Using Quantitative Methods to Gather Small Stream Flow Data for Habitat Characterization

by

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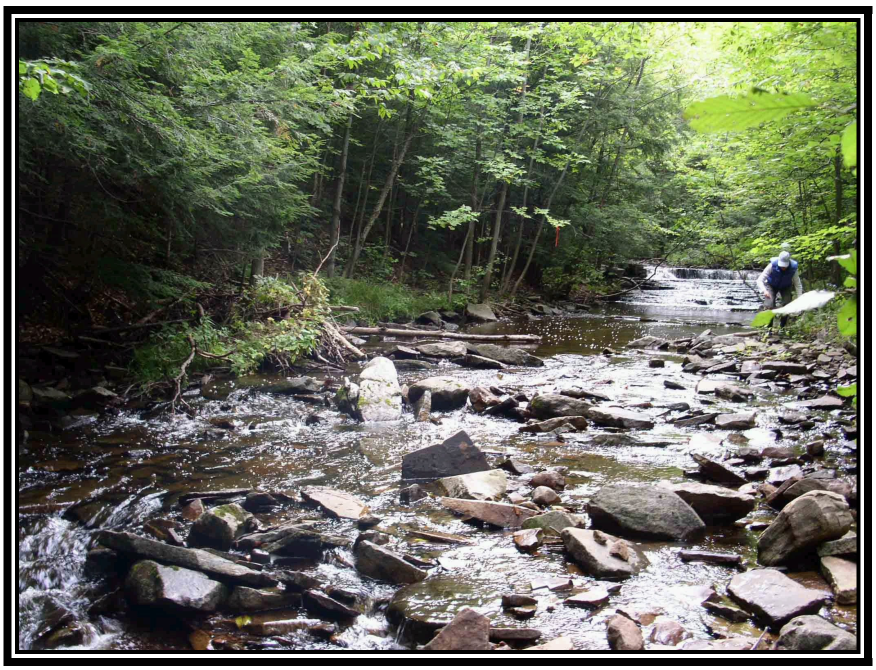

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Introduction

The Mountain Dusky Salamander (*Desmognathus ochrophaeus*) and Northern Dusky Salamander (*Desmognathus fuscus*), both stream salamander, have a limited Canadian distribution. *Desmognathus ochrophaeus* in particular, is present only on a 100 km^2 area known as Covey Hill, Quebec and this appears to be its northern limits (Alvo and Bonin, 1998). The species was listed in the category of "Special Concern" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 1998 (Alvo and Bonin, 1998) and as of November 2001 the species was up listed to "Threatened" status, meaning that the species is likely to become endangered if limiting factors are not reversed (COSEWIC 2004). The main limiting factor affecting the survival of Quebec's stream salamander is possible stream flow reduction by increased groundwater extraction in the area (Alvo and Bonin, 2003). Another emerging limiting factor is possible prolonged dry periods or reduced precipitation and overland flow due to climatic changes. Currently, little is known about the actual habitat requirements of this species in Canada. This is the first study which attempts to quantify the stream flow in the region's known salamander habitat. The stream flow quantification study was carried out in conjunction with a broader salamander habitat characterisation study. The objective of salamander habitat characterization study is to increase the knowledge of the ecosystem elements which are critical to the survival and success of the various stream salamander populations in southern Quebec.

Site description

The study area is located on Covey Hill, which is in the foothills of the Adirondack Mountains on the North side of the border between Canada and the United States of America. The research was conducted on privately owned property with prior consent obtained through formal access agreements with all landowners concerned. The sites, selected based on the abundance and diversity of salamanders present, were predetermined according to population surveys led by the *Société de la faune et des parcs du Québec* and the Quebec Ministry of Natural Resources during the summers of 2002 and 2003. Though the streams varied in width, depth and other physical characteristics, each research site consisted of a stream section measuring 25 meters in length. A total of 62 sites were monitored five times over the course of the summer of 2004. Locations of sampling sites are indicated in Figure 1.

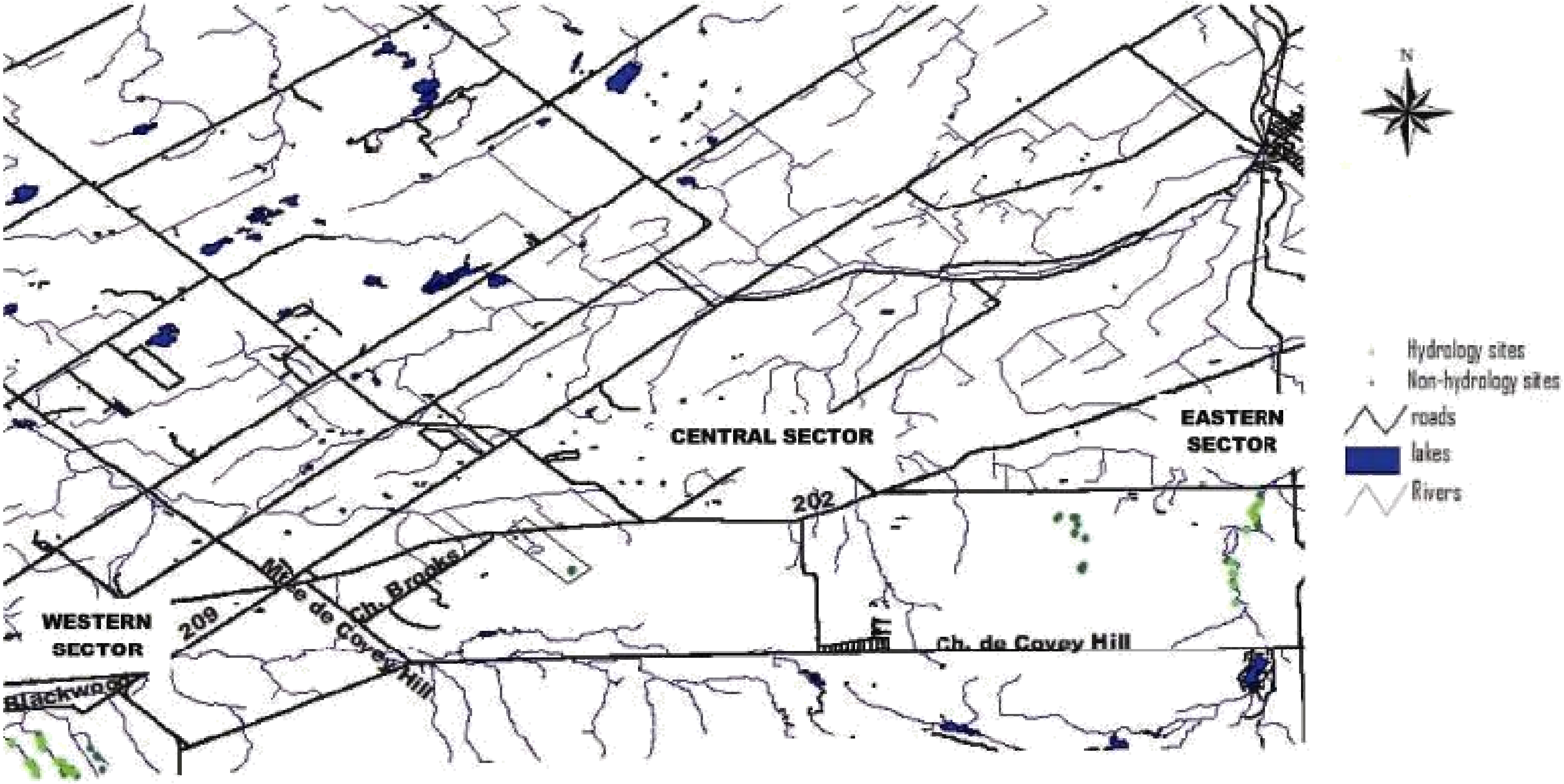


Figure 1. Study area and stream site locations

Materials and methods

In order to characterize the salamander habitat and to observe the evolution of the streams throughout the summer, a field research team visited the sites once per month from May to September. Field work dates for the summer of 2004 were 17-28 of May, 14-21 of June, 12-19 of July, 9-18 of August, and 6-17of September. The 25 meter sections of stream that were chosen as research sites were identified with flags and located with a handheld GPS unit in order to maintain the same locations for the duration of the study. The site labels set by the original research teams in 2002 and 2003 were respected.

The field research team was composed of Anaïs Boutin, graduate student at the University of Montréal currently studying the qualitative characteristics of stream salamander habitat in southern Quebec; Alexandra Rutherford, biologist with the *Société pour la conservation et l'aménagement du bassin de la rivière Châteauguay*; and Geneviève Leroux, hydrology field assistant at the Brace Centre for Water Resources Management. While Boutin collected qualitative stream flow data, Rutherford and Leroux collected quantitative stream flow data. Regrettably, stream flow was not measured quantitatively in May as the team was not yet authorized to mobilize.

<u>Factors affecting the choice of stream flow measurement method</u>

Several factors influenced the choice of the method for quantitative flow measurement. These include the difficult access to sites due to hilly and rocky forested terrain; the distance researchers were required to walk between sites; the need for a rapid instantaneous flow determination; the great variety of streams encountered, including many with extremely low flow; and the need to protect the habitat by using a non-disturbing measurement technology.

The Float method of stream flow measurement, though not as precise as other methods, was chosen for this study as it was by far the most favourable when taking all above mentioned factors into consideration. For instance, the Float method was preferred to the Flow meter method (propeller meter) as the former requires easily portable equipment and can be used in a greater range of stream sizes than the latter, particularly in smaller streams. The model of propeller meter available to the researchers requires a minimum water depth of 8 cm in the stream and most of streams at the research sites had depths of less than that, in addition to it being too heavy and delicate to be carried in the woods all day. The Float method was also preferred to the Flume method when taking into account the fragility of the salamander habitat, as installation of flumes would require modification of the habitat and possible disturbance. In addition, the Float method was the least expensive option, with all others requiring a substantial investment in equipment.

Where streams were extremely small, such that no section of the 25 m long site was suitable to perform the Float method of stream flow measurement, it was only possible to collect qualitative stream flow data according to Boutin's methodology. Qualitative data is to be presented and discussed separately by Boutin, but is mentioned here only as a comparison to the quantitative method. This condition was encountered particularly during dry periods over the summer months when the flow was insufficient to allow the float to travel freely in the stream channel.

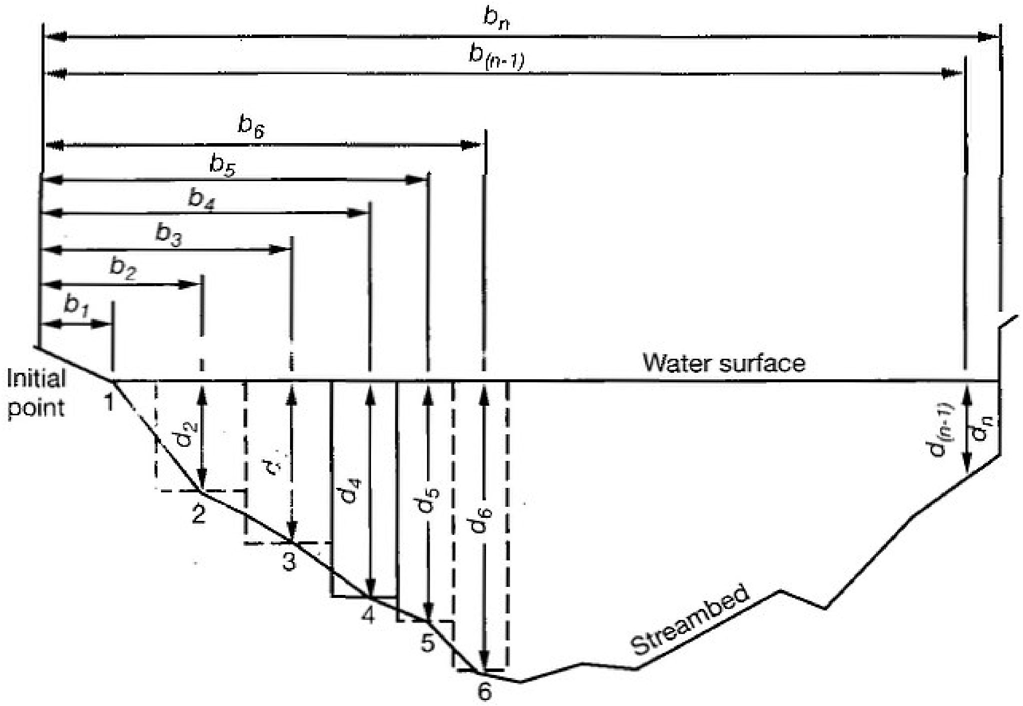
Application of the Float method

In order to allow an accurate characterisation of the salamander habitat, the stream flow was determined quantitatively at as many sites as possible throughout the study period. Stream flow, or discharge, is calculated by applying the discharge principle:

$$Q\ (m^3/s) = V(m/s) * A(m^2)$$
$$\text{Discharge} = \text{Velocity} * \text{Cross-Sectional Area}$$

Flow measurement thus involves the determination of the stream's cross-sectional area and the determination of the mean velocity in the stream channel. In the field, the operation carried out by two persons requiring approximately 5 minutes at each site. The equipment used included a 25 m tape measure, a meter stick, a float (cork) and a stopwatch.

Firstly, a uniform 1 meter length of stream was chosen within the 25 m long site. The cross-sectional area was calculated by measuring the width with the tape measure and measuring the depth at equal intervals with the meter stick. The number and width of the intervals varied according to the size of the streams. Details are shown in Figure 2.



Explanation

1, 2, 3...............n	Observation points
b_1, b_2, b_3...........b_n	Distance, in feet, from the initial point to the observation point
d_1, d_2, d_3...........d_n	Depth of water, in feet, at the observation point

Figure 2. Measurement of stream cross-sectional area (after fig. 3.21, Sander 1998)

Following this, the velocity of the water in the stream channel was determined by measuring the velocity of the water in the middle of each interval, where the number of intervals varied depending on the size of the stream section. This was done by using a stop watch to measure the time required for the cork to travel 1 m along the selected uniform length of stream. This operation was repeated 3 times to get an average. In some cases, where no uniform length of stream existed that permitted the cork to travel uninterrupted for a distance of 1 meter, the length was reduced to 50 cm instead. The assumption was made that the surface velocity of the stream represents accurately enough the mean velocity in the stream channel. Details are shown in Figure 3.

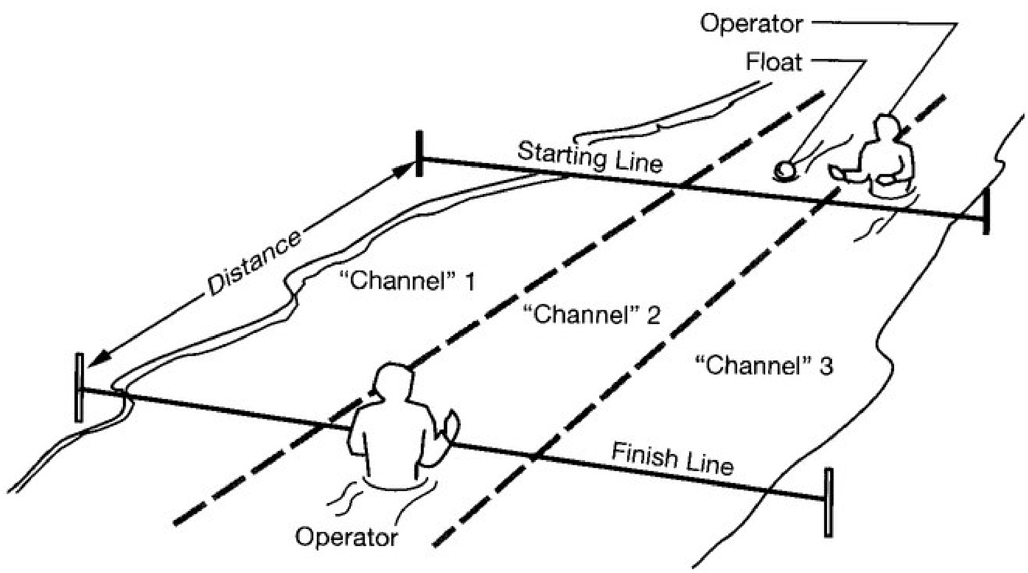


Figure 3.The Float method for velocity determination (after fig 3.17, Sander 1998)

Qualitative data collection

Qualitative observations related to the hydrology were made at each site for the following parameters: riverbed width; percentage of the site covered in water; degree of stream channel continuity; water velocity; and maximum depth. Qualitative data is only considered here in a comparison with the quantitative stream flow measurements. Complete qualitative data will be presented and analyzed by Boutin.

Comparison of quantitative and qualitative data

The data obtained by the Float method was compared to the qualitative data, which was observed simultaneously at the same sites, by means of a ranking system. For a given month, quantitative stream flow values were listed in descending order, highest flow to lowest flow, and given a ranking. Qualitative observations of riverbed width, area covered in water, continuous flow, water speed and maximum depth were used to calculate a representative value that would serve to distinguish the sites based on the qualitative flow observed. The value was calculated using the following formula specific to this study, as determined by Rutherford and Boutin:

Qualitative stream flow = [water speed] * [maximum water depth] * [(stream bed width* percentage area covered in water) + continuous flow]

Note that these parameters represent classes and not absolute values. In the case of water speed, a weighting factor of 1 was included for observed water flowing slowly, a factor of 2 for water flowing moderately and a factor of 3 for water flowing rapidly. This was done to differentiate the water speed results, as water speed was observed as percentage of each class such that adding total percentages equalled 100 at each site. The weighting factor allows the higher water speeds observed to contribute to corresponding higher flow. The ranked stream flows from the quantitative data and the qualitative data were then compared by a regression of the scatter plot to determine how far the points deviate from $R^2=1$.

Results and discussion

Stream flow

A total of 62 stream sites were inventoried over the course of the summer. Of these sites, 27 had a flow which was measurable using the Float method. Minimum stream flow values ranged from immeasurable to 0.084 m^3/s, while maximum stream flow values ranged from 0.002 m^3/s to 0.276 m^3/s. Stream sites included in the study were classified as either intermittent or permanent. The stream sites where the flow was stagnant or too low to be measured during at least any one month were classified as intermittent. Where a measurable flow was encountered for the duration of the study period, the stream sites were classified as permanent. The 27 sites with measurable stream flow were located along two distinct stream systems located in the western and eastern sectors of the study area. All inventoried sites are shown in Figure 1, while details of the stream sites with measurable flow are shown in Figures 4 and 6, western and eastern sectors respectively. The more centrally located stream sites shown in Figure 1 were the driest and were found to have very low immeasurable stream flow for the duration of the study period. It is assumed that the flow rates encountered there are in the order of less than 0.001 m^3/s. The stream sites in this central sector were classified as intermittent. The stream sites in the central sector were located on Cécyre, Lavallée, Joly and Vallière properties. A total of 45 out of the 62 stream sites included in the study were classified as intermittent, indicating that most streams studied have the potential to dry up at intervals over the summer. In general, stream flow decreased from June to August. September values were measured shortly after rain storms resulting from Hurricane Francis and were for the great majority higher than values recorded in June.

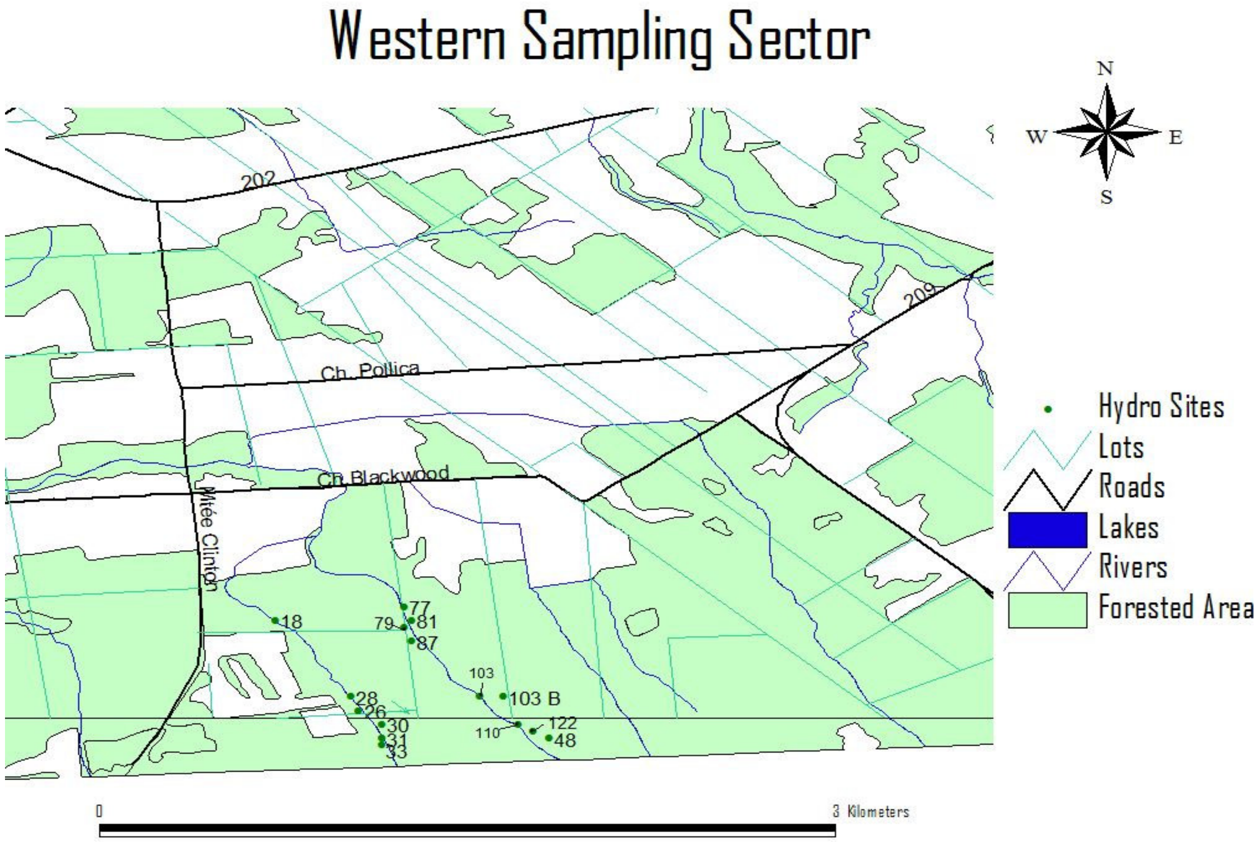


Figure 4. Western sampling sector.

Stream sites in the western sector were located on or adjacent to two distinct streams, both tributaries of the *Rivière aux Outardes Est* and situated on the Brown, Lamb and Boyer properties. Stream sites 18, 26, 28, 30, 31 and 33 are all located on the Brown property. These sites were found to have constant low flow throughout the summer months and were classified as permanent, with the exception of site 18. The minimum and maximum flows measured over the summer for these sites are shown in Table 1, while all measured values are shown in Table 2 (see appendix). Stream sites 48, 122, 110, 103B, 103, 87, 81, 79, and 77 were located on or adjacent to a stream flowing through the Boyer and Lamb properties. Of these sites 48 and 122 on the Boyer property and 103, 77 and 79 on the Lamb property were classified as permanent. The other measurable sites, 110 on the Boyer property and 103B, 87, and 81 on the Lamb property were classified as intermittent due to the extremely low flow or complete lack of water in the summer months. Note that the intermittent stream sites were situated adjacent to the main stream channel. The greatest variation between minimum flows and maximum flows observed during the study was found here in the Western sampling sector. The greatest difference was noted at stream site 103, where flow in June was 69 times greater than the flow measured in August. Stream flows measured at western sector stream sites are shown in Figure 5.

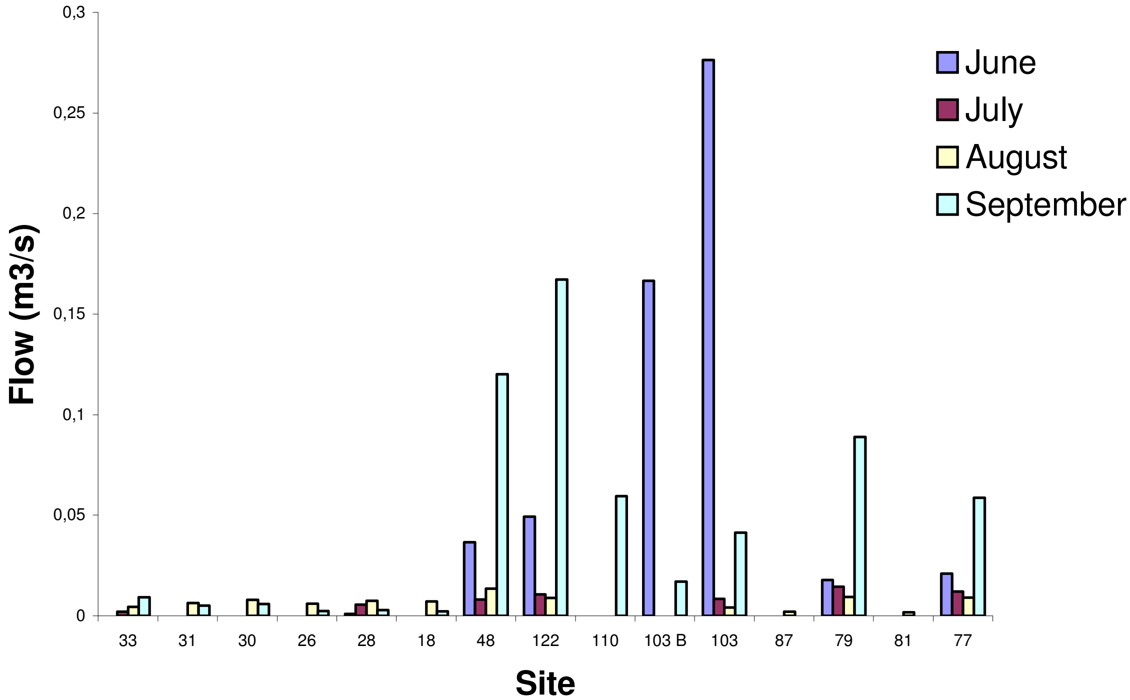


Fig. 5. Measured Stream flow in the western sector.

Note: where data is not present, levels were too low to measure flow using the Float method.

Stream flows measured in the eastern sector were found to be much greater in general than stream flows encountered in the western sector. Stream sites in the eastern sector were located on or adjacent to the *Ruisseau Allen*, a tributary of the *Rivière des Anglais* and situated on the Drummond, Edwards and Benoit properties. Stream sites E00511, E00004, E00101 are located on the Edwards property. Stream sites L00103 and L51001 are located on the Drummond property. Stream sites 507, L00010, NOUVELLE 02, L00008, NOUVELLE 01, and 503 are located on the Benoit property. Stream flow measured on the Benoit property was greatest as the stream flow direction is south to north. Stream flows measured at eastern sector stream sites are shown in Figure 7. The measured stream flow at these sites decreased slightly over the summer, but for the most part was fairly constant. The lowest flow observed for sites E00101 and E00511 was in June rather than July or August. This contradicts the pattern observed for all the other sites.

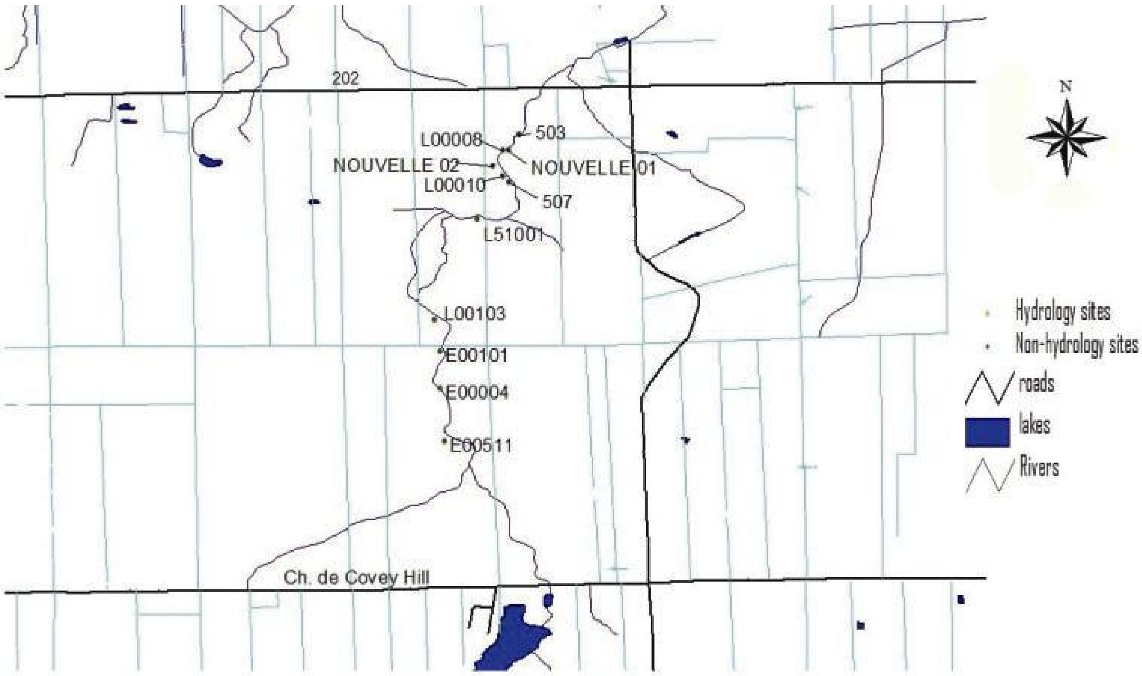


Figure 6. Eastern sampling sector

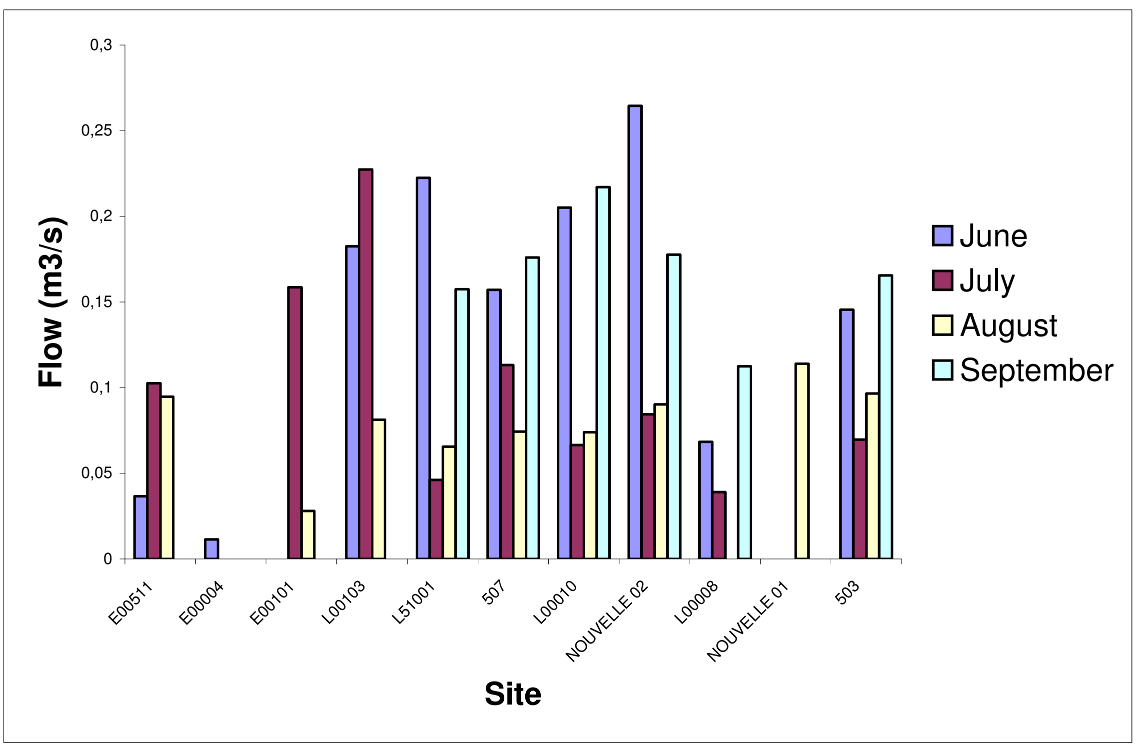


Figure 7. Stream flow in the eastern sector.

Note: For sites E00511, E00101 and L00103, hydrology data was not collected for the month of September, but qualitative observations show that flow was greater than in June. For all other sites where no data is present, levels were too low to measure flow using the Float method.

Distribution of salamander species relative to stream flow

A total of six different species of salamanders were found at the study sites during the summer of 2004. For the most part, the distribution of each salamander species was closely related to the stream type, i.e. intermittent or permanent. Two exceptions to this observation were *Euyrcea bislineata* (Two-lined Salamander) and *Gyrinophilus porphyriticus* (Spring Salamander), which were found in approximately identical ratios at the two different stream types. However, *Desmognathus ochrophaeus* (Mountain Dusky Salamander), *D. fuscus* (Northern Dusky Salamander), *D. ochrophaeus* and *D. fuscus* hybrids and *Plethodon cinereus* (Red-backed salamander) were much more densely concentrated at intermittent streams. The number of each salamander species found at sites classified as intermittent or permanent streams is shown in Table 3.

Table 3. Number of salamanders found at each stream type.

Salamander	permanent streams	intermittent streams
D. Ochrophaeus	20	78
D. fuscus	94	394
Hybrid	13	46
E. bislineata	222	214
P. cinereus	8	46
G. porphyriticus	19	35

The *Euyrcea bislineata* and *Gyrinophilus porphyriticus* were observed in approximately equal ratios at the two different stream types (permanent and intermittent), consistent with the literature. *E. bislineata* is considered a terrestrial species (Deroches and Rodrigue 2004, Grover and Wilbur 2002) and was observed most often on the stream banks up to 2m from the water's edge. *G. porphyriticus* tended to be located swimming in the streams, under submerged rocks, or in very close proximity to the water's edge, or in intermittent streams under protective cover objects, as has often been observed in the literature (Deroches and Rodrigue 2004). *G. porphyriticus* requires permanent streams for its main life stages. The larvae require well oxygenated water for growth and development, and the adults to stave off desiccation, as they tend to have a low tolerance to dehydration (Bonin 1999). These two species were found at the same stream sites, but using different micro-habitats.

Of the *D. ochrophaeus* specimens found, only 20% were observed at sites classified as permanent. Where this species was found at permanent stream sites (26,28,30,31, and 33) the flow was found to be constantly very low throughout the season with the maximum flow never exceeding 0.009 m^3/s. The exception to this was site 103 which had the greatest flow observed of all of the sites studied in this sector, and can be attributed to an extreme event occurring further upstream as the water level rose rapidly in a matter of minutes and decreased significantly the following day. *D.*

ochrophaeus was also found at three stream sites classified as intermittent (18, 87, and 110) where the maximum flow was still very low. No *D. ochrophaeus* were observed in the eastern sector where stream flow was much greater. The number of *D. ochrophaeus* found at each stream site is shown in Figure 8.

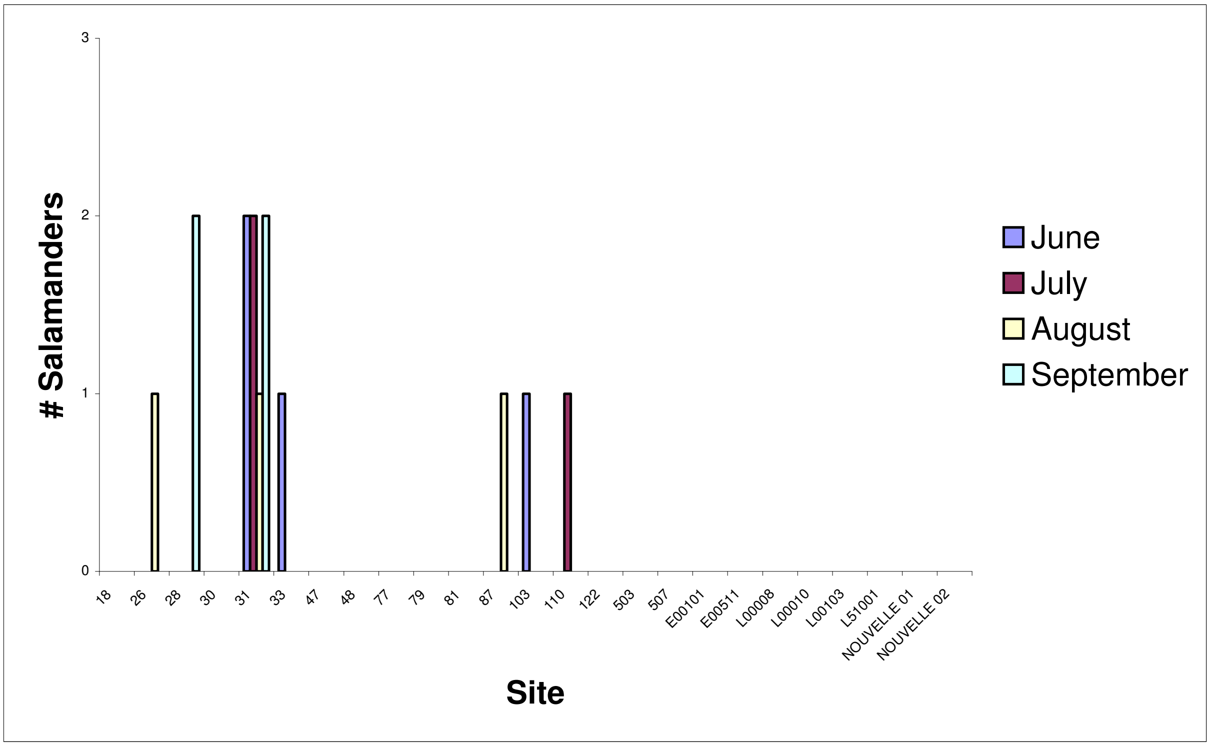


Figure 8. Distribution of *D. ochrophaeus* observed at sites where flow was measurable.

The *D. fuscus* specimens were observed at a wider variety of stream flow conditions than either *D. ochrophaeus* or the hybrids. The stream conditions varied from dry to constant low flow. *D. fuscus* was rarely observed at stream sites with relatively high flow (i.e. sites E00101, E00511, L00008, L00010, or L00103). At sites with a large variation between high and low water levels fewer salamanders were found in general, but those that were observed were found when the water level was at its lowest. The number of *D. fuscus* found at each stream site is shown in Figure 9.

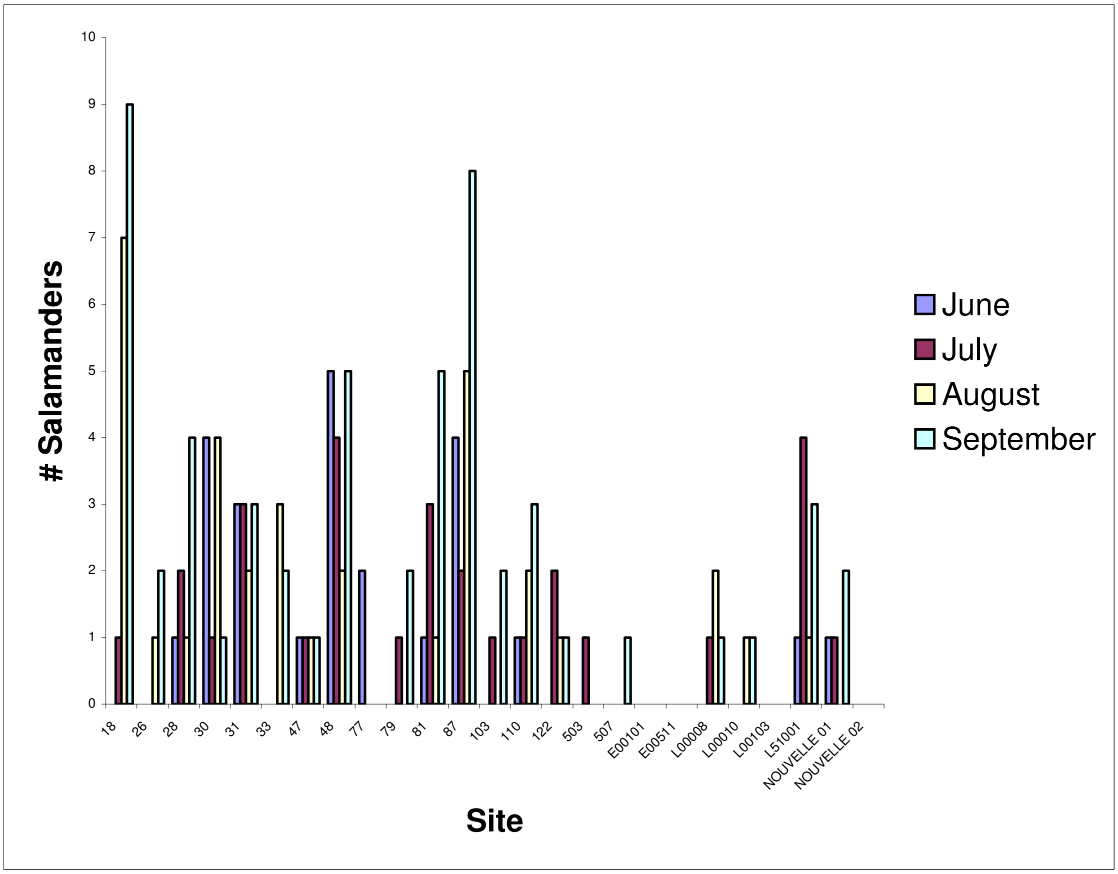


Figure 9. Distribution of *D. fuscus* observed at sites where flow was measurable.

Both of the *Desmognathus* species tended to be found at low flow intermittent stream sites rather than relatively high flow permanent streams sites, which may be due to two factors. Firstly, *G. porphyriticus* is much larger, more dependent on stream presence and likely able to out-compete and inflict predation pressures, allowing this species to colonize more permanent stream sites. Secondly, *D. ochrophaeus* and *D. fuscus* are both adept at using cover objects such as leaves, rocks, moss and fallen logs to provide suitable nesting sites and protection from dehydration (Alvo and Bonin 1998, 2003). In the present study, *D. fuscus* was more predominant than *D. ochrophaeus* particularly in the permanent stream sites with low flow. This may be due to the fact that the larger species of salamanders (*fuscus*) tend to inhabit the stream and wet portions of the bank, inhibiting the smaller salamanders (o*chrophaeus)* from these sites and forcing them to reside in the increasingly dry portions of stream sites and adjacent forest. Only a distance of two meters either side of the stream site was investigated here.

The hybrids of *D. ochrophaeus* and *D. fuscus* were observed only at sites with very low hydrological flow and were not observed at sites with relatively high flow. The number of hybrids found at stream sites with measurable flow is shown in Figure 10. The hybrids tended to be concentrated at the more terrestrial sites, i.e. where flow was mostly immeasurable for duration of the study period. This may be due in part to the fact that the majority of hybrids tend to back-crossed with *D. ochrophaeus* and would possibly have the genetics necessary to survive in drier regions, in addition to experiencing similar pressures of competition and predation experienced by *D. ochrophaeus.* The highest concentrations were found at the intermittent streams located in the central sector on the Joly property. These sites are shown in Figure 1 but not discussed in detail in this report due to the absence of measurable flow.

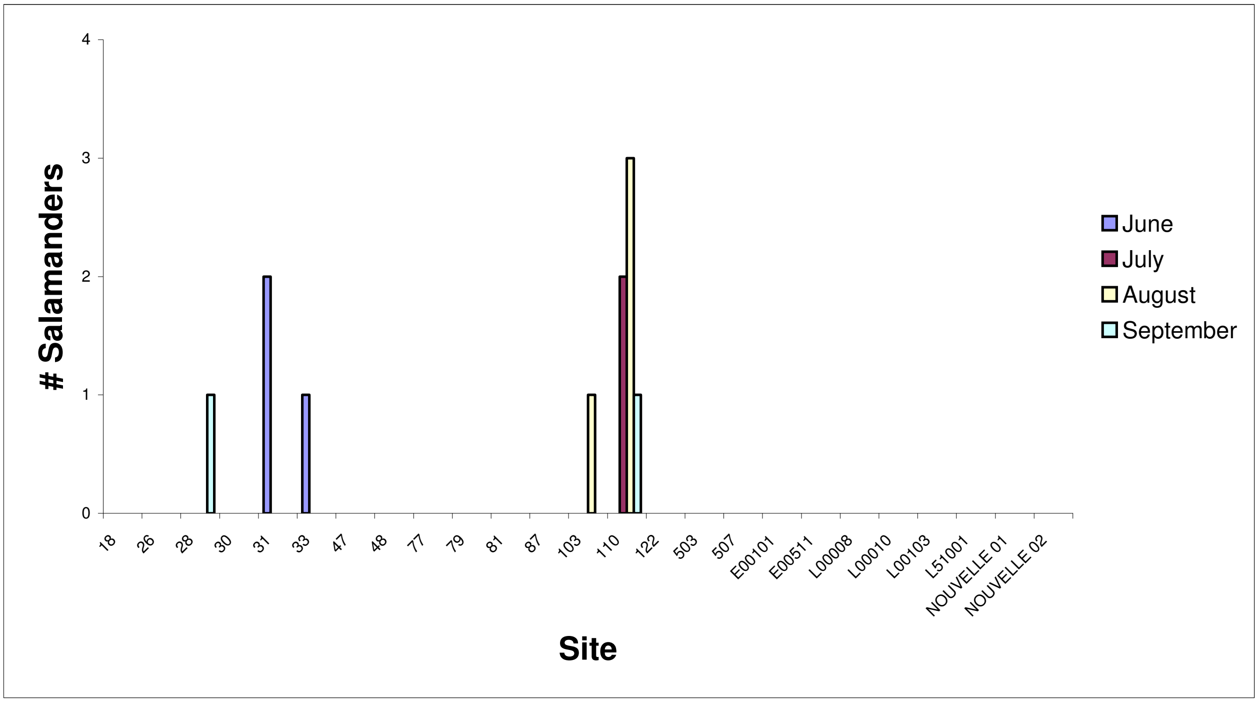


Figure 10. Distribution of observed hybrids at sites where flow was measurable.

Comparison of quantitative flow measurement to qualitative data collection

The two data methods were fairly comparable in terms of rank for June, with very few of the data points differing from each other. This was evident with the R^2 = 0,8132. The regression was much lower in July (R^2=0,3815). The difference between the two methods was greatest in August (R^2=0,2498). In September, the rankings had less of a difference than the previous two months as was noticed with the regression value of R^2=0,5654. The comparison of the qualitative ranking versus the quantitative ranking is shown in Figure 11.

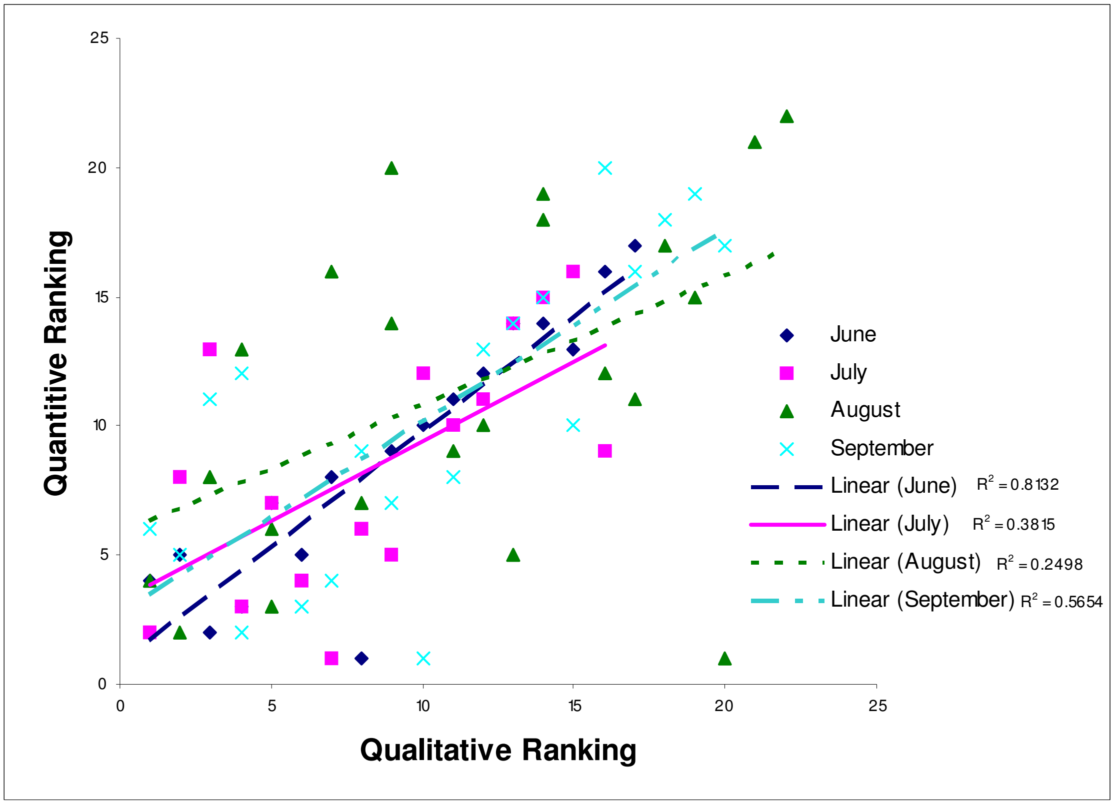


Figure 11. Comparison of the qualitative ranking versus the quantitative ranking

The large difference between rankings from both methods in the drier months (July and August) indicates a possible variation in assignment of qualitative classes as the summer went on, as this is based on human judgement. However, the improved correlation between rankings from both methods in September when the water flow increased indicates that the qualitative and quantitative information agreed most at higher stream flows. Both methods have their advantages. The quantitative Float method is most effective for conditions of higher flow and uniform stream channels. During periods of low flow, the water tends to flow in several separate channels making it difficult to accurately measure. During this study, best efforts were made to select uniform channel sections to apply the Float method, though this was not always possible. The qualitative method is therefore advantageous in conditions of extremely low flow. For conditions of high flow, the qualitative method had difficulty distinguishing among streams with significant flow, whereas the Float method gave precise flow values.

Conclusions

1. The Float method was a useful tool in determining values of stream flow encountered at the Covey Hill research stream sites and permitted the classification of stream sites as permanent or intermittent. This information will allow a more precise characterization of the salamander habitat.
2. Stream flow was found to be lowest in the central sector (Cécyre, Lavallée, Joly and Vallière properties), in the order of less than 0.001 m^3/s, with only intermittent streams present; highest in the eastern sector (Drummond, Edwards and Benoit properties) with flows up to 0.264 m^3/s with predominantly permanent stream sites; and consistent low flow in the western sector (Brown, Lamb and Boyer properties) ranging from immeasurable to 0.120 m^3/s (ignoring the anomaly of site 103) with a mix of permanent and intermittent stream sites.
3. The qualitative method of gathering hydrological information proved most accurate during periods of highest flow. However, in the absence of an appropriate quantitative method to measure the extremely low flows encountered in some salamander habitat, it is a valuable tool for acquiring hydrological information for the purpose of habitat characterisation.
4. Intermittent streams were found to be the preferred habitat of the species *D. fuscus* and *D. ocrophaeus*, i.e. constant low flows and some period of flow approximately less than 0.001 m^3/s.

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Appendix Table 1. Minimum and maximum flow values measured over the study period.

Stream site	Min (m^3/s)	Max (m^3/s)	Class	Min (l/s)	Max (l/s)
18	0,002	0,007	intermittent	2	7
26	0,002	0,006	permanent	2	6
28	0,001	0,007	permanent	1	7
30	0,006	0,008	permanent	6	8
31	0,005	0,006	permanent	5	6
33	0,002	0,009	permanent	2	9
47	low	0,005	intermittent	low	5
48	0,008	0,036	permanent	8	36
77	0,009	0,059	permanent	9	59
79	0,009	0,089	permanent	9	89
81	low	0,002	intermittent	low	2
87	low	0,002	intermittent	low	2
103	0,004	0,276	permanent	4	276
103 B	0,017	0,167	intermittent	17	167
110	low	0,059	intermittent	low	59
122	0,009	0,167	permanent	9	167
503	0,07	0,166	permanent	70	166
507	0,074	0,176	permanent	74	176
E00004	low	≥110,0	intermittent	low	≥11
E00101	0,028	≥951,0	intermittent	28	≥951
E00511	0,037	≥0,103	permanent	37	≥103
L00008	0,068	0,113	intermittent	68	113
L00010	0,067	0,217	permanent	67	217
L00103	0,081	≥722,0	permanent	81	≥722
L51001	0,046	0,223	permanent	46	223
NOUVELLE 01	low	0,114	intermittent	low	114
NOUVELLE 02	0,084	0,264	permanent	84	264

Note: low indicates flow not measurable due to extreme low water levels, but not necessarily fully dried up, and ≥ indicates maximum of measurements taken, as flow was likely higher in September but no measurements were taken.

Appendix Table 2. Flow values measured by the Float method.

Stream site	June (m^3/s)	July (m^3/s)	August (m^3/s)	September (m^3/s)	June (l/s)	July (l/s)	August (l/s)	September (l/s)
18	low	low	0,007	0,002	low	low	7	2
26	N/A	N/A	0,006	0,002	N/A	N/A	6	2
28	0,001	0,006	0,007	0,003	1	6	7	3
30	N/A	N/A	0,008	0,006	N/A	N/A	8	6
31	N/A	N/A	0,006	0,005	N/A	N/A	6	5
33	N/A	0,002	0,004	0,009	N/A	2	4	9
47	low	low	low	0,005	low	low	low	5
48	0,036	0,008	0,013	0,12	36	8	13	120
77	0,021	0,012	0,009	0,059	21	12	9	59
79	0,018	0,015	0,009	0,089	18	15	9	89
81	low	low	0,002	low	low	low	2	low
87	low	low	0,002	low	low	low	2	low
103	0,276	0,008	0,004	0,041	276	8	4	41
103 B	0,167	low	low	0,017	167	low	low	17
110	low	low	low	0,059	low	low	low	59
122	0,049	0,011	0,009	0,167	49	11	9	167
503	0,146	0,07	0,096	0,166	146	70	96	166
507	0,157	0,113	0,074	0,176	157	113	74	176
E00004	0,011	low	low	N/A	11	low	low	N/A
E00101	low	0,159	0,028	N/A	low	159	28	N/A
E00511	0,037	0,103	0,095	N/A	37	103	95	N/A
L00008	0,068	0,039	low	0,113	68	39	low	113
L00010	0,205	0,067	0,074	0,217	205	67	74	217
L00103	0,183	0,227	0,081	N/A	183	227	81	N/A
L51001	0,223	0,046	0,065	0,157	223	46	65	157
NOUVELLE 01	low	low	0,114	low	low	low	114	low
NOUVELLE 02	0,264	0,084	0,09	0,178	264	84	90	178

Note: low indicates immeasurable flow, and N/A indicates no data available