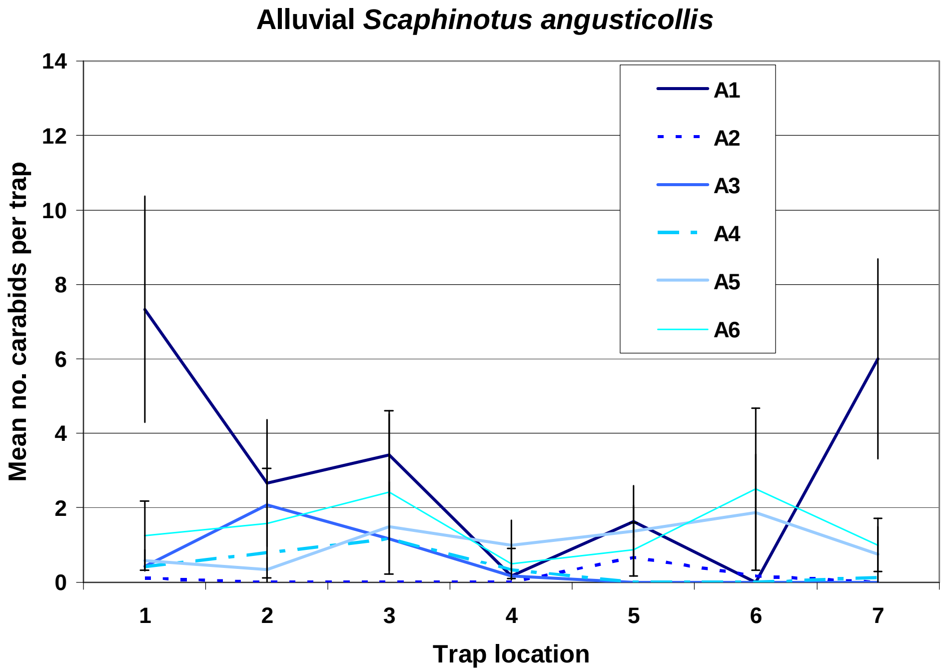

Figure 35a. Catches of *Scaphinotus angusticollis* along transects where trap location 1= stream edge in alluvial sites

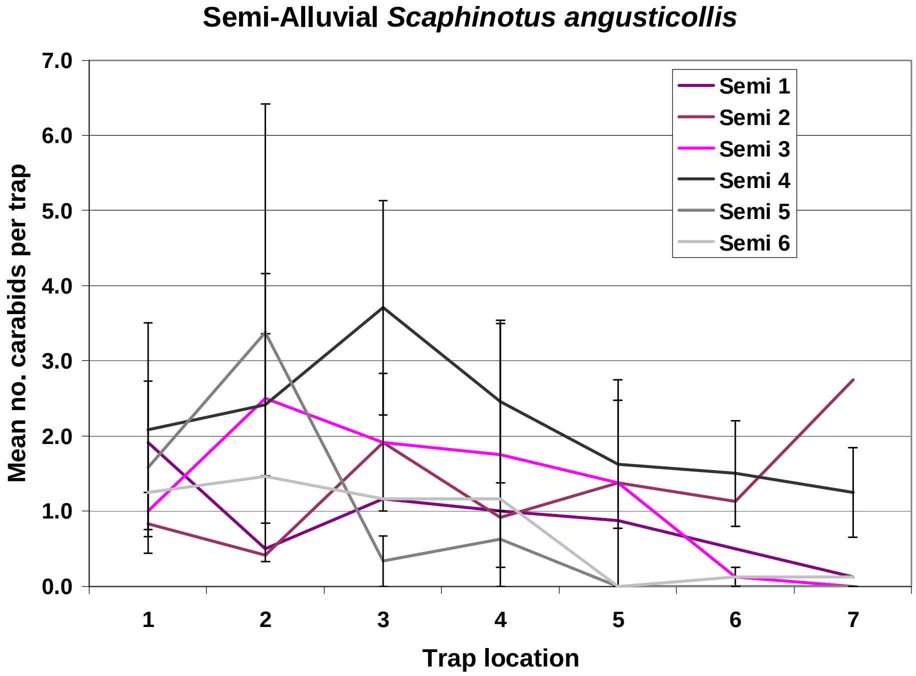

Figure 35b. Catches of *Scaphinotus angusticollis* along transects where trap location 1= stream edge in semi-alluvial sites

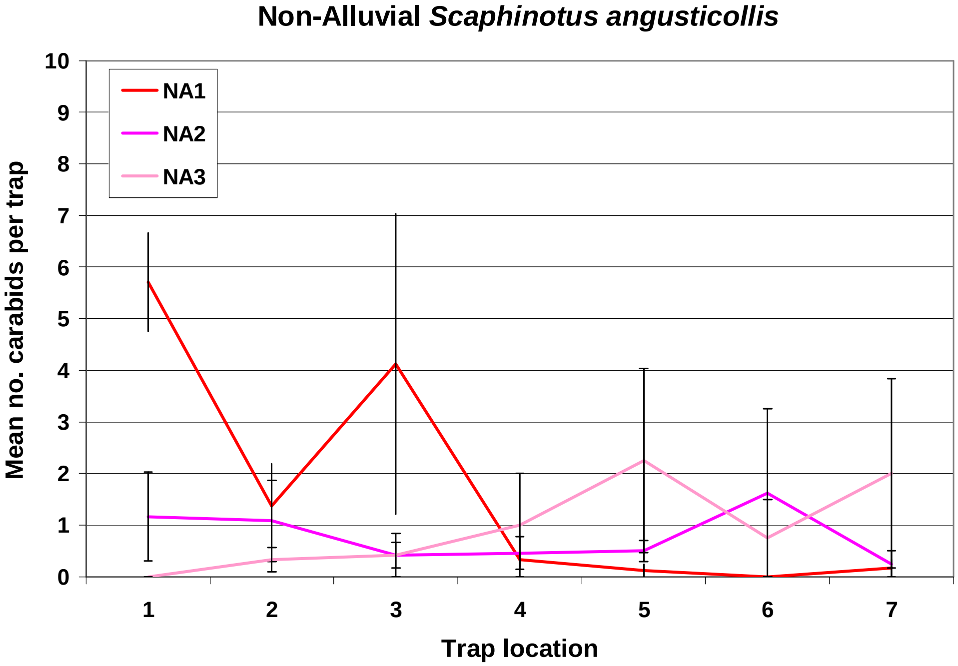

Figure 35c. Catches of *Scaphinotus angusticollis* along transects where trap location 1= stream edge in no-alluvial sites

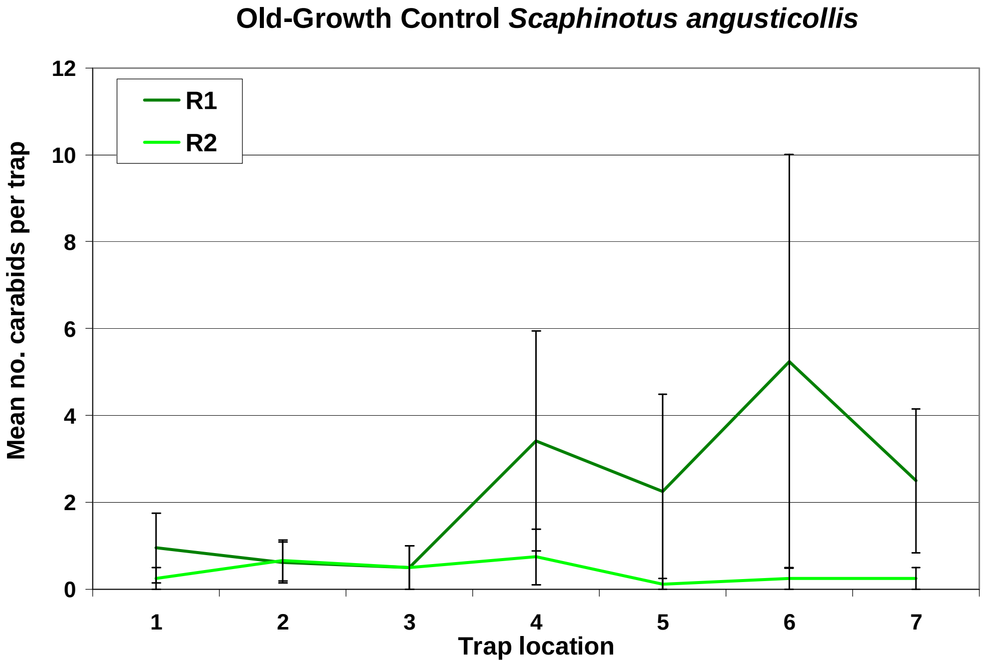

Figure 35d. Catches of *Scaphinotus angusticollis* along transects where trap location 1= stream edge in old-growth sites

5.2.3 Analyses

5.2.3.1 Individual species' responses to harvest treatments.

The responses of individual species to different treatments were analysed using Nested ANOVA using SYSTAT 10.2 for those months when sample size was adequate for statistical comparison. Abundance of carabids was compared among treatments using nested ANOVA with site type (alluvial, semi-alluvial and non-alluvial) as main factor and sites nested within site types. In this way we could examine if statistical differences existed, for example in the abundance of any one species among the various site types, given the variability existing among the sites in that category. The data for the riparian buffers only were analyzed (thus for traps 1-4 along transects). Thus, data for clearcuts and immature sites were not included in the analyses as I was most interested in whether differences in abundance of species could be discerned among the site types.

Degrees of freedom, F values and P values are listed in Appendix 4 at the end of this report. Values of $P < 0.05$ were taken to be significant.

For *S. angusticollis*, the forest species, although there were highest numbers in alluvial sites in most months, the differences were not significant. *S. marginatus*, another forest species, was more abundant in the alluvial site in July, but statistical differences could not be discerned for other months. *Zacotus matthewsii*, the old growth specialist, was statistically most abundant in the old-growth sites in July and August, and most abundant in the old-growth sites and alluvial sites in September. Numbers were too low in June to discern any differences. *P. crenicollis* was significantly more abundant in the alluvial sites than the other site types for all months. There were no significant differences in the abundance of *Cychrus tuberculatus* among site types for any month.

5.2.3.2 Multivariate community analysis

Multivariate community analysis (using PC-ORD software, McCune & Mefford 1999) was used to examine patterns of association across the different site types. Non-metric multidimensional scaling (NMS) was used to quantitatively summarize the overall distribution of species assemblages across the various gradients and to show how the treatments compare to one another in terms of "species space". NMS has been widely used in ecological gradient studies (Clarke 1993).

The analysis was run twice. For the first, I used a Sorensen distance measure, one final axis was chosen, 100 iterations and random starting coordinates. The second run gave a two dimensional solution. Overall, the 2-dimensional solution was chosen as this resulted in a lower value of stress (10.18) than a solution with more or less dimensions, but both NMS graph figures are shown below (Figures 36 & 37). This stress level is taken to be "fair' (Kruskal, 1964) and Clarke (1993) notes that a stress level between 5 and 10 is "a good ordination with no real risk of drawing false inferences". The final solution took 50 iterations and had a final instability of 0.00007, which is low. Axis 1 accounted for 42% of the variance and Axis 2 accounted for 46% of the variance based on the r^2 between the distance in the ordination space and the distance in the original space.

The resulting NMS plot produced were colour coded to show the different locations: Red for alluvial sites, green for semi-alluvial sites, turquoise for non-alluvial sites, purple for old-growth sites, and dark blue for catches from clearcuts or immature sites adjacent to riparian buffers (of Semi 1, Semi 3, Semi 5, Semi 6, A3 and A4). The NMS graph ordinations, both the 1-D and 2-D solutions showed separation of site types based on "species space" (Figures 36 & 37). NA1 and

NA2 are located close to one another, although the third non-alluvial site is a more separate. Site NA3 was slightly physically different to NA1 and NA2 in that there were flat banks on either side of the stream bed, and some evidence of alluvial deposits on the banks, even though the stream itself was bouldery and rocky. The riparian buffer of Semi 5 was also closer to the alluvial sites than the other semi-alluvial sites. This buffer contained particularly high abundances of *P. crenicollis*, which was characteristic of the alluvial sites. The 2 old growth sites, other semi-alluvial sites and most of the clearcuts also showed similarities amongst themselves.

Detailed results for the NMS are given in Appendix 5.

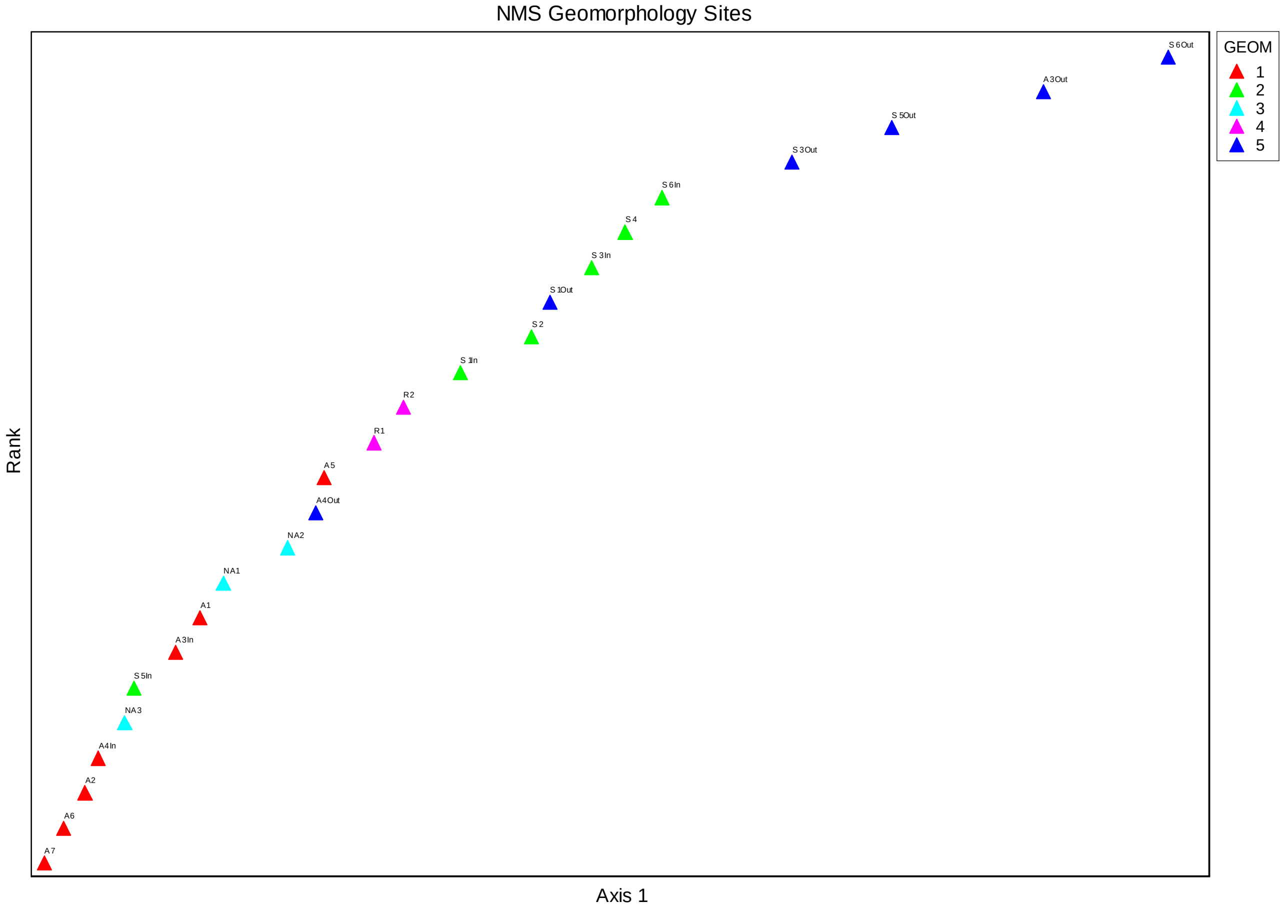

Figure 36. NMS for carabid captures for all location/treatment comparisons for alluvial (red), semi-alluvial (green), non-alluvial (turquoise), old-growth sites (purple) and clearcut sites adjacent to riparian buffers (dark blue). Solution with one axis.

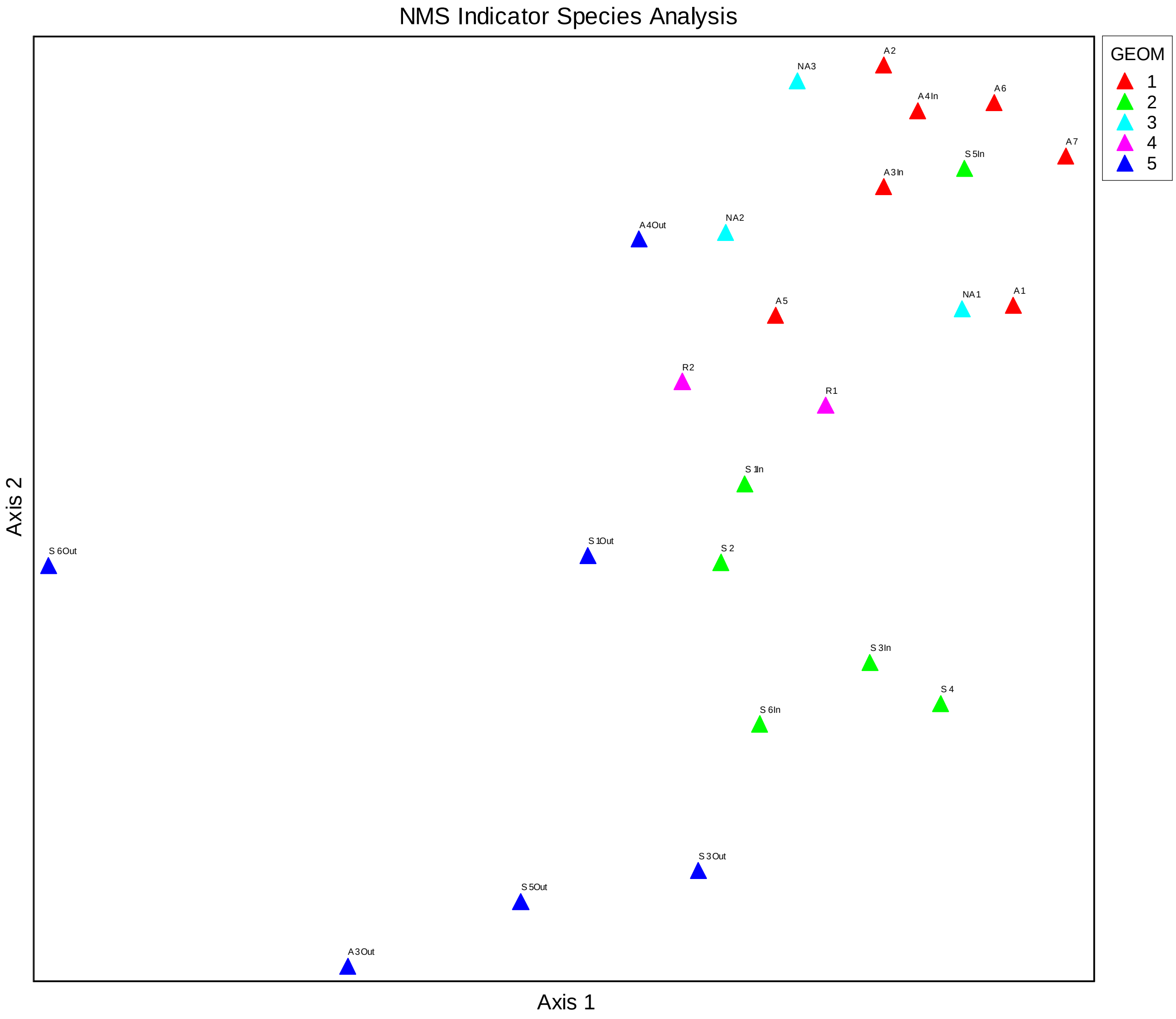

Figure 37. NMS for carabid captures for all location/treatment comparisons for alluvial (red), semi-alluvial (green), non-alluvial (turquoise), old-growth sites (purple) and clearcut sites adjacent to riparian buffers (dark blue). Solution with 2 axes.

5.2.3.3 Indicator Species Analysis

Using PC ORD 4, we also performed indicator species analysis (Dufrene & Legendre 1997) to examine the associations of individual taxa with predefined groups (ie. site type). This method combines information on the concentration of species abundance in a particular group and the faithfulness of occurrences of a species in a particular group. A perfect indicator of a group would be always faithful to that group (always present) and it should also be exclusive to that group, never occurring in other groups. The indicator values range from zero (no indication) to 100 (perfect indication). This technique produces indicator values for each species in group, and these are tested for significance using a randomization (Monte Carlo) technique (MCune and Grace, 2002). We performed indicator species analysis by inputting the carabid species data for all sites and coding for site types where group 1= alluvial, group 2= semi-alluvial, group 3= non alluvial, group 4 = old-growth, and group 5 = clearcut sites. Full results of the indicator species analysis are given in Appendix 6.

It appears from the analysis, that both *Pterostichus algidus* and *P. lama* have high indicator value, and are species that are most commonly associated with the non-alluvial site type (Table 34). *P. crenicollis* also has high indicator value is most commonly associated with the alluvial riparian strips, while *Zacotus matthewsii* has a high indicator value for old-growth sites.

Table 34. MONTE CARLO test of significance of observed maximum indicator value (IV) for each species collected in all sites (alluvial, semil-alluvial non-alluvial, and old-growth) based on 100 randomizations. The means and standard deviations of the IV from the randomization are given along with p-values for the hypothesis of no difference among groups. The p-value is based on the proportion of randomized trials with indicator value equal to or exceeding the observed indicator value.

			IV from randomized groups		
Column	Maxgrp	Observed Indicator Value (IV))	Mean	S.Dev	p *
1. A. affine	5	15.4	22.6	12.32	0.553
2. A. ferru	5	16.7	21.0	10.74	0.706
3. A. pic	3	33.3	20.5	10.57	0.193
4. Am. Lit	5	16.7	20.8	10.52	0.720
5. Brosco	2	16.7	21.0	10.67	0.072
6. Cychrus	3	30.0	28.7	4.34	0.349
7. H.cord	3	33.3	20.5	10.57	0.193
8. Leistus	3	60.6	23.2	14.15	0.022
9. Omus	3	27.8	21.5	13.56	0.377
10. P.alg	3	65.5	37.2	12.47	**0.034**
11. P. ameth	3	32.9	30.0	8.96	0.354
12. P. cren	1	41.1	30.3	4.65	**0.032**
13. P. herc	3	38.4	27.2	13.50	0.164
14. P. lama	3	71.2	40.8	10.63	**0.008**
15. P. prot.	5	13.3	22.5	12.71	0.753
16. P. pum	5	18.5	23.5	14.52	0.607
17. S. ang	2	27.8	25.3	11.60	0.302
18. S. angus	2	26.3	29.9	4.89	0.768
19. S. marg	1	44.8	32.6	8.83	0.117

20. Zacot	4	64.1	23.3	13.70	**0.016**

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* proportion of randomized trials with indicator value
equal to or exceeding the observed indicator value.
p = (1 + number of runs >= observed)/(1 + number of randomized runs)
Maxgrp = Group identifier for group with maximum observed IV

5.2.3.4 Species evenness.

Whittaker plots (Krebs 1989) were produced for each site type whereby the log of % abundance for each species was plotted against the species rank for each site. These plots allow for a simple visual comparison of the dominance or equality of species within the community. Total numbers of carabids caught in each particular treatment were summed for the whole season and the sum catches of each species were then expressed as a percentage of this yearly total. Plots are shown twice, for site type first, and then for the site type with the old-growth sites included for comparison.

For all sites pooled, the plots for alluvial sites (in blue) were generally steeper than the other sites, as a result of the greater dominance of *P. crenicollis* in most of these sites (Figure 38). Other sites had more even species distributions, and thus the lines were flatter in the plot. Of the alluvial and old growth sites, sites A2, A3, A4, R2 and A7 showed the lowest evenness (Figures 39 & 40). For the semi-alluvial sites, Semi 5 had the lowest evenness, due to the high catches of *P. crenicollis* in this site (Figure 41). Evenness in this site was similar to that found in R2 (Figure 42). Non-alluvial sites showed similar levels of evenness, and this was generally lower than found in R2 (Figures 43 & 44).

When we examine the site/location combinations, it is apparent that there is a huge decline in species richness in the clearcut of site A3, as compared to the riparian buffer of that site (Figure 45). There was also greater evenness in this location as compared to the buffers of A3 and A4 or the immature block of A4, where forest species were more prevalent. Most of the clearcuts associated with the semi-alluvial sites also showed greater evenness (due to loss of forest specialists) than the riparian forested buffers of the same sites (Figure 46).

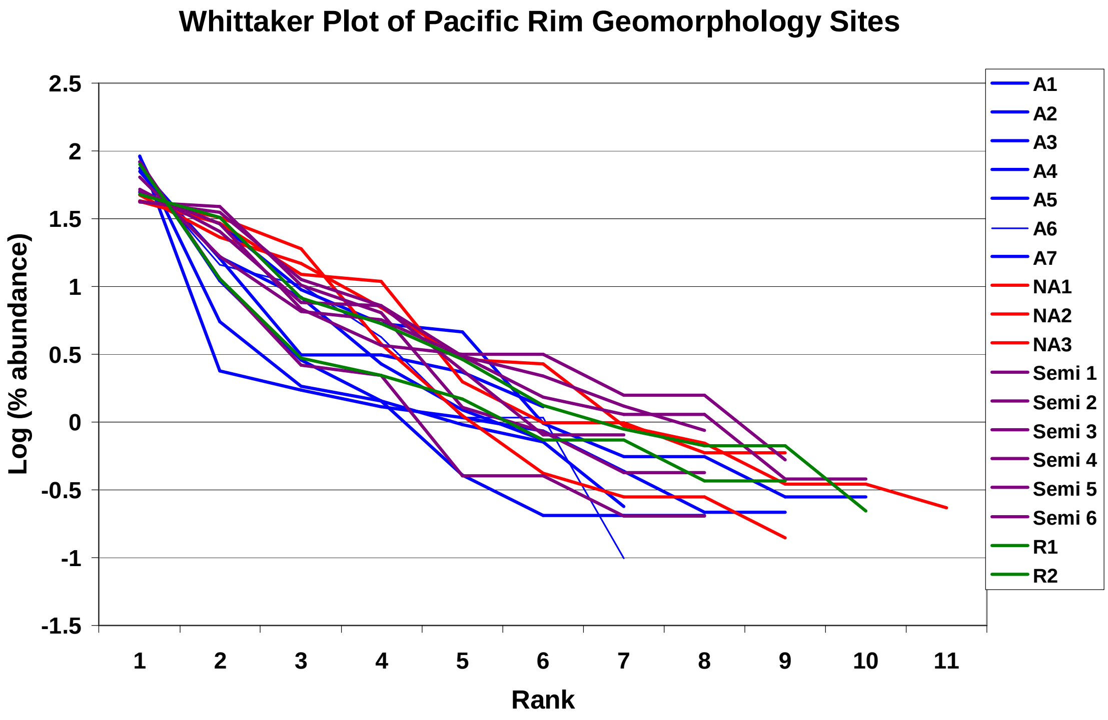

Figure 38. Whittaker Plot for all Pacific Rim sites.

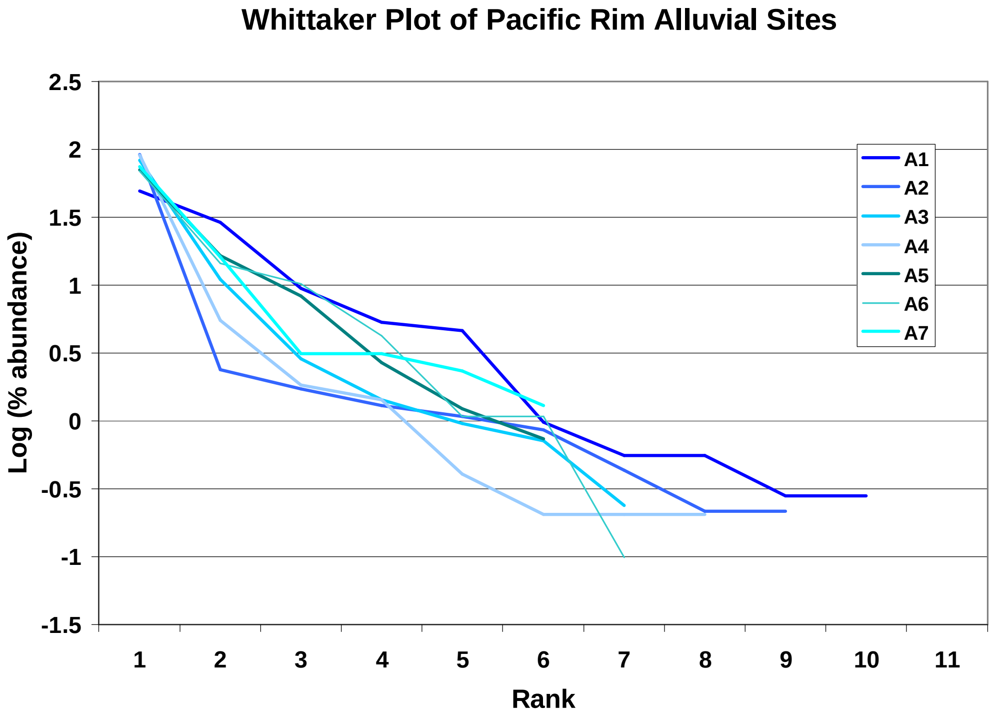

Figure 39. Whittaker Plot for all alluvial sites.

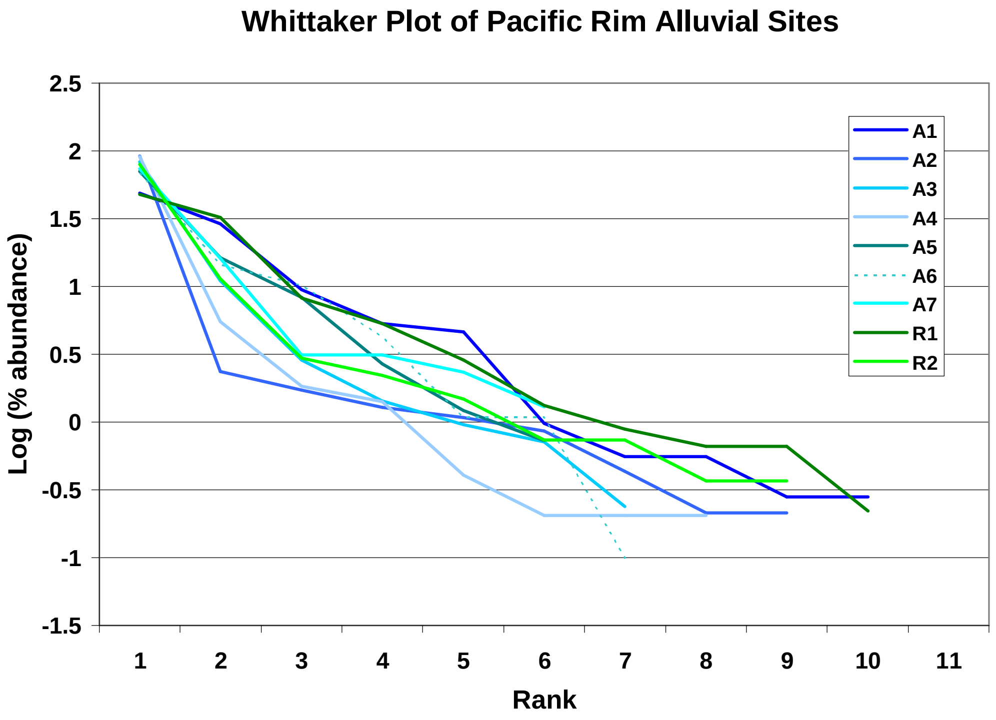

Figure 40. Whittaker Plot for all alluvial sites plus the old-growth sites for comparison.

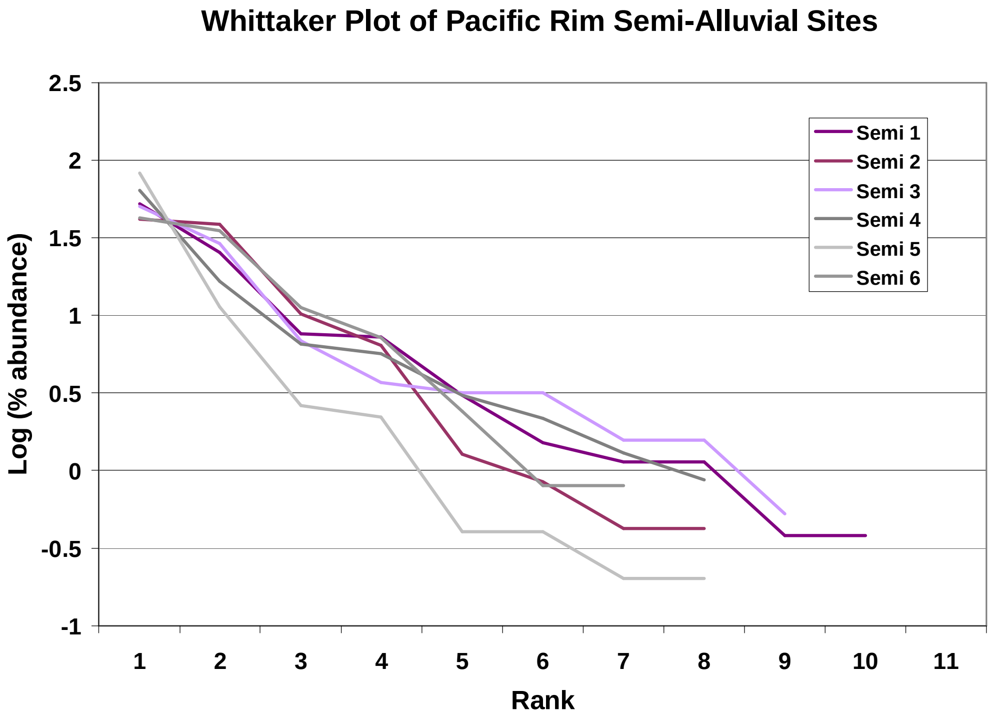

Figure 41. Whittaker Plot for semi-alluvial sites.

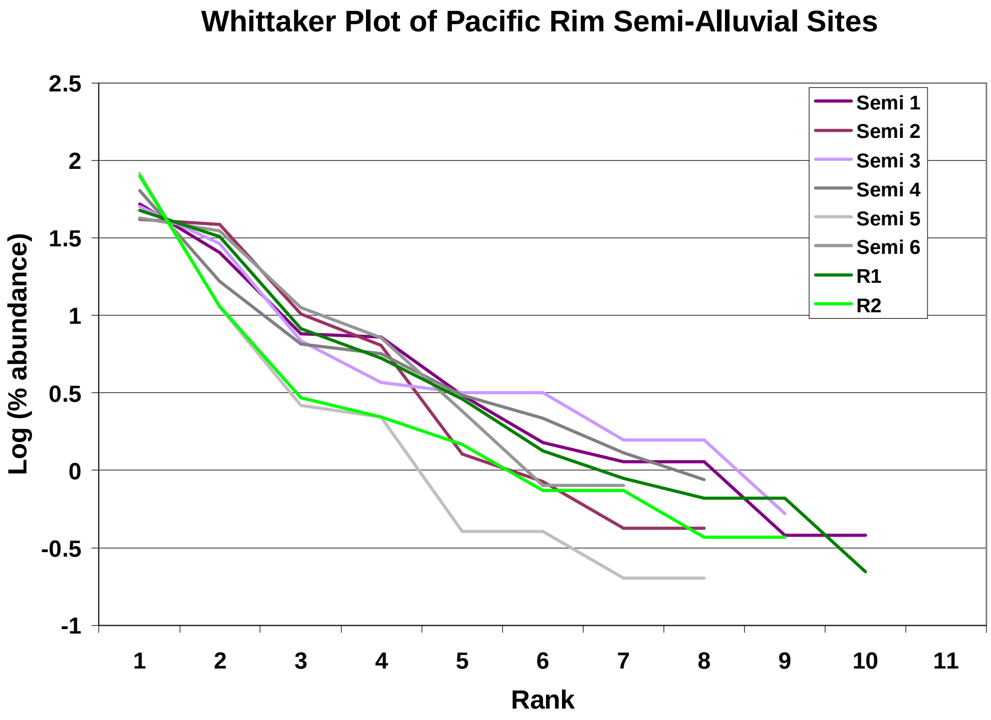

Figure 42. Whittaker Plot for all semi-alluvial sites plus the old-growth sites for comparison.

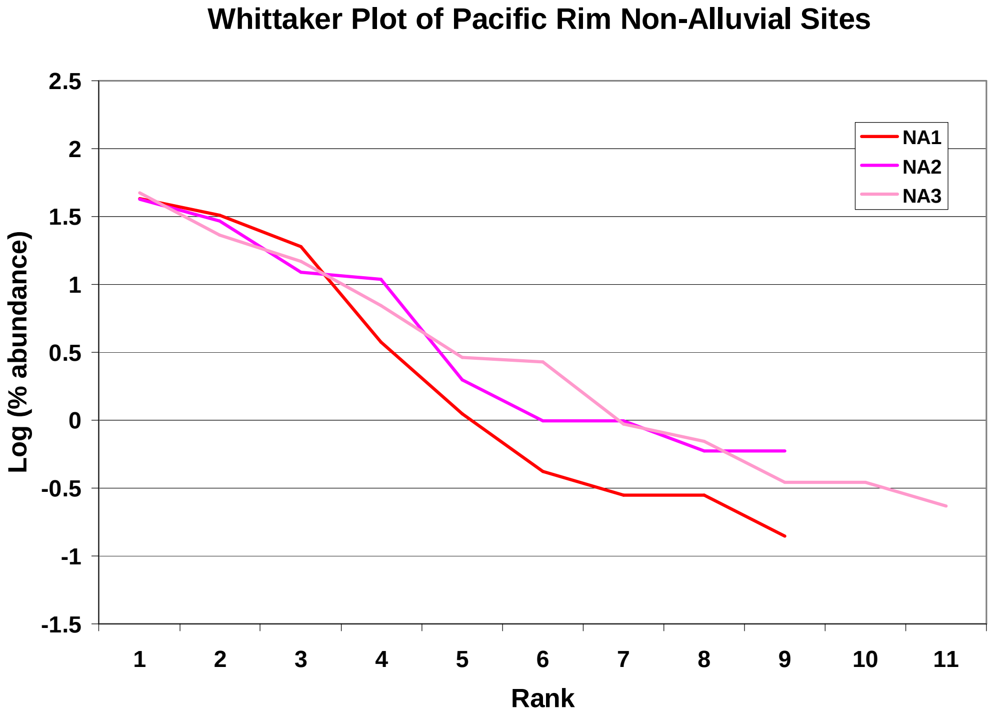

Figure 43. Whittaker Plot for non-alluvial sites.

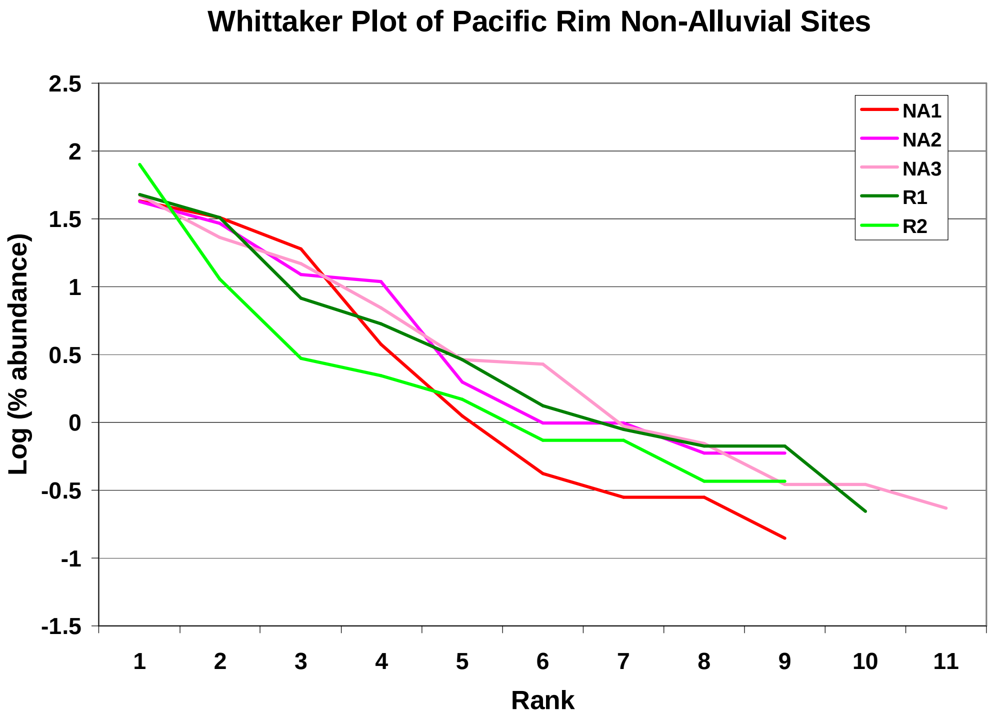

Figure 44. Whittaker Plot for all non-alluvial sites plus the old-growth sites for comparison.

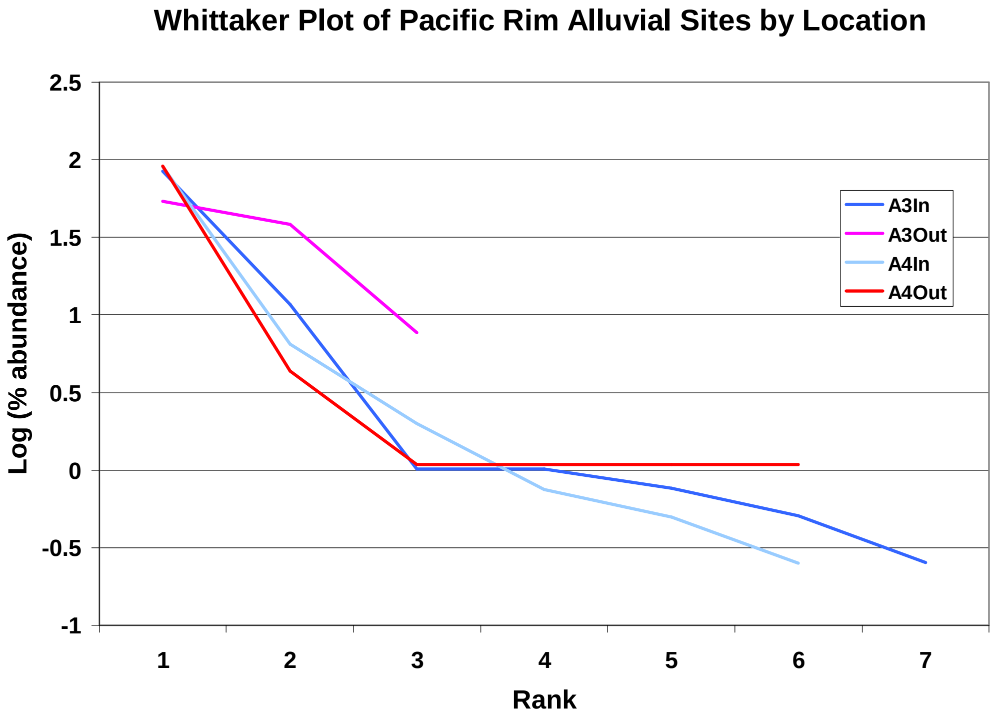

Figure 45. Whittaker Plot for alluvial sites by location (In or Out).

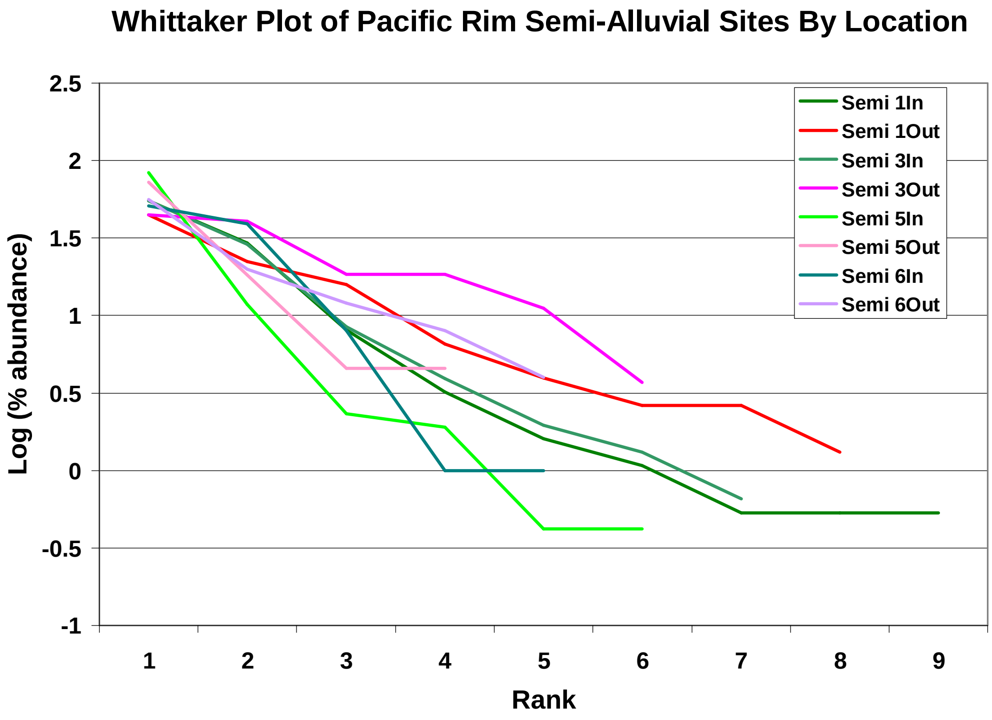

Figure 46. Whittaker Plot for semi-alluvial sites by location (In or Out).

5.2.3.5 Heterogeneity measures.

Several nonparametric diversity indices were calculated for the different treatments (Southwood 1978). These measures take into account both species richness and species evenness and are thus referred to as heterogeneous measures (Magurran 1988, Krebs 1989). They are valuable in that they allow for comparison across all treatments, despite differences in sample size and number of individuals caught, and are useful as they assume no statistical distribution. The Simpson index, 1-D and the Shannon Wiener index, H' are useful values in studies of this kind. These indices combine the effects of species richness and dominance within a community and allow for comparison across treatments. The Simpson index highlights the changes that occur in the most common species and the Shannon-Wiener index, a measure of entropy within the system, highlights the more rare species in the assemblage (Magurran 1988). I also examined evenness (or equitability), by calculating the inverse of Simpson's Index. These indices were calculated for the carabid beetle data only (Tables 35 & 36). Heterogeneity values were calculated using PC ORD 4.

Table 35: Diversity indices for all sites, alluvial, semi-alluvial, non-alluvial and old-growth, all seasons and locations combined.

Name	Mean	Stand.Dev.	Sum	Minimum	Maximum	S	E	H	D`
A1	23.900	73.479	717.000	0.000	351.000	10	0.593	1.365	0.6621
A2	15.500	77.768	465.000	0.000	427.000	9	0.197	0.432	0.1555
A3	14.000	63.666	420.000	0.000	348.000	7	0.336	0.654	0.3003
A4	16.400	80.928	492.000	0.000	444.000	8	0.214	0.446	0.1820
A5	13.633	53.738	409.000	0.000	289.000	6	0.522	0.936	0.4660
A6	33.900	129.807	1017.000	0.000	699.000	8	0.488	1.016	0.4942
A7	12.867	52.872	386.000	0.000	286.000	6	0.489	0.876	0.4226
Semi 1	8.833	27.406	265.000	0.000	137.000	11	0.593	1.422	0.6565
Semi 2	7.867	24.101	236.000	0.000	98.000	9	0.594	1.305	0.6642
Semi 3	6.333	19.780	190.000	0.000	96.000	9	0.631	1.386	0.6524
Semi 4	7.667	27.399	230.000	0.000	147.000	8	0.583	1.211	0.5551
Semi 6	4.167	12.474	125.000	0.000	53.000	7	0.685	1.333	0.6779
NA1	23.900	71.904	717.000	0.000	308.000	9	0.583	1.282	0.6750
NA2	16.900	48.028	507.000	0.000	215.000	9	0.660	1.451	0.7064
NA3	28.800	83.248	864.000	0.000	407.000	12	0.605	1.504	0.6974
R1	15.033	46.481	451.000	0.000	215.000	10	0.591	1.361	0.6586
R2	9.033	39.521	271.000	0.000	216.000	9	0.361	0.793	0.3499

Table 36: Diversity indices for buffer and clearcut traps placed from alluvial sites A3 and A4 and semi-alluvial sites Semi 1,3 5 and 6.

Name	Mean	Stand.Dev.	Sum	Minimum	Maximum	S	E	H	D`
A3 In	13.133	61.179	394.000	0.000	334.000	7	0.289	0.563	0.2675
A3 Out	0.867	3.093	26.000	0.000	14.000	3	0.818	0.898	0.5562
A4 In	13.333	65.659	400.000	0.000	360.000	6	0.239	0.429	0.1853
A4 Out	3.067	15.306	92.000	0.000	84.000	6	0.232	0.416	0.1640
Semi 1 In	6.267	20.955	188.000	0.000	103.000	10	0.533	1.227	0.6064
Semi 1 Out	2.567	7.035	77.000	0.000	34.000	9	0.724	1.591	0.7246
Semi 3 In	5.100	17.050	153.000	0.000	84.000	7	0.612	1.191	0.6065
Semi 3 Out	1.233	3.104	37.000	0.000	12.000	6	0.875	1.568	0.7626
Semi 5 In	15.800	72.181	474.000	0.000	394.000	6	0.343	0.615	0.2942
Semi 5 Out	0.733	2.982	22.000	0.000	16.000	4	0.593	0.823	0.4339
Semi 6 In	3.333	11.529	100.000	0.000	51.000	5	0.624	1.005	0.5812
Semi 6 Out	0.833	2.718	25.000	0.000	14.000	5	0.765	1.232	0.6240

Diversity was highest in the non-alluvial sites, then the semi-alluvial sites, and then the alluvial sites (Table 35). Both diversity and evenness were particularly low in the alluvial sites A2, A3 and A4 and the old-growth site R2. When examining diversity and evenness by location, they were both higher in the clearcuts of the semi-alluvial sites and A3 than in the riparian strips of each site, but similar among the riparian strip of A4 and the adjoining immature site (Table 36).

5.2.3.6 Distance coefficients: Cluster Analysis

Cluster analysis was used to assess how the assemblages of the different treatments compare to one another. We used the cluster analysis function in PC ORD4 and in Systat, using Ward's linkage method and Euclidean distance measure on the average yearly catches of each species in each site. This allows us to visualize the similarity of the different communities sampled from the different site types and locations.

The first analysis was to examine all site types where catches for any one site were the average catches for all locations (in and out) pooled (Figure 47). The semi-alluvial sites clustered together, apart from Semi 5. This site clustered together with alluvial sites and the old growth sites. The non-alluvial sites appeared to be more similar to the alluvial and old growth sites than the semi-alluvial sites.

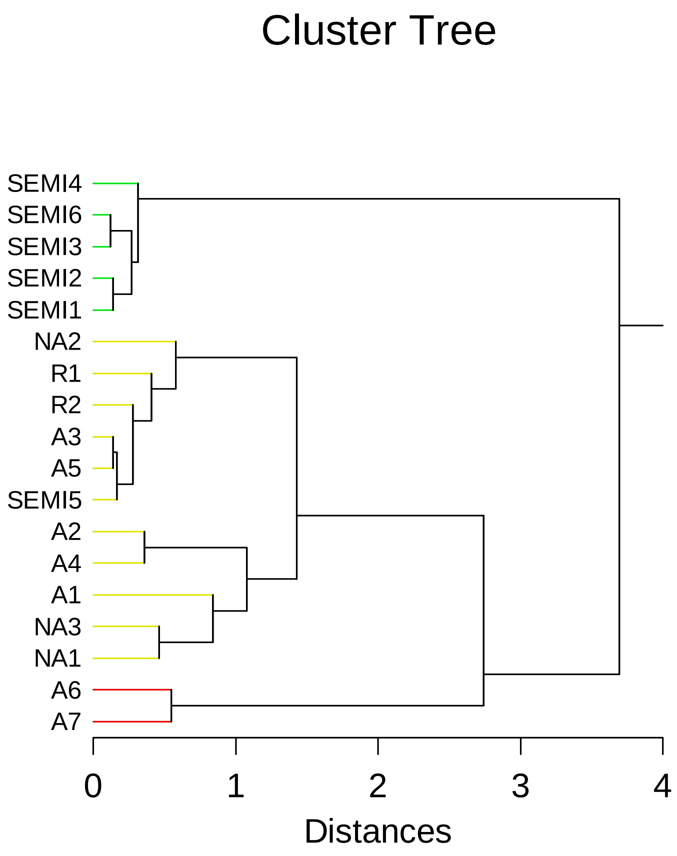

Figure 47. Cluster Analysis by site (all locations pooled).

The next cluster analysis used the average catches by location (in and out) (Figure 48). Here the clearcuts of Semi 3, 5, 6 and A3 all clustered relatively closely, while the catches from the buffers of Semi 2, 3, 4 and 6 also clustered closely. Old-growth communities clustered with NA2, A5 and the immature site of A4, and less directly with NA1 and NA3 and A1. Another group was made up of the riparian strip of A3 and A4 (A3 IN and A4IN), A2, Semi 5, A6 and A7. Overall, the semi-alluvial sites show the most separation from the other sites.

Repeating the cluster analysis above without the two old-growth sites allows us to examine the differences among the 3 different site-types more easily (Figure 49). The three non-alluvial sites cluster with A1, A5 and the immature site of A4, while the other alluvial sites form a separate cluster. The clustering of NA sites with A1 and A5 appeared to be due to the abundance of *Cychrus tuberculatus* in the latter two sites, where this species was more common than in the other alluvial sites.

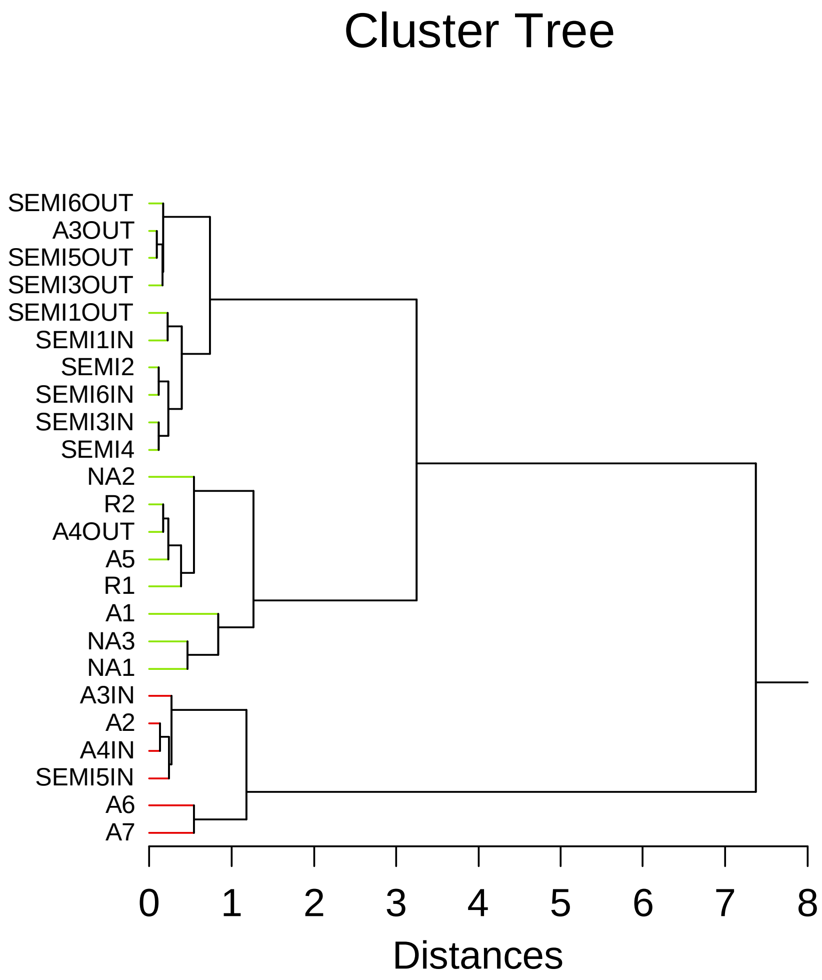

Figure 48. Analysis by Site/Location.

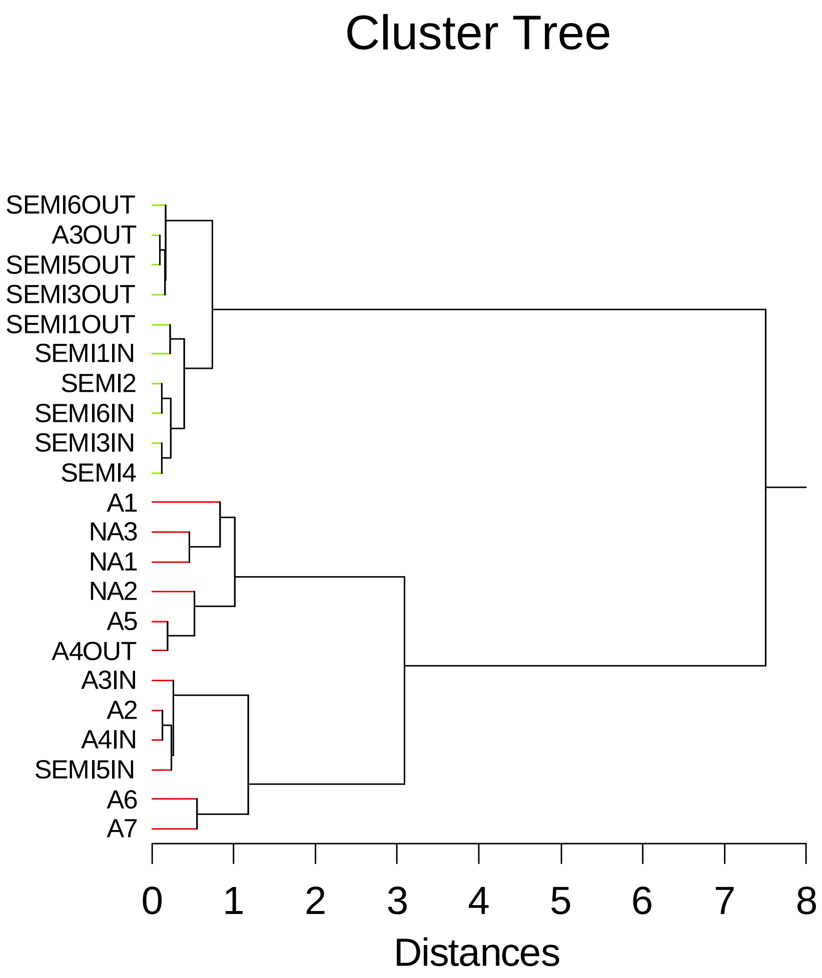

Figure 49. Goat Island Cluster Analysis by Treatment/Location.

6 SUMMARY

1. This project examined the site-level biodiversity of riparian reserves as affected by geomorphic characteristics of streams. Specifically, we wished to determine whether buffers in alluvial systems appear to retain greater wildlife values/secondary productivity than non-alluvial systems. Wildlife value was assessed using carabid beetles, an invertebrate indicator species that has been used in numerous studies of forest biodiversity.

2. Pitfall trapping was used to examine the epigaeic (ground-dwelling) carabid fauna in 20 riparian sites associated with 15 different streams (3 non-alluvial, 7 alluvial, 3 semi-alluvial and 2 old-growth) between June and September 2008. These sites were in the Kennedy Lake Flats region and several were located within the park boundary of the Pacific Rim National Park.

3. Carabid beetles were trapped using pitfall traps placed at 10 m intervals along transects that ran perpendicular to the stream course, starting at the stream edge, and extending through the riparian buffer and a further 75 m into the adjoining forest or adjoining clearcut. On the alluvial streams, a total of 9 sites were set up (3 sites with transects extending into old growth, 5 into 2nd growth and one into a recent clearcut). Six semi alluvial riparian sites were set up, with transects from riparian areas extending into 4 adjoining clearcuts and two 2nd growth sites. Three non-alluvial sites were set up, with transects from riparian areas extending into the adjoining 2nd growth forest. Thus, a total of 18 sites were set up and a total of 347 traps were sampled monthly between June and September.

4. Carabid beetles were identified to family or genus, and the by-catch was identified only to order. 14 carabid beetle species with a total of 3906 individuals were collected in the alluvial sites, 14 species with a total of 1542 individuals were collected in the semi-alluvial sites, 13 species with a total of 3230 individuals were collected in the non-alluvial sites, and 10 species with a total of 3785 individuals were collected in the old-growth sites. A total of 8258 carabids were trapped overall, from a total of 20 species.

5. In the alluvial sites, the most abundant species captured was a forest specialist, *Pterostichus crenicollis* Le Conte, while in the semi-alluvial sites both *P. crenicollis* and another forest specialist,

Scaphinotus angusticollis (Fischer von Waldheim) were similarly common. In the non-alluvial sites, the most common species caught was *P. crenicollis* but one generalist, *Pterostichus lama* (Menetries), was far more common in this site type than in any of the other site types. There was also a high component of another generalist, *P. algidus* in these sites. In the old-growth sites, *P. crenicollis* was most abundant. *Zacotus matthewsii* Le Conte, identified as an old-growth specialist, was only found associated with the old-growth control sites and one of the alluvial sites.

Other species were also found restricted to one or two site "types": *Agonum affine* Kirby and *A. ferruginosum* Dejean are both very hygrophilous species and were found only in alluvial sites; additionally *Leistus ferruginosus* Mannerheim, another species associated with moist ground, was also found only in alluvial sites; *Amara littoralis* Mannherheim, a more open country or meadow species was found only in semi-alluvial sites; while *Agonum piceolum* LeConte and *Harpalus cordifer* Notman were both found only in non-alluvial sites. The former species is often found on bare soil or under leaves.

6. Using non-metric multidimensional scaling, I examined how the sites differed in terms of "species-space". There appeared to be a clear separation of the alluvial, semi-alluvial, and non-alluvial communities.

7. Indicator species analysis showed that four species: *Pterostichus lama, P. algidus* LeConte*, P. crenicollis and Z. matthewsii* have high indicator value. The first two species are most commonly associated with the non-alluvial site type, while *P. crenicollis* is most commonly associated with the alluvial riparian strips, and *Zacotus matthewsii* has a high indicator value for old-growth sites.

8. Differences in biomass amongst site types were examined. Larger carabids such as *Cychrus tuberculatus*, *Omus dejeani*, *Pterostichus lama*, and the *Scaphinotus* genus had the highest biomass, and thus abundance of these species affected overall biomass in any one location. Highest biomass was noted in the non-alluvial sites, then the alluvial sites, and lowest average biomass for the season was seen in the semi-alluvial sites. Biomass for the adjoining clearcuts or immature sites was always much lower than that found in the adjacent riparian buffers. In alluvial sites, approximately 70% of the biomass was made up of *P. crenicollis*, while in the semi-alluvial sites, *P. crenicollis*, and *S. angusticollis* made similar contributions (42 and 38%, respectively). In non alluvial

sites, approximately 46% of the biomass was made up by *P. lama*, while in the old-growth sites most of the biomass (54%) was made up by *P. crenicollis*.

9. The invertebrate communities of the riparian sites sampled in this study showed differences to the communities of many of the sites that have been sampled on Vancouver Island in previous studies (Pearsall, 2002-2007). For most Vancouver Island forests, whether in dry or wet variants, the dominant species found has always been *Scaphinotus angusticollis*, which is a forest specialist and makes up a very high abundance in most forested blocks. Although this species was the second most commonly captured species in the Kennedy Flats, catches of *P, crenicollis* far surpassed the catches, with almost 5000 *P. crenicollis* versus 1500 *S. angusticollis* caught for all sites overall. Additionally, there did appear to be some hygrophilous species associated with the riparian buffers that we have not captured in previous communities. Finally, abundance of *P. lama* was much higher in the non-alluvial sites of this study that we have seen in sites at any other location on the island.

10. Diversity was highest in the non-alluvial sites, then the semi-alluvial sites, and then the alluvial sites. Both diversity and evenness were particularly low in the alluvial sites A2, A3 and A4 and the old-growth site R2. Diversity of the clearcuts adjacent to the alluvial and semi-alluvial riparian strips was much higher than within the adjoining buffers. This is in accord with results from previous work that has shown that older communities generally have lower species richness and diversity than younger communities. This is often the result of the dominance of the forest specialist, *S. angusticollis* in control sites, while clearcuts and younger sites tend to receive an influx of small, winged species that are open-habitat specialists, such as *Harpalus* and *Amara* species. In the Kennedy flats region, the loss of evenness and diversity was more associated with the dominance of *P. crenicollis* rather than *S. angusticollis* in the riparian buffers of the alluvial and old-growth sites, however.

11. In summary, there appear to be relatively distinct communities found in the different types of buffers, and associated with different stream geomorphology. Riparian buffers appear to be able to retain distinct communities of carabids which are not lost or degraded when the adjoining forest blocks are harvested. Although clearuts and immature sites adjacent to the buffers do lose biomass, species and diversity, this did appear to recover in time, and forest species were not entirely lost from these blocks.

However, this is not borne out in biomass values, since the most common generalist found in the non-alluvial sites is also one of the largest species that we collect. Given that the communities of non-alluvial sites show a high component (in terms of numbers and biomass) of two generalist species, while those of alluvial sites, both second growth and old-growth are dominated to a greater extent by a forest specialist, we may make a subjective declaration that the non-alluvial sites do have lower “wildlife value”.

12. Future monitoring will be vital, to examine how the carabid assemblages change over time in riparian buffers and the adjoining blocks. At this time, the direction of carabid species succession is uncertain, since we do not know the possible extent of competitive interactions and whether the size of buffers is adequate for long-term survival of beetles at any of the sites. Although we did find *Zacotus matthewsii*, an old-growth species, and somewhat of a “flagship” species, in the old-growth and one of the alluvial sites, we did not find it in any of the alluvial riparian buffers that were adjacent to areas that had been cut since 1995, when the Forest Practices Code came into effect and was augmented by recommendations from the Clayoquot Sound Scientific Panel (CSSP). It would be very interesting to examine alluvial riparian buffers that had retained *Zacotus* prior to harvest, and assess the changes post-harvest in this species. In addition, we chose only to examine buffers on S3 streams during 2008: future studies aim to extend this to S1 and S2 streams so that we can compare the impacts of buffer size.

7 INFORMATION ABOUT CARABIDS

More than 40,000 species of carabids have been described so far (Lovei and Sunderland 1996). They are variable in size, but have a relatively typical body form, with a slender, yet strongly built body, often dark coloured (brown to black) and nocturnal: others are brightly metallic coloured, sometimes with conspicuous patterns and a few may be diurnal. Their long legs allow them to run quickly along the soil surface.

Most temperate carabids live on the soil surface: only a few species move up into the vegetation layer. They have three larval stages and pupate in a specially constructed pupal chamber in the soil. Typically carabid larvae are true soil inhabitants. Adults sclerotinize and colour after hatching. They generally produce one generation per year.

They are typically polyphagous feeding on a variety of insects and other arthropods, including those considered pests, as well as varying amounts of plant matter. They are voracious feeders, consuming close to their own body weight each day. The feeding conditions during larval development determine adult size and potential fecundity (Nelemans 1987).

Most carabids move on foot, although some can fly. Three groups may be distinguished based on the hind wing development: macropterous species have fully developed hind wings in all individuals; brachypterous species have reduced vestigial wings; and dimorphic species have some individuals with fully developed wings, and others with vestigial ones. Macropterous wings are used for dispersal flights, especially in species of scattered or disturbed habitats (e.g. cultural land), whereas brachypterous species are often stenotypic forest inhabitants with low dispersal ability.

Habitat choice by carabids is so specific that they are often used to characterize habitats. Lovei and Sunderland (1996) stated that persistence in a habitat depends on the most vulnerable life stage, which is the larva. Larval mortality is most likely the key factor in overall mortality: larvae are weakly chitinized and thus intolerant to microclimatic extremes: and they also need a sufficient food supply to develop successfully. Their limited mobility makes them dependent on proper habitat choice by the egg-laying female. Habitat and microhabitat selection is influenced by temperature or humidity extremes (especially of overwintering sites), food availability, presence and distribution of potential predators, and the type of life history and seasonality.

8 DISCUSSION

This year's study allowed for comparison of alluvial, semi-alluvial, and non-alluvial carabid communities. The riparian buffers examined were all 2nd growth forest, except for one of the alluvial buffers (A5) which was a mixture of old growth and 2nd growth. Thus we also examined the communities of two old-growth sites so that we could compare the different 2nd growth riparian communities with a climax forest. We examined the species, abundance, diversity and biomass of the carabid communities, to enable us to compare the secondary productivity found in these different site types.

I will discuss the main findings of 2008 under the headings made up of the main objectives listed at the beginning of this paper.

1. Is wildlife value and secondary productivity, as assessed by carabid biodiversity and biomass, greater in alluvial than in semi-alluvial or non-alluvial systems?
2. How does the above impact the usage of the adjacent forest by carabids, and how does this vary with distance from the stream, and with age of adjoining forest?
3. Do riparian reserves of S3 streams adequately conserve terrestrial invertebrates, and do they result in repopulation of the surrounding forest? How does this vary with geomorphological characteristics of the stream?

For the first objective, it is important to place our findings in the context of the usual community patterns that are found in coastal western hemlock forests of Vancouver Island, as found in our previous studies carried out since 2001 (Pearsall 2002-2007). For carabid beetles, highest diversity and often species richness is generally found associated with recently harvested and immature forests, changing to lower species richness and lower diversity in the old-growth forest. This has been the pattern seen in all of my previous studies, and is generally the result of new, winged, disturbance specialist species quickly moving in to fill the niche left unoccupied as the original forest species disappear when a site is harvested. Many of the forest specialists seen in this study and in my previous studies are flightless. These species changes lead to increased species richness and higher diversity in clearcuts, whereas overall abundance (and beetle biomass) is generally reduced as a result of the (usually) highly abundant forest specialist, *Scaphinotus angusticollis,* in the forested blocks. In this study, *S. angusticollis* was far less common and not the dominant species in any of the sites. Instead, *P. crenicollis*, another forest specialist, was most abundant overall. Thus, we still saw the same patterns of lower diversity in the old-growth sites and higher diversity in the clearcuts, but this did not necessarily translate to increased biomass in the older sites, since *P, crenicollis* is not a particularly large beetle. We also saw the lower diversity pattern in the alluvial sites as compared to the non-alluvial and semi-alluvial sites. However, biomass values were relatively high in the non-alluvial sites since these sites had high catches of *Pterostichus lama*, a large-bodied carabid that has been identified as a generalist in my previous studies as well as those of others (Pearsall 2002-2007, Craig 1995). Given that the communities of non-alluvial sites are show a high component (in terms of numbers and biomass) of two generalist species, *P. lama* and *P. algidus* while those of alluvial sites, both second growth and old-growth are dominated to a greater extent by the forest specialist, *P. crenicollis*, we may make a subjective declaration that the non-alluvial sites do have lower "wildlife value".

It was apparent from this study that there are indeed very different communities associated with the different stream geomorphology types. *Zacotus matthewsii* Le Conte, identified as an old-growth specialist in previous studies, was only found associated with the old-growth control sites and one of the alluvial sites. Other species were also found restricted to one or two site "types": *Agonum affine* Kirby and *A. ferruginosum* Dejean are both very hygrophilous species and were found only in alluvial sites; additionally *Leistus ferruginosus* Mannerheim, another species associated with moist ground, was also found only in alluvial sites; *Amara littoralis* Mannherheim, a more open country or meadow species was found only in semi-alluvial sites; while *Agonum piceolum* LeConte and *Harpalus cordifer* Notman were both found only in non-alluvial sites. The former species is often found on bare soil or under leaves. These different species distributions are no doubt related to the different tolerances of these different species for the different soils and microclimates found in the different site types. Interestingly, the results from this study did illustrate that there is a typical "riparian" carabid community of hygrophilous species, in addition to an unusually high abundance of *P. crenicollis* in these sites. I had not recorded a similar community from any of my previous studies of non-riparian immature, 2nd growth and old-growth coastal western hemlock forests.

For the final two questions of the objectives, it was apparent that all the buffers examined were adequate for conservation of these terrestrial invertebrates, and there were significant differences in the communities of the buffers and adjacent clearcuts. The cluster analyses showed that the riparian communities of buffers adjacent to clearcuts did cluster together with riparian communities of uncut buffers, which were even-aged 2nd growth forest from the stream edge out for extended distances. This showed that the buffer communities were not degraded or impacted significantly when the adjoining forests were cut, but rather that the carabid communities were retained and these areas acted as retention patches for these species. In terms of how well the carabids were able to populate the cut areas, (ie to what extent "lifeboating" occurred) however, was dependent on the age of the surrounding forest. Recent clearcuts as found in Semi 1, 3, 5, 6 and A3 were not well populated by forest specialists, despite the fact that these forest species were found within the buffers. However, in 2nd growth forest, there were similar abundances of forest species of carabids at most trap locations along the transects, and sharp transitions in species abundances were not apparent, at least for the 75-80 m distance that the transects extended into the 2nd growth forests.

How might the stream geomorphology affect the communities of carabids? Vegetation type and soil moisture are likely key factors. Many other authors have suggested that microhabitats influence the assemblage structure of carabid beetles (e.g., Niemelä et al. 1992; Kinnunen et al. 2001). Habitat selection by carabid beetles will likely depend on many factors, such as vegetation composition and structure (Martel et al. 1991; Niemelä et al. 1992*a*; Magura et al. 1997, 2000, 2001; Werner and Raffa 2000), edaphic conditions (e.g., humidity, acidity, litter thickness, soil type) (Szyszko 1974; Paje and Mossakowski 1984; Baguette1993; Eyre and Luff 1994; Rykken et al. 1997; Guillemain et al. 1997; Magura et al. 2000; Pearce et al. 2003; Vance and Nol 2003), and the presence of coarse woody debris (Koivula and Niemelä 2003; Pearce et al. 2003). Werner and Raffa (2000) sampled mixed northern hardwood forests of the Great Lakes Region and noted that microsite features were important and resulted in high variability of carabid assemblages among sites and among traps within sites.

Soil moisture is likely to be the most influential factor of all, as has been shown in previous studies of carabid assemblages (e.g., Thiele 1977; Epstein and Kulman 1990). It is believed that soil moisture affects survival of carabids mainly through its effects on egg and larval development (e.g., Thiele 1977). In addition Niemela et al. 1992, suggested that soil moisture is important in determining the habitat associations of species among forest types. We did measure soil moisture, but it is probable that a huge number of replicate measurements need to be made at any one site given the tremendous variability in soil moisture that occurs on a microhabitat scale. We were not able to discern any consistent patterns along the transects placed within a site, or among site types.

Other studies have noted that prey availability (Lenski 1982*a*; Loreau 1987; Niemelä et al.1986; Guillemain et al. 1997; Magura et al. 2000) and the presence of other predators (Niemelä et al. 1992*b*; Koivula and Niemelä 2003) may affect the distribution of carabid beetle species. In these cases, abundance may be affected by the sensitivity of the prey and other predators to forest disturbances. There were numerous spiders caught in our traps, as well as ants (particularly in A1) and centipedes, thus carabid beetles were not the only predator caught in our study. However, interspecific competition in carabid beetle assemblages is not well understood (Niemelä 1993).

Some studies have shown that microarthopod biomass is severely reduced in clearcut sites in comparison with forested areas. Blair and Crossley (1988) found that mean annual densities of litter microarthropods, which will make up a significant proportion of the diet of carabids, were 28% lower in clearcut areas as compared to forested areas. This was explained by the difference in the litter quantity and quality between forested and clearcut areas (Wallwork 1976). Densities of microarthropods have been shown to be positively related to standing stocks of organic matter and moisture content (Blair et al. 1990) and to be present in greater abundance in litter as compared to the soil (Donegan et al. 2001). The litter in old growth forests is much deeper and moister than that of a clearcut, and this likely explains the loss of carabids that occured, particularly of forest specialists, in the clearcuts sampled in this study. However, we also wish to consider why the non-alluvial sites showed such a difference in terms of the dominant species present?

There are two important layers that provide habitats for invertebrate mesofauna and macrofauna in the soil, as well as possibly functioning as a seed bank for plants (e.g., Lavelle et al. 1995). These layers are termed the L and FH layers: the L layer consists of unaltered dead remains of plants and animals, and the FH layer consists partly or completely of decomposed, amorphous organic matter (e.g., Pritchett and Fisher 1987). Osawa et al. (2005) suggested that the mass of the L and FH layers may be an indicator of food availability for carabid beetles. There is not a great deal of literature on how the composition and mass of these layers may affect carabids. The riparian area adjacent to the non-alluvial systems was very rocky, and it was often difficult to dig in traps due to the lack of organic matter. This may result in altered prey composition in these sites, which results in altered carabid communities as seen in the non-alluvial sites.

Pterostichus lama is known to be constantly flightless, but the biology is not otherwise well known (Lindroth 1966). Lindroth (1966) stated that it prefers dark, dense coniferous forests and is often found under logs, but this species has not shown up in large abundances in any of the intact forests sampled in my previous studies. There is no dietary information available for this species. *Scaphinotus angusticollis* was far less abundant in all of the sites sampled this year than in my previous studies. This species generally appears unable or unwilling to reside in clearcuts, which was also the case in this study, and this may be a result of dietary constraints. These beetles belong to the tribe *Cychrini* and have very characteristic elongated heads which is believed to be an adaptation that allows them to feed on snails (Lindroth 1961, Thiele 1977, Digweed 1993). Clearcuts become hot and dry in the summer and thus unfavourable for gastropods. Snails were captured in all the Kennedy Flats sites, but no specific analyses were carried out on relative abundance among site types or locations within sites.

How do my results compare with previous studies of riparian buffers? There have been very few studies of the terrestrial invertebrate communities associated with riparian buffers: most studies focus on the aquatic invertebrates. However, Rykken et al. (2007) examined terrestrial invertebrate communities associated with riparian buffers of the Willamette National Forest, Oregon, USA. Their results showed that the invertebrate community composition in buffers was more similar to that of mature forests than to clearcuts, and the authors suggested that riparian buffers of 30-m width were able to provide habitat for many riparian and forest species.

The results of their study showed many similarities to my study: their community analyses showed that *Pterostichus crenicollis* (as well as a snail, *Striaria pugetensis*) to be the strongest indicators of the immediate (< 5m) streamside community. As noted above, we collected snails but did not determine the species within the riparian areas in this study. Rykken et al. (2007) stated that this was interesting since although *P. crenicollis* favors moist soils and stream edges (Kavanaugh 1992), this species is not known as a riparian obligate, and, has actually been reported in open, human-modified sites (Larochelle and Lariviere 2003). They also suggested that the patterns of invertebrate distribution that they saw throughout the riparian ecotones were more strongly associated with microclimatic gradients than with distance from the stream, and thus it was the cool and humid conditions that were most important to the community composition. This is not surprising, since carabid beetles do show high affinity for cool, humid microclimates (Thiele 1977, Andersen 1985), and this may also be related to the amount of herbaceous vegetation. Differences among my sites in terms of shrub and herb cover could influence forest-floor invertebrate communities by varying soil temperatures, habitat structure, food sources for herbivores, and/or affecting soil moisture. The non-alluvial sites in my study had relatively simple structure of ground vegetataion, and were generally dominated by either deer fern or sword fern in the herbaceous layer, and a relatively poor shrub cover as compared to the alluvial sites.

Riparian buffers have only been implemented in B.C. since 1995. However, these areas may represent some of the few intact forest remnants in a landscape of harvested blocks, and thus serve an important function as a refuge for many forest species (Hylander et al. 2004), or possibly function as connecting corridors between larger mature forest fragments (Harris 1984, Saunders et al. 1991). The main issue with a riparian "strip" will be its' size and shape, which will result in possible edge effects leading to changes in species composition.

Spence *et al.* (1996) showed that at locations 80m from the stand edge, species that were previously thought to be specialists of either open or forested habitat could be trapped in the opposite treatment type. Edges are known to have altered plant communities (De Casenava *et al.* 1995, Matlack 1994) and have been show to influence animals (Stamps *et al.* 1987). The microclimate at stand edges has been shown to change with respect to increased light, altered air movements, litter moisture and temperature (Carmago and Kapos 1995, Chen *et al.* 1993, Matlack 1993, Palik and Murphy 1990). Chen *et al.* (1995) reported that microclimate effects typically extend 30m to > 240m into residual Douglas fir stands left after harvest in Washington and Oregon. These microclimatic changes may make the edges of riparian buffers more suitable for open habitat species and habitat generalists, and encourage their movement into forest fragments (Halme and Niemela 1993). These results highlight the possible concern that riparian buffers would be open to invasion and possible competition with open habitat or disturbance specialist species that have flown into the cut matrices adjacent to buffers. We did find open habitat preferring macropterous species in this study, such as *Amara littoralis, Harpalus cordifer* and *Omus dejeani.* Other species such as *P. herculaneus, P. amethystinus, P. algidus* and *C. tuberculatus* have also been identified as showing a generalist habit in my previous studies.

The diversity of species found in the riparian buffers will likely depend on the type of organisms, their ability to disperse, the size of the remaining fragments, proximity to other fragments, and population size (Wilcove *et al.* 1986, Harris 1984). For example, many forest species require large areas of undisturbed habitat, and may fare poorly in remnant fragments of their original range (Harris 1984). Species such as *Zacotus matthewsii* cannot fly, and do not appear willing to venture into harvested areas. In my previous studies, it was apparent that forest specialist species of carabids such as this may be able to persist in fragmented habitats, at least in the short-term, but this ability appears to depend closely on the size of the fragment. Focus on temporal changes in the forest specialist species such as *Z. matthewsii, S. angusticollis* and *P. crenicollis* in buffers will be critical: in the longer-term, buffers may not be able to retain such species. Issues such as connectivity of buffers to intact forets fragments and to each other, will likely become increasingly crucial as the landscape is increasingly fragmented (Fagan 2002, Richardson et al. 2005).

It will be important to continue this study for streams that have different buffer sizes, to examine the relative impact of buffer width. Buffer width will be critical if windthrow is an issue, and also important if there are competitive effects as a result of invasive, clearcut species moving into the buffer forest fragments and competing with the forest species there. The “stand alone” buffers that were examined in my study had only been there for approximately 5 years as most of the clearcuts were very recent. It is possible that invertebrates within them may have persisted from the pre-harvest stand, representing forest “remnants,” especially for those species with limited dispersal potential or high affinity to the near-stream zone. This suggestion highlights the need to re-evaluate the functionality of riparian buffers over the long term.

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11 APPENDICES

11.1 Appendix 1. By-Catch Information

The method used to trap carabids was also highly effective at trapping a large number of other arthropod species. In the pitfall traps, I also collected arachnids (spiders and mites), springtails, millipedes, centipedes, crickets, flies, ants and other species of beetles such as staphylinidae (rove beetles), silphidae (carrion beetles), tenebrionidae (darkling beetles), elateridae (click beetles), oedemeridae (false blister beetles) or curculionidae (weevils) as well as a number of other more rarely caught beetle species (Table 1). I also assessed the number of shrews, salamanders, slugs and snails that fell into the traps. All of the by-catch was collected, counted and stored. The beetles were identified to family or genus, and the other groups were only identified to order.

Table 1: By-catch from pitfall traps

Group	**Genus/Species**
Invertebrates	
Coleoptera (beetles):	
Silphidae (carrion beetles)	*Nicrophorus* sp. others
Dascilloidea (polyphagan beetles)	*Araeopidius monachus* (LeConte)
Dytiscidae (predaceous diving beetles)	Not assessed to species
Staphylinidae (rove beetles)	Not assessed to species
Elateridae (click beetles)	*Hemicrepidius morio (LeConte)* *Ctenicera sp.*
Curculionidae (weevils)	*Nemocestes incomptus* (Horn) *Nemocestes horni* Van Dyke Others not assessed to species
Trachypachidae	*Trachypachus holmbergi* Mannerheim
Leiodidae (small fungus beetles)	*Catops* sp. *Catoptrichus frankenhaeuseri* (Mannerheim)
Oedemeridae (false blister beetles)	*Ditylus gracilis* LeConte *Ditylus quadricollis* LeConte
Agyrtidae (primitive carrion beetles)	*Necrophilus hydrophiloides* Guerin-M.
Cerambycidae (long-horned beetles)	*Xestoleptura crassipes* (LeConte)

Cephaloidae (false long-horned beetles)	Cephaloon tenuicorne LeConte
Pyrochroidae (fire-coloured beetles)	*Ischalia vancouverensis* Harrington
Zopheridae (used to be Tenebrionidae)	*Phellopsis obcordata* (Kirby)
Tenebionidae (darkling beetles)	*Ipthiminus serratus* Mannerheim
Arachnida:	
Spiders	not assessed to genus or species
Mites	not assessed to genus or species
Chilopoda:	
Millipedes	not assessed to genus or species except they were separated into groups: Grey (probably including *Caseya* spp., *Bollmanella* spp., *Taiyutyla* spp), pink (possibly *Nearctodesmus* spp) and yellow (yellow spotted millipede, *Harpaphe haydeniana haydeniana*).
Centipedes	not assessed to genus or species
Hymenoptera:	
Ants	not assessed to genus or species
Diptera	*Eros simplicus*
Hemiptera & Homoptera	Few, not assessed to species
Gastropoda:	
Slugs	not assessed to genus or species
Snails	not assessed to genus or species
Vertebrates	
Mammalia:	
Shrew	*Sorex vagrans* and *Sorex monticolus*
Amphibia:	
Frogs	not assessed to genus or species
Salamanders	*Ambystoma gracile, Ambystoma macrodactylum, Taricha granulose, Ensatina eschscholtzii, Plethodon vehiculum*

The most commonly caught by-catch were spiders, snails, weevils, millipedes, ants and crickets. Monthly catches of these groups are listed for all site by location in Tables 1- 10.

Tables 1a-d. Monthly catches by site and location for ants in a) alluvial, b) semi-alluvial, c) non-alluvial and d) old growth sites.

a.

month	A1	A2	A3 In	A3 Out	A4 In	A4 Out	A5	A6	A7
6	160		4	18	3	1	0	0	0
7	353	17	35	11	19	16	4	18	0
8	332	10	16	18	11	5	3	7	0
9	432	13	77	11	5	19	16	30	0

b.

month	Semi 1 In	Semi 1 Out	Semi 2	Semi 3 In	Semi 3 Out	Semi 4	Semi 5 In	Semi 5 Out	Semi 6 In	Semi 6 Out
6	0	0	0	0	0	0	0	0	0	1
7	0	0	2	6	1	0	12	1	0	5
8	0	0	14	0	0	1	9	0	2	3
9	1	0	5	0	0	0	5	0	1	2

c.

month	NA1	NA2	NA3
6	0	0	0
7	1	0	3
8	0	0	0
9	0	0	0

d.

month	R1	R2
6	0	0
7	0	1
8	0	1
9	0	0

Tables 2a-d. Monthly catches by site and location for staphylinids in a) alluvial, b) semi-alluvial, c) non-alluvial and d) old growth sites.

a.

month	A1	A2	A3 In	A3 Out	A4 In	A4 Out	A5	A6	A7
6	0	0	0	0	2	0	0	0	0
7	0	0	1	0	0	0	4	0	0
8	0	3	1	0	0	0	2	0	3
9	7	45	0	0	0	0	0	14	4

b.

month	Semi 1 In	Semi 1 Out	Semi 2	Semi 3 In	Semi 3 Out	Semi 4	Semi 5 In	Semi 5 Out	Semi 6 In	Semi 6 Out
6	0	1	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	1	0	0	0

8	1	5	0	0	3	20	0	0	0	0
9	0	25	0	0	1	0	0	0	0	0

c.

month	**NA1**	**NA2**	**NA3**
6	0	0	0
7	0	0	0
8	0	2	0
9	0	4	1

d.

month	**R1**	**R2**
6	0	0
7	0	0
8	2	0
9	7	0

Tables 3a-d. Monthly catches by site and location for snails in a) alluvial, b) semi-alluvial, c) non-alluvial and d) old growth sites.

a.

month	**A1**	**A2**	**A3 In**	**A3 Out**	**A4 In**	**A4 Out**	**A5**	**A6**	**A7**
6	9		3	2	15	7	9	10	3
7	10	12	4	0	24	5	32	11	4
8	13	23	4	0	10	6	18	6	5
9	12	25	4	0	13	3	1	22	14

b.

month	**Semi 1 In**	**Semi 1 Out**	**Semi 2**	**Semi 3 In**	**Semi 3 Out**	**Semi 4**	**Semi 5 In**	**Semi 5 Out**	**Semi 6 In**	**Semi 6 Out**
6	10	4	5	5	1	1	19	6	4	2
7	18	11	12	6	1	17	31	5	11	4
8	8	4	10	9	1	15	18	7	11	5
9	11	7	14	7	3	15	17	7	10	9

c.

month	**NA1**	**NA2**	**NA3**
6	22	27	19
7	40	31	35
8	39	64	42
9	52	51	30

d.

month	**R1**	**R2**
6	18	13
7	20	31
8	39	19
9	31	25

Tables 4a-d. Monthly catches by site and location for curculionidae (weevils) in a) alluvial, b) semi-alluvial, c) non-alluvial and d) old growth sites.

a.

month	A1	A2	A3 In	A3 Out	A4 In	A4 Out	A5	A6	A7
6	3		1	0	0	0	7	11	0
7	2	3	0	0	0	0	1	5	1
8	1	1	0	0	0	0	0	4	0
9	0	0	0	0	0	0	0	0	0

b.

month	Semi 1 In	Semi 1 Out	Semi 2	Semi 3 In	Semi 3 Out	Semi 4	Semi 5 In	Semi 5 Out	Semi 6 In	Semi 6 Out
6	2	3	3	5	0	1	6	21	1	1
7	1	2	7	3	4	4	0	21	1	0
8	0	3	4	4	0	2	1	7	0	0
9	0	1	1	0	4	3	0	24	0	2

c.

month	NA1	NA2	NA3
6	2	0	0
7	1	0	2
8	0	0	0
9	1	1	0

d.

month	R1	R2
6	3	2
7	5	3
8	1	2
9	0	1

Tables 5a-d. Monthly catches by site and location for crickets in a) alluvial, b) semi-alluvial, c) non-alluvial and d) old growth sites.

a.

month	A1	A2	A3 In	A3 Out	A4 In	A4 Out	A5	A6	A7
6	0		0	0	0	0	1	0	0
7	0	0	0	0	0	0	0	0	0
8	1	1	1	0	0	0	6	1	0
9	1	1	0	0	11	0	3	4	0

b.

month	Semi 1 In	Semi 1 Out	Semi 2	Semi 3 In	Semi 3 Out	Semi 4	Semi 5 In	Semi 5 Out	Semi 6 In	Semi 6 Out
6	0	1	0	5	2	1	0	0	0	2
7	0	2	1	0	4	0	1	0	3	4
8	0	4	14	1	16	4	1	4	4	1
9	2	2	5	6	3	1	1	2	2	8

c.

month	NA1	NA2	NA3
6	0	0	0
7	1	1	1
8	0	1	3
9	0	1	4

d.

month	R1	R2
6	0	0
7	3	0
8	1	5
9	20	6

Tables 6a-d. Monthly catches by site and location for grey millipedes in a) alluvial, b) semi-alluvial, c) non-alluvial and d) old growth sites.

a.

month	A1	A2	A3 In	A3 Out	A4 In	A4 Out	A5	A6	A7
6	11		1	0	0	3	4	2	3
7	9	9	2	0	5	0	6	9	3
8	12	7	1	0	0	1	2	2	3
9	28	9	1	0	1	0	2	11	4

b.

month	Semi 1 In	Semi 1 Out	Semi 2	Semi 3 In	Semi 3 Out	Semi 4	Semi 5 In	Semi 5 Out	Semi 6 In	Semi 6 Out
6	5	0	3	4	1	2	4	0	4	0
7	3	12	8	7	2	4	8	5	4	1
8	2	2	5	5	1	4	5	1	2	0
9	3	3	5	7	1	14	4	3	1	0

c.

month	NA1	NA2	NA3
6	2	5	2
7	6	5	6
8	2	11	0
9	2	8	14

d.

month	R1	R2
6	5	2
7	4	0
8	1	0
9	6	3

Tables 7a-d. Monthly catches by site and location for pink millipedes in a) alluvial, b) semi-alluvial, c) non-alluvial and d) old growth sites.

a.

month	A1	A2	A3 In	A3 Out	A4 In	A4 Out	A5	A6	A7
6	8		0	0	1	0	0	0	0
7	3	0	1	0	2	0	0	0	0
8	7	0	0	0	1	0	0	0	0
9	3	1	0	0	1	1	1	0	0

b.

month	Semi 1 In	Semi 1 Out	Semi 2	Semi 3 In	Semi 3 Out	Semi 4	Semi 5 In	Semi 5 Out	Semi 6 In	Semi 6 Out
6	0	0	1	1	0	0	0	0	1	0
7	1	0	0	0	0	0	1	0	1	0
8	0	0	0	1	0	0	2	0	1	0
9	0	0	0	0	0	0	2	0	0	0

c.

month	NA1	NA2	NA3
6	0	4	16
7	3	1	32
8	2	11	31
9	1	3	2

d.

month	R1	R2
6	1	0
7	2	5
8	12	0
9	9	1

Tables 8a-d. Monthly catches by site and location for yellow millipedes (*Harpaphe* sp.) in a) alluvial, b) semi-alluvial, c) non-alluvial and d) old growth sites.

a.

month	A1	A2	A3 In	A3 Out	A4 In	A4 Out	A5	A6	A7
6	7		0	0	1	6	4	5	1
7	3	6	0	0	4	5	4	12	1
8	3	1	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	1	0

b.

month	Semi 1 In	Semi 1 Out	Semi 2	Semi 3 In	Semi 3 Out	Semi 4	Semi 5 In	Semi 5 Out	Semi 6 In	Semi 6 Out
6	3	0	4	1	1	4	26	1	8	0
7	5	3	7	6	4	9	33	5	3	0
8	1	1	2	0	3	0	3	0	0	0
9	5	2	0	2	0	1	0	0	1	0

c.

month	NA1	NA2	NA3
6	2	11	0
7	10	17	3
8	2	6	10
9	1	0	0

d.

month	R1	R2
6	2	0
7	12	0
8	0	1
9	0	0

Tables 9a-d. Monthly catches by site and location for spiders in a) alluvial, b) semi-alluvial, c) non-alluvial and d) old growth sites.

a.

month	A1	A2	A3 In	A3 Out	A4 In	A4 Out	A5	A6	A7
6	2		3	7	2	3	6	10	1
7	15	14	24	26	27	8	21	20	6
8	22	21	11	8	21	13	26	14	7
9	36	35	31	5	37	9	16	28	8

b.

month	Semi 1 In	Semi 1 Out	Semi 2	Semi 3 In	Semi 3 Out	Semi 4	Semi 5 In	Semi 5 Out	Semi 6 In	Semi 6 Out
6	2	7	13	16	25	17	4	2	7	19
7	7	41	16	15	95	19	17	7	12	42
8	14	25	40	19	43	19	20	5	17	14
9	19	11	38	36	22	51	15	28	14	16

c.

month	NA1	NA2	NA3
6	3	8	5
7	16	14	13
8	12	28	34
9	22	27	34

d.

month	R1	R2
6	7	8
7	23	39
8	17	21
9	36	12

Tables 10a-d. Monthly catches by site and location for centipedes in a) alluvial, b) semi-alluvial, c) non-alluvial and d) old growth sites.

a.

month	A1	A2	A3 In	A3 Out	A4 In	A4 Out	A5	A6	A7
6	0		0	0	0	0	2	1	0
7	1	0	0	0	0	0	1	0	0
8	2	0	1	0	0	0	1	0	1
9	0	1	1	0	0	0	4	3	0

b.

month	Semi 1 In	Semi 1 Out	Semi 2	Semi 3 In	Semi 3 Out	Semi 4	Semi 5 In	Semi 5 Out	Semi 6 In	Semi 6 Out
6	0	1	0	3	0	0	1	0	1	0
7	0	0	0	0	0	0	0	0	0	0
8	1	0	5	0	0	3	0	1	0	1
9	0	3	7	3	2	2	0	1	1	2

c.

month	NA1	NA2	NA3
6	0	1	0
7	0	0	2
8	0	0	3
9	2	5	0

d.

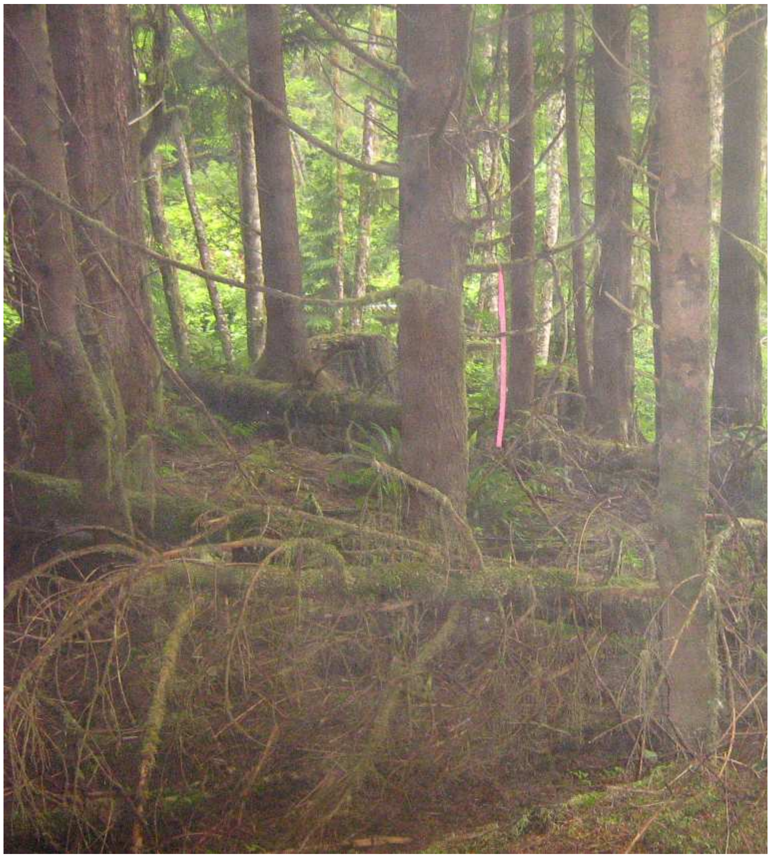
month	R1	R2
6	1	0
7	1	1
8	0	1
9	1	0

11.2 Appendix 2. Photographs of Experimental Sites.

R2, by creek

Alluvial stream bank

A1 Second growth forest



Alluvial bank trap

A3 clearcut and swampy site

A5 mixture of old growth and 2nd growth

A5 stream edge trap

A6

Stream bank of A7

Clearcut of Semi 1, looking towards the riparian buffer

Semi 3 and 4 creek

Semi 2

Semi 2

Semi 3 buffer

Clearcut Semi 4

Semi 5 buffer

Clearcut of Semi 6 looking towards the riparian buffer

Non alluvial stream NA3

Non alluvial stream NA2

Non alluvial stream NA1

11.3 Appendix 3. Descriptions of carabid species captured during 2008

The following information is taken from Lindroth (1961-69) and Kavanaugh (1992).

TRIBE CYCHRINI

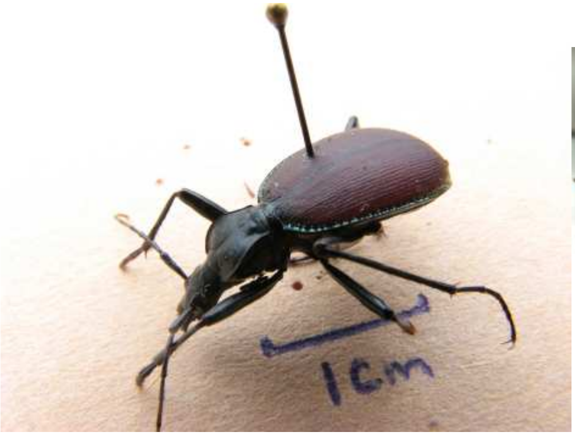
GENUS SCAPHINOTUS LATREILLE

Scaphinotus angusticollis (Mannerheim)

Description: A *Scaphinotus* with rufous-brown elytron with 18 regular, punctate striae. Size about 18.4-21.4mm.

Dispersal potential: Adults are markedly brachypterous, incapable of flight. Association with logs on the forest floor along streams or just above sea beaches may provide a mechanism for dispersal oversea: otherwise limited to walking.

Habitat preference: On mainland: restricted generally to forested areas, from sea level to tree line with dispersing adults also found on sea beaches and slightly above treeline. Lindroth states that this species is a "true woodland" species, almost restricted to the coastal "Vancouverian" forests. During the daytime it is apparently found under bark, and moss of dead, standing or fallen trees in shady places, and at night the beetle runs around and may climb the trunks to considerable heights. Hibernation apparently takes place in more than one stage.



Scaphinotus marginatus (Fischer)

Description: A *Scaphinotus* with black elytron with faint or marked metallic violet or green reflection with 16 or fewer striae. Size about 11.6-19.9 mm.

Dispersal potential: Adults are markedly brachypterous, incapable of flight. Association with logs on the forest floor along streams or just above sea beaches may provide a mechanism for dispersal oversea: otherwise limited to walking.

Habitat preference: species is widespread, with adults found in subratidal meadows, on open ground under cover, in disturbed areas, in all areas of deciduous and coniferous forest from sea level to timberline; also in subalpine and alpine areas under stones; absent only from waterside areas. Lindroth stated that this species is rather eurytopic, but in southern regions it is mainly found in forests. Larval hibernation is normal, and the adults probably live more than one year.

Scaphinotus angulatus Harris

Identification: Deep black, shiny elytra often with pronounced violaceous or coppery lustre. Elytra with 14 deep regular, punctate striae. 18-24mm length. All the *S. angulatus* captured on Vancouver Island between 2002-2007 were very black in colouration (Pearsall 2002-2007). The body size is similar, but the body shape is distinctive from that of *S. angusticollis.* It appears more rounded and the prothorax tends to be more bulbous that that of *S. angusticollis.*

Range /Habitat preference: Restricted to heavy "Vancouverian" forests. Both larvae and adults are able to hibernate. Pearsall (2002-2007) found this species to be a forest specialist, similar to *S. angusticollis* and *S. marginatus*.

Dispersal Potential: Brachypterous. This insect can only walk out of site, and is unable to fly.

Summary of habits of *S. angusticollis* and *S. marginatus*: These beetles are commonly seen in moist forests of the Northwest. All members of this genus feed on snails and slugs, but have also been observed feeding on earthworms, other arthropods including the larvae of the western hemlock looper. The peculiar elongated shape of the head, pronotum, and mandibles of these species is directly associated with their feeding behaviour. Their narrow anterior end can fit into the aperture of a snail's shell to feed. The larvae of these species also feed on snails. Both larvae and adults of both species live upon moist forest ground. *S. marginatus*, is considered a forest litter predator and its smaller size allows it to move more freely within the duff layer rather than on top of it. Multiple individuals of *S. angusticollis* have been observed attacking large slugs together in captivity and sharing small shelters in groups, perhaps suggesting more complex social behaviour than is typical of predatory beetles.

They are believed to have high potential as indicator species: both species are clearly associated with moist forest. There is also strong evidence supporting a correlation between these species and mature forest.

GENUS CYCHRUS FABRICIUS

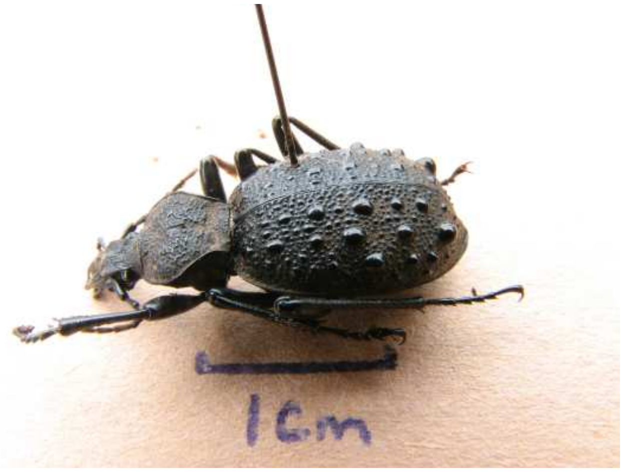
Cychrus tuberculatus Harris 1839

Identification: A very large (21-25.3 mm) species with a dull black body and appendages. The surface of head and pronotum with thin, raised, irregularly shaped interconnecting ridges. Elytra covered with distinct, shiny tubercles of varied size; the largest tubercles arranged in three or four longitudinal rows.

Range: Found on the west coast of North America, north to the Queen Charlotte Islands, south to northwestern California and east to the Cascade Range.

Dispersal potential: Adults are brachypterous, incapable of flight, association with logs on the forest floor along streams or just above sea beaches may provide a method for oversea dispersal on rafts. Otherwise limited to ambulatory dispersal.

Habitat distribution: Restricted to heavy deciduous and coniferous forests, occurring in leaf litter and under logs on forest floor. Lindroth stated that this species was apparently restricted to heavy "Vancouverian" forests. Both adults and larvae hibernate.



TRIBE PTEROSTICHINI

GENUS PTEROSTICHUS BONELLI

Specifically, the species *Pterostichus lama, P. herculaneus, P. amethystinus, P. algidus, P. crenicollis, P. protractus, P. pumilus. pumilus*

Description: This genus contains over 230 species in the U.S. Most are very similar in appearance, but vary in size. All of the above listed species are black, shiny, strong-jawed, flattened, ground dwelling beetles with striate elytra. Though practically identical in form, they vary greatly in size. Several species are similar in size and can only be identified by looking at micro-characteristics of the pronotum and shades of coloration.

Habits: These species are generally considered nocturnal, tending to rest under stones and logs by day. They are predacious, but have been known to eat plant materials such as seeds and berries. *P.*

algidus is one of the principal beetles that feed on Douglas-fir seeds. Species are believed to feed mainly on caterpillars and other soft bodied insects.

Range and Habitat: Members of this genus range throughout North America in a wide variety of habitats. However, the species listed above are local forest dwelling species. Species range from abundant to uncommon in appropriate habitat.

Indicator Value: Questionable for most species. *P. crenicollis* has been listed as a late successional forest associate and a riparian predator in Appendix J2 of the Northwest Forest Plan. This species can be keyed out by the existence of micro-serrations along the margins of the pronotum. It shares this trait with *P. lama* but is much smaller. *Pterostichus lama* and *P. amethystinus* have been considered late successional forest related by regional specialists.

Each species will be dealt with individually below:

***Pterostichus lama* (Menetries)**

Adults are markedly brachypterous, incapable of flight. Association with logs on the forest floor along streams or just above sea beaches may provide a mechanism for dispersal oversea: otherwise limited to walking. About 23.6-27.4mm length.

***Pterostichus crenicollis* LeConte**

Adults are markedly brachypterous, incapable of flight. Association with logs on the forest floor along streams or just above sea beaches may provide a mechanism for dispersal oversea: otherwise limited to walking. Body length 16.0- 19.5mm.

Adults are widespread and abundant at low and middle elevations (up to 800m) where they occur under stones and logs and in leaf litter in areas of deciduous or coniferous forest. They also occur on shaded cobble-type upper sea beaches above the high tide line, under stones along margins of small shaded streams and under debris in open areas.

***Pterostichus algidus* LeConte**

Adults are markedly brachypterous, incapable of flight. Association with logs on the forest floor along streams or just above sea beaches may provide a mechanism for dispersal oversea: otherwise limited to walking. Body length 12.1-14.8mm.

Adults of this species are widespread, very abundant, almost ubiquitous at low and middle elevations (up to 250m) where they occur under cover in all habitats except sandy beach areas and bogs and marshes.

***Pterostichus amethystinus* Mannerheim**

Adults are markedly brachypterous, incapable of flight. Association with logs on the forest floor along streams or just above sea beaches may provide a mechanism for dispersal oversea: otherwise limited to walking. Body length 10.8-15.3mm.

This species is widespread in areas of coniferous forest, from sea level to treeline on mountain peaks. Adults occur under loose bark of fallen trees or under logs on the forest floor.

***Pterostichus herculaneus* Mannerheim**

Occurs in dense, dry conifer or mixed forests, mostly under logs. Hibernation may take place in the larval stage. Body length 13.5-17mm.

Pterostichus pumilus pumilus Casey 1913

Distribution: In the mountains and foothills near the Pacific coast S to Oregon.

Ecology: On Mt. Arrowsmith, this species was found in dense, old forest, with *Pseudotsuga taxifolia, Abies grandis, Thuja plicata*.

Pterostichus protractus LeConte 1860

Distribution: Rocky mountains and northern Cascades, South to California, up to Canada.

Ecology: Apparently confined to mountain forests.

TRIBE PLATYNINI

GENUS AGONUM BONELLI

Members of this genus have a characteristic, rather uniform appearance. World-wide distribution, most are hygrophilus. Occur most frequently at the margin of standing, often quite small, waters, where the vegetation is rich. Some are restricted to forests. Most are able flyers

Agonum piceolum LeConte 1879

Distribution: Transamerican. B.C., and Vancouver Island.

Ecology. Usually occurs near rivers, in considerable distance from water, in shaded positions (under poplars etc), on bare or sparsely vegetated soil, often among dead leaves.

Dynamics: Generally flightless.

Agonum ferruginosum Dejean 1828

Distribution: In western half of the continent, south to California. Within B.C., Vancouver area, Vancouver Island.

Ecology. Very hygrophilous. At the margin of standing waters, often small ponds, on soft clay or mud.

Dynamics: this species has true dimorphism of wings so some will be alate and others flightless.

Agonum affine Kirby 1837

Distribution: Transamerican and mainly northern. B.C., and Vancouver Island.

Ecology. Very hygrophilous. At the border of ponds and in swamps with dense vegetation of Carices, Menyanthes and brown mosses.

TRIBE ZABRINI

GENUS AMARA BONELLI 1810

Over 100 species occur in North America. Most species are xerophilous, occurring in open country with sparse vegetation. Although many of the larvae are carnivorous, adults are mainly vegetarian, feeding chiefly on seeds and flowers. Among carabids, these are unusual in being most diverse in drier habitats (such as in open, grassy fields with sparse vegetation).

***Amara littoralis* Mannerheim, 1843**

Identification: small size, body length 7.4-8.4mm, body black or piceous

Dispersal potential: Adults macropterous and probably capable of at least short-range aerial dispersal as well as ambulatory dispersal.

Habitat distribution: In QCI, they were restricted to supratidal meadows and other open areas at low and middle elevations. Adults occured under debris (e.g. driftwood, boards) or are active by day in dry sites with low, sparse vegetation. They were especially abundant in synanthropic sites. In general, they are found in open, moderately dry country with rich vegetation, usually of pronounced weedy character; clearly favoured by human activities.

TRIBE BROSCINI

GENUS BROSCODERA LINDROTH

Broscoderus insignis Mannerheim 1852

Distribution: In coastal mountain ranges of Pacific Northwest, S to W Oregon. Very local and rare. Found in Canada.

Ecology: Lowlands, mountains, subalpine and alpine zones. Below tree line: margins of small streams, with wet, loose stony or rocky soil. Above tree line: barren slopes and edges of snowfields. Open ground. Nocturnal; sheltering during the day in loose rocky substrate (below tree line), or under stones (above tree line). Gregarious.

Biology: Seasonality: July-August.

Dispersal power: Macropterous, probably capable of flight. Slow runner. Strong burrower.

GENUS ZACOTUS LECONTE

Restricted to western North America.

***Zacotus matthewsii* LeConte**

Description: This ground beetle is most recognizable by its striking coloration. The entire upper side of its head, pronotum, and abdomen are a brightly iridescent bronze/maroon. Its underside and legs are black. The frons, or top of the head, is irregularly wrinkled. *Zacotus matthewsi* is roughly tubular in form, rather than the flattened oval shape typical of this family. Body length is 12.0-18.0mm

Habits: Adults of this species are forest floor dwelling predators. Larvae live within the forest floor litter and are also predaceous. Relatively little is known about the lifestyle and behaviour of this species. Sources refer to it as a litter and soil predator, feeding mainly upon millipedes. Adults are markedly brachypterous, incapable of flight. Association with logs on the forest floor along streams or just above sea beaches may provide a mechanism for dispersal oversea: otherwise limited to walking.

Range and Habitat: This species can be found within mature forests along the pacific coast, from British Columbia to Northern California. Some sources extend the range eastward to Montana and North to Alaska. Lindroth stated that members of this species occur in dense coniferous

forest, where they are found under logs and deep in the needle duff layer during the day. At night they are active on the surface, particularly in areas where needle duff is very deep and free of low plant cover (understory). They are generally uncommon to common in appropriate habitat.
Indicator potential: They are believed to have high potential as indicators. Data collected from the Mt. Hood National Forest surveys suggests a strong association between *Zacotus matthewsii* and old growth forest. This species has been listed with the old growth associated arthropods in the J2 Appendix of the Northwest Forest Plan.

TRIBE HARPALINI

GENUS HARPALUS LATREILLE

Worldwide in distribution, with ~ 25 genera and >300 species in North America. Many are primarily phytophagous, at least as adults. As a group, they occupy a broad habitat range, from xeric habitats in desert regions, to mesic habitats in both temperate and tropical regions.

Harpalus cordifer Norman 1919
Distribution: On the westcoast, from Oregon to Canada. Common on Vancouver Island.
Ecology. On Mt. Arrowsmith, Vancouver Island, this species occurs on the forested North slope in a shaded position on soild rich with humus.
Dynamics: The wings are full, wirh reflexed apex, but varying in size, in some specimens so small that they cannot be functional. The species may be functionally dimorphic.

TRIBE NEBRINI

GENUS LEISTUS FROHLICH

Leistus ferruginosus Mannerheim 1843
Identification: This species is small (8.2-8.5 mm) and dark brouwn to yellow-brown, elytra often with a trace of irridescent lustre. Prothorax strongly constricted towards base; third elytral stria with three to four dorsal punctures. In the Genus *Leistus* , springtails and other small insects, and mites form the bulk of the adult and larval diets.
Range: Western North America from the Kenai Peninsula, Alaska to Oregon, extending to western Alberta.

Habitat distribution: Restricted to lowland areas of deciduous forest; adults found in red alder leaf litter or on moist half shaded ground usually near running water. Often found under *Alnus* and *Salix* bushes.

Dynamics: wings are full but varying in size- it is thus unknown if this species is able to fly.

TRIBE CICINDELINI

GENUS OMUS

Omus dejeani Reiche

The tiger beetle *Omus* is endemic to the coastal region of western North America, from southern British Columbia to southern California. Several species are restricted to the coastal ranges and foothills, whuile a large number of species are inhabitants of the Sierra Nevada of California.

The beetles of the genus *Omus* are flightless and are primarily nocturnal. They usually occur in the forest/meadow ecotones, with some species, like *Omus dejeani* Reiche, having an affinity toward the meadow. During the daylight hours the beetles are found under leaf litter and in/under fallen tree trunks.

11.4 Appendix 4. Details of nested ANOVAs performed for site/ treatment type comparisons

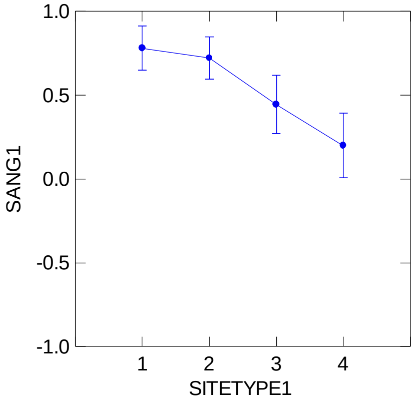
Nested ANOVA were done to assess whether there are differences among site types (alluvial, semi-alluvial, non-alluvial, old-growth), given the variability among the different sites. The design set up in Systat was a GLM where site types were coded as alluvial =1, semi-alluvial=2, non-alluvial=3, old-growth =4, and sites were nested within site types. For example, within the non-alluvial site type were the three sites, NA1, NA2 and NA3. Data for the clearcut areas adjacent to riparian buffers of sites A3, A4, Semi 1, Semi 3, Semi 5 and Semi 6 are excluded from the analysis, since the communities of cut areas are so different from the communities of intact forest, and thus these data will affect the results. Line 1 of results shows degrees of freedom, F and P value for the comparison of site type, whereas line 2 of results is the same data for the comparison of sites nested within site types. A P-value <0.05 for the site type comparison denotes that despite the variance within the different sites within that category (e.g. variability between NA1, NA2 and NA3 in non-alluvial types, or variability among R1 and R2 in the old-growth types), there was still sufficient statistical difference among the site types that this resulted in a significant P value using the nested ANOVA. Post-hoc testing was carried out to determine which of the site types were statistically different if the T term was significant. These analyses were done using the abundance of the most commonly captured beetle species: *Cychrus tuberculatus, Scaphinotus angusticollis, S. marginatus, Zacotus matthewsii,* and *Pterostichus crenicollis.* The analyses were done for each month of capture separately.

June *Scaphinotus angusticollis*

Dep Var: SANG1 N: 235 Multiple R: 0.502 Squared multiple R: 0.252
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
SITETYPE	9.622	3	3.207	2.633	0.051
SITE(SITETYPE)	77.620	13	5.971	4.901	0.000
Error	265.567	218	1.218		

Least Squares Means

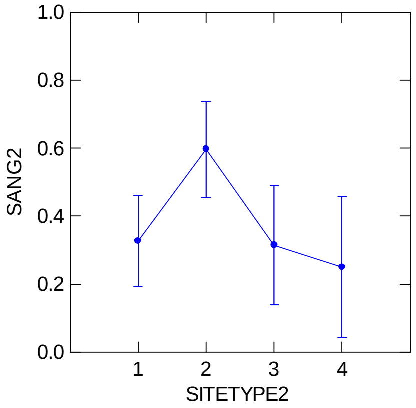


July *Scaphinotus angusticollis*

Dep Var: SANG2 N: 270 Multiple R: 0.376 Squared multiple R: 0.142
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
SITETYPE	4.678	3	1.559	1.001	0.393
SITE(SITETYPE)	59.537	14	4.253	2.729	0.001
Error	392.698	252	1.558		

Least Squares Means



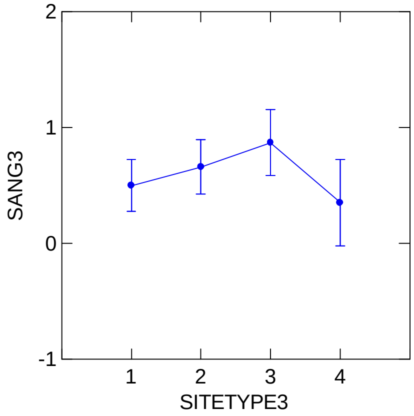
August *Scaphinotus angusticollis*

Dep Var: SANG3 N: 265 Multiple R: 0.308 Squared multiple R: 0.095

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
SITETYPE	6.977	3	2.326	0.540	0.655
SITE(SITETYPE)	104.688	14	7.478	1.736	0.049
Error	1064.016	247	4.308		

Least Squares Means



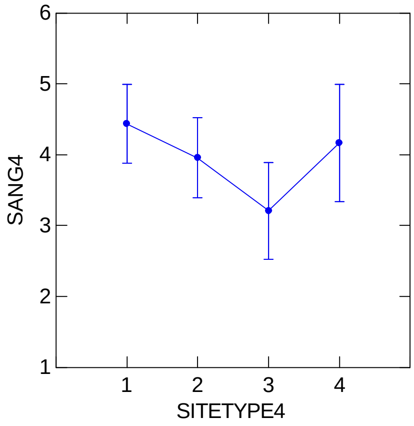
September *Scaphinotus angusticollis*

Dep Var: SANG4 N: 262 Multiple R: 0.388 Squared multiple R: 0.151

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
SITETYPE	49.381	3	16.460	0.673	0.569
SITE(SITETYPE)	1033.051	14	73.789	3.017	0.000
Error	5967.018	244	24.455		

Least Squares Means



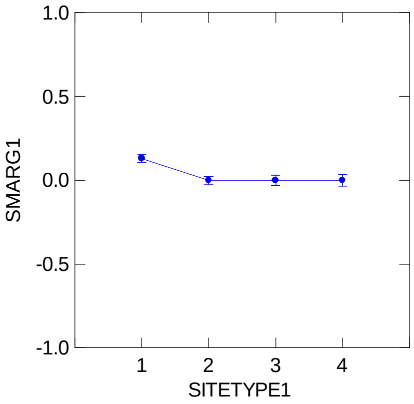
June *Scaphinotus marginatus*

Dep Var: SMARG1 N: 235 Multiple R: 0.423 Squared multiple R: 0.179

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
SITETYPE	0.813	3	0.271	7.394	0.000
SITE(SITETYPE)	1.223	13	0.094	2.568	0.003
Error	7.987	218	0.037		

Least Squares Means



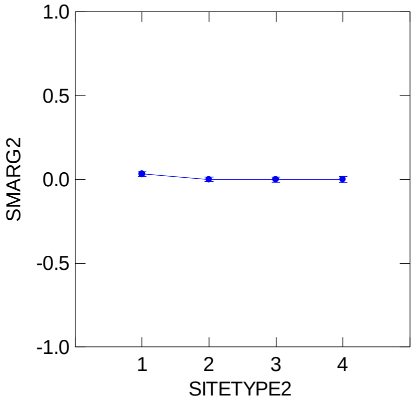
Site Type: post-hoc testing showed that significantly more *S. marginatus* were caught in the alluvial site types than in all others.

July *Scaphinotus marginatus*

Dep Var: SMARG2 N: 270 Multiple R: 0.270 Squared multiple R: 0.073
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
SITETYPE	0.061	3	0.020	1.406	0.242
SITE(SITETYPE)	0.188	14	0.013	0.926	0.531
Error	3.654	252	0.014		

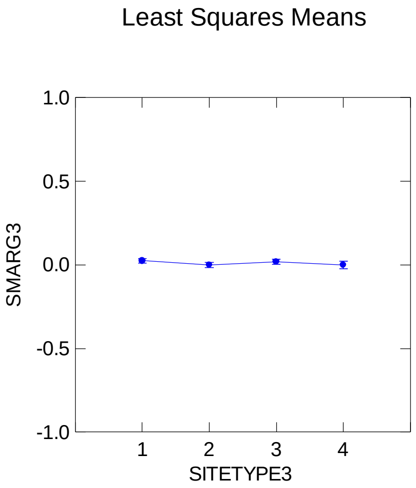
Least Squares Means



August *Scaphinotus marginatus*

Dep Var: SMARG3 N: 265 Multiple R: 0.207 Squared multiple R: 0.043
Analysis of Variance

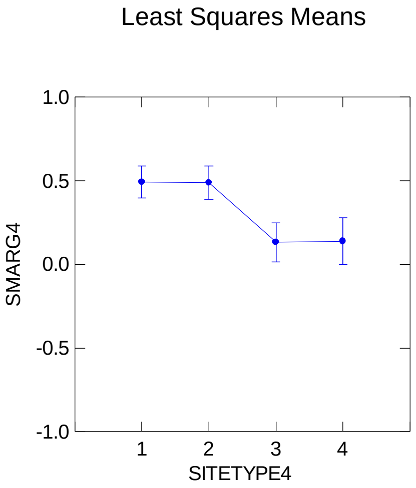
Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
SITETYPE	0.032	3	0.011	0.695	0.556
SITE(SITETYPE)	0.119	14	0.009	0.558	0.895
Error	3.771	247	0.015		



September *Scaphinotus marginatus*

Dep Var: SMARG4 N: 261 Multiple R: 0.391 Squared multiple R: 0.153
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
SITETYPE	7.144	3	2.381	3.317	0.021
SITE(SITETYPE)	26.921	14	1.923	2.679	0.001
Error	174.423	243	0.718		

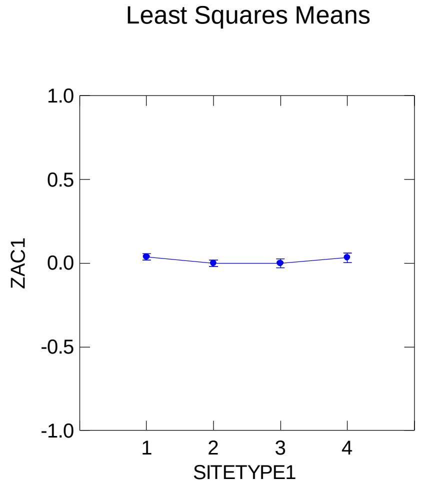


Site Type: post-hoc testing was unable to discern any significant differences in abundance of *S. marginatus* among the different site types.

June *Zacotus matthewsii*

Dep Var: ZAC1 N: 235 Multiple R: 0.351 Squared multiple R: 0.123
Analysis of Variance

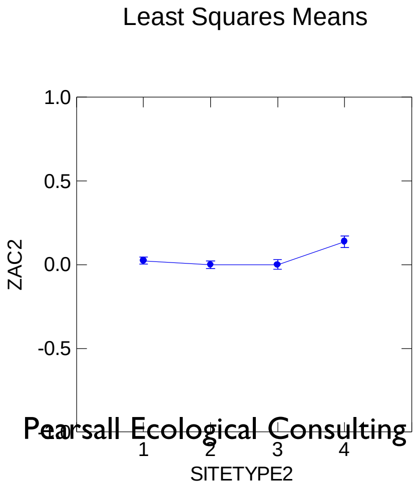
Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
SITETYPE	0.071	3	0.024	0.850	0.468
SITE(SITETYPE)	0.728	13	0.056	2.019	0.020
Error	6.044	218	0.028		



July *Zacotus matthewsii*

Dep Var: ZAC2 N: 270 Multiple R: 0.320 Squared multiple R: 0.103
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
SITETYPE	0.545	3	0.182	4.340	0.005
SITE(SITETYPE)	0.661	14	0.047	1.127	0.334
Error	10.556	252	0.042		

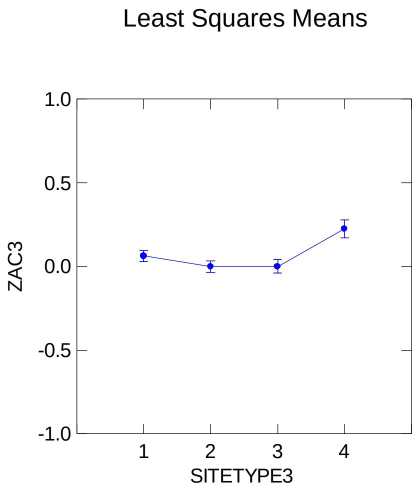


Site Type: post hoc testing showed that the highest abundance of *Z. matthewsii* was found in the old-growth control site type.

August *Zacotus matthewsii*

Dep Var: ZAC3 N: 265 Multiple R: 0.406 Squared multiple R: 0.165
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
SITETYPE	1.293	3	0.431	4.875	0.003
SITE(SITETYPE)	2.928	14	0.209	2.365	0.004
Error	21.844	247	0.088		

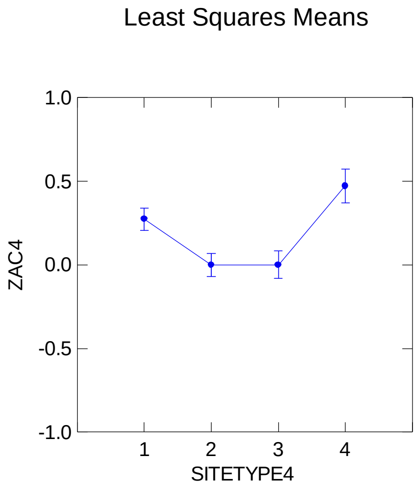


Site Type: post hoc testing showed that the highest abundance of *Z. matthewsii* was found in the old-growth control site type.

September *Zacotus matthewsii*

Dep Var: ZAC4 N: 261 Multiple R: 0.611 Squared multiple R: 0.373
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
SITETYPE	7.827	3	2.609	7.234	0.000
SITE(SITETYPE)	44.583	14	3.185	8.830	0.000
Error	87.639	243	0.361		

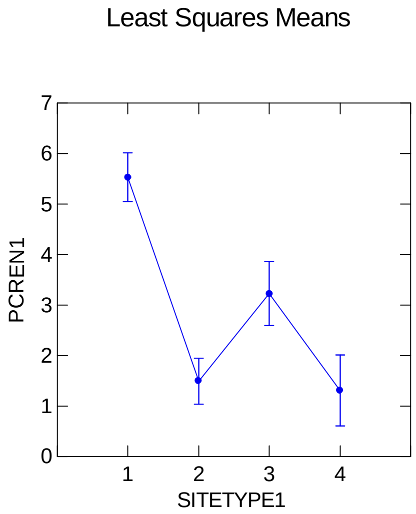


Site Type: post hoc testing showed that there were significantly more *Z. matthewsii* found in the old-growth and alluvial site types than in the semi-alluvial and non-alluvial site types.

June *Pterostichus crenicollis*

Dep Var: PCREN1 N: 235 Multiple R: 0.525 Squared multiple R: 0.276
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
SITETYPE	714.787	3	238.262	14.696	0.000
SITE(SITETYPE)	727.521	13	55.963	3.452	0.000
Error	3534.306	218	16.212		



Site Type: post hoc testing showed that there were significantly more *P. crenicollis* found in the alluvial site type than in the other site types.

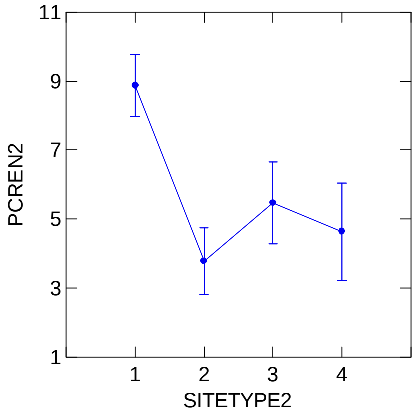
July *Pterostichus crenicollis*

Dep Var: PCREN2 N: 270 Multiple R: 0.439 Squared multiple R: 0.192

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
SITETYPE	1188.217	3	396.072	5.502	0.001
SITE(SITETYPE)	3212.893	14	229.492	3.188	0.000
Error	18141.214	252	71.989		

Least Squares Means



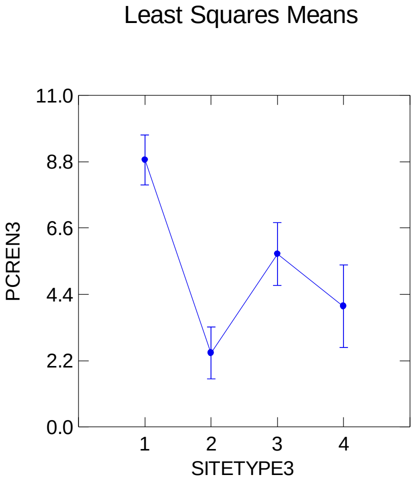
Site Type: post hoc testing showed that there were significantly more *P. crenicollis* found in the alluvial site type than in the semi-alluvial site type.

August *Pterostichus crenicollis*

Dep Var: PCREN3 N: 265 Multiple R: 0.426 Squared multiple R: 0.181

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
SITETYPE	1757.461	3	585.820	10.089	0.000
SITE(SITETYPE)	1377.642	14	98.403	1.695	0.057
Error	14341.750	247	58.064		

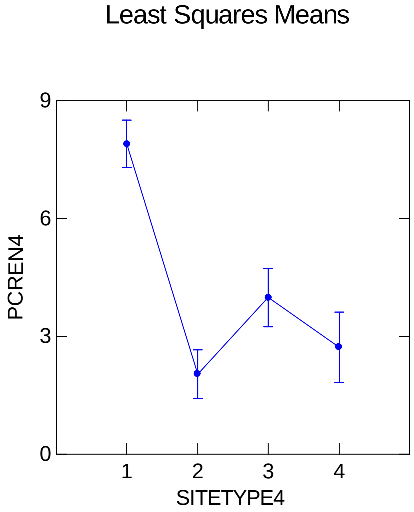


Site Type: post hoc testing showed that there were significantly more *P. crenicollis* found in the alluvial site type than in the semi-alluvial or old-growth site type.

September *Pterostichus crenicollis*

Dep Var: PCREN4 N: 261 Multiple R: 0.521 Squared multiple R: 0.272
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
SITETYPE	1503.468	3	501.156	17.270	0.000
SITE(SITETYPE)	1183.729	14	84.552	2.914	0.000
Error	7051.678	243	29.019		



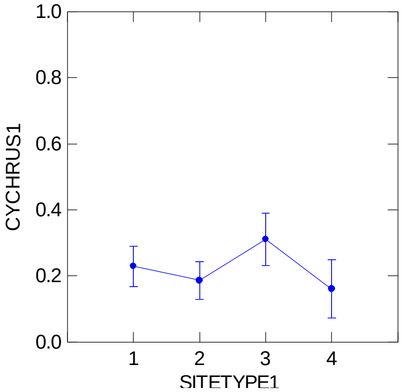
Site Type: post hoc testing showed that there were significantly more *P. crenicollis* found in the alluvial site type than in the other site types.

June *Cychrus tuberculatus*

Dep Var: CYCHRUS1 N: 235 Multiple R: 0.341 Squared multiple R: 0.116
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
SITETYPE	0.544	3	0.181	0.706	0.549
SITE(SITETYPE)	6.925	13	0.533	2.074	0.017
Error	55.993	218	0.257		

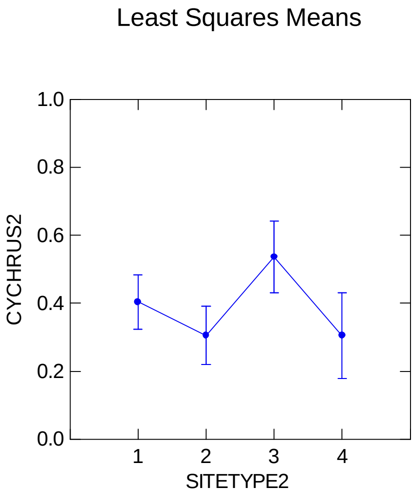
Least Squares Means



July *Cychrus tuberculatus*

Dep Var: CYCHRUS2 N: 270 Multiple R: 0.336 Squared multiple R: 0.113
Analysis of Variance

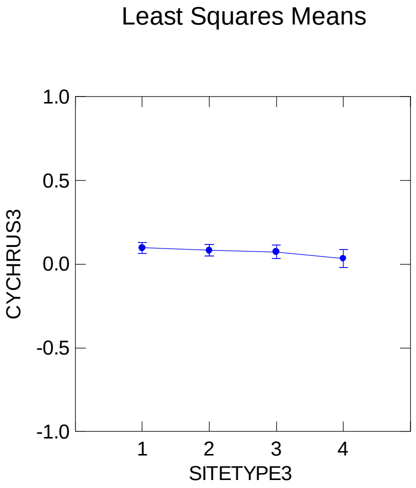
Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
SITETYPE	1.916	3	0.639	1.112	0.345
SITE(SITETYPE)	16.655	14	1.190	2.071	0.014
Error	144.743	252	0.574		



August *Cychrus tuberculatus*

Dep Var: CYCHRUS3 N: 266 Multiple R: 0.225 Squared multiple R: 0.051
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
SITETYPE	0.096	3	0.032	0.347	0.792
SITE(SITETYPE)	1.105	14	0.079	0.852	0.612
Error	22.959	248	0.093		

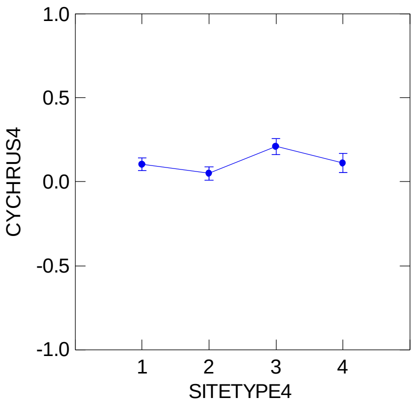


September *Cychrus tuberculatus*

Dep Var: CYCHRUS4 N: 261 Multiple R: 0.311 Squared multiple R: 0.097
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
SITETYPE	0.806	3	0.269	2.302	0.078
SITE(SITETYPE)	2.096	14	0.150	1.283	0.218
Error	28.368	243	0.117		

Least Squares Means



11.5 Appendix 5. Non-metric Multidimensional Scaling

NMS Indicator Species Analysis
Ordination of sites in species space.
24 sites: 20 species

Secondary matrix is the category matrix. Categories were as follows: Codes: Group 1= Alluvial, 2= Semi-alluvial, 3= Non-Alluvial, 4= Old-growth, 5=cut areas adjacent to riparian buffers

```
          The following options were selected:
ANALYSIS OPTIONS
        1.  SORENSEN = Distance measure
        2.         4 = Number of axes (max. = 6)
        3.       200 = Maximum number of iterations
        4.    RANDOM = Starting coordinates (random or from file)
        5.         1 = Reduction in dimensionality at each cycle
        6.      0.20 = Step length (rate of movement toward minimum stress)
        7.  USE TIME = Random number seeds (use time vs. user-supplied)
        8.        15 = Number of runs with real data
        9.        30 = Number of runs with randomized data
       10.       YES = Autopilot
       11.  0.000100 = Stability criterion, standard deviations in stress
                       over last  10 iterations.
       12.    MEDIUM = Speed vs. thoroughness
OUTPUT OPTIONS
       13.        NO = Write distance matrix?
       14.        NO = Write starting coordinates?
       15.        NO = List stress, etc. for each iteration?
       18.        NO = Plot stress vs. iteration?
       17.        NO = Plot distance vs. dissimilarity?
       16.        NO = Write final configuration?
       19. UNROTATED = Write varimax-rotated or unrotated scores for graph?
       20.       YES = Write run log?
       21.        NO = Write weighted-average scores for species ?
------------------------------------------------------------------------------

       415 = Seed for random number generator.
```

STRESS IN RELATION TO DIMENSIONALITY (Number of Axes)

```
--------------------------------------------------------------------
          Stress in real data          Stress in randomized data
               15 run(s)               Monte Carlo test,   30 runs
      -------------------------  -----------------------------------
Axes  Minimum     Mean  Maximum  Minimum     Mean  Maximum      p
```

```
-------------------------------------------------------------------
   1   17.590   35.910   55.211   20.548   44.444   55.183    0.0323
   2   10.185   10.767   12.036   10.354   13.828   19.338    0.0323
   3    6.301    7.041    7.624    6.064    7.630   10.160    0.0968
   4    4.703    5.117    6.266    3.339    5.049    6.796    0.2581
-------------------------------------------------------------------
```

p = proportion of randomized runs with stress < or = observed stress
i.e., p = (1 + no. permutations <= observed)/(1 + no. permutations)

Conclusion: a 2-dimensional solution is recommended.
Now rerunning the best ordination with that dimensionality.

10.18558 = final stress for 2-dimensional solution
0.00007 = final instability
50 = number of iterations

```
Final configuration (ordination scores) for this run
    sites             Axis
Number Name              1          2
     1 A1           0.7080     0.3239
     2 A3In         0.3369     0.6627
     3 A3Out       -1.1914    -1.5608
     4 A4In         0.4341     0.8795
     5 A4Out       -0.3599     0.5122
     6 A5           0.0287     0.2944
     7 A2           0.3369     1.0098
     8 NA1          0.5618     0.3138
     9 NA2         -0.1139     0.5333
    10 NA3          0.0922     0.9627
    11 R1           0.1716     0.0379
    12 R2          -0.2367     0.1084
    13 S 1In       -0.0583    -0.1862
    14 S 1Out      -0.5067    -0.3888
    15 S 2         -0.1279    -0.4096
    16 S 3In        0.2974    -0.6932
    17 S 3Out      -0.1920    -1.2872
    18 S 4          0.4999    -0.8110
    19 S 5In        0.5668     0.7142
    20 S 5Out      -0.6970    -1.3776
    21 S 6In       -0.0150    -0.8703
    22 S 6Out      -2.0448    -0.4196
    23 A6           0.6517     0.9019
    24 A7           0.8576     0.7496
```

NMS GEOM Variance

Coefficients of determination for the correlations between ordination distances and distances in the original n-dimensional space:

```
         R Squared
Axis   Increment   Cumulative
```

```
 1      .424       .424
 2      .462       .886

Increment and cumulative R-squared were adjusted for any lack
of orthogonality of axes.

Axis pair     r     Orthogonality,% = 100(1-r^2)
  1 vs 2    0.544     70.4

Number of entities = 24
Number of entity pairs used in correlation = 276
Distance measure for ORIGINAL distance: Sorensen (Bray-Curtis)
```

11.6 Appendix 6. Indicator Species Analysis

NMS Indicator Species Analysis

Groups were defined by values of: GEOM
Input data has: 24 sites by 20 species
Codes: Group 1= Alluvial, 2= Semi-alluvial, 3= Non-Alluvial, 4= Old-growth, 5=cut areas adjacent to riparian buffers

RELATIVE ABUNDANCE in group, % of perfect indication (average abundance of a given species in a given group of sites over the average abundance of that species in all sites expressed as a %). The data matrix contains 24 sites and 20 species. "Sequence" is the sequence of occurrence of the group in the data; "Max" is the maximum relative abundance of the species.

```
                                   Group
                     Sequence:    1    2    3    4    5
                   Identifier:    1    5    3    4    2
              Number of items:    7    6    3    2    6
    Column       Avg Max MaxGrp
   1 Aaffi        20  92      5    8   92    0    0    0
   2 Aferru       20 100      5    0  100    0    0    0
   3 Apic         20 100      3    0    0  100    0    0
   4 Amlit        20 100      5    0  100    0    0    0
   5 Brosco       20 100      2    0    0    0    0  100
   6 Cychrus      20  30      3   24   11   30   16   18
   7 Hcord        20 100      3    0    0  100    0    0
   8 Leist        20  91      3    9    0   91    0    0
   9 Omus         20  83      3    0    0   83    0   17
  10 Palg         20  66      3   22    7   66    2    3
  11 Pameth       20  33      3   12   25   33   18   12
  12 Pcren        20  41      1   41    6   24   16   13
  13 Pherc        20  58      3    8    9   58   26    0
  14 Plama        20  71      3    9    6   71   10    5
  15 Pprot        20  80      5    0   80    0    0   20
  16 Ppum         20  55      5    9   55    0   36    0
  17 Sang         20  42      2   31    0   28    0   42
  18 Sangus       20  26      2   25    3   24   21   26
  19 Smarg        20  45      1   45    3   10    9   34
  20 Zacot        20  64      4   36    0    0   64    0
       Averages   20  69         14   25   36   11   14
```

RELATIVE FREQUENCY in group, % of perfect indication (% of sites in given group where given species is present). "Max" is the maximum relative frequency of each species.

```
                                   Group
                     Sequence:    1    2    3    4    5
                   Identifier:    1    5    3    4    2
              Number of items:    7    6    3    2    6
    Column       Avg Max MaxGrp
   1 Aaffi         6  17      5   14   17    0    0    0
   2 Aferru        3  17      5    0   17    0    0    0
   3 Apic          7  33      3    0    0   33    0    0
   4 Amlit         3  17      5    0   17    0    0    0
   5 Brosco        3  17      2    0    0    0    0   17
```

```
   6 Cychrus    94 100      3   86   83  100  100  100
   7 Hcord       7  33      3    0    0   33    0    0
   8 Leist      16  67      3   14    0   67    0    0
   9 Omus       10  33      3    0    0   33    0   17
  10 Palg       75 100      3   57   50  100  100   67
  11 Pameth     71 100      3   57   33  100  100   67
  12 Pcren     100 100      1  100  100  100  100  100
  13 Pherc      42 100      4   29   17   67  100    0
  14 Plama      90 100      1  100   67  100  100   83
  15 Pprot       7  17      5    0   17    0    0   17
  16 Ppum       20  50      4   14   33    0   50    0
  17 Sang       29  67      2   43    0   33    0   67
  18 Sangus     93 100      1  100   67  100  100  100
  19 Smarg      80 100      1  100   17  100  100   83
  20 Zacot      23 100      4   14    0    0  100    0
      Averages  39  63          36   27   48   48   36
```

INDICATOR VALUES (% of perfect indication, based on combining the above values for relative abundance and relative frequency) for each species for each group. “Max” is the maximum indicator value of the species across the three groups.

```
                                Group
                    Sequence:    1    2    3    4    5
                  Identifier:    1    5    3    4    2
             Number of items:    7    6    3    2    6
    Column     Avg Max MaxGrp
   1 Aaffi       3  15      5    1   15    0    0    0
   2 Aferru      3  17      5    0   17    0    0    0
   3 Apic        7  33      3    0    0   33    0    0
   4 Amlit       3  17      5    0   17    0    0    0
   5 Brosco      3  17      2    0    0    0    0   17
   6 Cychrus    19  30      3   21   10   30   16   18
   7 Hcord       7  33      3    0    0   33    0    0
   8 Leist      12  61      3    1    0   61    0    0
   9 Omus        6  28      3    0    0   28    0    3
  10 Palg       17  66      3   13    3   66    2    2
  11 Pameth     15  33      3    7    8   33   18    8
  12 Pcren      20  41      1   41    6   24   16   13
  13 Pherc      14  38      3    2    1   38   26    0
  14 Plama      19  71      3    9    4   71   10    4
  15 Pprot       3  13      5    0   13    0    0    3
  16 Ppum        8  18      5    1   18    0   18    0
  17 Sang       10  28      2   13    0    9    0   28
  18 Sangus     20  26      2   25    2   24   21   26
  19 Smarg      18  45      1   45    0   10    9   28
  20 Zacot      14  64      4    5    0    0   64    0
      Averages  11  35           9    6   23   10    7
```

MONTE CARLO test of significance of observed maximum indicator value (IV) for each species collected in the riparian sites, based on 100 randomizations. The means and standard deviations of the IV from the randomization are given along with p-values for the hypothesis of no difference among groups. The p-value is based on the proportion of randomized trials with indicator value equal to or exceeding the observed indicator value.

```
----------------------------------------------------
                                  IV from
                       Observed  randomized
                      Indicator    groups
   Column      Maxgrp Value (IV) Mean  S.Dev    p *
------------- -------- -------- ----- ------ -------
   1 Aaffi           5    15.4   22.6  12.32  0.5530
   2 Aferru          5    16.7   21.0  10.74  0.7060
   3 Apic            3    33.3   20.5  10.57  0.1930
   4 Amlit           5    16.7   20.8  10.52  0.7200
   5 Brosco          2    16.7   21.0  10.67  0.7200
   6 Cychrus         3    30.0   28.7   4.34  0.3490
   7 Hcord           3    33.3   20.5  10.57  0.1930
   8 Leist           3    60.6   23.2  14.15  0.0220
   9 Omus            3    27.8   21.5  13.56  0.3770
  10 Palg            3    65.5   37.2  12.47  0.0340
  11 Pameth          3    32.9   30.0   8.96  0.3540
  12 Pcren           1    41.1   30.3   4.65  0.0320
  13 Pherc           3    38.4   27.2  13.50  0.1640
  14 Plama           3    71.2   40.8  10.63  0.0080
  15 Pprot           5    13.3   22.5  12.71  0.7530
  16 Ppum            5    18.5   23.5  13.52  0.6070
  17 Sang            2    27.8   25.3  11.60  0.3020
  18 Sangus          2    26.3   29.9   4.89  0.7680
  19 Smarg           1    44.8   32.6   8.83  0.1170
  20 Zacot           4    64.1   23.3  13.70  0.0160
----------------------------------------------------
```

* proportion of randomized trials with indicator value
equal to or exceeding the observed indicator value.
p = (1 + number of runs >= observed)/(1 + number of randomized runs)
Maxgrp = Group identifier for group with maximum observed IV