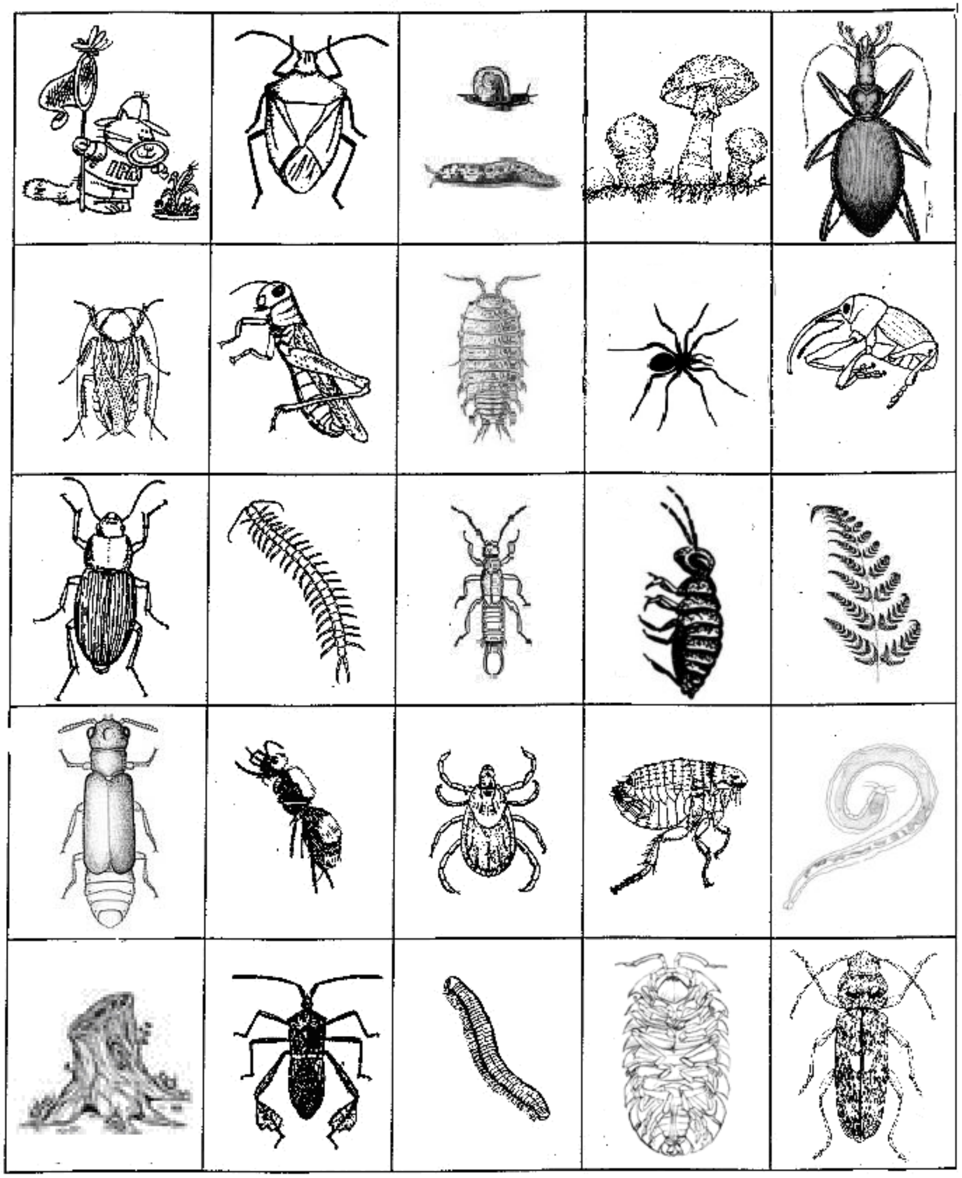

A Preliminary Field Study of Ground-dwelling Invertebrates from Stanley Park

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INTRODUCTION

On 27 September 1887, a 400 hectare tract of a large logged peninsula near Vancouver, BC, was officially opened as a park. The next year it was named “Stanley Park” after Lord Stanley, Governor General of Canada. This evergreen space, now within the city of Vancouver, is the third largest urban park in North America and is bounded by Burrard Inlet, Coal Harbor, and English Bay. It receives an estimated eight million visitors yearly. Stanley Park attracts many visitors for recreation, but also its forests and clearings provide habitat for many organisms. Western hemlock, western redcedar, and deciduous trees such as vine maples are present in the forest ecosystem and berry bushes, ferns and salal patches cover the forest floor (Vancouver Board of Parks and Recreation 2008). Depending upon the location in Stanley Park, one can see a wide variety of vegetation types such as coniferous and deciduous forest, mixed forest, open clearings, and even cultivated flower gardens.

Finding invertebrates in the forest is not an easy job because they tend to blend into the color of soil and some are extremely small. Depending upon the type of invertebrates, a number are active at night and hide under objects such as bark and rocks during the daytime. An abundance of invertebrates can inhabit the park because of the rich soil and decaying organic material, which provides both food and shelter.

Christensen (1983) indicates that centipedes (Subphylum Myriapoda, Class Chilopoda) favor moist environments and are carnivores, have one pair of legs in each segment and kill their prey, such as insects and spiders, using their first pair of legs which have poison glands. Millipedes (Order Polidesmida) also live in moist environments but prefer habitats that are higher in moisture content. Polidesmids, with two pairs of legs in each segment, feed on

decaying organic material. Christensen (1983) also discusses the habitat and biology of springtails (Subphylum Hexapoda, Class Entognatha) and sow bugs (Subphylum Crustacea, Subclass Peracarida), which also prefer highly moist situations. Both groups feed on decaying organic matter and springtails also consume algae and fungi.

Beetles are abundant and widespread; the family Carabidae (ground beetles) is the second largest family of beetles. Ground beetles are found in varied habitats and many take the role of generalist predators (unspecialized as to prey), taking arthropods and other small animals, even slugs and snails. Predatory carabids are typically nocturnal, using their characteristic large mandibles; both adults and larvae are predatory (Haggard and Haggard 2006). Other carabid species feed on decomposing organic material or plant material (McGregor n.d.).

The family Amphizoidae (trout-stream beetles) have large mandibles and are closely allied with the Carabidae (J. McLean, pers. comm., 2008). Triplehorn and Johnson (2005, p.405) describe amphizoids as oval and dark colored, ranging from about 11.0 to 15.5 mm in length. There are six species in the genus *Amphizoa*, three in western North America and the other three in China. These authors state that adults and larvae of this group live in cold water, often in relatively quiet mountain streams. The larvae do not have gills and do not swim, so they crawl out of water onto floating objects such as twigs to obtain oxygen at the water surface. The adults swim very little and often run about on the stream shore at night. Both adults and larvae are predaceous, feeding largely on stonefly nymphs, but they also scavenge dead insects (Evans and Hogue 2006, p.68).

The aim of the present project was to set a number of ground traps in monitoring sites in Stanley Park, and to collect preliminary information as to the condition of the habitat in each

monitoring station based on the captured invertebrates. At the same time, this invertebrate survey monitored the abundance and the seasonal "awakening" of invertebrate activity in relation to the weather and particularly temperature changes in the park between 27 January and 6 April 2008. This was a preliminary project to give the author experience in field research, to examine the sampling potential of sites, and to set out directions for future student research. Identifications of invertebrates are made here with caution, given the author's relative inexperience and the need for adequate comparative material.

METHODS AND MATERIAL USED

Pitfall traps are commonly used in biological research to collect ground-dwelling invertebrates. This simple trapping method allows ground-dwelling invertebrates to fall into a container such as a plastic beverage cup, or any other plastic or glass container with a slippery inner surface, so that the invertebrates are unable to escape. Traps are simple to make and require few tools. The pitfall traps used in this project were plastic beverage cups screened with mosquito netting on the bottom to drain the accumulated water and prevent invertebrates from drowning, and to make it easier to collect small invertebrates (Raworth et al. 1997).

To set a pitfall trap, first one digs a hole in the soil deep enough for two plastic cups, one cup nested inside the other. Place a set of cups in the hole with the rim of the upper cup at the ground surface to allow invertebrates to fall into the trap while walking or jumping (Figure 1). Then the traps are retrieved after at least a week, and placed in a container if necessary for later counting and identification of the captured invertebrates. Traps removed from sites were either discarded or were reused after cleaning for further sampling.

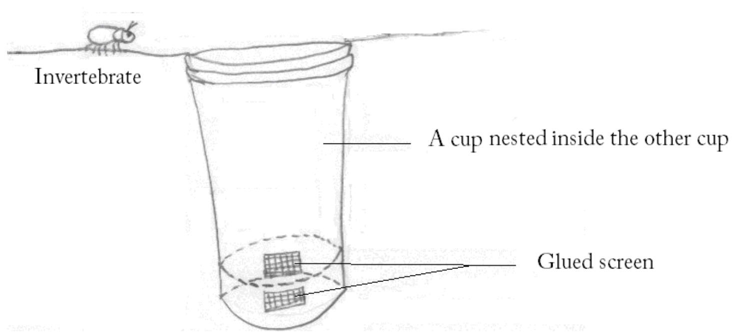

Figure 1. Diagram of example pitfall trap using two plastic beverage cups.

Invertebrate identifications were made using an insect guide for the Pacific Northwest (Haggard and Haggard 2006), an identification sheet provided from Stanley Park and illustrations compiled from a variety of internet sources. Advice was also provided by Dr. John McLean, a UBC entomologist conducting research in cooperation with the Stanley Park Ecology Society (SPES).

Most of the specimens died in the traps. Live specimens were released near the original stations after counting. Identifications reported here are preliminary, consistent with the intention that this was a pilot project to assess feasibility and techniques. Start times for monitoring differed from site to site (see tables), so not all sites were sampled for the full project period.

Two sets of pitfall traps were placed at each of six sites: SPES monitoring stations S4-2, S4-28, BR1-1, N3-1, R1-1, and D1-1 (see map in Figure 2). Individual monitoring sites differed in forest situation and in conditions such as vegetation types, substrate, and moisture content.

Location coordinates were established using GPS and sites were relocated readily by following the GPS device. Bright-colored flags or tapes were used for marking in some trap sites. The park was heavily impacted by strong windstorms in December 2006, so sampling sites were chosen from both intact and damaged ("blowdown") areas.

SITE DESCRIPTIONS

Monitoring station S4-2 (UTM: E 489615 N 5460596)

Vegetation. Mature western hemlock, young western hemlock, huckleberry, ferns, skunk cabbage and salal patches.

Site condition. This site is on the edge between a mature coniferous forest and a blowdown area with a tendency of flood hazard. Elevation is 11 m, the lowest land compared to the other monitoring sites. The surface shape is flat and the soil is organic and contains no rocky substrate. This site is always wet, with small puddles near the traps. There are several decaying logs and branches on the forest floor. Considerable light reaches the surface as a result of the blowdown, but previously the mature forest would have limited the direct light.

Monitoring station S4-28 (UTM: E 489392 N 5460533)

Vegetation. Western hemlock, western redcedar.

Site condition. This site is coniferous forest and also a blowdown area with several western hemlock still standing. Several recently blown down logs about a meter in diameter and 5 m in length are lying on the ground and the traps were set below the overhang of a log. The elevation is 19 m, surface shape is flat and the soil is a mix of organic material and mineral substrate. Cobbles and pebbles are found on the forest floor. It is an open area with much sunlight available at ground level. Not much vegetation is around this site but branches and pieces of bark are on the forest floor. There is a small creek 8 m away from the traps.

Monitoring station BR1-1 (UTM: E 489462 N 5460963)

Vegetation. Young western hemlock, vine maple, holly bush, spiny fern, salal, huckleberry, mosses, fungi.

Site condition. This is a blowdown area of young and mature coniferous forest with maple. The elevation is 24 m, the site has a flat forest floor, and soil contains organic material but no rocky substrate. There are many rotten logs covered with moss, fungi and lichen on the floor. Relatively shaded, but little direct light penetrates and hits the floor. The forest floor is lightly covered with deciduous leaf litter.

Monitoring station N3-1 (UTM: E 489607 N 5461711)

Vegetation. Douglas fir, red alder, spiny wood fern, sword fern, salmonberry, lichens.

Site condition. This site is a mixed forest with mostly deciduous trees. Slightly blown down area with some logs on the ground and a pile of debris. About 95% of the forest floor is covered by vegetation and leaf litter; soil is organic with no rocky substrate, and the floor surface is undulating. It is an open forest with sunlight able to reach the floor. The site elevation is 62 m, the highest among the set of monitoring stations. One trap was set in a low area amongst piled decayed organic material and the other trap was in an open area just under a patch of fern. A dry ditch is beside the site.

Monitoring station R1-1 (UTM: E489977 N5461469)

Vegetation. Young and mature western hemlock, western hemlock on nurse stump, ferns.

Site condition. Riparian coniferous forest. A creek flows 4 m away from the traps and a puddle is beside them. The forest soil contains organic material but not many decaying logs and no rocky substrate. It is a dense forest and not much direct light penetrates. Elevation is 14 m and the ground surface is very muddy in some areas but flat. This monitoring site is noted as an environmentally sensitive area.

Monitoring station D1-1 (UTM: E490766 N5461026)

Vegetation. Western hemlock, vine maple, red alder, spiny fern, sword fern, salmonberry, red huckleberry and many shrubs. Heavily vegetated.

Site condition. Deciduous forest near the shore. This site contains highly moist organic soil, no rocky substrate and 95% of the forest floor is covered with leaf litter. A few conifers grow here. Many decaying logs and stumps, and piled decaying material are at this site. The elevation is 33 m and the surface of the forest floor is flat. Abundant flies (Diptera) were observed in flight from mid-March onward.

RESULTS AND DATA

Abundance of Invertebrates in Monitoring Stations

Weekly site capture data are presented in Tables 2-7 (see Table 1 for letter codes). The earliest invertebrates observed were spiders, followed by springtails, then by other groups. Spiders, millipedes, and long and round-bodied springtails were found in all sites including coniferous, deciduous and mixed forest, and riparian zones in Stanley Park; while mites and unidentified worms (Figure 3) were not found at D1-1, a deciduous forest site.

When all sites are compared, site D1-1 nevertheless yielded the largest number of organisms, with 34 identified individuals and more than 200 unidentified individuals of extremely small jumping arthropods (probably springtails) collected. Moreover, the highest numbers of springtails and sow bugs were caught here as compared to other monitoring stations and there was a high number of sow bugs captured in the first week, by 11 March. The number of individuals in this site would therefore have been even higher if the trapping had started earlier before the invertebrates' activity began. Other than springtails and sow bugs, several millipedes and some predators (spiders, centipedes, and one *Loricera pilicornis* or *Leistus ferrugineus)* were collected here. We had no sample or a photograph available at the time to determine which of these two beetles was captured here. However, in a previous survey by Dr. John McLean, *Leistus ferrugineus* was captured near site D1-1, by the aquarium area in summer 2007; therefore, this beetle could possibly be *Leistus ferrugineus.* Additional collection at site D1-1 is needed to confirm the identification.

The total number of individuals in site N3-1 is lower compared to station D1-1; however, site N3-1 seems to be the most diverse in terms of species captured and the numbers of individual invertebrates are also high. For example, 12 spiders, 5 centipedes, 2 amphizoid larvae (Figure 5) and one *Scaphinotus marginatus*, were recovered, all being predators. This is the highest number of predators found in any sampled site. Other than predators, this site also yielded the highest number of round-bodied springtails as well as an unidentified arthropod (Figure 7), which is about 8 mm in length, similar to long-bodied springtails in terms of body shape but which moved its body from side to side vigorously to escape instead of jumping. This arthropod was found between 24 February and 23 March in site N3-1. Relatively higher numbers of long-bodied springtails and lower numbers of round-bodied springtails were seen in almost every site in winter to early spring.

Riparian site R1-1 was not as productive as in site N3-1 in terms of the number of predators found but was the highest in the number of amphizoid larvae. Amphizoid larvae were found only in the trap near the creek side and puddles and not in the trap located in the drier area at this site. On the other hand, in the dry area, three types of unidentified species were found. Three of the springtail-like species (Figure 7) were found between 24 February and 01 March. Another unidentified species, possibly a springtail as well, was very small and had a blue pigment and a stout body, yet unlike springtails, it did not have the distinctive movement by jumping: only a rolling-up movement was observed. This tiny blue pigmented organism was only collected in the 09 March sample. On 16 March a small brown round-bodied unidentified beetle was found.

Unidentified worm-shaped beetle larvae (Figure 4) were collected in R1-1, and also in S4-2 and S4-28. These monitoring stations seem to have differing forest conditions but the common

feature is that water is available, whether it is a stream margin, a flood hazard area, or muddy forest floor with a small creek nearby.

Sites S4-2 and S4-28 are both in blowdown areas but site S4-2 is located at the boundary of unaffected forest and damaged forest. The variety of invertebrate types was similar in both sites except that only S4-28 had sow bugs and the unidentified worm in Figure 1. The other difference is that S4-28 site seems to have a higher number of individuals as compared to site S4-2.

Two individuals of *Notiophilus* sp. (Figure 6) were collected in site BR1-1, along with spiders, millipedes, long and round-bodied springtails, mites and unidentified worms. Site BR1-1 is located in a forest area unaffected by the storm, yet the variation of organisms is comparable to S4-2 and S4-28. There were no centipedes captured, and spiders and *Notiophilus* sp. were the only predators captured in this time interval at sites S4-2, S4-28, or BR1-1.

Sow bugs were found in sites S4-28, N3-1, R1-1 and D1-1 and by far the greatest numbers were noted in site D1-1. There seemed to be a pattern such that as the monitoring stations become closer to Burrard Inlet, there was an increase in the number of sow bugs captured. Moreover, centipedes were also more likely to be captured in sites N3-1, R1-1, and D1-1, the monitoring stations in the east side or nearest to Burrard Inlet.

Weather and Invertebrate Activity

Temperature change and precipitation rate are presented in graphic form in Tables 2-7 and as values in Table 8. These environmental factors may have affected the timing of emergence (first observed activity) of some or all of the sampled invertebrates. First activity was recorded for groups at multiple sites (see data tables) where initial sampling yielded no captures. Long-bodied springtails showed earlier activity and higher populations than round-bodied springtails in all sites. Long bodied springtails are dominant arthropods in most of the sites. For example, at site N3-1 long-bodied springtails started to be active between 16 February and 01 March with a total of 21 long-bodied springtails collected, in addition to a group of approximately 100 tiny springtails. The highest number (22) of long-bodied springtails 2 mm or larger was found in site S4-28; and a cluster of more than 50 of springtails smaller than 2 mm in a single sample was unlikely to be observed in other sites but was encountered at D1-1 almost every week. In comparison, the earliest round-bodied springtails were found in traps on 30 March.

Amphizoid larvae also showed a distinct pattern of activity period. Larvae tentatively identified with this group (Figure 5) were captured at site N3-1 occasionally and at R1-1 every week from their first occurrence in the 01 March sampling. By 23 March, three weeks after the first collection of amphizoid larvae, the traps were not catching any more larvae at either site.

It is premature to analyze in detail the connection between the timing of invertebrate emergence and the pattern of temperature change and precipitation rate because few clear numerical trends are observed in these data. However it was possible to record the date of first activity of invertebrates at several sites (see tables). Moreover, it is evident that the date of the

earliest activity was different from site to site, possibly reflecting differences in aspect, ground temperature, or other factors.

It is important also to note that trapped predators such as spiders and ground beetles may have influenced the numbers of other types of invertebrates captured in a trap, a factor to be considered in future sampling.

DISCUSSION

“Dead wood makes its greatest contribution to biological richness as substrate for fungi, cryptogams and invertebrates. There are no sharp distinctions between declining trees and snags as the most favorite habitat. Some dependent lichens are common on both, but more abundant on snags” (Bunnell et al. 2000). All of the monitoring sites in Stanley Park have in common the presence of dead wood, yet the level of decay and the abundance of decaying material are different in each site; therefore, the fungus growth rate and types of associated species are likely to differ.

Certain types of invertebrates such as millipedes, springtails and sow bugs prefer habitat that is abundant in decaying organic material and highly moist. This explains why these invertebrates tended to be captured much more in sites N3-1 and D1-1. These monitoring stations have deciduous trees such as vine maple, and berry bushes. Their forest floors are heavily vegetated and covered with leaf litter. Especially in site D1-1, the air seems relatively warmer and moister as compared to the other monitoring stations. A breeze was often blowing onshore from Burrard Inlet to the monitoring site. Given the combination of moist air and

abundant decaying logs and leaves, this habitat condition seems highly favorable to sow bugs because their trapped numbers were by far highest in site D1-1. Not only sow bugs but also a large number of springtails were found in this site. Ferguson and Joly (2002) indicate that springtail populations are strongly influenced by temperature and moisture.

In addition to the direct impact by moisture content as favorable habitat for these invertebrates, Ferguson and Joly (2002) show that addition of moisture results in an increase in litter decomposition. Thus not only general habitat condition but also food availability for invertebrates feeding on decayed organic material likely resulted in their increased numbers at particular sites in Stanley Park.

Although the ground surfaces at sites S4-2 and R1-1 are moist, only one or no sow bugs and fewer springtails than in other moist site were found. However, since S4-2 and R1-1 are in coniferous forest and the temperature is cooler, less organic material may be decomposed. Site N3-1 is drier as compared to S4-2 and R1-1 yet its forest floor is 95% covered with vegetation and leaf litter. Therefore we can hypothesize that favorable habitats for invertebrates such as springtails, sow bugs and millipedes are not only high in moisture content but also have abundant organic material such as leaf litter. Chemical differences between deciduous and coniferous forest soils may also be a factor influencing invertebrate abundance, a matter for future testing.

Ferguson and Joly (2002) indicate that both springtails and mites are common prey of spiders, beetles and centipedes. Is the rate of captured predators related to the numbers of their potential prey? According to the survey results of this project, the number of predators increased slightly when there were high numbers of springtails and mites in sites. However, more data and are needed to test this proposition further.

The unidentified worm-like beetle larvae noted above were only found in coniferous forest sites at elevations lower than 20 m. I have noticed that temperatures are different from location to location depending upon elevation and forest type in Stanley Park. Not only elevation but also moisture content of the ground may differ and could be significant in describing the habitat condition. All of sites where the unidentified beetle larvae were found were highly moist, with water always available. For instance, sites S4-2, R1-1, and S4-28 are a flood hazard area, a riparian area, and a blowdown area lacking vegetation on the forest floor. The forest floor in the blowdown site becomes very muddy and some puddles persist after it rains; in addition, there is a small creek flowing beside monitoring site S4-28. The unidentified beetle larvae could therefore be of species that favor wet environments.

Amphizoid larvae were found in a similar habitat situation to the unidentified beetle larvae. Amphizoids are usually found in stream sites, so site R1-1 would be most favorable for this family. However, two amphizoid larvae were recorded in site N3-1, an open and heavily vegetated forest site that has no steady water available. However, there is a dry ditch right beside this monitoring station. The identification needs to be confirmed by further sampling, and it will require examination whether the dry ditch has any function in sustaining the water needs of amphizoids at this site. Amphizoids appear to be a previously undocumented group in Stanley Park, so further study and identification are of considerable importance.

CONCLUSIONS

Not only vegetation but also temperature changes and weekly variations in precipitation rates may have influenced the number of invertebrates captured as well as their variety and their dates of earliest activity. The data from this monitoring survey as yet reveal no significant trends and characteristics to confirm that precipitation and weather influenced the activity of invertebrates once they had emerged. Additional monitoring and data collection are needed to investigate the relationships between invertebrate behavior and trends in weather pattern. From the survey findings, however, it was possible to record the timing of first activity of individual groups. The "awakening" or emergence of invertebrates could be weather-related, though other "biological clock" factors such as daylight period must also be considered. Aside from these factors, availability and accessibility of food sources also must determine the types of invertebrates inhabiting the different monitored areas in Stanley Park. The degree to which the storm in 2006 changed the habitat conditions of blowdown areas in Stanley Park could not be determined from this monitoring project but the new data will contribute to further research projects comparing undamaged and blowdown areas.

RECOMMENDATIONS

It is recommended that researchers undertaking future invertebrate monitoring projects try as best possible to start all trapping on the same day in order that results will be more clearly comparable amongst all of the monitoring stations. When research is to be focused on collecting adult Carabidae, summer and fall would be better times for sampling. Also, it would be interesting to make more detailed studies of changes in abundance of other invertebrate groups during and after their first weeks of activity.

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DATA TABLES

Table 1. List of letter codes for Invertebrate Groups in Tables 2 to Table 7.

Symbol	**Name**	**Symbol**	**Name**
W	Unidentified Worm	RS	Round-bodied springtails
M	Mite	SM	*Scaphinotus marginatus*
SP	Spider	LP	cf. *Loricera pilicornis*
MI	Millipedes	NO	*Notiophilus* sp.
CE	Centipedes	AM	Amphizoid larvae
SB	Sow bugs	BL	Beetle larvae
LS	Long-bodied springtails	UN	Unidentified

Figure 2 Stanley Park Ecology Society Monitoring Station Map

Six monitoring stations were monitored in the forest ground-dwelling invertebrate survey. Sites D1-1, S3-1, R1-1 were unaffected by the storm in 2006, sites S4-2, S4-28 were affected, and station N3-1was slightly affected yet is located near the blowdown area.

Table 2 Invertebrate samples at station S4-2 compared to weather records.

Station S4-2

Date	SP	MI	CE	LS	RS	SB	SM	LP	NO	AM	BL	M	W	UN	Total
Jan27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb24	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Mar01	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Mar09	0	0	0	2	0	0	0	0	0	0	0	3	0	0	5
Mar16	0	0	0	2	0	0	0	0	0	0	1	1	0	0	4
Mar23	0	0	0	4	0	0	0	0	0	0	1	1	0	0	6
Mar30	1	0	0	2	1	0	0	0	0	0	0	0	0	0	4
Apr06	2	1	0	2	0	0	0	0	0	0	0	0	0	0	5
Total	4	2	0	12	1	0	0	0	0	0	2	5	0	0	24

N= no data

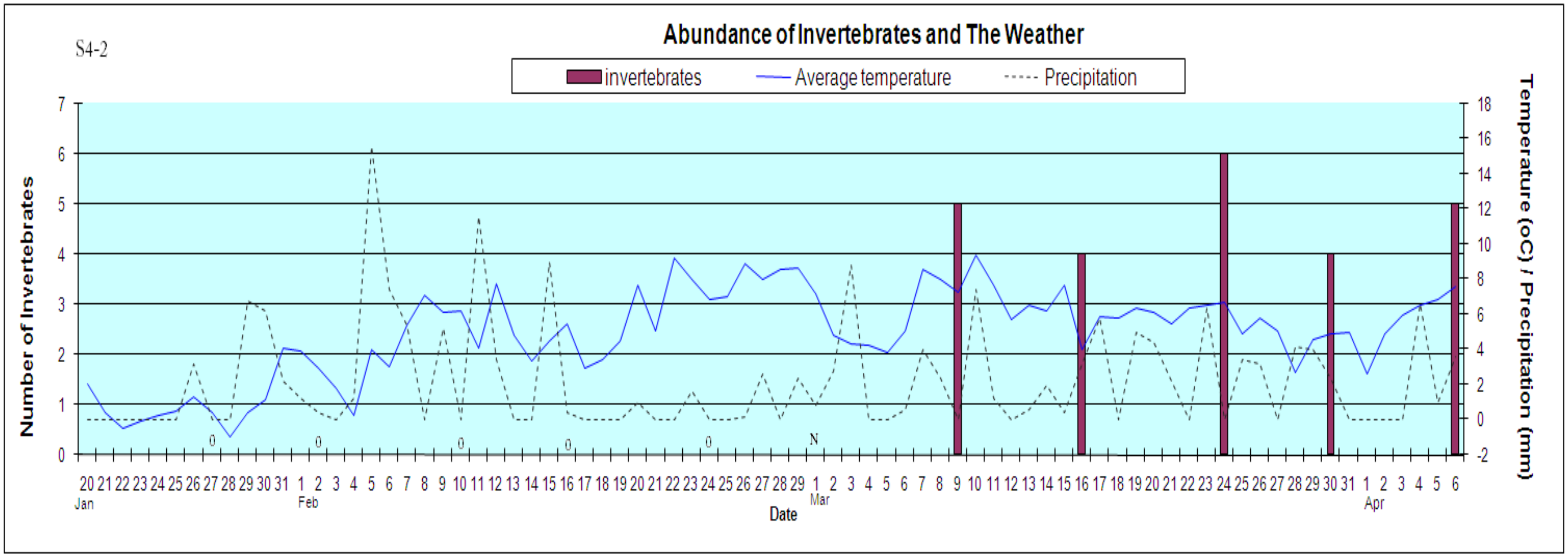

Table 3 Invertebrate samples at station S4-28 compared to weather records.

Station S4-28

Date	SP	MI	CE	LS	RS	SB	SM	LP	NO	AM	BL	M	W	UN	Total
Jan27	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Feb02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mar01	1	0	0	1	0	0	0	0	0	0	1	0	1	0	4
Mar09	2	0	0	1	0	0	0	0	0	0	0	0	0	0	3
Mar16	0	0	0	4	0	0	0	0	0	0	0	3	0	0	7
Mar23	2	0	0	2	0	1	0	0	0	0	0	0	1	0	6
Mar30	0	2	0	8	2	0	0	0	0	0	0	0	1	0	13
Apr06	0	0	0	6	3	0	0	0	0	0	0	0	0	0	9
Total	5	2	0	22	5	1	0	0	0	0	1	3	3	0	42

N= no data

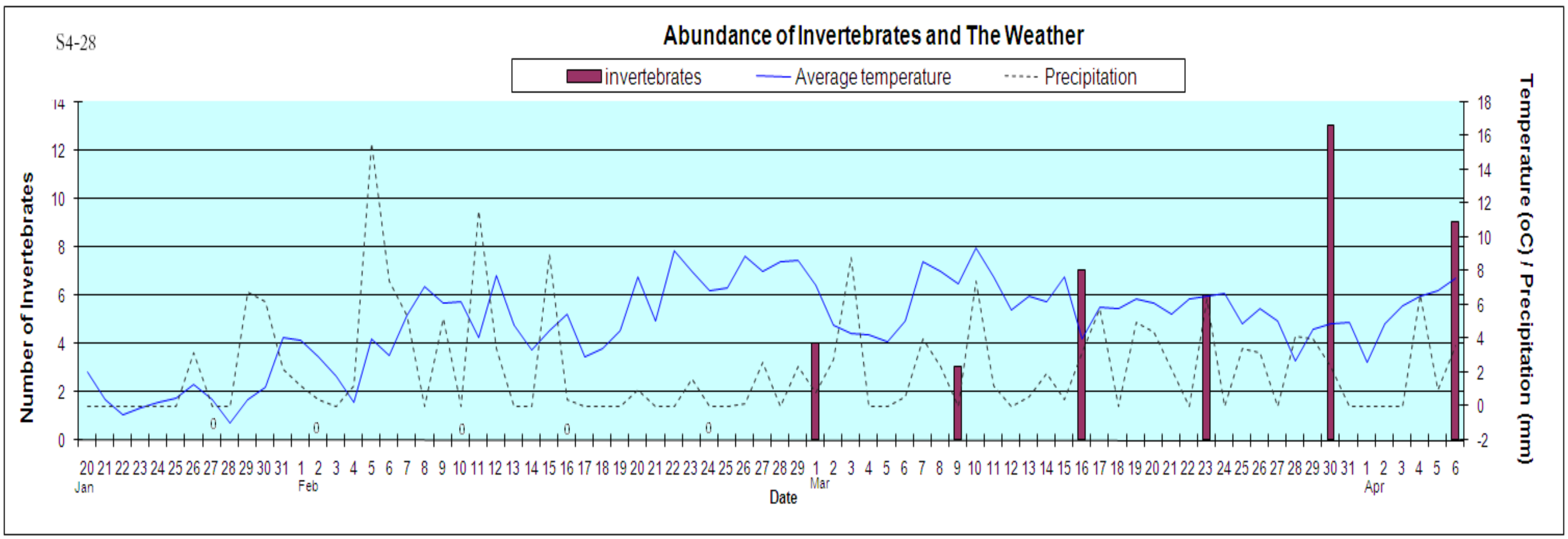

Table 4 Invertebrate samples at station BR1-1 compared to weather records.

Station BR1-1

Date	SP	MI	CE	LS	RS	SB	SM	LP	NO	AM	BL	M	W	UN	Total
Jan27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb24	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Mar01	1	0	0	4	0	0	0	0	0	0	0	0	1	0	7
Mar09	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Mar16	1	1	0	2	0	0	0	0	0	0	0	2	0	0	6
Mar23	2	1	0	0	0	0	0	0	0	0	0	0	0	0	3
Mar30	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2
Apr06	1	0	0	0	3	0	0	0	1	0	0	0	0	0	5
Total	7	2	0	6	6	0	0	0	2	0	0	2	1	0	26

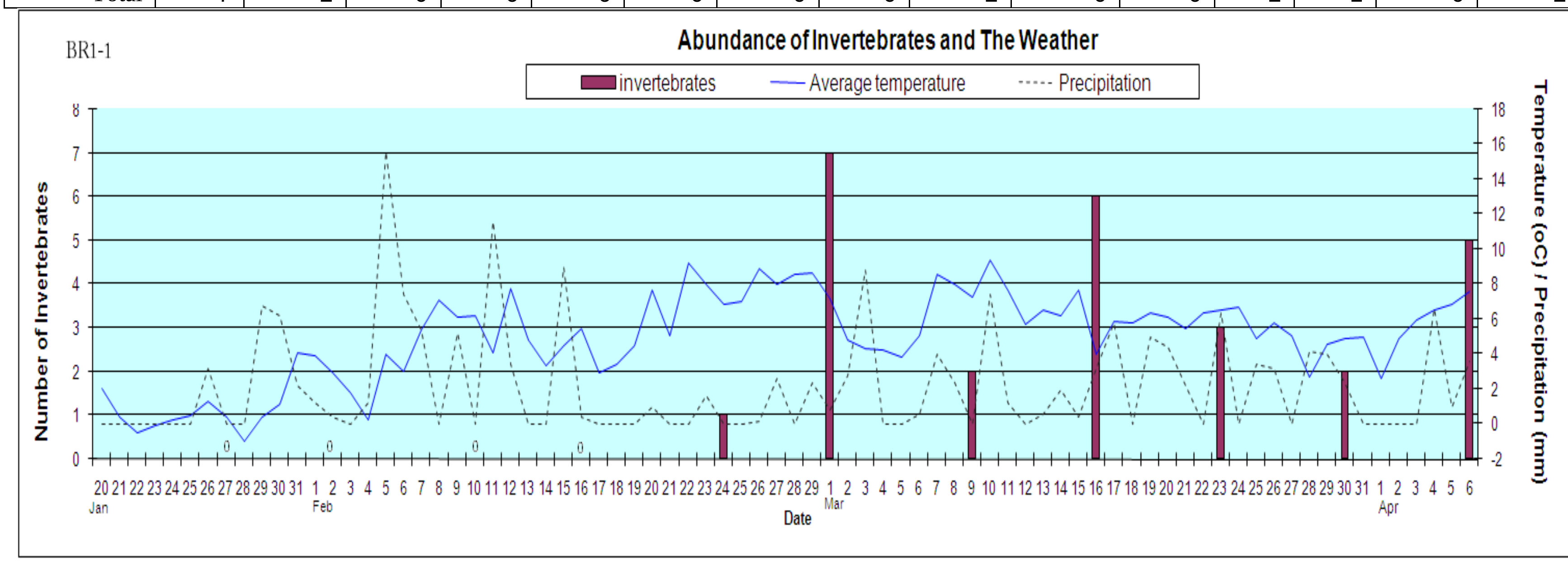

Table 5 Invertebrate samples at station N3-1 compared to weather records.

Station N3-1

Date	SP	MI	CE	LS	RS	SB	SM	LP	NO	AM	BL	M	W	UN	Total
Jan27	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Feb02	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Feb10	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Feb16	0	0	0	0	0	0	0	0	0	0	0	0	0	*50<	*50<
Feb24	2	0	0	2	0	0	0	0	0	0	0	0	0	0	4
Mar01	2	2	1	1	0	0	0	0	0	1	0	0	0	1	8
Mar09	3	1	0	1	0	0	1	0	0	0	0	1	0	2	9
Mar16	0	6	1	5	0	0	0	0	0	0	0	3	0	0	15
Mar23	1	0	1	2	0	1	0	0	0	1	0	0	0	1	7
Mar30	2	1	1	4	6	0	0	0	0	0	0	0	1	0	15
Apr06	2	0	1	6	3	0	0	0	0	0	0	0	0	*50<	12,*50<
Total	12	10	5	21	9	1	1	0	0	2	0	4	1	4,*100<	70,*100<

N = no data, * Many tiny jumping arthropods were likely springtails

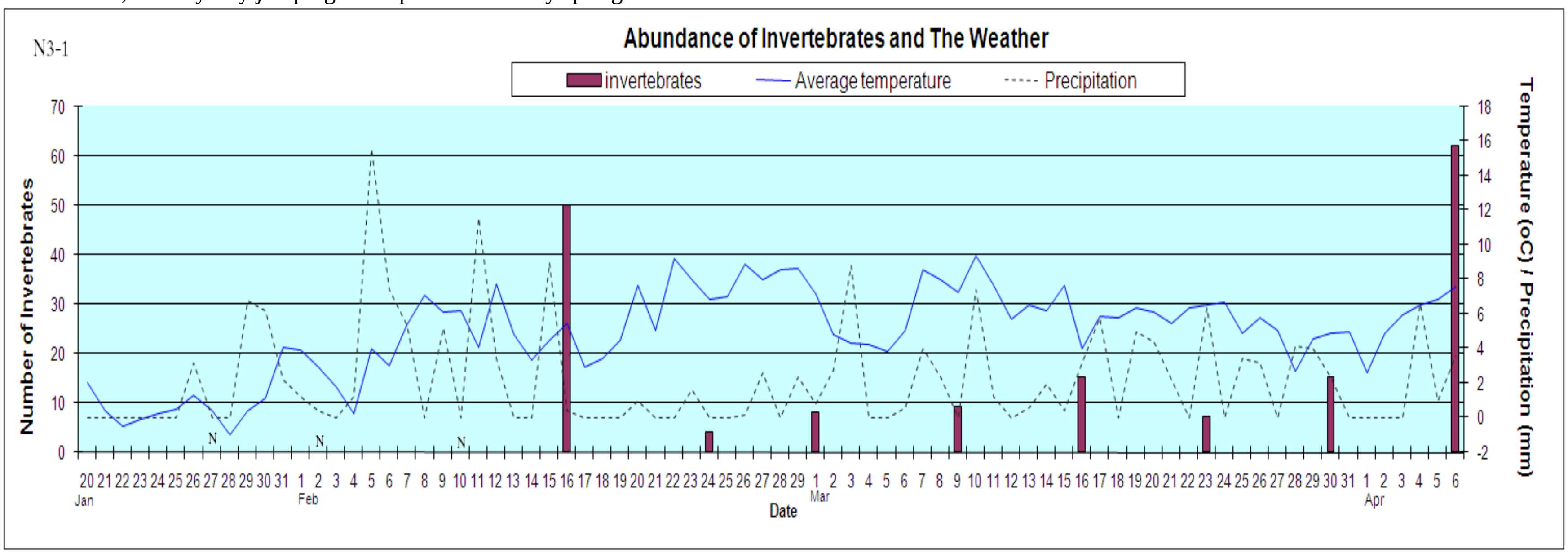

Table 6 Invertebrate samples at station R1-1 compared to weather records.

Station R1-1

Date	SP	MI	CE	LS	RS	SB	SM	LP	NO	AM	BL	M	W	UN	Total
Jan27	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Feb02	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Feb10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb16	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2
Feb24	2	0	0	0	0	0	0	0	0	0	0	0	0	1	3
Mar01	3	0	0	0	0	0	0	0	0	1	0	0	0	2	6
Mar09	1	0	0	2	0	0	0	0	0	1	0	2	0	4	10
Mar16	1	1	0	5	0	0	0	0	0	1	1	4	1	1	15
Mar23	0	0	2	2	0	1	0	0	0	1	0	0	0	0	6
Mar30	1	0	0	3	4	0	0	0	0	0	0	1	1	0	10
Apr06	0	0	0	1	1	0	0	0	0	0	0	0	0	0	2
Total	9	1	3	13	5	1	0	0	0	4	1	7	2	8	54

N= no data

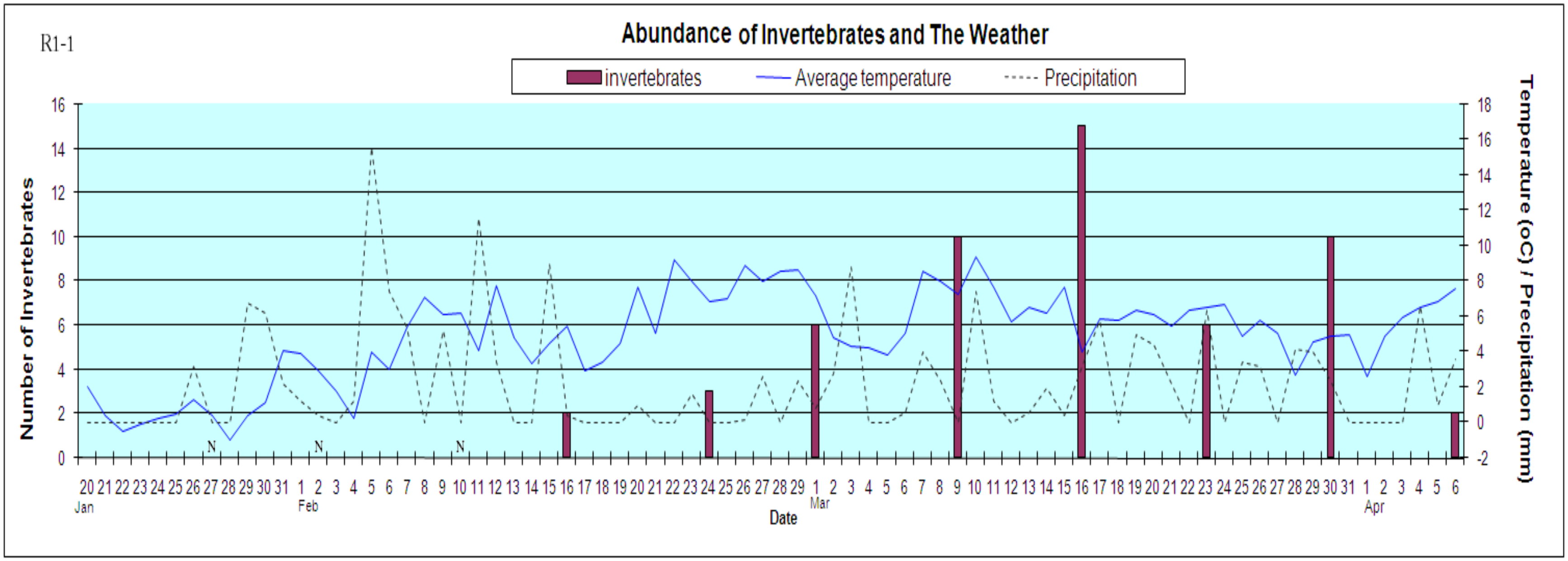

Table 7 Invertebrate samples at station D1-1compared to weather records.

Station D1-1

Date	SP	MI	CE	LS	RS	SB	SM	LP	NO	AM	BL	M	W	UN	Total
Jan27	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Feb02	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Feb10	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Feb16	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Feb24	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Mar01	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Mar09	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Mar16	0	2	1	1	0	11	0	0	0	0	0	0	0	*50<	15, *50<
Mar23	1	1	0	0	0	3	0	1	0	0	0	0	0	*50<	6,*50<
Mar30	0	0	0	0	1	6	0	0	0	0	0	0	0	*100<	7,*100<
Apr06	2	1	0	0	0	3	0	0	0	0	0	0	0	0	6
Total	3	4	1	1	1	23	0	1	0	0	0	0	0	*200<	34,*200<

N = no data, * Many tiny jumping arthropods were likely springtails

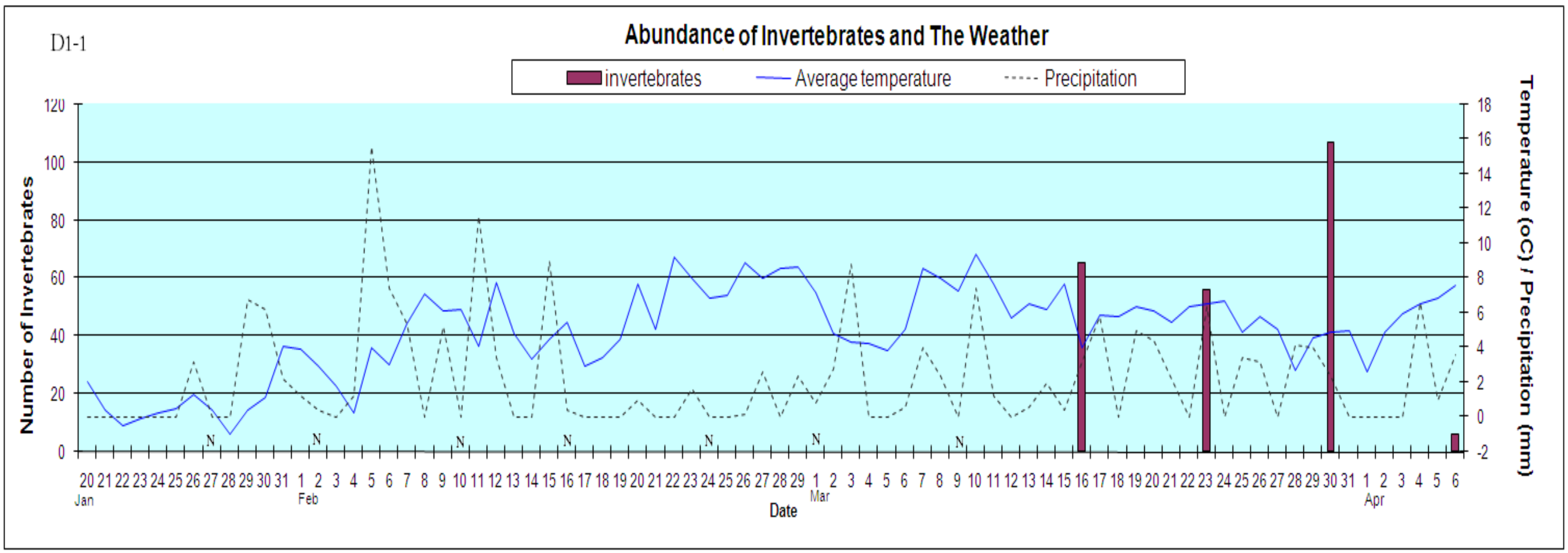

Table 8. Average temperatures and precipitation between January 20 and April 6.

Date	Ave. Temp (°C)	Precipitation (mm)	Date	Ave. Temp (°C)	Precipitation (mm)
20-Jan	2	0	1-Mar	7.2	0.8
21-Jan	0.4	0	2-Mar	4.8	2.8
22-Jan	-0.5	0	3-Mar	4.3	8.8
23-Jan	-0.1	0	4-Mar	4.2	0
24-Jan	0.2	0	5-Mar	3.8	0
25-Jan	0.5	0	6-Mar	5.1	0.6
26-Jan	1.3	3.2	7-Mar	8.6	4
27-Jan	0.4	0	8-Mar	8	2.4
28-Jan	-1	T	9-Mar	7.3	0
29-Jan	0.4	6.8	10-Mar	9.4	7.4
30-Jan	1.1	6.2	11-Mar	7.7	1.2
31-Jan	4.1	2.2	12-Mar	5.7	0
1-Feb	3.9	1.2	13-Mar	6.5	0.6
2-Feb	2.9	0.4	14-Mar	6.2	2
3-Feb	1.8	0	15-Mar	7.7	0.4
4-Feb	0.2	1.2	16-Mar	4	3.2
5-Feb	4	15.6	17-Mar	5.9	5.8
6-Feb	3	7.4	18-Mar	5.8	T
7-Feb	5.4	5.4	19-Mar	6.4	5
8-Feb	7.1	0	20-Mar	6.1	4.4
9-Feb	6.1	5.2	21-Mar	5.5	2.2
10-Feb	6.2	T	22-Mar	6.4	0
11-Feb	4.1	11.6	23-Mar	6.5	6.4
12-Feb	7.8	3.4	24-Mar	6.7	0
13-Feb	4.8	0	25-Mar	4.9	3.4
14-Feb	3.3	0	26-Mar	5.8	3.2
15-Feb	4.5	9	27-Mar	5.1	0
16-Feb	5.5	0.4	28-Mar	2.7	4.2
17-Feb	2.9	0	29-Mar	4.6	4
18-Feb	3.4	0	30-Mar	4.9	2.4
19-Feb	4.5	0	31-Mar	5	0
20-Feb	7.7	1	1-Apr	2.6	0
21-Feb	5.1	0	2-Apr	4.9	0
22-Feb	9.2	T	3-Apr	6	0
23-Feb	8	1.6	4-Apr	6.5	6.6
24-Feb	6.9	0	5-Apr	6.9	1
25-Feb	7	0	6-Apr	7.6	3.6
26-Feb	8.9	0.2			
27-Feb	8	2.6			
28-Feb	8.6	0			
29-Feb	8.7	2.4			

T = Trace

Photo by Peter Woods

Figure 3 One of the unidentified worms as found in sites BR1-1, S4-28, N3-1, and R1-1.

Photo by Peter Woods

Figure 4 Unidentified worm-shaped beetle larvae as found in sites S4-2, S4-28, and R1-1.

Dorsal view

Photo by Peter Woods

Lateral view

Photo by Peter Woods

Figure 5 Family Amphizoidae larva from site N3-1; also found at site R1-1.

Photo by Hideko Yagi

Figure 6 *Notiophilus* sp. found in site BR1-1.

Dorsal view Oblique view

Photo by Peter Woods Photo by Peter Woods

Figure 7 Springtails like unidentified species found in site N3-1

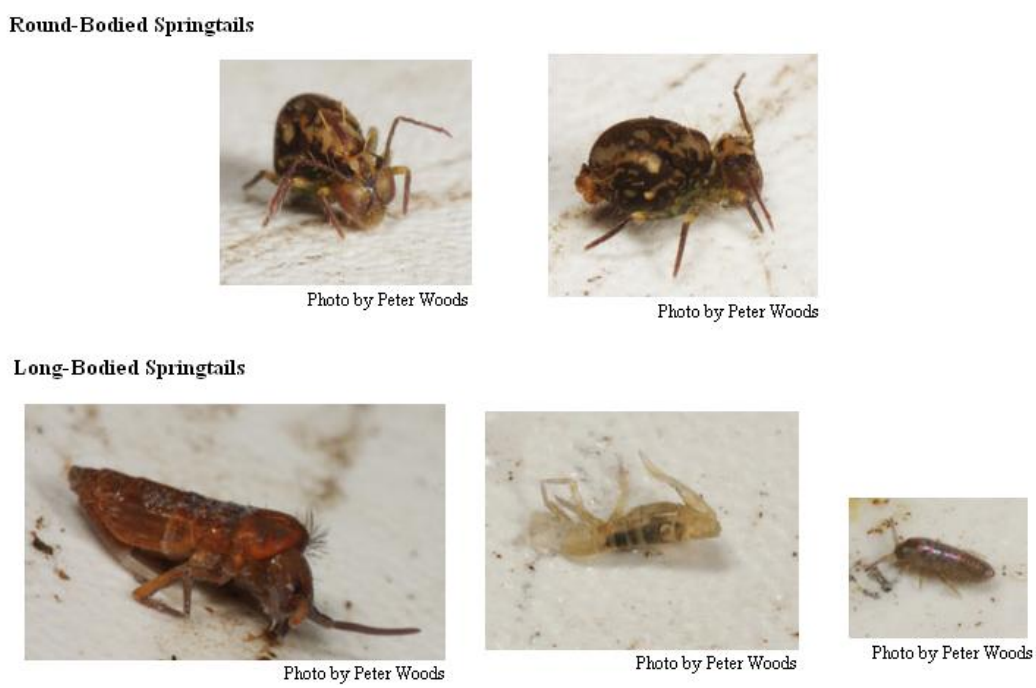

Figure 8 Long-bodied and Round-bodied springtails found in all sites.