AN ABSTRACT OF THE THESIS OF

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Title: Invertebrate Composition And Distribution In Desert Springs Of Oregon.

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Judith L. Li

In the summers of 1998 and 1999, aquatic invertebrate and plant communities were sampled from nineteen springs in the Warner Basin of southeastern Oregon. Across the landscape, these springs exhibited a broad range in water temperature (5 - 24 °C), pH, conductivity, elevation, and gradient. Within a particular spring, water temperature and chemistry fluctuated little diurnally or annually providing a constant environment for aquatic organisms. Benthic hand net samples, emergence traps, and hand-picking methods were employed to determine the invertebrate composition of each spring. Non-metric Multidimensional Scaling (NMS) invertebrate ordination showed a strong temperature and chemical gradient. For example, invertebrate communities on Abert Rim and Hart Mountain were similar because water temperature, chemistries, and elevation were similar. On the second NMS ordination axis, communities responded to topographic gradients. Differences in the presence of specific taxa in Abert Rim and Hart Mountain springs were related to topographic separation of these sub-basins. For example, only Abert Rim springs contained nemourid stoneflies, *Malenka* sp., and limniphilid caddisflies, *Pseudostenophylax edwarsii*. Hart Mountain springs were distinctive in the presence of certain dytiscid beetle and chironomid taxa. TWINSPAN analysis confirmed differences in invertebrate composition in Abert Rim and Hart Mountain springs and identified variation in invertebrate communities within sub-basins. When riparian and emergent plant taxa and plant-type variables were overlaid on the NMS invertebrate ordination,

neither were related to invertebrate composition. However, there was a significant correlation between invertebrate taxa and percent open area and percent vegetative cover. Open water may be an important habitat attribute for more active invertebrates such as *Labiobaetis* sp., a mayfly, and *Rhyacophila* sp., a free-swimming caddisfly that were correlated with open water and faster-flowing springs in this study. *Dixa* sp., a midge, was prevalent in marshy systems. Longitudinal patterns of invertebrate taxa richness showed an increase as distance from the spring source increased, and may be related to increased temperature fluctuations as groundwater influences decrease. These springs make a significant contribution to the invertebrate diversity of the Warner Basin; forty-three taxa were collected in this study that have not been found in Warner Basin streams.

Invertebrate Composition And Distribution In Desert Springs Of Oregon

by

Susan Mauger

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Susan Mauger, Author

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Once in his life a man ought to concentrate his mind upon the remembered earth. He ought to give himself up to a particular landscape in his experience, to look at it from as many angles as he can, to wonder upon it, to dwell upon it.

He ought to imagine that he touches it with his hands at every season and listens to the sounds that are made upon it.

He ought to imagine the creatures there and all the faintest motions of the wind. He ought to recollect the glare of the moon and the colors of the dawn and dusk.

N. Scott Momaday

INVERTEBRATE COMPOSITION AND DISTRIBUTION IN DESERT SPRINGS OF OREGON

CHAPTER 1

GENERAL INTRODUCTION

Most permanent freshwater springs are very stable environments. Many of their physical and chemical features fluctuate less than in streams, rivers, and lakes. Factors that are most stable are water chemistry and discharge (Odum 1957, Teal 1957). Springs typically have distinctive water chemistry; however, the chemistry of a particular spring will depend on the variety of rocks and soils through which the water passes before reaching the surface and the length of time that the water has been underground. Landscape-level patterns of spring biota may be related to topography and geology, whereas more local phenomena may relate to water chemistry or vegetation patterns. Diversity and dominance within these stable environments also may be the result of biological interactions among fish and invertebrate prey.

Springs often contain taxa that are not found in other aquatic habitats (Roughley and Larson 1991, Williams and Williams 1999). In desert systems particularly, springs make an important contribution to a region's biodiversity (Shepard 1993, Anderson and Anderson 1995). In Great Basin springs, some invertebrate taxonomic groups have received significant attention (Hershler 1998, Shepard 1992, Sheldon 1979), yet community analyses are lacking generally. As agriculture, cattle grazing, and demands for drinking water increase with growing human populations, water quality and availability for spring habitats are threatened (Myers and Resh 1999). In Oregon, there is no legal protection of springs as they are too small to be included under stream or wetland protection measures. Of particular concern is Foskett Spring in the Warner Basin of southeastern Oregon which contains a listed population of speckled dace (*Rhinichthys osculus*). The Bureau of Land Management (BLM) is interested in the ecology of Warner Basin spring habitats that could guide decision-makers in setting conservation priorities.

If a habitat templet were based on flow conditions, spring systems would be in a stable zone (Minshall 1988), where a high level of biotic interaction might be expected. Using this model, species exhibiting K-strategies would be predicted in spring systems. K-selection tends to favor competitive ability, predator avoidance, and low reproductive investment, and can result in high diversity in predictable environments (MacArthur and Wilson 1967). However, species diversity is typically low in springs. This low diversity may be related to the nearly constant environmental conditions found in these habitats and may be the consequence of stable temperatures, which reduce thermal niches (Ward and Stanford 1982). Increased conductivity, pH, and trace elements also may be limiting factors for invertebrates in springs. Springs with biologically limiting chemistries, a predictably unfavorable environment, may result in species that are A (adversity)-selected. A-selection is a concept derived from terrestrial log-inhabiting staphylinid beetles and arctic invertebrates; it may be appropriate for invertebrates in aquatic habitats under adverse abiotic conditions (Greenslade 1983). For example, a historical study revealed that arsenic was probably a limiting factor in one Warner Basin spring (Alan Munhall, pers. comm.). These habitats typically support communities of low diversity in which inter-specific competition is infrequent and trophic relationships are simple.

Low species diversity in desert springs may be related to the small size of these systems and the great distances between spring habitats (MacArthur and Wilson 1967). Dispersal could be limited to taxa with strong aerial adult flyers or by connectivity between adjacent systems during high flow events following spring snowmelt. The unique water chemistries of springs may reduce the suitability of habitat for dispersers; each spring community would be more isolated and the rate of endemism would increase.

Riparian and emergent vegetation are important to aquatic invertebrates as sources of nutrients, refuge from predators, shade from direct sunlight, and habitat. The flora associated with springs in the Lakeview BLM district are variable; plant abundance appears to fluctuate seasonally and over a period of years depending on water availability. Invasion of rooted plants into open water of these springs dramatically changes habitat availability for invertebrates. Because of direct and indirect effects, the invertebrate fauna of springs may be strongly associated with both the distribution and composition of vegetation.

The overall objectives of this study were to explore the influence of water chemistry, physical attributes, and vegetation on invertebrate composition and distribution in desert springs of the Warner Basin in southeastern Oregon. Fifty-three springs were considered in this study. The criteria for inclusion were that a spring appeared to be perennial, and it had enough flow and depth for the selected sampling methods. A spring was selected if it had not been significantly altered by land-use practices at the time of sampling, and it had a definable source area. Finally, springs needed to be located on land where permission to sample had been granted by the landowner and to be reasonably accessible by a four-wheel drive vehicle. Nineteen springs were identified that met these criteria. Only one spring had a resident fish population. A subset of springs sampled in the first field season (1998) were re-sampled in 1999 to evaluate year-to-year variability.

In Chapter 2, effects of water chemistry and physical attributes on invertebrate composition and distribution in desert springs are considered. My expectation was that composition of invertebrates would be similar in springs that had similar temperature, pH, conductivity, and trace element levels. Richness (i.e. number of invertebrate taxa) was expected to decrease along a gradient of increasing temperature, pH, and conductivity; conversely, percent of non-insect invertebrates would increase along the same gradient. An increase in invertebrate richness was predicted as the distance from the spring source increased.

Chapter 3 explores the relationship between riparian and emergent vegetation and the composition of invertebrates in Warner Basin springs. I predicted that springs with similar riparian and emergent vegetation would have similar invertebrate communities, and that the amount of cover provided by riparian and emergent vegetation would affect the composition of invertebrates.

Low diversity of aquatic invertebrates and low variability in water temperature and chemistry of springs provided an opportunity to distinguish between abiotic and biotic effects on benthic invertebrates. I chose Non-metric Multidimensional Scaling

(NMS), a multivariate ordination technique, to determine which springs were most similar to each other. To understand the reason for the distribution of springs in ordination space, I used clustering techniques (i.e. hierarchical agglomerative cluster analysis and Two-Way Indicator Species Analysis). With this combination of tools, I was able to discern abiotic and biotic patterns at both landscape and local scales.

CHAPTER 2

INFLUENCE OF WATER CHEMISTRY AND PHYSICAL ATTRIBUTES ON INVERTEBRATE COMPOSITION AND DISTRIBUTION IN DESERT SPRINGS

ABSTRACT

In the summers of 1998 and 1999, aquatic invertebrates were sampled from nineteen springs in the Warner Basin of southeastern Oregon. Within a particular spring, water temperature and chemistry fluctuated little diurnally or annually, providing a constant environment for aquatic organisms. Across the landscape, springs exhibited a broad range in water temperature (5 – 24 °C), pH, conductivity, elevation, and gradient. Benthic hand net samples, emergence traps, and hand-picking methods were employed to determine the invertebrate community composition of each spring. Non-metric Multidimensional Scaling (NMS) invertebrate ordination showed a strong temperature and chemical gradient. For example, invertebrate communities on Abert Rim and Hart Mountain were similar because water temperature and chemistries were similar. On the second ordination axis, communities responded to topographic gradients. Differences in the presence of specific taxa were related to the topographic separation of cold-water springs. TWINSPAN analysis confirmed differences in invertebrate composition in Abert Rim and Hart Mountain springs and identified variation in invertebrate communities within sub-basins, which was not explained by water temperature or chemistry. Invertebrate taxa richness increased longitudinally as distance from the spring source increased; these patterns may be related to temperature fluctuations that increase as groundwater influences decrease.

INTRODUCTION

Little is known about the assemblage composition or ecological role of Great Basin spring habitats. Springs often contain taxa that do not occur in other aquatic habitats; in arid systems particularly they make an important contribution to a region's biodiversity (Shepard 1993, Anderson and Anderson 1995). Several springs of the Warner Basin in southeastern Oregon contain isolated populations of tui chub (*Gila bicolor*) and speckled dace (*Rhinichthys osculus*); listed populations, such as Foskett Spring speckled dace, illustrate the potential for endemic species and point out the importance of understanding the ecology of these small systems.

Among recent regional comparisons of aquatic invertebrates in springs, most have concentrated on a single taxonomic group (Forester 1991, Erman and Erman 1995), relied on methods that favor insect taxa (Anderson and Anderson 1995), or considered springs with similar water temperature and chemistry (Glazier and Gooch 1987, Pritchard 1991, Webb et al. 1998). Within the Great Basin, certain taxonomic groups have been intensively studied: hydrobiid snails (Hershler 1998), elmid beetles (Shepard 1992), and stoneflies (Sheldon 1979); however, community analyses from broad geographic areas are lacking. This study's contribution is its focus on benthic invertebrate spring communities across a Great Basin landscape.

The objectives of this study are to 1) explore the influence of water chemistry and physical attributes on invertebrate composition and distribution in Great Basin springs, 2) determine seasonal and between-year variability in chemical and physical characteristics, and 3) assess changes in downstream invertebrate communities associated with desert springs.

METHODS

Study Area

Nineteen springs were sampled in the Warner Basin of southeastern Oregon, which is in the upper extent of the Great Basin (Figure 2.1). Springs were distributed across a wide geographic area (52 km^2), from Abert Rim, through the Warner Valley, to the top of Hart Mountain. Abert Rim and Hart Mountain are two in a series of long and narrow, north-south trending fault-block mountain ranges alternating with broad basins in this region (Orr et al. 1992). As a result of this extensive east-west stretching and

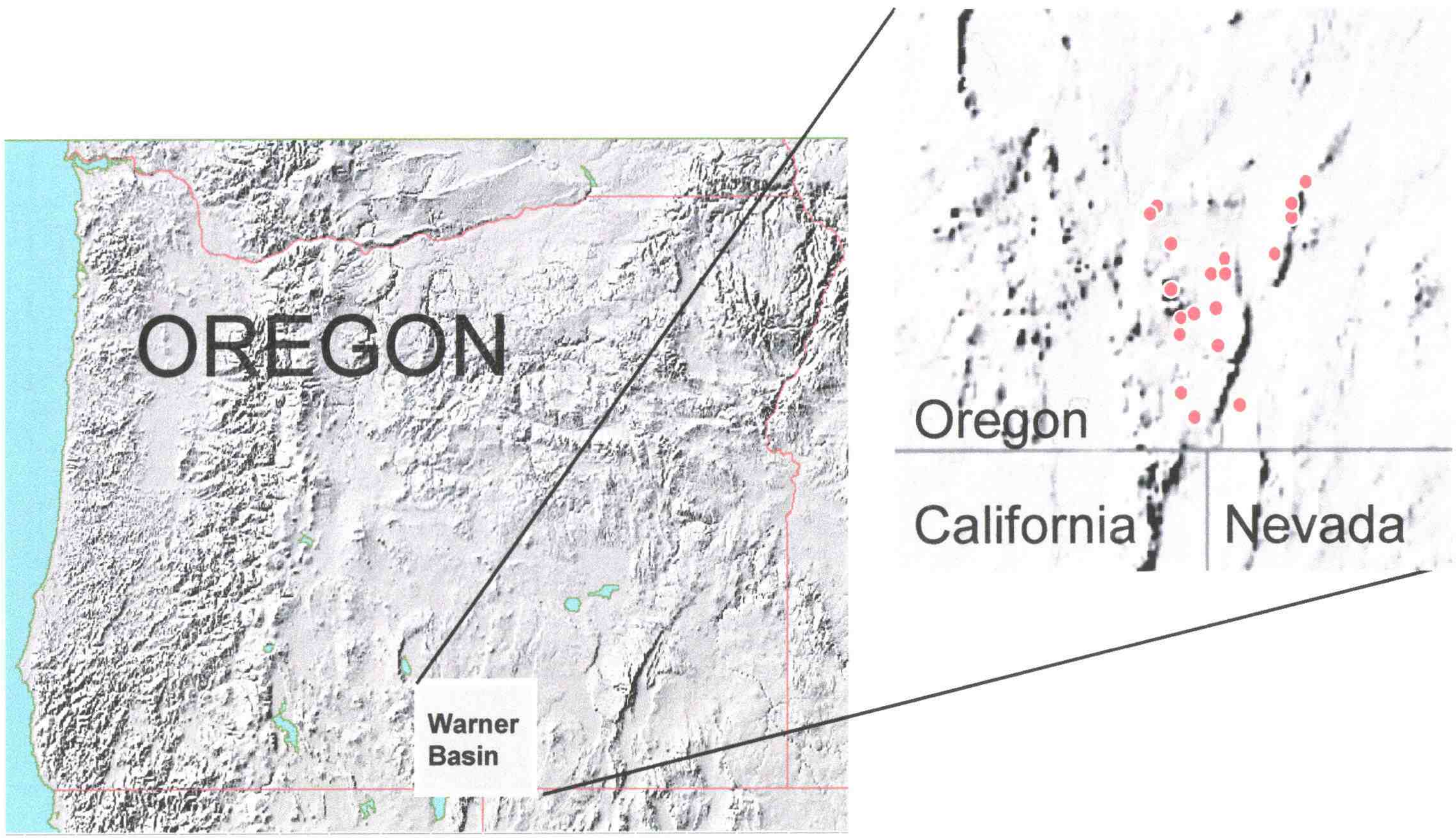

Figure 2.1 Nineteen springs (represented by circles) were sampled in the Warner Basin of southeastern Oregon.

thinning of the Earth's crust in recent geologic history, springs are common in this high desert, semi-arid landscape.

In general, Warner Basin springs have been altered by agriculture, cattle grazing, and increased water withdrawals. Springs included in this study were selected because they 1) did not appear to be significantly altered by land-use practices at the time of sampling, 2) had definable source areas, 3) appeared to be perennial, and 4) had enough flow and depth for the selected sampling methods. For this study, a spring system extended from the spring source to an area ten meters downstream.

From July – September 1998, all springs were sampled to measure water chemistry, physical attributes, and to collect invertebrates. To determine temporal variability, two springs were sampled twice in 1998 and eight springs were re-sampled in July 1999. (See Appendix 1 for list of springs sampled in 1998 and 1999.) Invertebrates were collected at three 40-meter intervals downstream from the spring source in 1999 to assess changes in downstream invertebrate communities.

Water Temperature and Chemistry Methods

Temperatures were collected with a hand-held glass thermometer (calibrated with boiling water at 6100 feet). Readings were taken at six transects within ten meters from the spring source. Repeated measurements were taken throughout the day as invertebrates were collected to assess diurnal variability. Temperature was measured downstream to determine where a change of 2 °C occurred in relation to the spring source temperature.

Conductivity and pH were recorded at three transects using a Myron L pH/conductivity meter (Model #EP11). The meter was calibrated weekly with a 7000 µS conductivity solution, and 4, 7, 10 pH buffers. Conductivity was considered accurate to ±20 µS and pH was accurate to ±0.2. A 250-ml water sample was collected at each spring source for trace element analysis. The water sample was kept in a cool, dry place and within 4 hours, 3 ml of sulfuric acid was added to lower the pH and prevent bacterial growth. Samples were analyzed with an ICP Spectrometer at the OSU Central Analytical Lab in Corvallis, Oregon. In 1999, dissolved oxygen was measured, using an ATI Orion meter (Model #830), by placing the probe directly into each spring at its source and at three locations downstream.

Physical Data Methods

Location (i.e. latitude, longitude, township, range, section, quarter section, and county) and elevation were taken from U.S.G.S. topographic maps (7.5 minutes). Percent gradient was measured with a clinometer facing downstream at a distance of ten meters. Aspect was determined with a compass. Flow was measured using fluorescein dye, a stopwatch, and meter stick. At three different transects, a drop of fluorescein dye was released and the time it took to travel one meter was recorded and averaged over the three trials. This provided a relative measurement of flow velocity. Most springs were too shallow or thick with vegetation to use a flow meter.

U.S.G.S. topographic and geologic maps (Walker and Repenning 1965, Walker 1977) were used to determine sub-basin boundaries within the Warner Basin. Sub-basins may reflect common aquifers or surface connectivity during high flow events. I de-lineated sub-basin boundaries by considering topography, aspect, watershed boundaries, and transverse fault lines.

Invertebrate Survey Methods

In 1998, five sampling methods were employed to collect spring-associated invertebrates. Benthic invertebrates were collected with a small hand net (14 cm x 15.25 cm, 250 µm mesh). The net was placed on the bottom of a spring, and a 15-cm^2 area in front of the net was disturbed. Four samples were taken within each spring area. A visual search was conducted for large and rare specimens in margin and slow-water habitats. An emergence trap (0.5 m^2) was set out for at least 8 days to collect emergent aquatic insect adults that were used to verify difficult benthic identifications. An activity trap, designed to collect more active aquatic invertebrates that could avoid a net (Swanson 1978), was set in open-water areas. Pan traps (15.25 cm x 21.5 cm, Tupperware container), filled with soapy water (4 cm deep), were placed in open-water areas and set for 18 hours to collect aquatic adults and riparian invertebrates. A Cyalume light stick (12 hours of illumination) was attached to each pan trap and activated just before sunset to attract nocturnal insects.

In 1999, only two invertebrate collecting techniques were repeated. Hand net samples were taken at 1.0 meter, 10.0 meters, and at three downstream locations spaced at 40-meter intervals. An emergence trap ($0.5m^2$) was set at each spring for eight days.

Laboratory Methods

All identifications and counts were performed in the laboratory under 20X with a Zeiss dissecting scope using taxonomic keys (Merritt and Cummins 1996, Borror et al. 1989). All samples were counted in their entirety. Taxonomic resolution varied across the orders. (See Appendix 2 for taxonomic resolution.)

Statistical Analysis

Because benthic sampling methods were not considered quantitative, invertebrate communities were described by taxa present. For the 1998 invertebrate analysis, four benthic samples from each spring were combined to generate as complete a taxonomic list as possible. To compare 1998 and 1999 data, samples taken at 1.0 meter and 10.0 meters from both years were used. Physical and chemical measurements used in the analysis were from the spring source.

Using 1998 benthic invertebrate presence/absence data, Non-metric Multidimensional Scaling (NMS) determined which springs had similar invertebrate communities (invertebrate ordination). NMS is an ordination technique based on rank similarity distances (Mather 1976, Kruskal 1964), which tend to relieve the zero-truncation problem often associated with community data (Beals 1984). NMS used Sorensen's distance measure to determine similarities. Fifteen runs were made with real data, 30 with randomized data. The appropriate number of dimensions for the final ordination was determined by examining stress values. Final stress for a given dimensionality was lower than that for 95% of the randomized runs (i.e. $p <= 0.05$ for the Monte Carlo test). Stress is a measure of distance in the ordination space and the corresponding dissimilarity between sample units (i.e. springs). For the invertebrate data, a three-dimensional solution was selected with a final stress of 12.71.

Graphic overlays or joint plots of 19 quantitative environmental variables were used to relate individual variables to the invertebrate ordination space. Vector angle and length in the joint plots illustrate the direction and strength of environmental gradients. Squared values of Pearson's correlation coefficients (r^2) expressed the proportion of variation in axis positions explained by the variable in question. This analysis was conducted after deleting rare taxa (i.e. those found in only a single spring) from the invertebrate data set.

Hierarchical agglomerative (HA) cluster analysis, using Euclidean distance measure and Ward's method, was performed with nineteen environmental variables to determine which springs were most similar based on water chemistry and physical data. Multi-Response Permutation Procedures (MRPP) determined if these spring clusters were significantly different. MRPP is a non-parametric method that tests whether there are significant differences between groups. MRPP provides a measure of within-group homogeneity (A) to estimate the tightness of the group associations generated by the HA cluster analysis. When $A > 0$, heterogeneity within groups is greater than expected by chance. Sorensen's distance measure was used to determine distances between springs and the weighting of groups was n/sum(n), where n = number of springs in a group. Springs were coded by their abiotic-group associations on the NMS ordination to assess graphically whether springs with similar water chemistry and physical attributes had similar invertebrate communities.

Two-way indicator species analysis or TWINSPAN (Hill 1979, Gauch and Whittaker 1981) identified springs with similar invertebrate composition. TWINSPAN is a divisive clustering technique, which means that the analysis proceeds by dividing clusters rather than by joining clusters as in the HA cluster analysis technique described above. The TWINSPAN invertebrate groupings were compared with the NMS ordination of invertebrate taxa.. Taxa found predominately in springs of one TWINSPAN group were identified as significant invertebrate taxa.

An outlier analysis in PC-ORD version 4.01 (McCune and Mefford 1999) was performed on both the invertebrate and environmental data by calculating the average distance (Sorensen's distance measure) from each spring to all other springs in ordination space. Outliers were springs that were ±2 standard deviations greater than the mean distance and were identified through cluster analysis and visual examination of ordination graphs.

Analysis of variance (ANOVA) and Tukey Test (all pairwise multiple comparison procedures), were used to detect and measure differences in taxonomic richness and non-insect taxa between groups determined by HA cluster analysis on the environmental data. These methods, also, were used to detect differences in taxa richness between years and along a longitudinal (downstream) gradient.

RESULTS

Chemical and Physical Attributes

The nineteen springs represented a wide range in water temperature, pH, conductivity, elevation, and gradient (Table 2.1). Temperature at spring sources ranged from 5 – 24 °C, pH varied from 5.9 to 7.7, and conductivity ranged from 20 to 350 μS (Figure 2.2 a-c). In 1998, water temperature at each spring source varied no more than 1.0 °C over 24 hours. For the eight springs sampled in 1999, water temperature at the source varied no more than 0.5 °C between years at a given spring, pH values varied by ±0.3 and conductivity remained the same or decreased by 50 μS.

Arsenic (As) and selenium (Se) levels had been identified at the start of the project as possible limiting factors for spring biota; however in this study, these trace elements were not of concern. (See ICP Spectrometer Scan analysis in Appendix 1.) In 1998, Falls and Stockade Springs had the most distinctive chemistries overall. (See Appendix 3 for spring names and locations in the Warner Basin.) A comparison of 1998 and 1999 data suggests a decrease in Ca^{2+}, Mg^{2+}, Na^{+} concentrations in 1999 (Table 2.2).

For all springs sampled in 1999, dissolved oxygen was greater than 6.0 mg/l (Figure 2.3); oxygen is unlikely to be a limiting factor for the biota of these springs.

Table 2.1 Selected water chemistry, physical measurements, and sub-basin information from the nineteen springs sampled in 1998. Temperature, pH, and conductivity measurements were taken at the spring source. Cricket and Foskett Springs were sampled twice.

Spring Name	Latitude	Longitude	Sampling period (1998)	Temp (°C)	pH	Conduc-tivity (µS)	Elevation (meters)	Gradient (%)	Topographic sub-basin
LOP	42°13'45"	120°05'45"	7/08 - 7/27	9.0	6.8	70	1729	1.5	Abert Rim
Cricket	42°18'00"	119°58'00"	7/09 - 8/12	9.5	7.2	118	1774	3.5	Central
Cricket	42°18'00"	119°58'00"	8/23 - 9/10	10.0	7.3	100	1774	4.0	Central
Foskett	42°04'15"	119°50'15"	7/10 - 7/18	19.0	7.7	330	1360	0.5	Foskett
Foskett	42°04'15"	119°50'15"	8/01 - 9/10	18.0	7.9	360	1360	0.5	Foskett
Spot Creek	42°02'20"	119°59'30"	7/17 - 8/14	24.0	7.0	145	1476	4.0	Southern
Drake	42°17'30"	120°11'00"	7/18 - 8/11	5.5	5.9	35	2083	17.0	Abert Rim
Can	42°22'50"	120°10'00"	7/20 - 8/11	5.5	6.5	160	1920	16.0	Abert Rim
Matilda	42°13'50"	120°05'40"	7/26 - 8/11	9.5	6.6	80	1726	9.0	Abert Rim
Juniper	42°13'40"	120°05'50"	7/27 - 8/11	9.5	6.1	75	1719	4.0	Abert Rim
Clover	42°27'17"	120°10'00"	7/29 - 8/11	9.0	6.6	70	1884	1.0	Abert Rim
Thunder	42°27'15"	120°10'00"	7/29 - 8/11	9.5	6.6	95	1884	8.0	Abert Rim
Finucane	42°18'30"	119°58'50"	8/12 - 8/23	9.5	7.3	120	1756	7.5	Central
Hopper	42°18'00"	119°58'00"	8/12 - 8/23	10.0	7.2	120	1768	3.0	Central
Falls	42°10'30"	119°57'00"	8/17 - 8/29	16.0	7.4	350	1534	30.0	Central
Crackle	42°15'15"	120°01'10"	8/20 - 9/10	11.0	6.9	160	1738	2.0	Central
Pope	42°03'45"	120°04'00"	8/22 - 9/10	7.0	6.6	165	1799	3.0	Southern
Stockade	42°25'15"	119°45'45"	8/25 - 9/09	5.0	6.7	80	2201	8.5	Hart Mountain
Goat	42°25'00"	119°46'15"	8/26 - 9/09	6.0	6.5	75	2262	7.5	Hart Mountain
Basque	42°30'50"	119°43'30"	8/28 - 9/09	5.0	6.4	20	2195	13.0	Hart Mountain
Hidden	42°21'30"	119°46'45"	8/30 - 9/09	9.0	6.6	120	1823	2.0	Hart Mountain

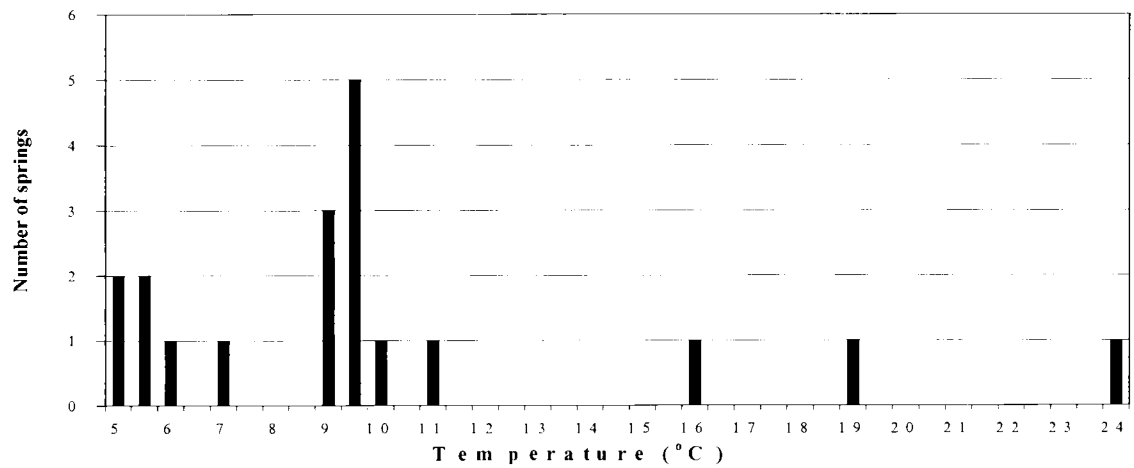

Figure 2.2a Water temperatures at the nineteen springs sampled in 1998.

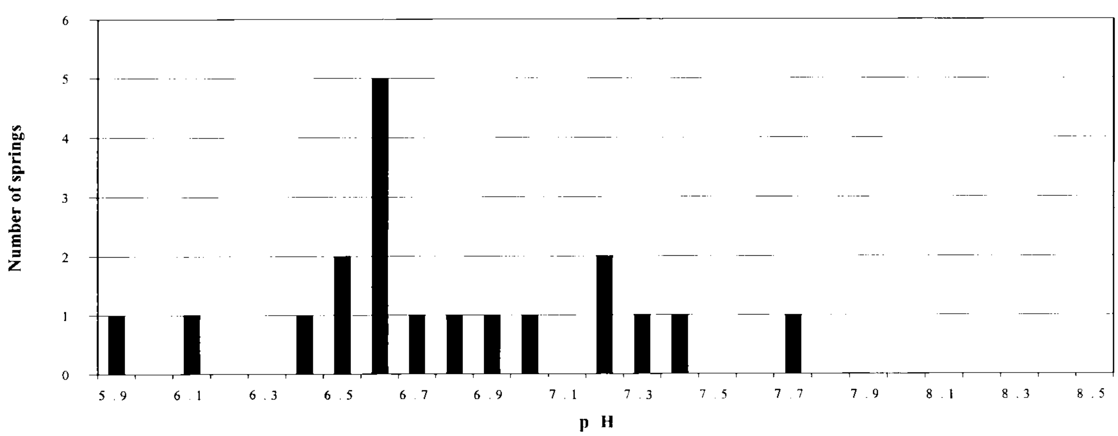

Figure 2.2b Values for pH at the nineteen springs sampled in 1998.

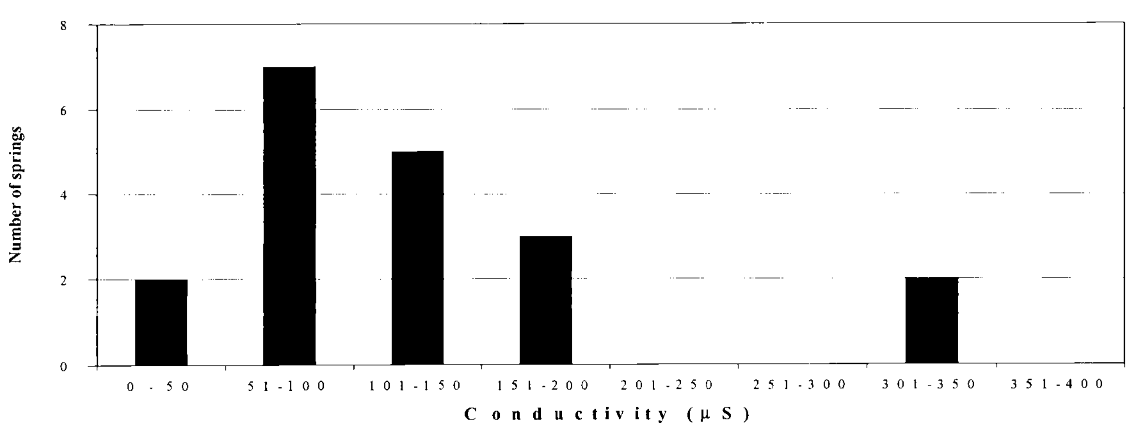

Figure 2.2c Conductivity at the nineteen springs sampled in 1998.

Table 2.2 Comparison of 1998 and 1999 trace element data from Warner Basin springs. All results are in parts per million (ppm). Shaded columns show the greatest change within springs from 1998 to 1999.

Spring name + sample year	Ba	Ca	Cd	Cu	K	Mg	Mn	Zn	Al	As	P	S	B	Fe	Pb	Co	Cr	Mo	Se	Si	Na	Ni
Can 98	0.01	18.88	<0.01	<0.01	1.68	7.94	0.01	0.02	0.29	<0.08	<1.00	639	<0.16	0.23	<0.20	<0.01	<0.02	<0.02	<0.10	32.80	6.88	<0.09
Can 99	<0.01	19.53	<0.10	<0.01	1.74	8.27	0.02	<0.10	<0.50	<0.10	0.88	724	<0.01	<0.02	<0.10	<0.02	<0.02	<0.10	0.31	26.40	8.68	<0.10
Clover 98	<0.01	8.24	<0.01	<0.01	1.06	3.96	<0.01	0.01	0.27	<0.08	<1.00	600	<0.16	0.27	<0.20	<0.01	<0.02	<0.02	<0.10	20.80	4.22	<0.09
Clover 99	<0.01	1.16	<0.10	<0.01	<0.50	0.85	<0.10	<0.10	<0.50	<0.10	<0.50	513	<0.01	0.09	<0.10	<0.02	<0.02	<0.10	0.06	10.10	<1.00	<0.10
Drake 98	0.02	2.36	<0.01	<0.01	1.54	0.69	<0.01	0.01	0.12	<0.08	<1.00	684	<0.16	<0.15	<0.20	<0.01	<0.02	<0.02	<0.10	18.20	3.15	<0.09
Drake 99	<0.01	<0.10	<0.10	<0.01	<0.50	<0.10	<0.10	<0.10	<0.50	<0.10	<0.50	458	<0.01	<0.02	<0.10	<0.02	<0.02	<0.10	<0.05	3.77	<1.00	<0.10
Foskett 98 (1)	0.01	9.82	<0.01	<0.01	8.62	4.84	<0.01	0.01	0.16	0.10	<1.00	635	0.58	0.16	<0.20	<0.01	<0.02	<0.02	<0.10	40.90	65.80	<0.09
Foskett 98 (2)	0.01	9.72	<0.01	<0.01	8.53	4.75	<0.01	0.01	0.17	0.10	<1.00	506	0.59	0.14	<0.20	<0.01	<0.02	<0.02	<0.10	38.00	62.00	<0.09
Foskett 99	<0.01	0.40	<0.10	<0.01	1.92	0.46	<0.10	<0.10	<0.50	<0.10	<0.50	488	0.13	<0.02	<0.10	<0.02	<0.02	<0.10	0.05	9.79	11.07	<0.10
Juniper 98	0.02	6.58	<0.01	<0.01	2.69	3.86	<0.01	0.01	0.61	<0.08	<1.00	669	<0.16	0.41	<0.20	<0.01	<0.02	<0.02	<0.10	26.20	5.22	<0.09
Juniper 99	0.02	5.41	<0.10	<0.01	2.66	3.20	<0.10	<0.10	1.54	<0.10	<0.50	523	<0.01	0.62	<0.10	<0.02	<0.02	<0.10	0.11	21.70	4.71	<0.10
LOP 98	0.01	5.70	<0.01	<0.01	2.39	3.59	<0.01	0.01	0.87	<0.08	<1.00	646	<0.16	0.52	<0.20	<0.01	<0.02	<0.02	<0.10	26.40	4.36	<0.09
LOP 99	<0.01	2.27	<0.10	<0.01	1.81	1.73	<0.10	<0.10	1.18	<0.10	<0.50	531	<0.01	0.47	<0.10	<0.02	<0.02	<0.10	0.09	18.70	2.28	<0.10
Matilda 98	0.01	6.02	<0.01	<0.01	2.44	3.82	<0.01	0.01	0.76	<0.08	<1.00	690	<0.16	0.47	<0.20	<0.01	<0.02	<0.02	<0.10	26.90	4.74	<0.09
Matilda 99	<0.01	4.20	<0.10	<0.01	2.32	2.77	<0.10	<0.10	1.51	<0.10	0.60	569	<0.01	0.55	<0.10	<0.02	<0.02	<0.10	0.10	20.90	3.54	<0.10
Thunder 98	0.01	10.61	<0.01	<0.01	1.18	5.07	<0.01	0.01	0.22	<0.08	<1.00	616	<0.16	0.22	<0.20	<0.01	<0.02	<0.02	<0.10	21.30	5.26	<0.09
Thunder 99	<0.01	0.68	<0.10	<0.01	<0.50	0.60	<0.10	<0.10	<0.50	<0.10	<0.50	511	<0.01	0.05	<0.10	<0.02	<0.02	<0.10	<0.05	7.54	<1.00	<0.10

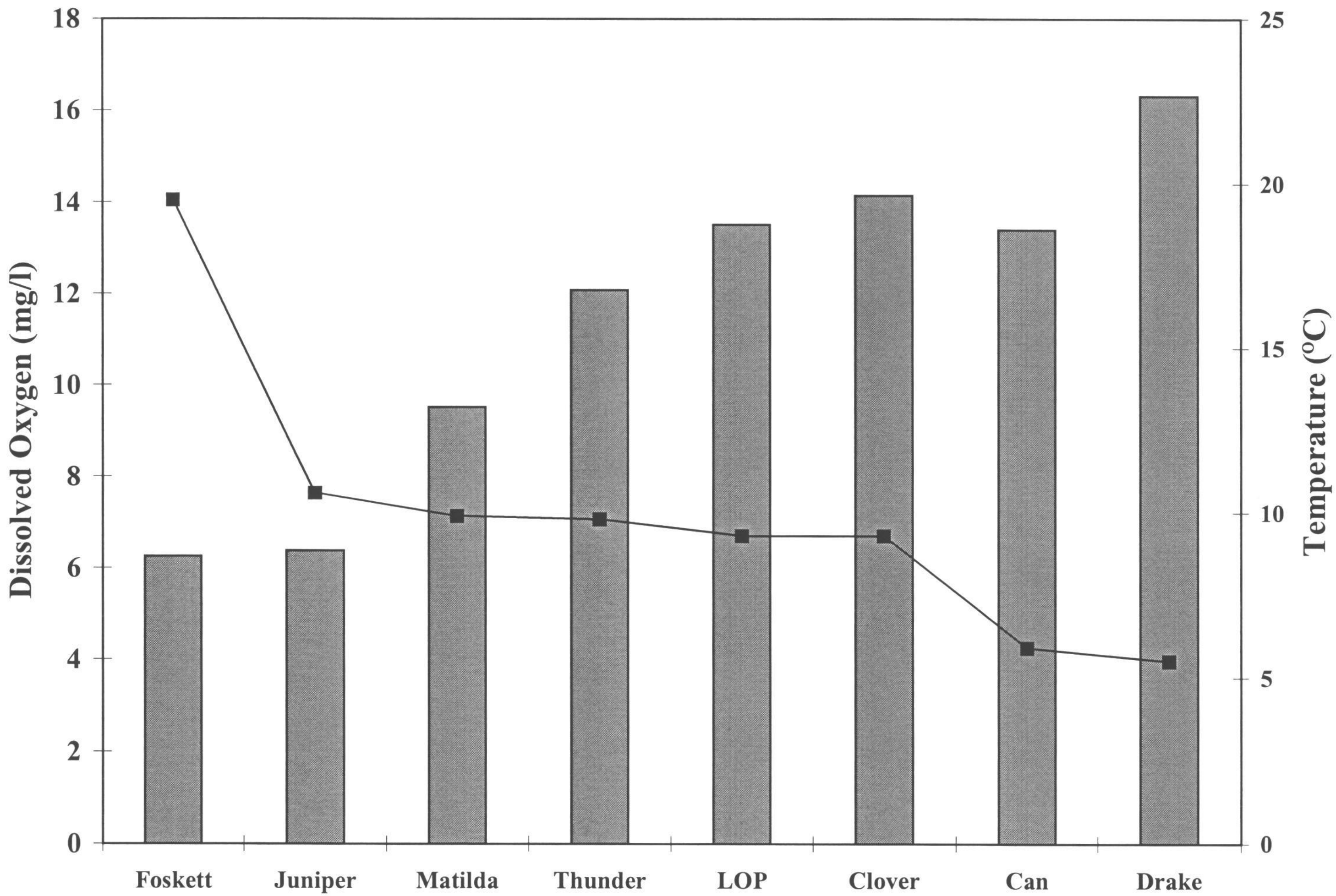

Figure 2.3 Dissolved oxygen (bar graph) and temperature (line graph) values measured at the sources of Warner Basin springs sampled in 1999.

Percent saturation of oxygen was above 80% at all spring sources, except for Foskett and Juniper Springs. Foskett was 59% saturated at its source. Juniper was 49% saturated and increased to 80% saturated ten meters from the source. Dissolved oxygen values increased as distance from the source increased, except in Foskett Spring, where dissolved oxygen did not change substantially within the first ten meters of the spring.

Benthic Invertebrates

In 1998, mean taxa richness was 20.9 taxa per spring. One hundred one taxa were identified across the nineteen springs. (See Appendix 2 for the invertebrate composition of each spring.) No taxon was found in all springs; 37 (36%) taxa were found in only a single spring.

Community Composition

On the NMS ordination, springs that were closer together had more similar invertebrate taxa than springs farther apart (Figure 2.4). Six environmental variables (temperature, conductivity, pH, potassium (K), sodium (Na), silicon (Si)) had significant positive correlations with invertebrate taxa on the first axis that captured 66.8% of the variance. Elevation was negatively correlated with Axis 1. Sulfur (S) was correlated with Axis 2, which explained 15.9% of the variance. Flow was correlated with Axis 3, which explained 5.8% of the variance. Cumulative variance explained by all three axes was 88.5%.

TWINSPAN generated five groups of springs based on invertebrate assemblages. By placing these TWINSPAN groups on the NMS ordination, some of the significant taxa in the ordination space could be determined (Figure 2.5). Springs in the top left corner of the ordination (T1) had *Heterlimnius* sp., a riffle beetle; *Yoraperla* sp., a peltoperlid stonefly; and *Pseudostenophylax edwarsii*, a limnephilid caddisfly. In contrast, springs to the right in the ordination (T2) typically had Hydrobiidae and Physidae snails, damselfly nymphs, and sphaerid clams. Other groups were characterized by *Malenka* sp., a nemourid stonefly, and planaria (T3); dytiscid beetles, Colymbetini and Hydroporini (T4); or chironomid taxa (T5).

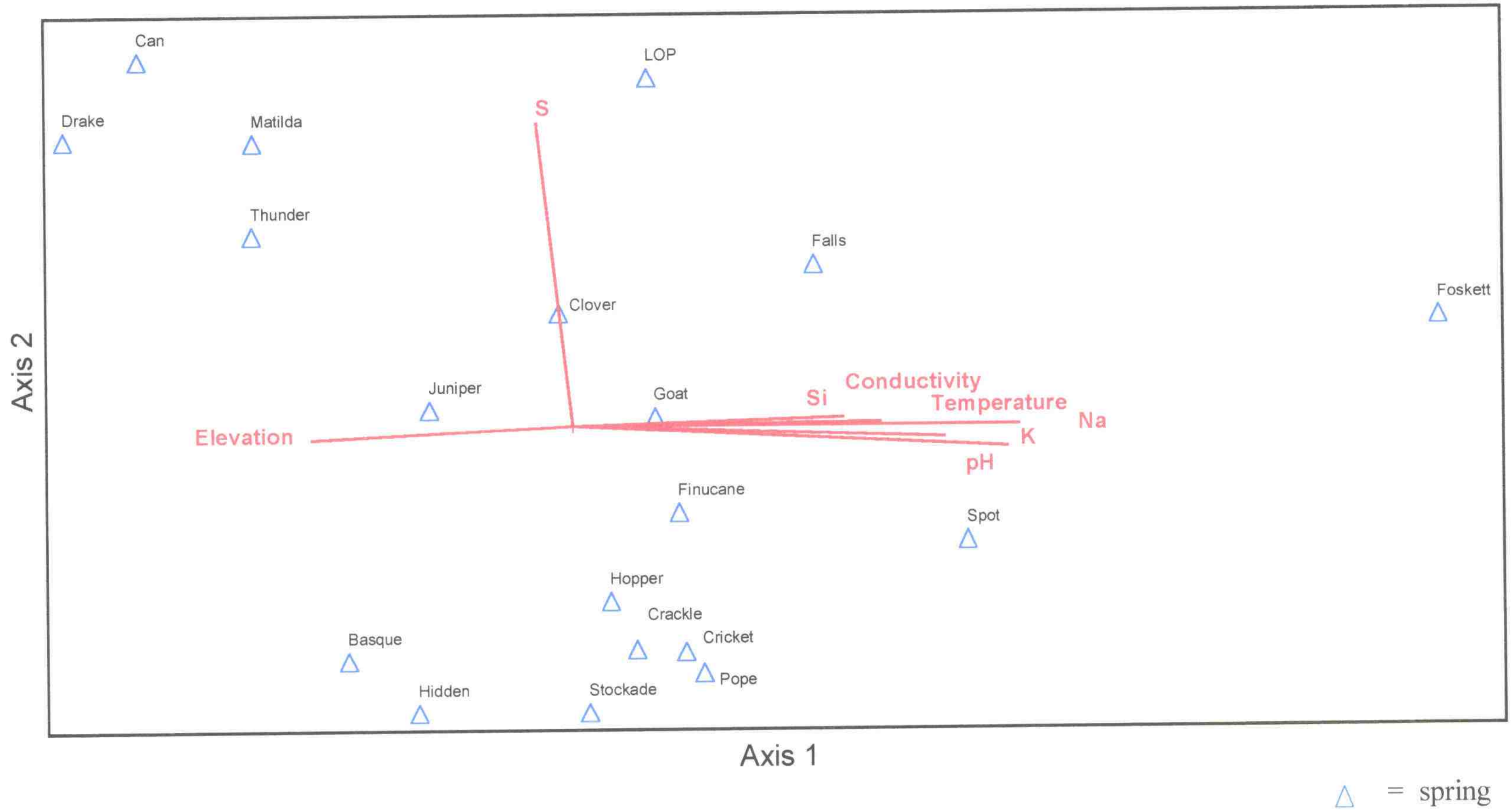

Figure 2.4 Three-dimensional NMS ordination, based on benthic invertebrate data with rare taxa deleted, projected onto Axes 1 and 2. Vectors are environmental variables that have a significant correlation ($r^2 > .300$) with the invertebrate taxa.

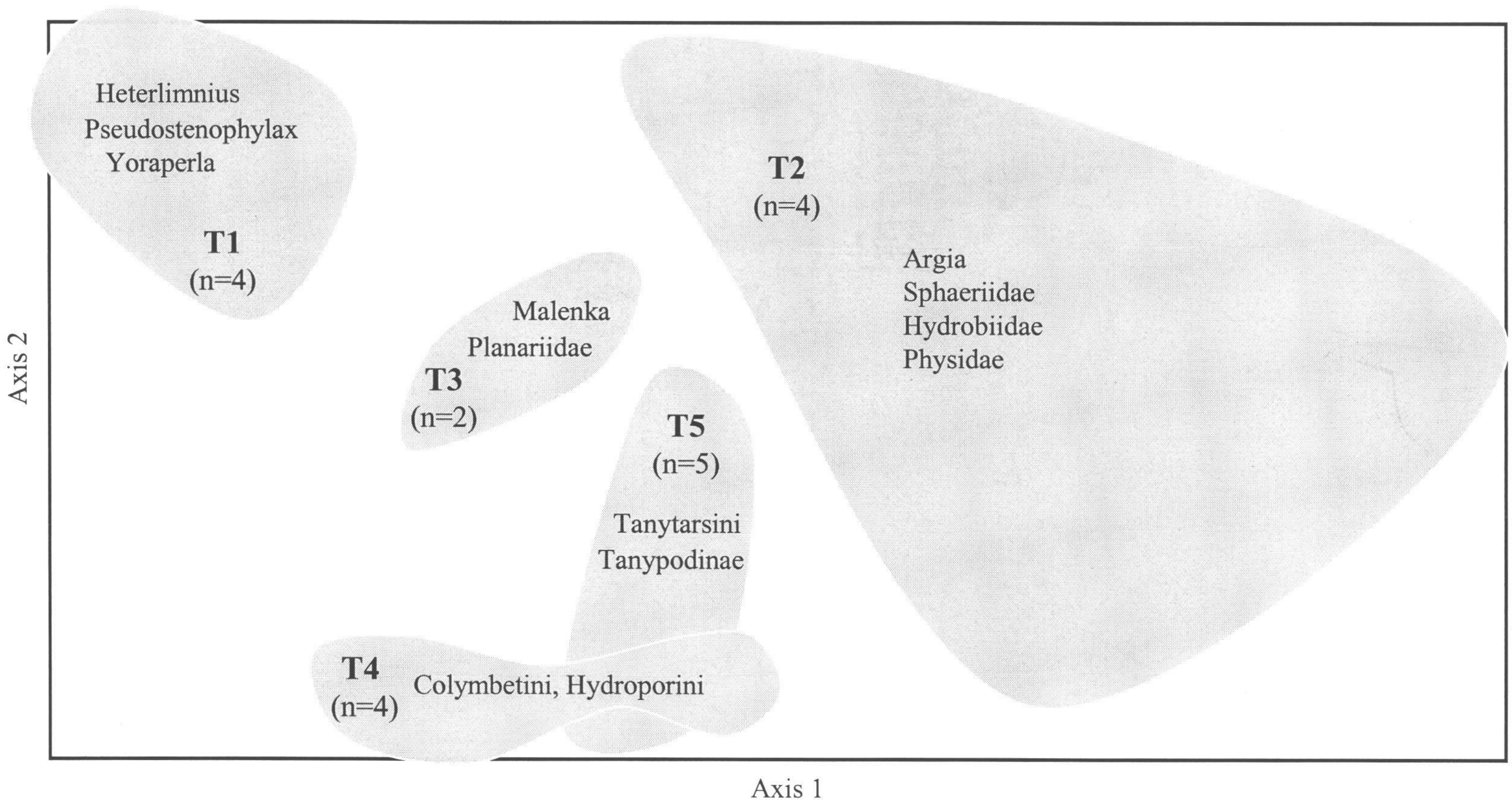

Figure 2.5 NMS invertebrate ordination with TWINSPAN groups circled (T1 – T5). Taxa that were significant in determining TWINSPAN groups are identified. Number of springs/group is in parentheses.

To assess whether springs with similar environmental characteristics had similar invertebrate communities, springs were grouped with HA cluster analysis based on water chemistry and physical information. Four groups of springs were identified with 90% of the information remaining in the dendrogram (Figure 2.6). Group association did not change when the analysis was run using only the nine significant variables identified in the NMS ordination instead of all 19 variables. Based on MRPP analysis, the four abiotic groups had strong within-group agreement (A) of 0.651 ($p = 0.00000002$).

Coding the springs in the NMS ordination by their abiotic group associations revealed that springs with similar environmental variables did not fall consistently into similar TWINSPAN groups (Figure 2.7). For example, the four springs in abiotic group 4, which had low water temperatures (5–6 °C) and were above 2000-meters elevation, fell into three different TWINSPAN groups. The three warm springs in abiotic group 3 (16-24 °C) did have similar invertebrate taxa and were found in TWINSPAN group T2.

Mean taxa richness of abiotic groups tended to decrease as temperature increased (Figure 2.8), but there was no statistical significance between group means ($F_{3,15} = 0.87$, $P = 0.478$). However, means from abiotic groups 3 and 4, at opposite ends of the temperature gradient, were significantly different ($F_{1,5} = 11.68$, $P = 0.019$). Non-insects (e.g. amphipods, copepods, ostracods, planaria, snails) contributed 38% of the total taxa richness across the nineteen springs. There was no difference in the mean percent of non-insect taxa between abiotic groups ($F_{3,15} = 0.909$, $P = 0.460$).

By considering topography, aspect, fault lines, and watershed boundaries, five sub-basins were identified: Abert Rim, central, southern, Foskett, and Hart Mountain (Figure 2.9). Springs from the same sub-basin were grouped on the invertebrate ordination (Figure 2.10). Invertebrate taxa in Abert Rim and Hart Mountain springs were different along Axis 2. These differences were apparent in the TWINSPAN groupings (Figure 2.5). Abert Rim springs were in TWINSPAN groups T1, T2, and T3, while Hart Mountain springs were in T4 and T5.

Because Abert Rim and Hart Mountain sub-basins had similar water temperature and chemistries, they were in similar ordination space along Axis 1, which was correlated with water temperature and chemistry. For example, Abert Rim and Hart Mountain

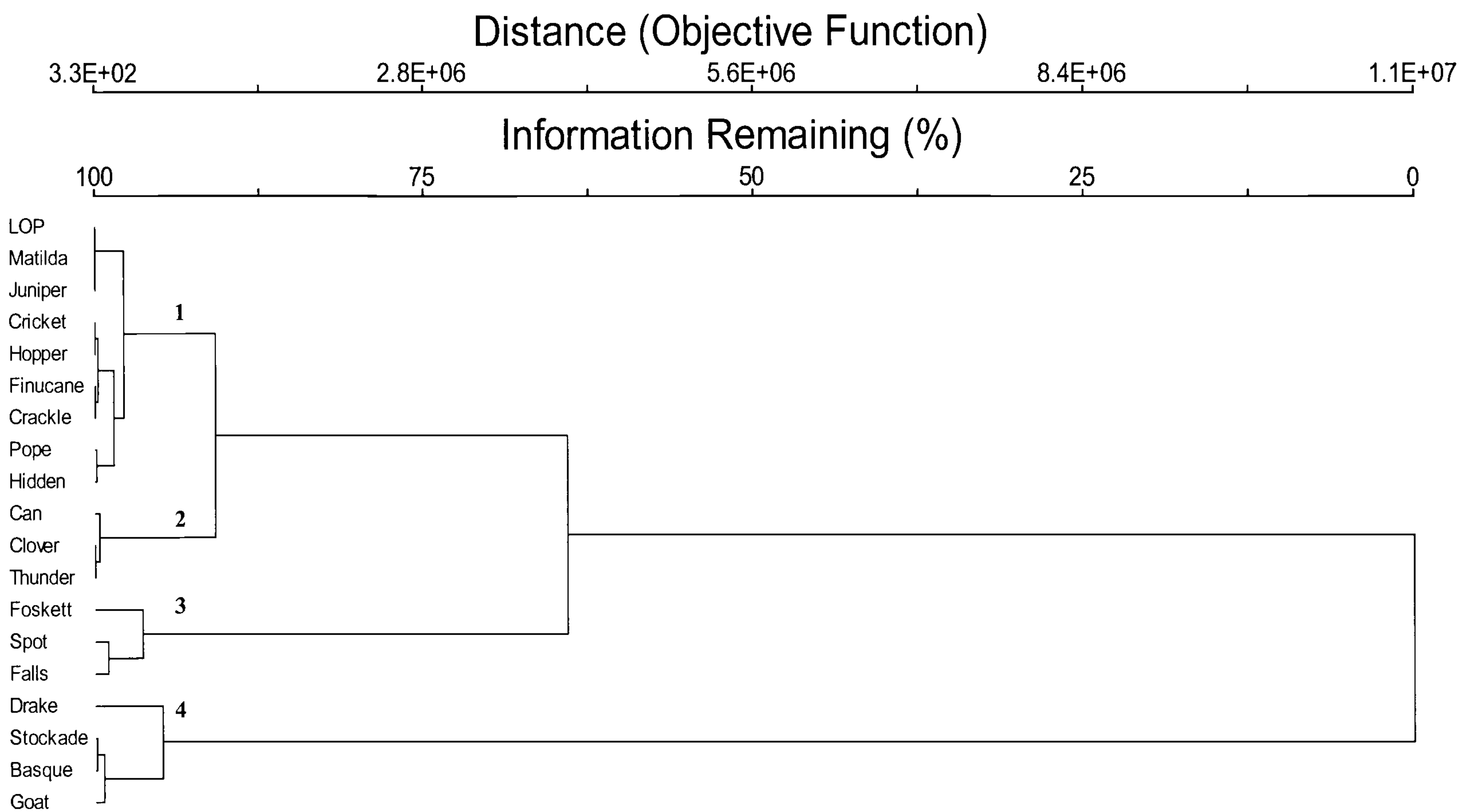

Figure 2.6 Dendrogram of hierarchical agglomerative cluster analysis based on 19 abiotic variables. Numbered clusters identify abiotic groups.

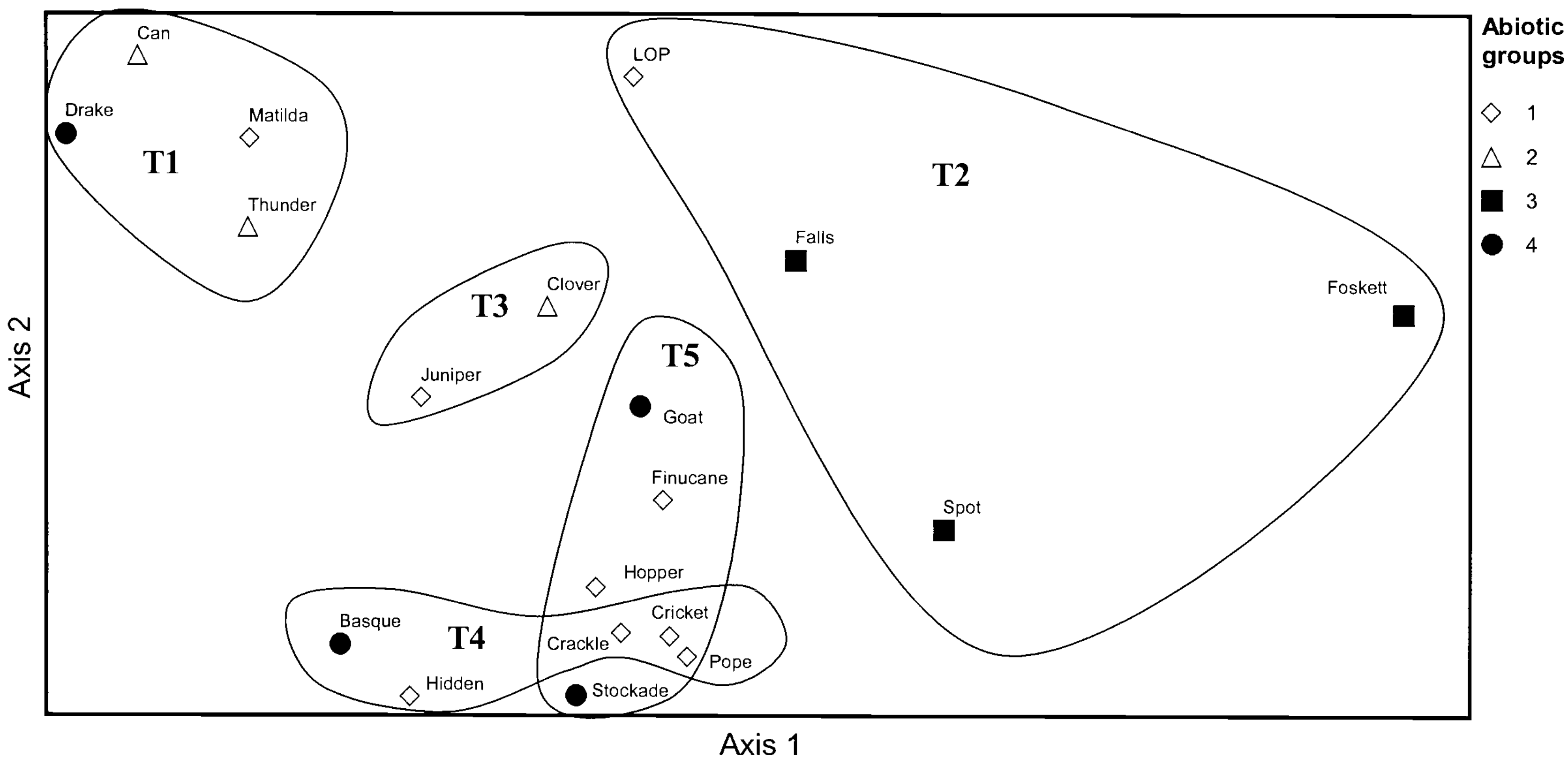

Figure 2.7 NMS invertebrate ordination with springs coded by abiotic groups determined by hierarchical agglomerative cluster analysis. TWINSPAN groups based on invertebrate taxa are circled and labeled T1 - T5.

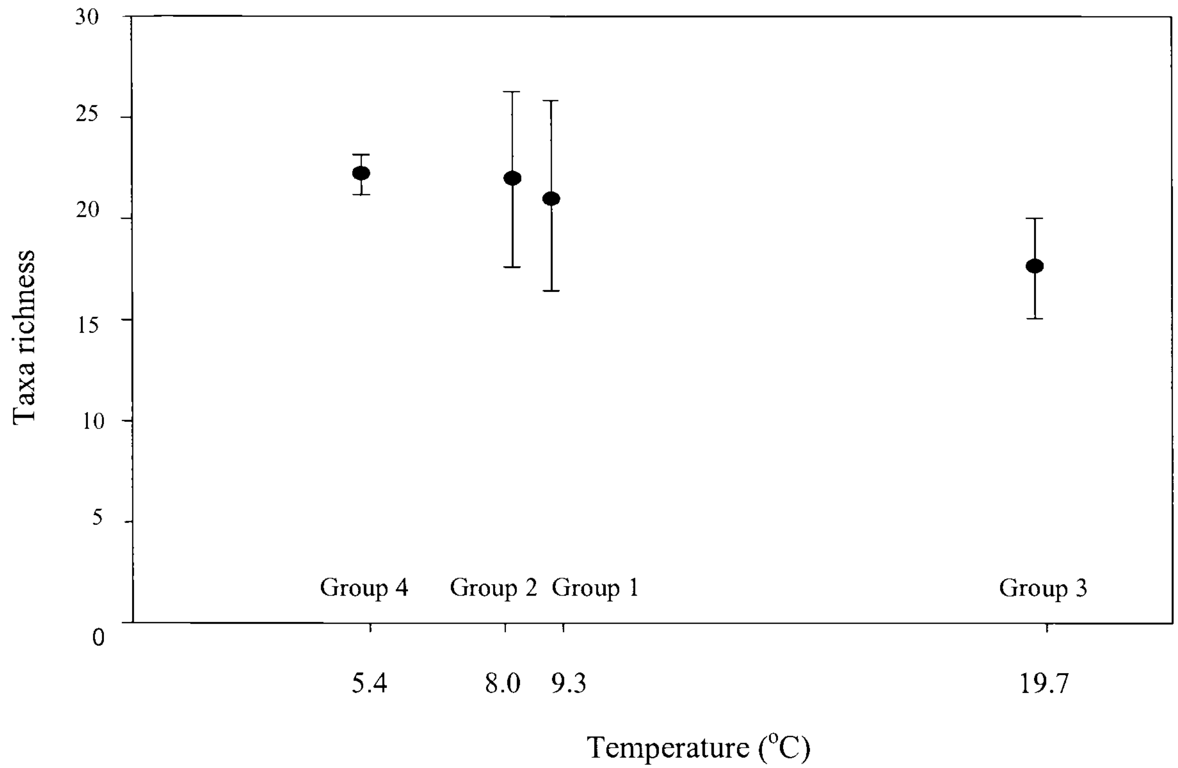

Figure 2.8 Invertebrate taxonomic richness across abiotic groups, which are arranged from low to high group mean temperature.

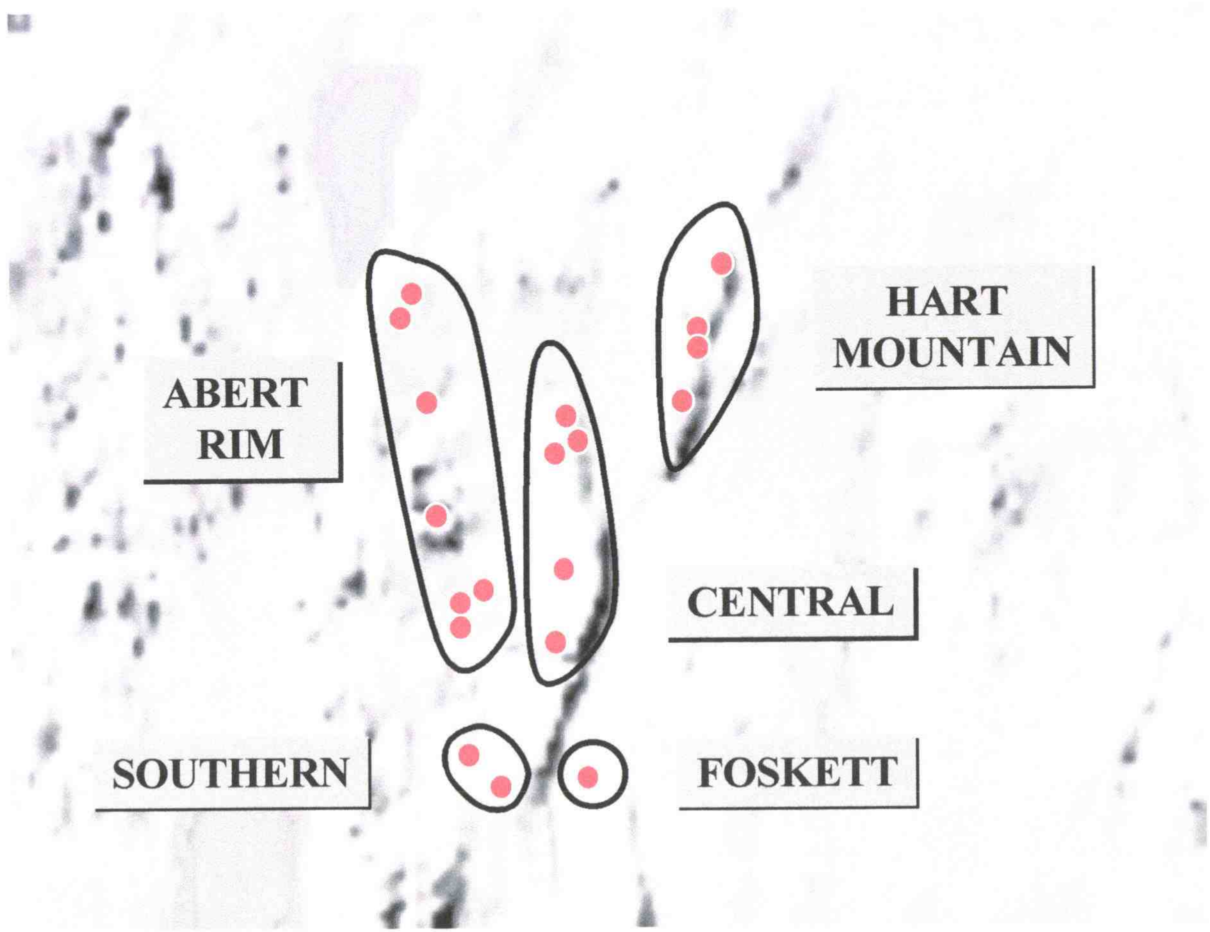

Figure 2.9 Five sub-basins: Abert Rim, central, southern, Foskett, and Hart Mountain, were delineated based on topography, aspect, fault lines, and watershed boundaries. Spring locations are identified by circles.

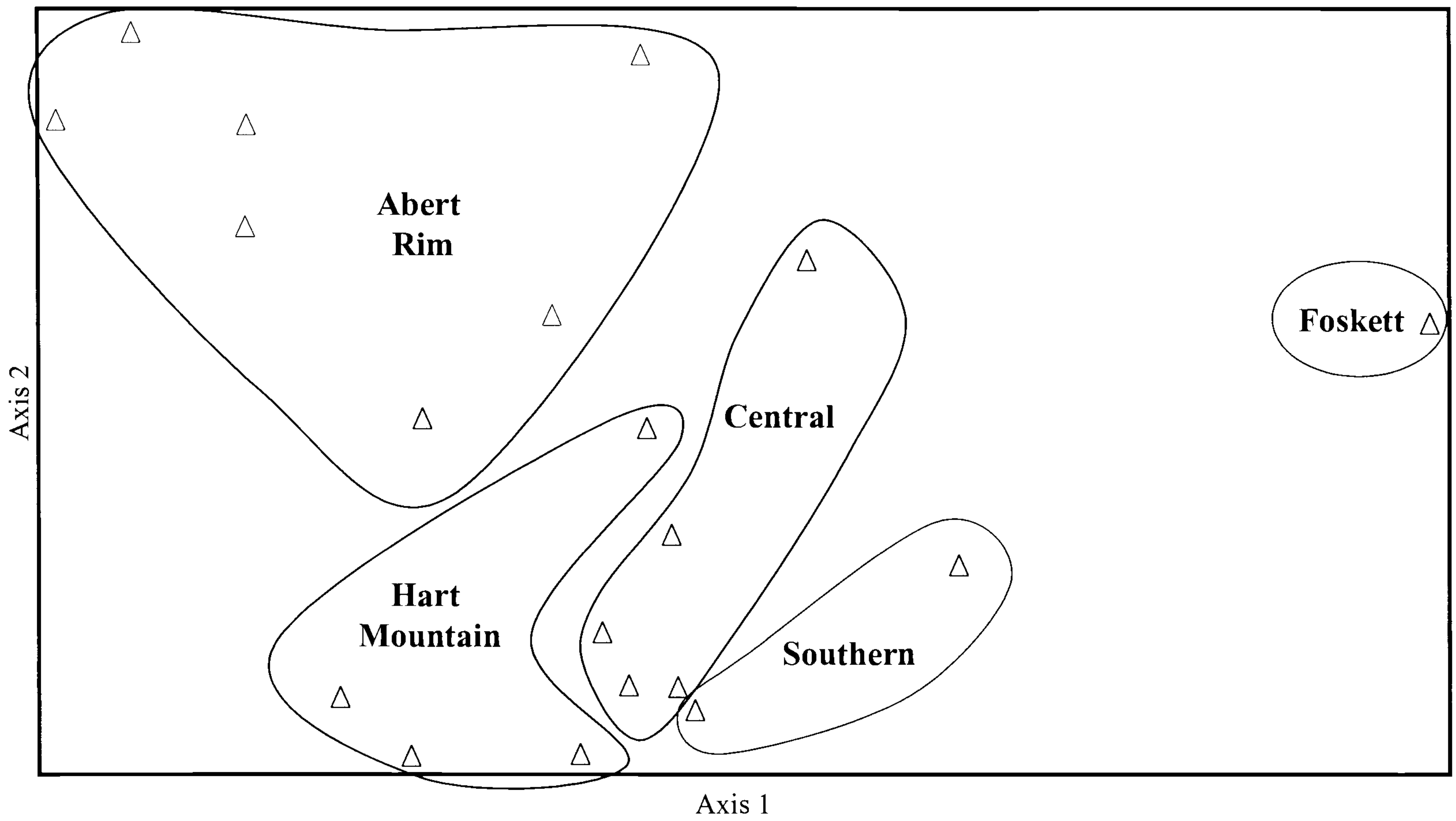

Figure 2.10 NMS invertebrate ordination with springs in the same sub-basin circled and labeled. Sub-basins were determined by examining topography, aspect, fault lines, and watershed boundaries.

springs ranged from 5.0-9.5 °C and pH ranged from 5.9-6.6. Central sub-basin springs ranged from 9.5-16.0 °C and pH ranged from 6.9-7.4. Invertebrates with a preference for cold-water habitats, such as stoneflies (Order: Plecoptera) were found only in Abert Rim and Hart Mountain springs.

Temporal Variability

Cricket and Foskett Springs were sampled in July and September, 1998 to assess within-season variability. Invertebrate richness varied from 15 to 16 taxa during the two visits at Cricket Spring. At Foskett Spring, richness increased from 15 to 27 taxa. Variability in richness between 1998 and 1999 in Foskett Spring was not significant. In fact, there was no difference between mean taxa richness of the eight springs sampled in both 1998 and 1999 ($F_{1,14} = 0.00432$, $P = 0.949$). Springs with larger substrates tended to have greater variance between years than springs with smaller substrates (Figure 2.11).

Longitudinal Pattern

In the eight springs sampled in 1999, water temperature changed by 2 °C from the spring source in an average of 76 meters. Temperature in springs with low flow changed by 2 °C in a shorter distance than springs with faster flow. For example, Juniper Spring, which was a marshy system with low flow changed from 9.5 to 11.5 °C in 10 meters. Drake Spring, a swift stream-like spring, changed from 5.5 to 7.5 °C in 220 meters. In these eight springs, water temperature increased downstream during the summer months when mean air temperature was high; this patterns may change as the mean air temperature decreases in winter.

There was a significant increase in mean taxa richness for samples from the source to 120 meters downstream ($F_{4,35} = 4.119$, $P = 0.008$). Richness increased from 13.6 to 20.4 taxa over 120 meters (Figure 2.12). Means were significantly different between the 1.0 meter and 80.0 meter samples as well. However, mean taxa richness at 10 meters and 120 meters were not different.

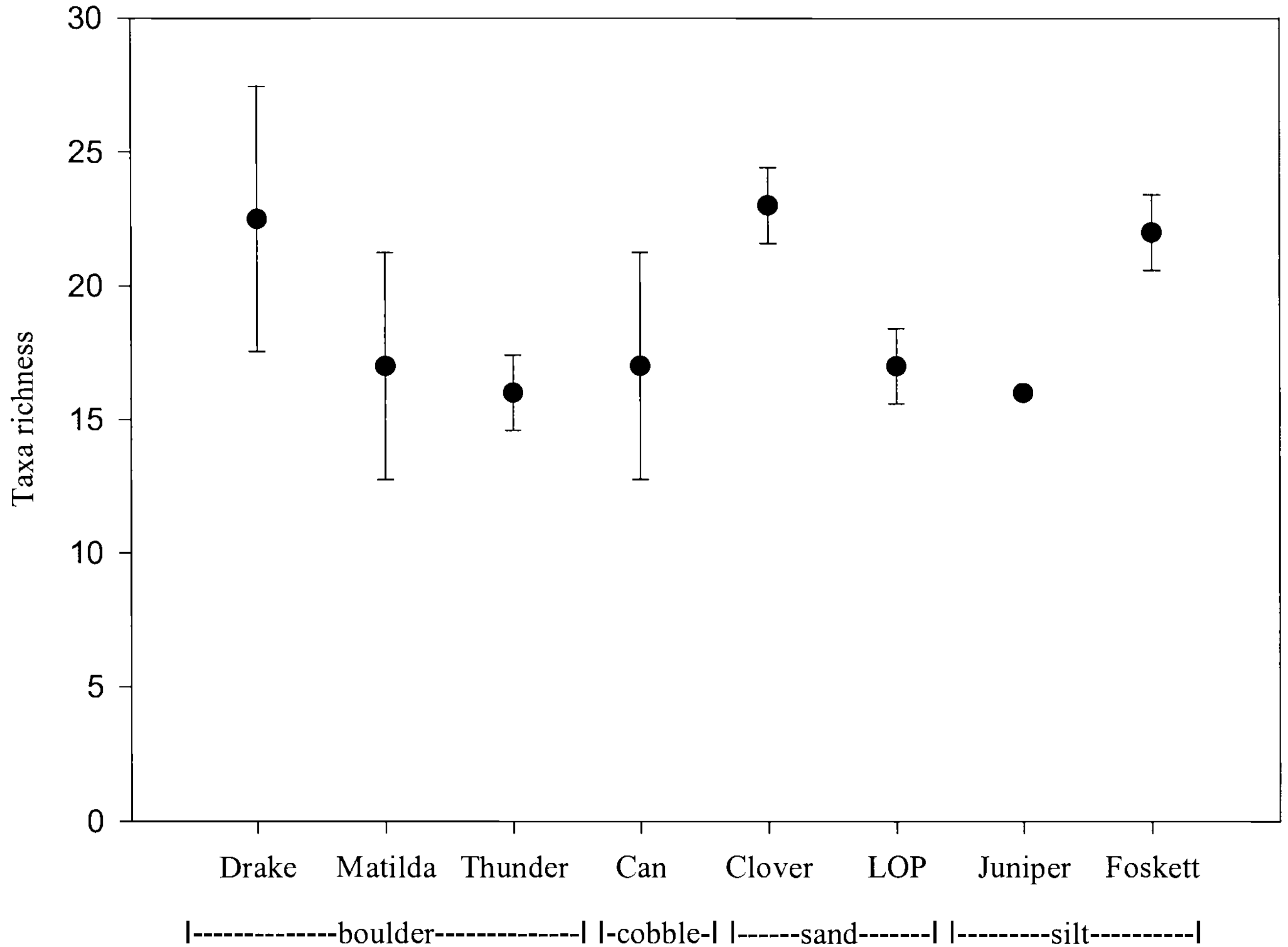

Figure 2.11 Mean invertebrate taxa richness in springs sampled in 1998 and 1999. Springs are grouped based on their dominant (>50%) substrate size which ranged from boulder to silt. Error bars express range in taxa richness between years.

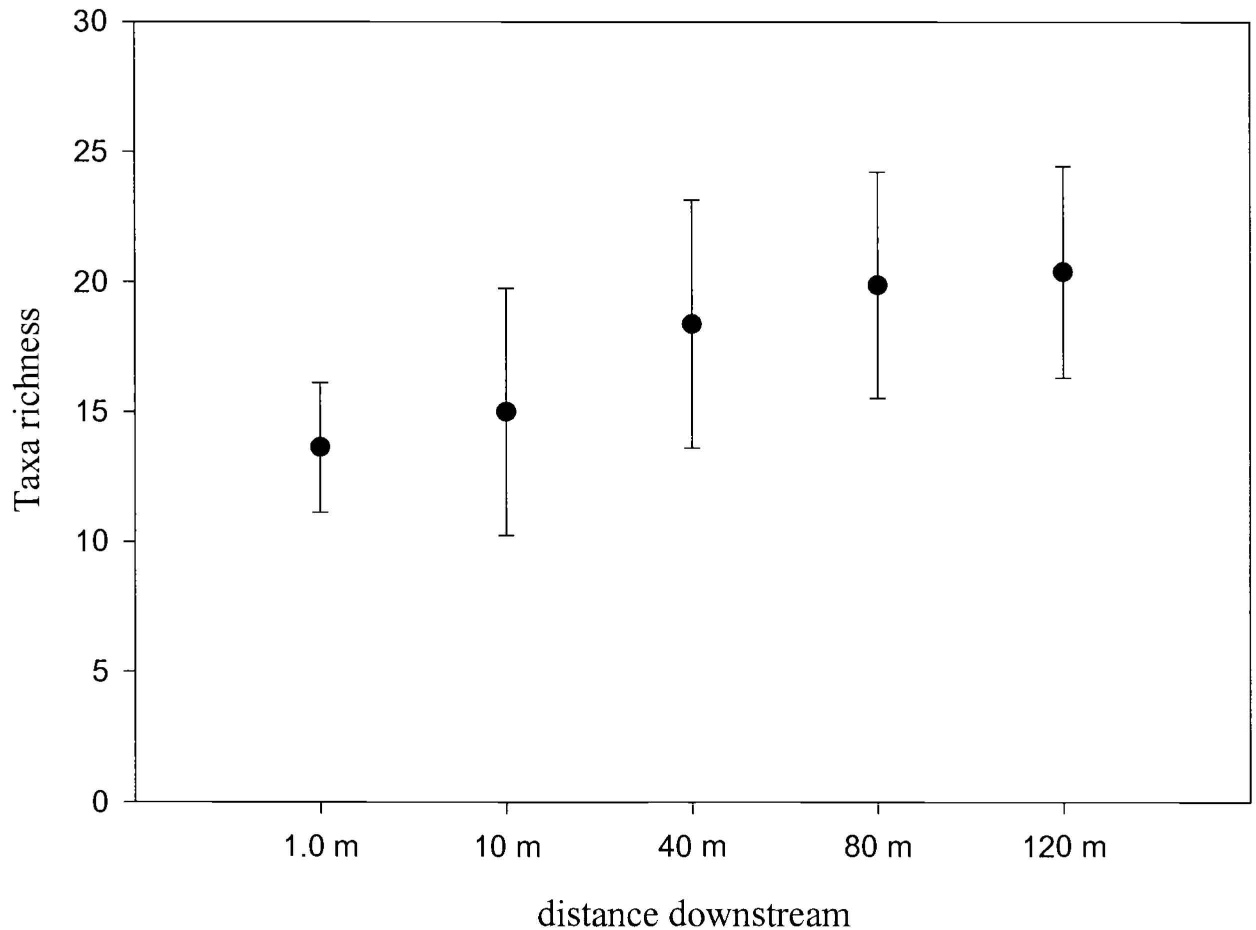

Figure 2.12 Mean invertebrate taxa richness at five locations downstream from the spring source for eight springs sampled in 1999.

Riparian, Emergent, and Swimming Invertebrates

Invertebrates collected using pan traps and emergence traps were identified to the order-level. These methods targeted different components of the spring biota than the benthic hand net samples. However, these methods proved to be cumbersome and, due to the lack of replicates, conclusions based on these data were questionable. For example, one pan trap sample was taken at each spring. With no replicates, the relationship between trap placement and vegetation could not be understood. Variations caused by the placement of the emergence traps, the amount and kind of vegetation underneath, and possible seasonal effects created similar analytical dilemmas.

In 1998, an activity trap was deployed in one spring. Foskett was significantly deeper than other springs and the activity trap was expected to collect more active swimmers in this large spring. This sampling method has been used widely in wetland habitats and shallow lakes (Swanson 1978). The trap was set in the upper water column near the edge of the spring bank and left for twenty-five hours. Twenty speckled dace (*Rhinichthys osculus)* were found in the collecting funnel when the trap was retrieved. Four were alive and released. Sixteen were dead. Six were preserved in formalin for a week and then transferred to 95% ethanol. The incident was reported to the Bureau of Land Management and a Scientific Taking Permit (#98113) was issued on July 27, 1998 by the Oregon Department of Fish and Wildlife. The dace were given to Dr. Douglas Markle for storage in the fish collection at Oregon State University. The activity trap was not used again in this study.

DISCUSSION

Patterns of Invertebrate Composition and Distribution

In my study of Warner Basin springs, invertebrate composition was related to water temperature, water chemistry and elevation. In addition, similarities in spring biota were explained by topographic sub-basins. These sub-basins do not necessarily reflect geographic distances. Certain springs in the Abert Rim sub-basin are closer to springs in the central sub-basin, so sub-basin assemblages are not simply a reflection of aerial dispersal patterns. However, invertebrate assemblages may reflect connectivity during snow-melt events that could facilitate dispersal of non-insect taxa.

Springs at elevations above 1800 meters on Abert Rim and Hart Mountain had low water temperatures, pH, and conductivity. High elevation springs would be expected to have shorter annual water cycles. The shorter the water residence time, the lower the mineral content of the water (van Everdingen 1991). It follows that water chemistries in high elevation springs would be more diluted than in valley springs. Invertebrate communities of Abert Rim and Hart Mountain springs did reflect the similarities in water chemistry, although certain taxa were found in just one sub-basin. For example, only Abert Rim springs contained nemourid stoneflies of the genus *Malenka* and the limniphilid caddisflies, *Pseudostenophylax edwarsii*. Nemourid stoneflies of the genus *Zapada* were found in both Abert Rim and Hart Mountain springs. Hart Mountain springs were distinctive from Abert Rim springs in the presence of certain dytiscid beetle and chironomid taxa. However, no taxon was found exclusively in the four Hart Mountain springs.

Groundwater differs from surface water in reduced water chemistry, water temperature, and discharge fluctuations (Odum 1957, Teal 1957). Reflecting groundwater origins, water temperature and chemistry were relatively constant within these Great Basin spring systems across sampling events. A comparison of 1998 and 1999 data suggests a decrease in certain trace element concentrations (e.g. Ca^{2+}, Mg^{2+}, Na^{+}) in 1999. These cations originate from the weathering of sedimentary rocks. One hypothesis for this decrease is that the groundwater may have had less residency time within the aquifer in 1999 and consequently less time in contact with rocks; but precipitation in 1997/1998 was greater than in the 1998/1999-water year in the Lakeview and Hart Mountain areas (Taylor 1999). This suggests that residency time may have been greater in 1999; thus, cation concentrations should have been higher. The rate of recharge to groundwater varies in time and place depending on the dynamic balance between precipitation, infiltration, runoff, evaporation from the soil, and land-use practices. As the contributions from different recharge points change, the mixture of groundwater throughout the flow system changes and the output from the spring may vary in flow and chemical composition (van der Kamp 1995). Without information on all these variables it is difficult to speculate on the cause of decreased trace element concentrations.

In general, within-season and between-year variability among invertebrate assemblages was low. As an exception, within-season samples from Foskett Spring showed great variability in taxonomic richness, though variability between years was low. This variation may reflect true seasonal difference as found in springs in California (Erman 1998) or may be due to Foskett's large area and depth. The hand net designed for this study may not have been large enough to effectively sample a spring as large and deep as Foskett.

Another factor that might have reduced the hand net's efficiency was substrate size. Foskett Spring had a false silt bottom. The silt clogged the mesh which may have reduced flow into the net. In other springs, variability in invertebrate richness between years was found to be greater in springs with larger substrates than with sand or silt. The hand net was small enough that a boulder could have influenced taxa richness greatly. Apparently, substrates at either end of the spectrum, large boulders or fine silts, reduced the efficiency of the hand net.

In other studies aimed at understanding landscape-level patterns of spring biota, the prevalence of certain invertebrates were linked to water chemistry and geology (Glazier 1991). Hard-water limestone springs were dominated by amphipods and/or isopods, mollusks, and flatworms; relatively acidic soft-water springs were dominated by insects. A study of ten karst springs in Illinois found that non-insect invertebrates dominated all springs in number though not in diversity. The springs included both hard and soft water types with pH ranging from 6.9 to 8.0 (Webb et al. 1998). In springs of the Sierra Nevada, biota did not fit into the two categories described by Glazier, nor did the dominance of insect vs. non-insect taxa seem significant (Erman 1998).

Similarly, these Great Basin springs did not have significant differences between insect and non-insect distribution across the landscape. Copepods, amphipods, and ostracods typically were very abundant but species diversity is unknown. Unlike distributions in cold-water, limestone springs, amphipods and planaria were more common in Warner Basin springs with pH < 7.0.

Longitudinal Patterns

Increased taxa richness at sites sampled downstream from the spring source was a pattern consistent with other studies (Ward and Dufford 1979, Meffe and Marsh 1983) but differed from work in Mendocino County, CA (Resh 1983). This latter study sampled a spring system with high water temperature (16°C) and conductivity (330-440μS). In the Warner Basin, only Foskett Spring would be comparable; Foskett showed the least increase in invertebrate richness downstream from the spring source. Perhaps downstream patterns differ between springs of varying temperature regimes, with increasing diversity in colder systems and more constant or decreasing diversity in warmer, more mineralized systems.

In Warner Basin springs, invertebrate richness at 10-meters downstream was more similar to 120-meters downstream than it was to the richness at the spring source. This suggests that a shift in the number of taxa occurs quickly. Changes in water chemistry and increased temperature fluctuations downstream likely produce changes in the community composition. The area downstream from the spring source provides a more heterogeneous habitat, with more thermal niches and varied flow patterns. Increased invertebrate richness in the downstream community reflects the decreasing influence of groundwater as the system begins to resemble a more stream-like environment.

Patterns that are discernable at the landscape-level appear to differ depending on the choice of springs and the environmental gradients they encompass. Studies that look at springs across a wide geographic area but that select springs with similar water temperatures and chemistries may not show the same patterns identified here. Similarly, patterns of invertebrate communities in springs that have been altered by land-use practices, such as grazing or water withdrawal, may reflect habitat degradation more strongly than water chemistry gradients.

Patterns along chemical and physical gradients were found by using a combination of multivariate statistical tools. The NMS invertebrate ordination showed a strong chemical gradient along Axis 1 but the communities were responding to topographic gradients along Axis 2. TWINSPAN analysis provided information about the individual taxa, which clarified interpretation of the NMS ordination. Although these are descriptive tools and not quantitative, they provide clues to develop predictive parameters to test across a broader landscape. This study highlighted invertebrate community patterns across a broad geographic area while providing evidence of the uniqueness of each spring within the Warner Basin.

CHAPTER 3

RELATIONSHIP BETWEEN RIPARIAN AND EMERGENT VEGETATION AND INVERTEBRATE COMPOSITION AND DISTRIBUTION IN DESERT SPRINGS

ABSTRACT

In the summers of 1998 and 1999, plant and benthic invertebrate communities were sampled from nineteen springs in the Warner Basin of southeastern Oregon. A total of sixty plant taxa were identified; mean taxa per spring was 11.7. Plant community composition and percent vegetative cover varied greatly between the springs. *Mimulus guttatus* (seep-spring monkey flower) was the only species found in all springs. Relative abundance of emergent forbs, riparian forbs, and riparian graminoids were important in distinguishing between plant communities of Warner Basin springs; however, these plant-type classifications may be variable across seasons as soil moisture changes. Benthic hand net samples, emergence traps, and hand-picking methods were employed to determine the invertebrate community composition of each spring. When plant taxa and plant-type variables were overlaid on the Non-metric Multidimensional Scaling (NMS) invertebrate ordination, neither were related to invertebrate presence/absence. However, there was a significant correlation between the invertebrate taxa and percent open area and percent vegetative cover. Open water may be an important habitat attribute for more active invertebrates such as *Labiobaetis* sp., a mayfly, and *Rhyacophila* sp., a free-swimming caddisfly that were correlated with open water and faster-flowing water in this study. *Dixa* sp., a midge, was prevalent in marshy systems.

INTRODUCTION

Riparian and emergent vegetation are important to aquatic invertebrates as sources of nutrients, refuge from predators, shade from direct sunlight, and shelter from current. Plant abundance fluctuates seasonally and annually depending on water availability. Increasing human demands on water resources in the Great Basin affect groundwater levels which supply desert springs (Shepard 1993, Myers and Resh 1999). Semi-arid springs in eastern Oregon typically lack a woody, riparian plant community and are dominated by emergent, in-channel vegetation (Anderson and Anderson 1995). Changing water tables likely influence emergent vegetation patterns in these springs.

Invertebrates are frequently associated with aquatic plants. Some insects are closely associated with a single species of plant, depending on it for food and for support of all life stages, while others show almost no specificity (McGaha 1952). Other associations may be related to plant surface area rather than species. Submerged parts of aquatic plants provide a surface for periphyton growth. Plants with greater leaf dissection provide more surface area for periphyton growth and support a greater density and diversity of invertebrates than plants with less surface area (Krecker 1939).

Aquatic macrophytes may alter the distribution of invertebrates by reducing current velocity. Plants obstruct the flow of water and can provide a haven for invertebrates in swift-flowing streams; however, plants vary in their resistance to the current. For example, *Rorippa nasturtium-aquaticum* is a broad-leaved, thick stemmed, emergent plant that slows the water down more than *Ranunculus aquatilis*, a fine-leafed, submerged plant (Gregg and Rose 1982). The reduction of current velocity is important also for the deposition of detritus, a valuable food resource for invertebrates. Because of these direct and indirect effects, the invertebrate fauna of springs may be associated with both the distribution and composition of vegetation.

This study focuses on plant and invertebrate spring communities across a Great Basin landscape. The objectives are to 1) explore the relationship between riparian and emergent vegetation and invertebrate composition of Warner Basin springs, and 2) determine seasonal and annual variability in plant community characteristics.

METHODS

Study Area

Nineteen springs were sampled in the Warner Basin of southeastern Oregon, which is in the upper extent of the Great Basin (Figure 3.1). Springs were distributed across a wide geographic area (52 km^2), from Abert Rim, through the Warner Valley, to

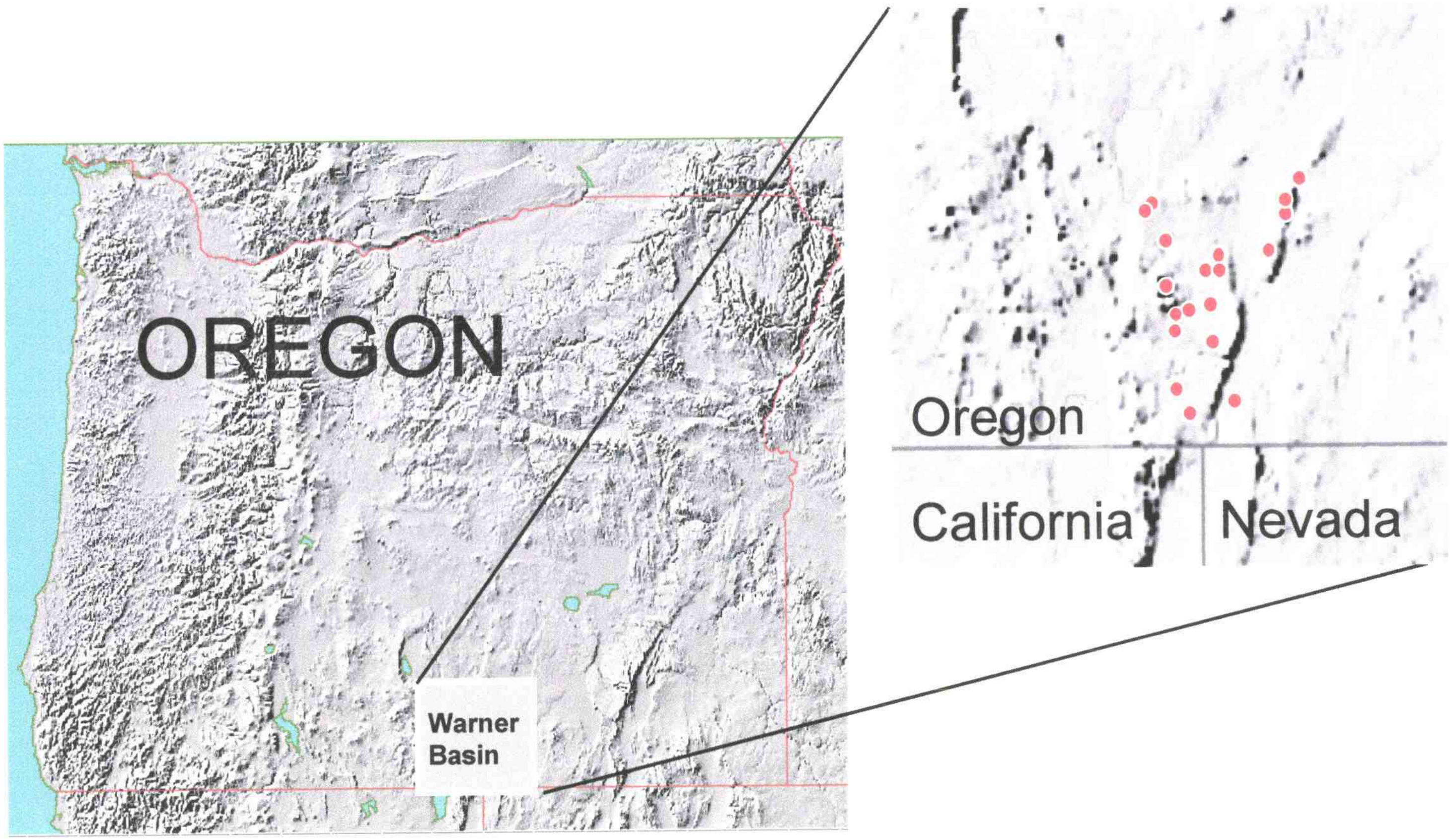

Figure 3.1 Nineteen springs (represented by circles) were sampled in the Warner Basin of southeastern Oregon.

the top of Hart Mountain. Abert Rim and Hart Mountain are two in a series of long and narrow, north-south trending fault-block mountain ranges alternating with broad basins in this region (Orr et al. 1992). As a result of this extensive east-west stretching and thinning of the Earth's crust in recent geologic history, springs are common in this high desert, semi-arid landscape.

In general, Warner Basin springs have been altered by agriculture, cattle grazing, and increased water withdrawals. Springs included in this study were selected because they 1) did not appear to be significantly altered by land-use practices at the time of sampling, 2) had definable source areas, 3) appeared to be perennial, and 4) had enough flow and depth for the selected sampling methods. For this study, a spring system extended from the spring source to an area ten meters downstream.

From July - September 1998, all springs were sampled to explore the relationship of vegetation patterns and invertebrate composition. To determine temporal variability, two springs were sampled twice in 1998 and eight springs were re-sampled in July, 1999.

Vegetation Survey Methods

Channel dimensions and vegetation cover along twenty, cross-sectional transects within the first ten meters of each spring were mapped onto gridded paper. One to three distinct vegetation communities at each spring were delineated based on visual assessment. A vegetation community was typically an assemblage of plants of similar height, similar composition, and with definable visual boundaries. Identification of all plants to genus or species was completed in the field for each community using taxonomic keys (Guard 1995, Hitchcock and Cronquist 1973). Graminoids (grasses, sedges, and rushes) were identified to genus; forbs and mosses were taken to species. Voucher specimens of graminoids were dried; herbaceous plants were pressed. Dr. Richard Halse, OSU Herbarium Curator, verified vouchers for taxonomic accuracy. Wetland indicator status was assigned to each plant based on the *National List of Plant Species That Occur in Wetlands* (Reed 1988, Guard 1995).

Percent dominance of each plant taxa within a community was estimated visually. Vegetation within each community was expressed as plant type: submerged, emergent graminoid, emergent forb, riparian graminoid, riparian forb, moss, and trees/shrubs.

These values were converted from percent dominance of each plant taxa and plant type within a community to percent dominance for the total spring area. Total area for each spring and for each community within a spring was determined from the hand-drawn map using a planimeter. For example, in Clover Spring, *Juncus* sp. was present in two of the three vegetation communities. It was an emergent plant covering 25% of one community and a riparian plant covering 3% of a second community. Percent dominance of *Juncus* sp. was calculated by determining the area of each vegetation community relative to the total spring area and multiplying by the percent dominance of *Juncus* sp. within each of those communities. *Juncus* sp. dominated 19.8% of Clover Spring and was both an emergent graminoid and riparian graminoid plant type (see Appendix 4).

Invertebrate Survey Methods

Benthic invertebrates were collected with a small hand net (14 cm x 15.25 cm, 250 μm mesh). The net was placed on the bottom of a spring and a 15-cm^2 area in front of the net was disturbed. Four samples were taken within each spring area. A visual search was conducted for large and rare invertebrate specimens in margin and slow-water habitats. An emergence trap (0.5 m^2) was set out for at least 8 days to collect emergent aquatic insect adults that were used to verify difficult benthic invertebrate identifications. Insect sweep nets were used to collect riparian invertebrates. Three (1.0 m^2) sweeps were combined to make up one sweep sample in each vegetation community. All samples were preserved in 70% ethanol with the exception of snails that were "relaxed" with menthol crystals prior to preservation. All identifications and counts were done in the laboratory under 20X with a Zeiss dissecting scope using taxonomic keys (Merritt and Cummins 1996, Borror et al. 1989).

Statistical Analysis Methods

Non-metric Multidimensional Scaling (NMS) was performed twice: first with relative plant abundance data to identify which springs had similar plant communities (plant ordination), and second with the benthic invertebrate data to determine which springs had similar invertebrate communities (invertebrate ordination). Because benthic sampling methods were not considered quantitative, invertebrate communities were described by taxa present. NMS is an ordination technique based on rank similarity distances (Mather 1976, Kruskal 1964), which tend to relieve the zero-truncation problem often associated with community data (Beals 1984). NMS used Sorensen's distance measure to determine similarities. Fifteen runs were made with real data, 30 with randomized data. The appropriate number of dimensions for the final ordination was determined by examining stress values. Final stress for a given dimensionality was lower than that for 95% of the randomized runs (i.e. $p <= 0.05$ for the Monte Carlo test). Stress is a measure of distance in the ordination space and the corresponding dissimilarity between sample units (springs). For the plant and invertebrate ordinations, three-dimensional solutions were selected with a final stress of 8.04 and 12.71, respectively.

Graphical overlays or joint plots were used to relate individual variables to the ordination space. For example, an overlay of plant types on the invertebrate ordination provided a graphical display of which springs have similar invertebrate communities and similar plant types. Vector angle and length in the joint plots illustrate the direction and strength of gradients. Squared values of Pearson's correlation coefficients (r^2) expressed the proportion of variation in axis positions explained by the variable in question. Analyses were conducted after deleting rare taxa (i.e. those found in only a single spring) from invertebrate and plant lists.

Two-way indicator species analysis or TWINSPAN (Hill 1979, Gauch and Whittaker 1981), a divisive clustering technique, identified springs with similar plant relative abundance. Pseudo-species cut levels were set at: 0, 2, 5, 10, 20. These plant groupings were overlaid on the NMS ordination of invertebrate taxa to assess whether springs with similar plants had similar invertebrate communities. Analysis of variance (ANOVA) was used to detect differences in invertebrate taxonomic richness, contribution of non-insect taxa, and plant dominance between springs.

An outlier analysis in PC-ORD version 4.01 (McCune and Mefford 1999) was performed on both the invertebrate and plant data by calculating Sorensen's distance measure from each spring to all other springs in ordination space. Outliers were springs that were ±2 standard deviations greater than the mean distance and were identified through visual examination of ordination graphs.

RESULTS

Plant Assemblages

In 1998, sixty plant taxa were identified at the nineteen springs (see Appendix 5). Mean plant taxa per spring was 11.7, ranging from 6 to 15 taxa. Thirty taxa (50%) were rare and occurred at only a single spring. *Mimulus guttatus* (seep-spring monkey flower) was the only species found in all springs. Fifteen plants (25%), including *M. guttatus*, were categorized as facultative wetland plants that are usually found in wetland areas (>67% of the time) (Reed 1988). An additional twelve plants (20%) were wetland obligates – plants that almost always occur under natural conditions in a wetland (e.g. *Montia fontana, Ranunculus aquatilis*). Upland plants (i.e. not usually associated with wetlands or hydric soils) were present and were typically found along the spring bank.

Study areas ranged from 11 to 66 m^2 and averaged 28 m^2. Vegetative cover (i.e. spring area covered in vegetation as opposed to open water) ranged from 61 – 100 % (Table 3.1). Based on visual assessment and percent vegetative cover values, spring type classifications were developed. In general, springs with the greatest vegetative cover (>90%) were marshy systems. Typically, marshy springs were dominated by a few plant taxa; 50% of the vegetative cover at a marshy spring was composed of 2.2 taxa. Springs with 70 – 90% vegetative cover had a large, open-water area or head pool at the source. In these head pool springs, relative abundance of 3.4 plant taxa was more than 50% cover. Springs with ≤70% cover were faster flowing, stream-like systems and were dominated by more riparian than emergent vegetation. Stream-like springs were the most heterogeneous in their plant composition, with an average of 4.3 taxa making up 50% of the vegetative cover. As vegetative cover decreased across the springs, the number of dominant plant taxa increased significantly ($F_{2,17} = 3.6$, $p = 0.05$). (See Appendix 4 for plant taxa and percent dominance of each taxon across the total spring area.)

Based on plant composition, Drake Spring was significantly different from the other springs. Drake Spring had a standard deviation of 2.37 above the mean distance in the outlier analysis. Drake was dominated by upland species and moss. Drake Spring remained in the analysis because it did not have any undue influence on the ordination results (Figure 3.2).

Table 3.1 Total area delineated, percent vegetative cover, and spring type for nineteen Warner Basin springs sampled in July - August 1998.

Spring name	Total area (m^2)	Percent cover	Spring type
Hidden	12.94	100.0	Marshy
Falls	52.73	100.0	Marshy
Goat	17.53	99.3	Marshy
Crackle	28.84	99.2	Marshy
Matilda	66.05	99.2	Marshy
Stockade	14.92	96.1	Marshy
Pope	27.64	95.3	Marshy
Juniper	25.73	92.0	Marshy
Basque	17.48	88.7	Head pool
Cricket	22.66	83.8	Head pool
LOP	28.69	80.8	Head pool
Foskett	46.56	79.7	Head pool
Spot	37.22	79.1	Head pool
Clover	34.72	73.6	Head pool
Hopper	18.66	72.0	Head pool
Finucane	25.86	71.0	Head pool
Drake	26.33	68.9	Stream-like
Can	17.28	66.6	Stream-like
Thunder	10.73	60.7	Stream-like

On the NMS plant ordination, springs that were closer together had more similar plant taxa than springs farther apart (Figure 3.2 a,b). Percent of emergent forbs (*Mimulus guttatus*) and percent of graminoids (*Agrostis* sp., *Glyceria* sp., *Hordeum* sp., *Juncus* sp.) were correlated significantly (r^2>.350) with similarities in plant communities. Percent of riparian forbs was correlated also; however, no specific riparian forb taxa were significant in the ordination. Vegetative cover was not correlated to plant communities because marshy springs were dominated by a variety of taxa, including *M. guttatus* or *Rorippa nasturtium-aquaticum,* (forbs) and *Scirpus* sp. or *Juncus* sp. (graminoids). Axis 1 explained 46.2% and Axis 2 explained 32.4% of the variance; cumulative variance explained for all three axes of the plant ordination was 91.0%.

TWINSPAN delineated five groups of spring assemblages that expressed patterns of plant taxa and plant types similar to those in the plant ordination (Figure 3.3). T1

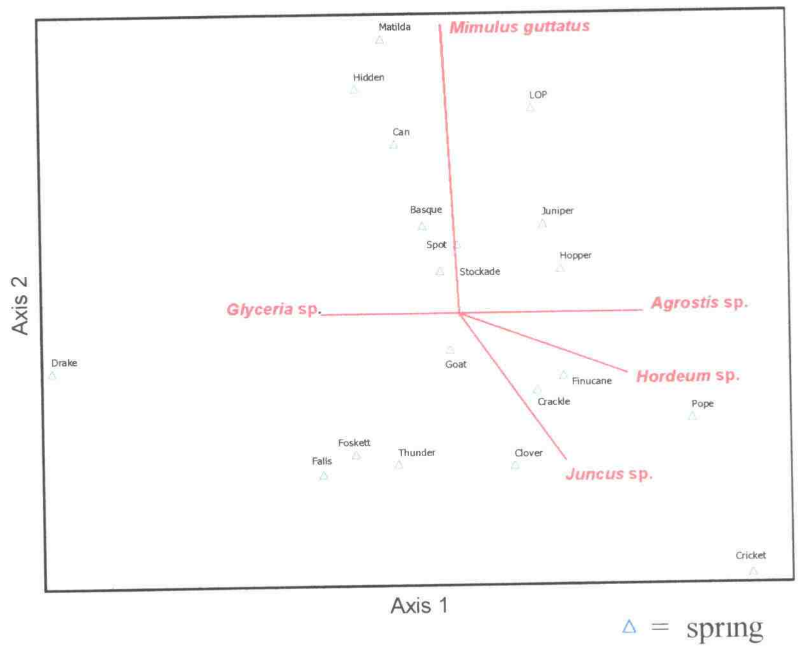

Figure 3.2a Three-dimensional NMS ordination, based on plant relative abundance data with rare taxa deleted, projected onto Axes 1 and 2. Vectors are plant taxa that have significant correlations (r^2 >.350) with the plant ordination.

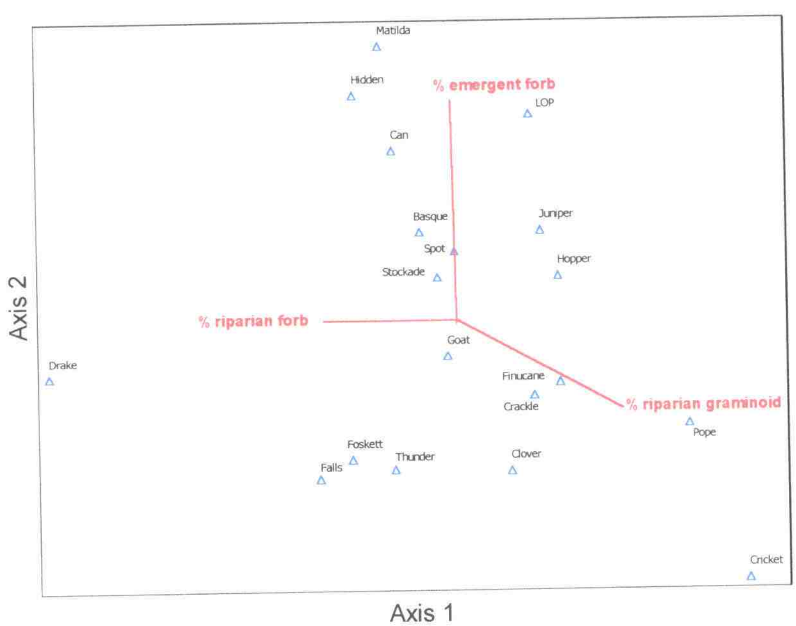

Figure 3.2b Three-dimensional NMS ordination, based on plant relative abundance data with rare taxa deleted, projected onto Axes 1 and 2. Vectors are plant types that have significant correlations (r^2 >.350) with the plant ordination.

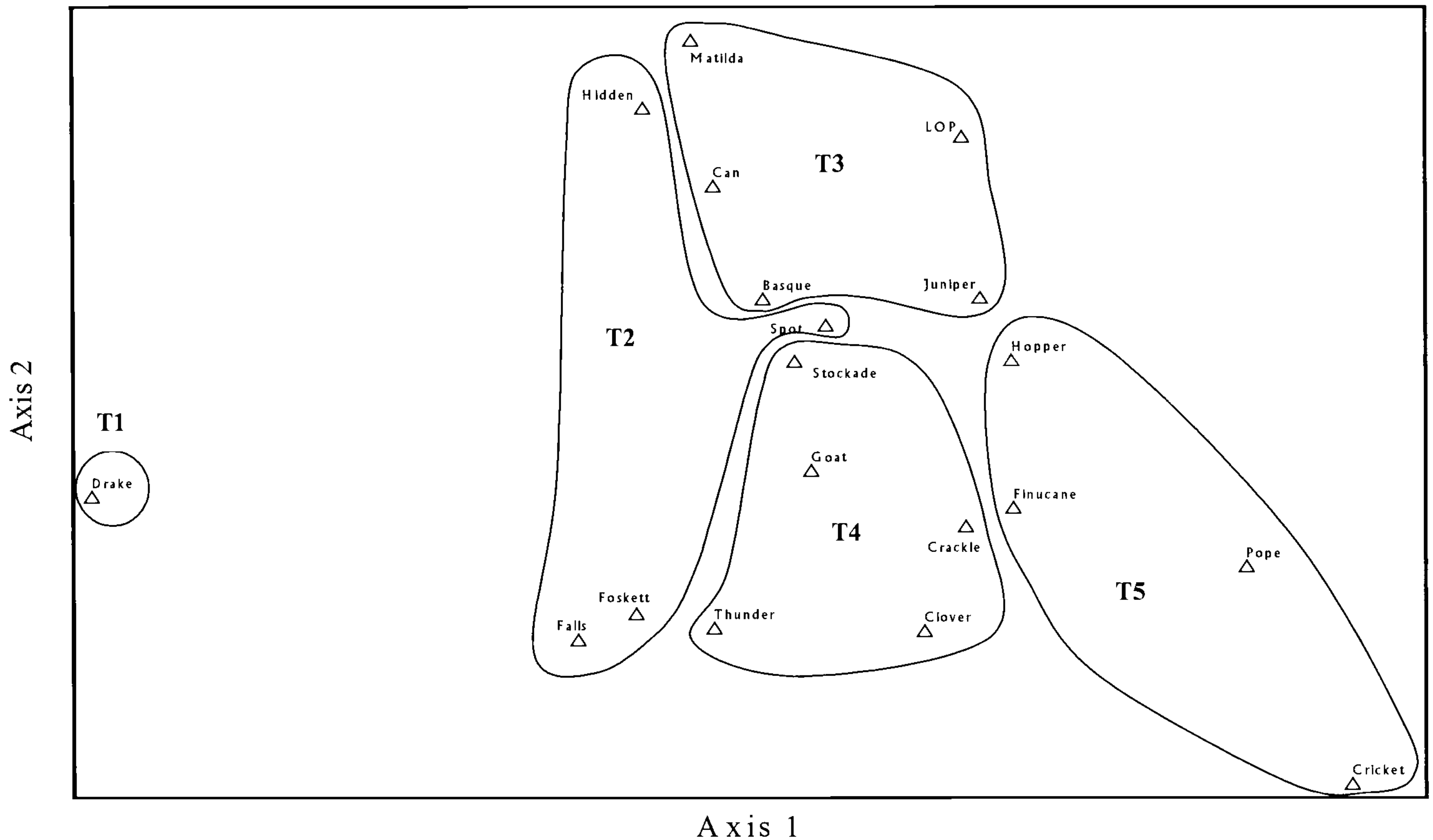

Figure 3.3 NMS plant ordination with TWINSPAN groups circled (T1 – T5).

included only Drake Spring, which had a number of riparian forb species that were found in few other springs. T2 was a very heterogeneous group with only the occurrence of *Cirsium vulgare* in common. All T3 springs had >20% cover of *Mimulus guttatus*. T4 included springs with an abundance of *Carex* sp. and *Juncus* sp., and T5 springs were dominated by grasses: *Hordeum* sp., *Agrostis* sp., and *Poa* sp.

Within-season variability was measured at Cricket and Foskett Springs in 1998. Plant taxa did not change between July and September; percent of each plant type within a spring did change. Plants that were classified as emergent early in the growing season were classified as riparian later in the summer as soils dried out and channel width decreased. Overall vegetative cover increased by 5.5% at Cricket Spring over 45 days and by 10.5 % at Foskett Spring over 40 days. Percent vegetative cover at each spring varied little between years (Figure 3.4). Can Spring was the exception with a considerable decrease in cover (27.6%) in 1999.

Invertebrate Assemblages

On the NMS invertebrate ordination, springs that were closer together had more similar invertebrate taxa than springs farther apart (Figure 3.5). Axes 1 and 3 of the invertebrate ordination explained 72.6 % of the variance; cumulative variance explained by all three axes was 88.5%. Springs, coded by TWINSPAN group on the invertebrate ordination, indicated no relationship with plant assemblages. Similarly, when plant taxa and plant-type variables were overlaid on the invertebrate ordination, neither were related to invertebrate presence/absence. However, there was a significant correlation between the invertebrate taxa and percent open area and percent vegetative cover (Figure 3.6).

Benthic invertebrates present in marshy systems with greater vegetative cover were different than invertebrates found in more open-water systems (Figure 3.7). *Labiobaetis* sp., a mayfly, and *Rhyacophila* sp., a free-swimming caddisfly, were present in stream-like and head-pool springs. Both these taxa are common in lotic systems. *Dixa* sp., a midge, was prevalent in marshy systems. There was no difference in mean invertebrate taxa richness between marshy, head pool, and stream-like springs ($F_{2, 16}$ = 0.00694, p = 0.993); likewise, the number of non-insect taxa was not different between spring types ($F_{2, 16}$ = 1.25, p = 0.313).

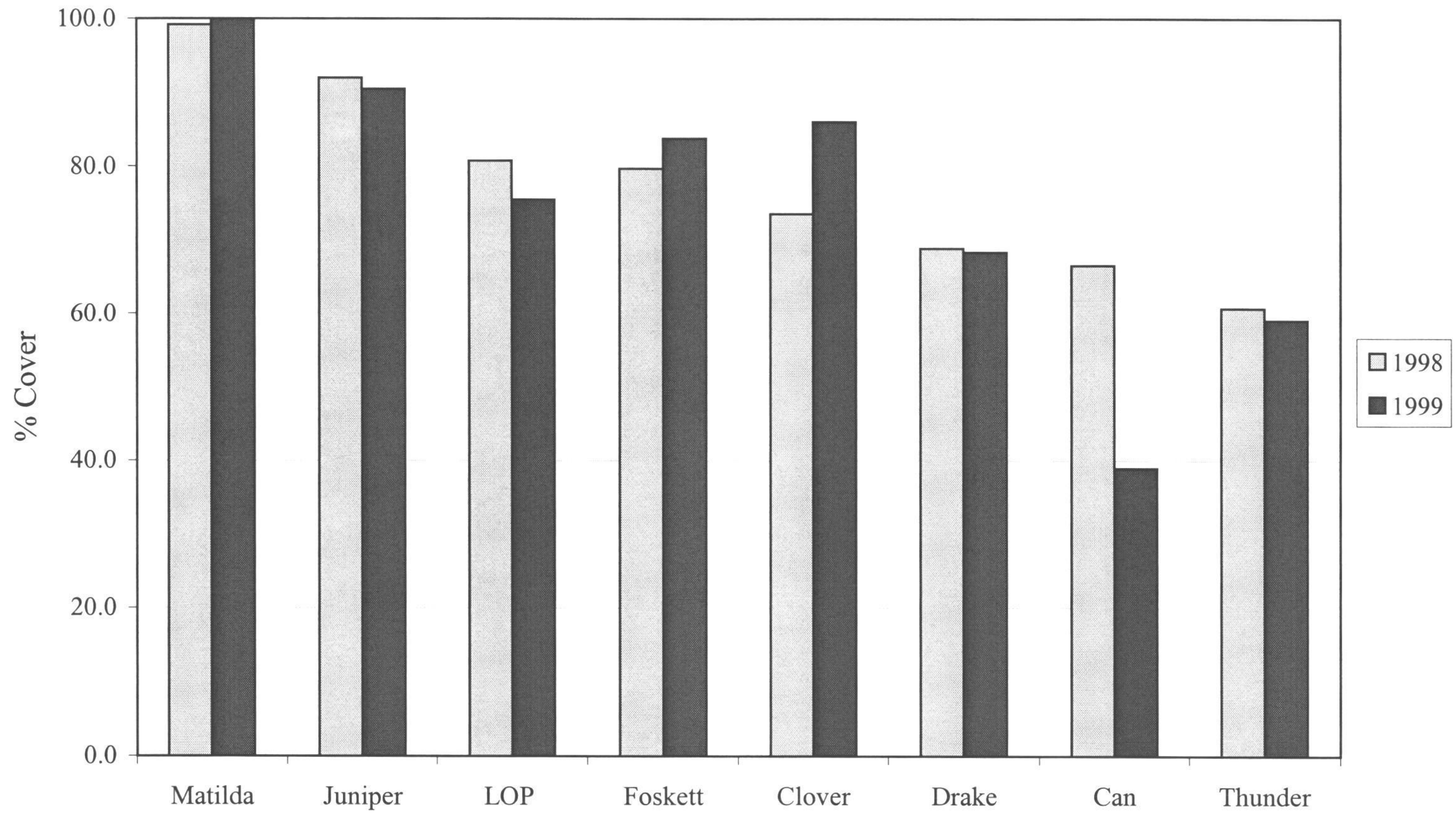

Figure 3.4 Comparison of percent vegetative cover of Warner Basin springs sampled in July/August 1998 and July 1999.

Figure 3.5 Three-dimensional NMS ordination, based on benthic invertebrate data with rare taxa deleted, projected onto Axes 1and 3. Springs are coded by TWINSPAN groups (T1 – T5), which were determined by plant assemblage similarities.

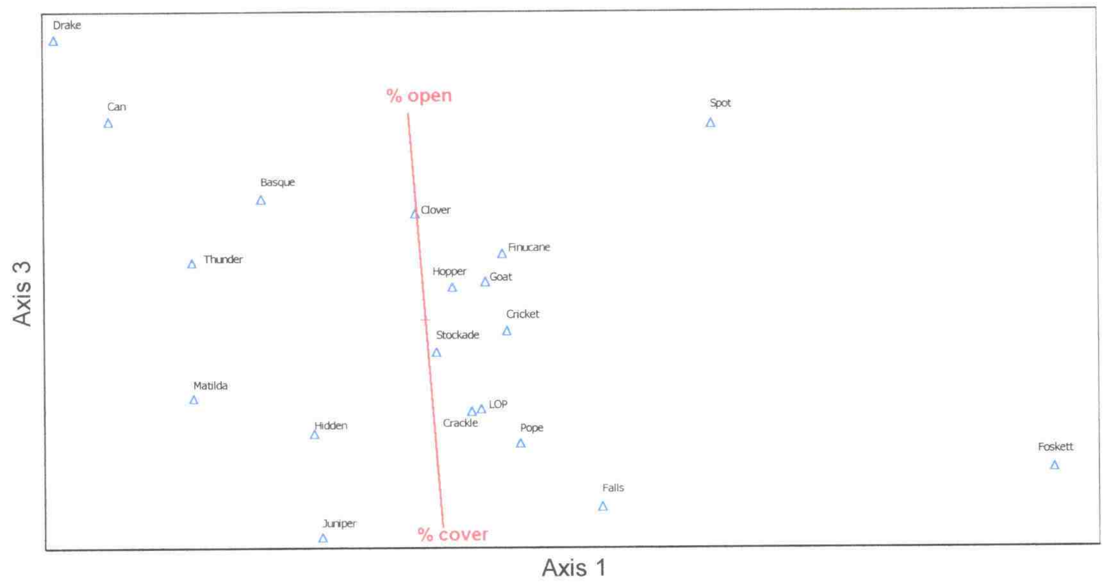

Figure 3.6 NMS invertebrate ordination with vectors of plant community attributes that have significant correlations ($r^2 = .350$) with the invertebrate taxa.

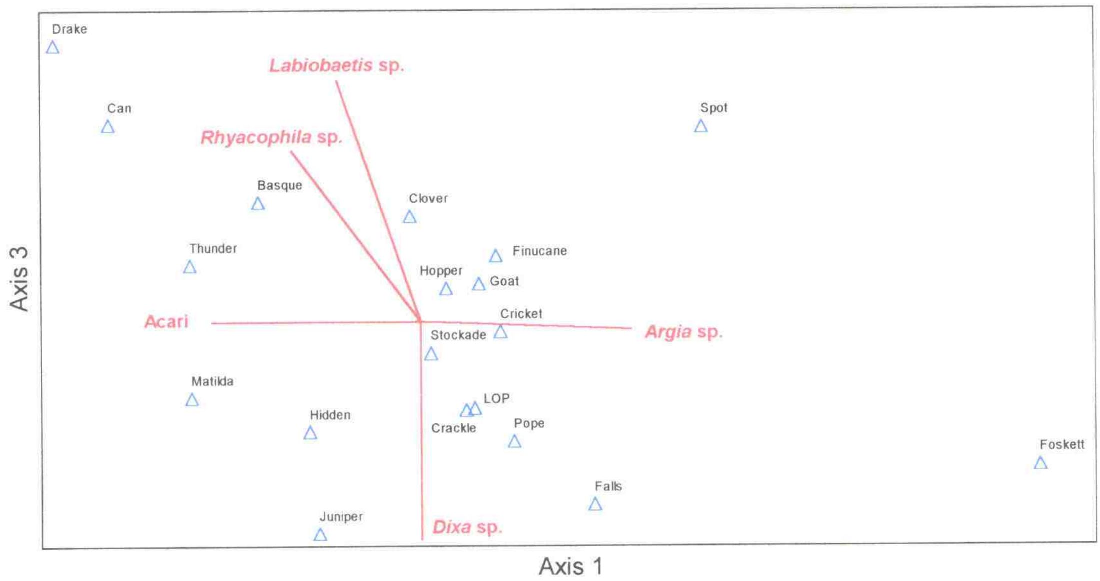

Figure 3.7 NMS invertebrate ordination with vectors of invertebrate taxa that have significant correlations ($r^2 = .500$) with the invertebrate ordination.

Rain events, morning dew, high winds, and flowering, thorny or tall plants all reduced the efficiency of sweep netting for riparian invertebrates. Variability in conditions at each spring made these data difficult to interpret. Diptera, Homoptera, and Thysanoptera were typically the most abundant riparian invertebrates at each spring. Twelve orders were represented overall; Ephemeroptera and Trichoptera were not collected in any of the sweeps.

DISCUSSION

Plant Communities

Plant communities of Warner Basin springs were diverse in composition with plant species typical of wetland prairie communities and marshy shore communities. Relative abundance of emergent forbs, riparian forbs, and riparian graminoids were important in distinguishing between Warner Basin springs; however, these plant-type classifications may be variable across seasons as soil moisture changes. These temporal changes may account for why invertebrate composition was not related to plant type classifications.

Broad ranges in water temperature, chemistry, and elevation provided an array of habitat conditions for plant taxa in these springs. However, water temperature and chemistry were not significant in determining the distribution of plants across the Warner Basin. Similarities in plant assemblages did not correlate with the primary axis of the invertebrate ordination, which was found to be related to water chemistry variables in Chapter 2.

Plant dispersal across this arid landscape is likely driven by wind and enhanced by connectivity during snow-melt events. Typically, plant dispersal is accomplished by seeds and plant fragments moving in water or sediments, or seeds are eaten and transported by birds and mammals (Guard 1995). Wind is an important vector for seed dispersal also. Water-associated plants may be remnants from the Pleistocene when the Great Basin was filled with lakes. Random dispersal events may account for the varied plant assemblages in the Warner Basin springs.

Usually permanent springs are not included in wetland classifications, though they are systems that typically have hydrophytic vegetation and sustained inundation during the growing season. Presence of hydric soils may be variable among springs depending on substrate and local hydrology. The reason for their exclusion from a national inventory may be that springs are often small, diverse habitats, and are challenging to classify because their boundaries are difficult to delineate. Presence of upland plant species in Warner Basin springs suggests that saturated soil patterns may change year-to-year and seasonally. The most abundant plant in 63% of the springs can be classified as a wetland obligate species (e.g. *Mimulus guttatus*, *Scirpus* sp., *Rorippa nasturtium-aquaticum*, *Veronica americana*). Most wetland plants are able to reproduce vegetatively by fragmentation and can form large colonies. The twelve wetland-obligate species found in these springs contributes to plant diversity in this desert landscape.

Relationship to Invertebrate Communities

Springs with similar plant relative abundance did not have similar invertebrate taxa (Figure 3.5). Association of aquatic invertebrates with particular plant species was not evident in these springs. Invertebrate composition in Warner Basin springs was influenced by the amount of open water in a spring area. Flow was also positively correlated to Axis 3 in the invertebrate ordination in Chapter 2. Flow increased as the percent of open water increased. The presence of emergent plants may obstruct the flow of water creating a more depositional habitat than swifter, open-water areas. Open water may be an important habitat attribute for more active invertebrates and, in these springs, was correlated with the presence of an active mayfly and free-living caddisfly.

Most studies investigating the relationship between aquatic invertebrates and aquatic plants focus on density-related phenomena. Densities of invertebrates in lakes and ponds were greater on aquatic macrophytes than on adjacent non-vegetated substrates (Krull 1970, Crowder and Cooper 1982, Rabe and Gibson 1984), and greater on moss-covered than on moss-free channels (Brusven et al. 1990). Due to their small size and the fragile nature of spring systems, sampling intensively to determine invertebrate densities was not possible. Although certain taxa showed an affinity towards highly vegetated springs (i.e. *Dixa* sp.), taxa richness was not significantly different in springs with varying amounts of aquatic vegetation.

Can Spring had significantly less vegetative cover in 1999 than in 1998. This was due to cattle grazing in 1999 just prior to sampling. Emergent vegetation was grazed below the water surface and trampling of the banks increased the channel width. This study was not designed to assess the influence of cattle grazing on spring plant and invertebrate communities. However, this study has shown that vegetative cover influences invertebrate composition; land-use practices that influence vegetative cover will likely affect spring fauna. A lack of emergent vegetation at certain times of the year might be detrimental to invertebrates that use vegetation to climb out of the water as they emerge into their aerial, adult stage.

This study has shown that vegetative cover in springs is an important characteristic that influences invertebrate distribution. The structure provided by vegetation within a spring may be more significant to the invertebrates than the presence of a particular plant species. The most important functions of emergent vegetation may be to provide refuge from current and to create depositional areas, a function implied by the correlation between vegetative cover and flow. Changes in groundwater levels may influence the invertebrate communities indirectly by the affect of decreased water levels on vegetation patterns and influence plant diversity directly by affecting permanence of spring habitats.

CHAPTER 4

SUMMARY

Springs provide critical habitat and water for wildlife as well as cattle in a Great Basin landscape. With increasing demands on water resources, there is a need to understand these small, fragile systems before they disappear or are altered irreparably. The majority of Warner Basin springs (65%) considered for inclusion in this study had been disturbed by cattle grazing or capped to capture water for agriculture or grazing purposes. Fences excluding cattle surrounded most of the undisturbed springs. This study identified chemical, physical, and vegetative characteristics of undisturbed springs that influence invertebrate composition and distribution across the Warner Basin; this knowledge can aid in designing management schemes to protect spring systems.

To detect biotic and abiotic patterns in the composition and distribution of invertebrates, I used a combination of ordination techniques. I searched for statistical methods that would help me understand the variation in the Non-metric Multidimensional Scaling (NMS) ordinations. Two-Way Indicator Species Analysis and hierarchical agglomerative cluster analysis were the best tools to explore the NMS ordinations. I concluded that each axis on the invertebrate ordination was describing variability that related to a different spatial scale. Axis 2 of the invertebrate ordination was the most challenging to understand and required that I search for geologic maps after preliminary analysis had begun.

Invertebrate distribution in Warner Basin springs appeared to be influenced by variability at landscape and local scales; invertebrate composition within a spring was influenced by local and small-scale variation. Landscape-level patterns of spring biota were related to topography and perhaps reflect common aquifers, geology, or soil type. Connectivity during snow-melt events may facilitate dispersal of non-insect taxa across springs in the same sub-basin. Local patterns of invertebrate communities, within sub-basins, were related to water chemistry, temperature, and elevation.

For example, invertebrate communities on Abert Rim and Hart Mountain were similar because water temperature and chemistries were similar. Differences in the presence of specific taxa were related to the topographic separation of these cold-water springs. TWINSPAN analysis confirmed differences in invertebrate composition in Abert Rim and Hart Mountain springs and identified variation in invertebrate communities within sub-basins. Vegetation cover and flow were related to small-scale variation between springs with similar water temperature and chemistry.

Invertebrate taxa richness in Warner Basin springs was low. None of the springs included in this study had adverse abiotic conditions which were biologically limiting; the A (adversity)- selection concept (Greenslade 1983) is not appropriate for explaining the low taxa diversity. The nineteen springs had consistently favorable environments. A habitat model, based on flow conditions, predicted high diversity and K-strategy species for stable habitats (Minshall 1988); this model does not appear to be relevant for spring systems.

Low diversity in these springs may be related to reduced habitat and thermal heterogeneity within springs or a result of habitat isolation and dispersal limitations between springs. Increasing taxa richness downstream from the spring source suggests that constancy in water chemistry and flow may not be suitable for all aquatic taxa. Springs typically have invertebrate taxa that are not found in streams (Roughley and Larson 1991, Williams and Williams 1999). In fact, forty-three taxa were collected in this study that were not found during stream surveys in the Warner Basin by the Bureau of Land Management, Lakeview District (Vinson 1995) (see Appendix 6).

Dispersal for invertebrates that prefer spring habitats may be challenging particularly in an arid landscape. Preliminary genetic results from a study of Great Basin springs show that caddisflies (Order: Trichoptera) that are strong fliers are part of one meta population, whereas caddisflies that are poorer fliers form isolated populations (Myers and Resh 1999). This suggests that dispersal for certain insect taxa may be limited when distances between springs are great. Warner Basin springs spanned a broad area (52 km^2), as well as range in water temperature and chemistry; dispersal between springs with similar attributes may be limited. The low diversity of aquatic invertebrates in Warner Basin springs is likely a result of poor habitat suitability for many aquatic invertebrates and limited dispersal opportunities for aerial adults to reach springs with similar water chemistry and temperature.

This study was unique by including plant composition in an analysis of invertebrate communities associated with spring systems. Although water temperature, chemistry, and topographic characteristics were most strongly correlated with invertebrate distribution, vegetation cover explained some of the variation and may be influenced by land-use practices more than other correlates. Vegetation cover also was related to flow. Cattle grazing on spring vegetation will likely decrease vegetation cover. Because reduced vegetation will increase flow, grazing can directly alter habitat characteristics important to aquatic invertebrates. Higher flow may be detrimental to less mobile organisms that utilize depositional areas and avoid swift currents.

Unlike the invertebrates, plant community composition was not influenced by water chemistry, but was affected most by the temporal availability of water. It was surprising that plant composition and invertebrate composition were not related. However, plants in these springs were dominated by riparian and emergent vegetation with only a few truly aquatic plants (i.e. *Rorippa nasturtium-aquaticum, Ranunculus aquatilis*) present. Algal community composition might show a stronger link to water chemistry and invertebrate composition than vascular plant communities.

The presence of fish (i.e. *Rhinichthys osculus*) in Foskett Spring makes it unique among springs in this study and unusual across the entire basin. It had greater spring area and depth than other springs in the Warner Basin; therefore, it was not surprising that the invertebrate community was significantly different. Unfortunately, the sampling methods used in this study did not do an adequate job of characterizing the invertebrate community of Foskett Spring. Both the size of the hand net and mesh size were not well suited for a large, silty system. Despite this shortcoming, Foskett Spring proved to be unique both physically and biologically.

This study suggests that management schemes concerned with spring systems and their biota should consider landscape, local, and small-scale patterns. Conservation priorities should be given to a suite of springs that encompass a broad range of chemical and physical attributes. Based on the results from the Warner Basin springs, these diverse springs should have equally diverse invertebrate communities. Springs that are isolated within a sub-basin are of special interest as they may have more rare and endemic species as connectivity with other spring systems may not occur.

With only nineteen relatively undisturbed springs remaining in the Warner Basin, strategies should be aggressive to conserve invertebrate taxa that are found only in springs. The area from each spring source downstream to 80 meters should be given highest priority. Beyond 80 meters, Warner Basin invertebrate communities were similar to those farther downstream and more typical of stream habitats. Excluding grazing along these 80-meter stretches and monitoring water withdrawals to ensure that groundwater levels are not significantly reduced should be a priority for management of spring habitats.

Research on springs in the Great Basin have concentrated on certain taxonomic groups (Hershler 1998, Shepard 1992, Sheldon 1979) or have compared springs with similar chemical and physical attributes (Glazier and Gooch 1987, Pritchard 1991). This community analysis of Great Basin springs is an important contribution to our understanding of invertebrate distributions across a desert landscape. The distinct patterns seen at different spatial scales needs to be investigated further to see if these patterns are unique to the Warner Basin or the Great Basin. These same patterns were not evident in plant communities, which have different dispersal mechanisms and habitat requirements.

This study found invertebrate taxa and plant species that contribute to the overall biodiversity of the Warner Basin. Invertebrate identifications were challenging and taxonomic resolution was usually above the species-level, but the likelihood that rare or un-described species exist in these Warner Basin springs is high. Monitoring these communities every 2 – 5 years will provide a measure of annual variability that will be valuable as water withdrawal pressures increase. Ecologists and land managers should continue to prioritize research on spring habitats and their unique invertebrate and plant communities.

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APPENDICES

APPENDIX 1

1998 and 1999 trace element data from Warner Basin springs processed by the Central Analytical Laboratory, Oregon State University. All results are in parts per million (ppm). Bold values are apparent extremes.

Spring name and sample year	Ba	Ca	Cd	Cu	K	Mg	Mn	Zn	Al	As	P	S	B	Fe	Pb	Co	Cr	Mo	Se	Si	Na	Ni
Basque 98	0.01	3.39	<0.01	<0.01	1.02	0.90	0.01	0.01	0.10	<0.08	<1.00	551	<0.16	0.18	<0.20	<0.01	<0.015	<0.02	<0.10	15.50	3.92	<0.09
Can 98	0.01	**18.88**	<0.01	<0.01	1.68	7.94	0.01	0.02	0.29	<0.08	<1.00	639	<0.16	0.23	<0.20	<0.01	<0.015	<0.02	<0.10	32.80	6.88	<0.09
Can 99	<0.01	**19.53**	<0.10	<0.01	1.74	8.27	0.02	<0.10	<0.50	<0.10	0.88	724	<0.01	<0.02	<0.10	<0.02	<0.02	<0.10	0.31	26.40	8.68	<0.10
Clover 98	<0.01	8.24	<0.01	<0.01	1.06	3.96	<0.01	0.01	0.27	<0.08	<1.00	600	<0.16	0.27	<0.20	<0.01	<0.015	<0.02	<0.10	20.80	4.22	<0.09
Clover 99	<0.01	1.16	<0.10	<0.01	<0.50	0.85	<0.10	<0.10	<0.50	<0.10	<0.50	513	<0.01	0.09	<0.10	<0.02	<0.02	<0.10	0.06	10.10	<1.00	<0.10
Crackle 98	0.05	**19.23**	<0.01	0.02	4.18	7.35	0.04	0.02	**4.27**	<0.08	<1.00	518	<0.16	2.80	<0.20	<0.01	<0.015	<0.02	<0.10	32.20	11.80	<0.09
Cricket 98 (1)	0.01	9.59	<0.01	<0.01	1.39	5.91	0.25	0.01	1.32	<0.08	<1.00	600	<0.16	2.14	<0.20	0.01	<0.015	<0.02	<0.10	26.30	6.78	<0.09
Cricket 98 (2)	0.01	8.98	<0.01	<0.01	1.33	5.58	0.02	0.01	0.36	<0.08	<1.00	519	<0.16	0.29	<0.20	<0.01	<0.015	<0.02	<0.10	23.30	6.36	<0.09
Drake 98	0.02	2.36	<0.01	<0.01	1.54	0.69	<0.01	0.01	0.12	<0.08	<1.00	684	<0.16	<0.15	<0.20	<0.01	<0.02	<0.02	<0.10	18.20	3.15	<0.09
Drake 99	<0.01	<0.10	<0.10	<0.01	<0.50	<0.10	<0.10	<0.10	<0.50	<0.10	<0.50	458	<0.01	<0.02	<0.10	<0.02	<0.02	<0.10	<0.05	3.77	<1.00	<0.10
Falls 98	0.01	**22.98**	<0.01	0.01	5.30	7.67	**0.48**	0.01	**5.34**	<0.08	<1.00	599	<0.16	**4.83**	<0.20	<0.01	<0.02	<0.02	<0.10	**45.40**	25.30	<0.09
Finucane 98	0.01	9.90	<0.01	<0.01	1.20	5.98	0.01	<0.01	0.57	<0.08	<1.00	533	<0.16	0.43	<0.20	<0.01	<0.02	<0.02	<0.10	22.90	6.66	<0.09
Foskett 98 (1)	0.01	9.82	<0.01	<0.01	8.62	4.84	<0.01	0.01	0.16	0.10	<1.00	635	0.58	0.16	<0.20	<0.01	<0.02	<0.02	<0.10	**40.90**	**65.80**	<0.09
Foskett 98 (2)	0.01	9.72	<0.01	<0.01	8.53	4.75	<0.01	0.01	0.17	0.10	<1.00	506	0.59	0.14	<0.20	<0.01	<0.02	<0.02	<0.10	38.00	**62.00**	<0.09
Foskett 99	<0.01	0.40	<0.10	<0.01	1.92	0.46	<0.10	<0.10	<0.50	<0.10	<0.50	488	0.13	<0.02	<0.10	<0.02	<0.02	<0.10	0.05	9.79	11.07	<0.10
Goat 98	0.03	6.13	<0.01	<0.01	1.55	4.03	<0.01	0.01	0.10	<0.08	<1.00	494	<0.16	<0.15	<0.20	<0.01	<0.02	<0.02	<0.10	26.20	5.44	<0.09
Hidden 98	0.03	10.67	<0.01	<0.01	3.71	6.45	<0.01	0.01	0.05	<0.08	<1.00	531	<0.16	<0.15	<0.20	<0.01	<0.02	<0.02	<0.10	27.20	7.91	<0.09
Hopper 98	0.01	9.14	<0.01	<0.01	1.23	5.64	<0.01	0.01	0.48	<0.08	<1.00	615	<0.16	0.34	<0.20	<0.01	<0.02	<0.02	<0.10	22.30	6.28	<0.09
Juniper 98	0.02	6.58	<0.01	<0.01	2.69	3.86	<0.01	0.01	0.61	<0.08	<1.00	669	<0.16	0.41	<0.20	<0.01	<0.02	<0.02	<0.10	26.20	5.22	<0.09
Juniper 99	0.02	5.41	<0.10	<0.01	2.66	3.20	<0.10	<0.10	1.54	<0.10	<0.50	523	<0.01	0.62	<0.10	<0.02	<0.02	<0.10	0.11	21.70	4.71	<0.10
L. O. Parsnip 98	0.01	5.70	<0.01	<0.01	2.39	3.59	<0.01	0.01	0.87	<0.08	<1.00	646	<0.16	0.52	<0.20	<0.01	<0.02	<0.02	<0.10	26.40	4.36	<0.09
L. O. Parsnip 99	<0.01	2.27	<0.10	<0.01	1.81	1.73	<0.10	<0.10	1.18	<0.10	<0.50	531	<0.01	0.47	<0.10	<0.02	<0.02	<0.10	0.09	18.70	2.28	<0.10
Matilda 98	0.01	6.02	<0.01	<0.01	2.44	3.82	<0.01	0.01	0.76	<0.08	<1.00	690	<0.16	0.47	<0.20	<0.01	<0.02	<0.02	<0.10	26.90	4.74	<0.09
Matilda 99	<0.01	4.20	<0.10	<0.01	2.32	2.77	<0.10	<0.10	1.51	<0.10	0.60	569	<0.01	0.55	<0.10	<0.02	<0.02	<0.10	0.10	20.90	3.54	<0.10
Pope 98	0.05	12.10	<0.01	<0.01	3.42	5.23	0.01	0.01	0.20	<0.08	<1.00	501	<0.16	0.19	<0.20	<0.01	<0.02	<0.02	<0.10	26.20	16.30	<0.09
Spot Creek 98	0.01	5.36	<0.01	<0.01	6.46	2.18	0.01	<0.01	0.14	<0.08	<1.00	614	<0.16	0.16	<0.20	<0.01	<0.02	<0.02	<0.10	37.60	19.30	<0.09
Stockade 98	**0.15**	7.41	<0.01	0.01	4.96	4.72	0.03	**1.10**	0.83	<0.08	<1.00	598	**0.97**	0.81	<0.20	<0.01	<0.02	<0.02	<0.10	29.10	14.40	<0.09
Thunder 98	0.01	10.61	<0.01	<0.01	1.18	5.07	<0.01	0.01	0.22	<0.08	<1.00	616	<0.16	0.22	<0.20	<0.01	<0.02	<0.02	<0.10	21.30	5.26	<0.09
Thunder 99	<0.01	0.68	<0.10	<0.01	<0.50	0.60	<0.10	<0.10	<0.50	<0.10	<0.50	511	<0.01	0.05	<0.10	<0.02	<0.02	<0.10	<0.05	7.54	<1.00	<0.10

APPENDIX 2

Benthic invertebrate taxonomic names for each Warner Basin spring sampled in July - August, 1998.

Spring	Order	Family/Tribe	Genus/species
LOP	Acari		
	Annelida	Planariidae	
	Coleoptera	Dytiscidae	Agabini
	Coleoptera	Dytiscidae	Hydroporini
	Coleoptera	Dytiscidae	Bidessini
	Coleoptera	Helophoridae	Helophorus
	Coleoptera	Hydrophilidae	Hydrobius
	Coleoptera	Hydrophilidae	Paracymus
	Copepoda	Harpacticoid	
	Diptera	Chironomidae Orthocladiinae	
	Diptera	Chironomidae Prodiamesinae	Prodiamesa
	Diptera	Chironomidae Tanypodinae	
	Diptera	Dixidae	Dixa
	Diptera	Ptychopteridae	Ptychoptera
	Diptera	Tipulidae	Dicranota
	Diptera	Unknown 1	
	Ephemeroptera	Ameletidae	Ameletus
	Gastropoda	Physidae	Physa/Physella
	Hemiptera	Gerridae	Gerris
	Hemiptera	Mesoveliidae	Mesovelia
	Oligochaeta		
	Ostracoda		
	Pelecypoda	Sphaeriidae	
	Plecoptera	Perlodidae	Skwala
	Trichoptera	Limnephilidae	Pseudostenophylax edwarsii
Cricket	Acari		
	Coleoptera	Dytiscidae	Colymbetini
	Coleoptera	Dytiscidae	Hydroporini
	Coleoptera	Helophoridae	Helophorus
	Collembola		
	Copepoda	Cyclopoid	
	Copepoda	Harpacticoid	
	Diptera	Chironomidae Orthocladiinae	
	Diptera	Chironomidae Tanytarsini	
	Diptera	Ephydridae	Unknown 3

APPENDIX 2 (Continued)

Spring	Order	Family/Tribe	Genus/species
Cricket	Diptera	Unknown 3	
	Diptera	Unknown 4	
	Nematoda		
	Oligochaeta		
	Ostracoda		
Foskett	Coleoptera	Helophoridae Helophorinae	
	Copepoda	Cyclopoid	
	Diptera	Chironomidae Orthocladiinae	
	Diptera	Chironomidae Tanypodinae	
	Diptera	Chironomidae Tanytarsini	
	Ephemeroptera	Baetidae	Callibaetis
	Gastropoda	Hydrobiidae	
	Gastropoda	Physidae	Physa/Physella
	Gastropoda	Pleuroceridae	Juga
	Hemiptera	Corixidae	Hesperocorixa
	Odonata	Anisoptera	
	Odonata	Coenagrionidae	Argia
	Ostracoda		
	Pelecypoda	Sphaeriidae	
	Trichoptera	Hydroptilidae	Hydroptila
Spot	Amphipoda		
	Annelida	Hirudinoidae	
	Coleoptera	Dytiscidae	Agabini
	Coleoptera	Dytiscidae	Colymbetini
	Coleoptera	Dytiscidae	Hydroporini
	Coleoptera	Elmidae	Heterlimnius
	Coleoptera	Elmidae	Optioservus
	Coleoptera	Elmidae	Zaitzevia
	Coleoptera	Hydrophilidae	Unknown 1
	Copepoda	Cyclopoid	
	Copepoda	Harpacticoid	
	Diptera	Chironomidae Tanypodinae	
	Diptera	Chironomidae Tanytarsini	
	Diptera	Tabanidae	Tabanus
	Ephemeroptera	Baetidae	Labiobaetis
	Odonata	Coenagrionidae	Argia
	Oligochaeta		
	Ostracoda		

APPENDIX 2 (Continued)

Spring	Order	Family/Tribe	Genus/species
Drake	Acari		
	Annelida	Planariidae	
	Coleoptera	Elmidae	Heterlimnius
	Collembola		
	Copepoda	Harpacticoid	
	Diptera	Chironomidae Orthocladiinae	
	Diptera	Simulidae	Prosimilium
	Diptera	Thaumaleidae	
	Ephemeroptera	Ameletidae	Ameletus
	Ephemeroptera	Baetidae	Labiobaetis
	Ephemeroptera	Ephemerellidae	Ephemerella
	Ephemeroptera	Heptageniidae	Cinygmula
	Gastropoda	Planorbidae	Gyraulus
	Oligochaeta		
	Ostracoda		
	Plecoptera	Chloroperlidae	Haploperla
	Plecoptera	Nemouridae	Malenka
	Plecoptera	Nemouridae	Zapada
	Plecoptera	Peltoperlidae	Yoroperla
	Plecoptera	Perlodidae	Rickera/Kogotus
	Trichoptera	Limnephilidae	Clostoeca
	Trichoptera	Limnephilidae	Psychoglypha
	Trichoptera	Rhyacophilidae	Rhyacophila
Can	Acari		
	Annelida	Planariidae	
	Coleoptera	Elmidae	Heterlimnius
	Copepoda	Harpacticoid	
	Diptera	Chironomidae Orthocladiinae	
	Diptera	Simulidae	Prosimilium
	Diptera	Tipulidae	Dicranota
	Ephemeroptera	Baetidae	Labiobaetis
	Ephemeroptera	Ephemerellidae	Serratella
	Gastropoda	Planorbidae	Gyraulus
	Nematoda		
	Oligochaeta		
	Pelecypoda	Sphaeriidae	
	Plecoptera	Nemouridae	Malenka
	Plecoptera	Peltoperlidae	Yoroperla

APPENDIX 2 (Continued)

Spring	Order	Family/Tribe	Genus/species
Can	Plecoptera	Perlodidae	Rickera/Kogotus
	Trichoptera	Limnephilidae	Pseudostenophylax edwarsii
	Trichoptera	Limnephilidae	Psychoglypha
	Trichoptera	Rhyacophilidae	Rhyacophila
Matilda	Acari		
	Amphipoda		
	Annelida	Hirudinoidae	
	Annelida	Planariidae	
	Coleoptera	Elmidae	Heterlimnius
	Collembola		
	Copepoda	Harpacticoid	
	Diptera	Chironomidae Orthocladiinae	
	Diptera	Dixidae	Dixa
	Diptera	Ephydridae	Discocerina
	Diptera	Psychodidae	Pericoma/Telmatoscopus
	Diptera	Simulidae	Simulium
	Diptera	Thaumaleidae	
	Diptera	Tipulidae	Dicranota
	Diptera	Unknown 6	
	Diptera	Unknown 7	
	Ephemeroptera	Ameletidae	Ameletus
	Ephemeroptera	Baetidae	Labiobaetis
	Gastropoda	Physidae	Physa/Physella
	Nematoda		
	Oligochaeta		
	Ostracoda		
	Plecoptera	Nemouridae	Malenka
	Trichoptera	Hydropsychidae	Parapsyche
	Trichoptera	Lepidostomatidae	Lepidostoma
	Trichoptera	Limnephilidae	Hesperophylax
	Trichoptera	Limnephilidae	Pseudostenophylax edwarsii
Juniper	Acari		
	Amphipoda		
	Annelida	Planariidae	
	Coleoptera	Dytiscidae	Colymbetini
	Coleoptera	Dytiscidae	Hydroporini
	Coleoptera	Helophoridae	Helophorus
	Copepoda	Harpacticoid	

APPENDIX 2 (Continued)

Spring	Order	Family/Tribe	Genus/species
Juniper	Diptera	Chironomidae Orthocladiinae	
	Diptera	Chironomidae Prodiamesinae	Prodiamesa
	Diptera	Chironomidae Tanytarsini	
	Diptera	Dixidae	Dixa
	Diptera	Tipulidae	Dicranota
	Diptera	Tipulidae	Tipula
	Diptera	Unknown 4	
	Gastropoda	Physidae	Physa/Physella
	Oligochaeta		
	Ostracoda		
	Plecoptera	Nemouridae	Malenka
	Trichoptera	Lepidostomatidae	Lepidostoma
Clover	Acari		
	Annelida	Planariidae	
	Coleoptera	Dytiscidae	Colymbetini
	Coleoptera	Dytiscidae	Hydroporini
	Coleoptera	Helophoridae	Helophorus
	Coleoptera	Hydraenidae	Hydraena
	Coleoptera	Hydrophilidae	Ametor
	Coleoptera	Hydrophilidae	Paracymus
	Collembola		
	Copepoda	Cyclopoid	
	Copepoda	Harpacticoid	
	Diptera	Chironomidae Orthocladiinae	
	Diptera	Chironomidae Prodiamesinae	Prodiamesa
	Diptera	Chironomidae Tanypodinae	
	Diptera	Chironomidae Tanytarsini	
	Diptera	Stratiomyidae	Odontomyia
	Ephemeroptera	Ameletidae	Ameletus
	Ephemeroptera	Baetidae	Labiobaetis
	Hemiptera	Gerridae	Limnoporus
	Hemiptera	Notonectidae	Notonecta
	Nematoda		
	Oligochaeta		
	Ostracoda		
	Plecoptera	Nemouridae	Malenka
	Trichoptera	Limnephilidae	Clostoeca
	Trichoptera	Limnephilidae	Pseudostenophylax edwarsii

APPENDIX 2 (Continued)

Spring	Order	Family/Tribe	Genus/species
Clover	Trichoptera	Limnephilidae	Psychoglypha
Thunder	Acari		
	Amphipoda		
	Annelida	Planariidae	
	Coleoptera	Elmidae	Heterlimnius
	Coleoptera	Helophoridae	Helophorus
	Coleoptera	Hydraenidae	Hydraena
	Collembola		
	Copepoda	Harpacticoid	
	Diptera	Chironomidae Orthocladiinae	
	Diptera	Thaumaleidae	
	Diptera	Tipulidae	Dicranota
	Ephemeroptera	Baetidae	Labiobaetis
	Nematoda		
	Oligochaeta		
	Ostracoda		
	Plecoptera	Nemouridae	Malenka
	Plecoptera	Perlidae	Hesperoperla
	Trichoptera	Hydropsychidae	Arctopsyche
	Trichoptera	Limnephilidae	Pseudostenophylax edwarsii
	Trichoptera	Limnephilidae	Unknown 1
Finucane	Acari		
	Amphipoda		
	Annelida	Planariidae	
	Coleoptera	Dytiscidae	Agabini
	Coleoptera	Dytiscidae	Colymbetini
	Coleoptera	Dytiscidae	Hydroporini
	Coleoptera	Dytiscidae	Laccophilus
	Coleoptera	Helophoridae	Helophorus
	Coleoptera	Hydrophilidae	Laccobius
	Copepoda	Cyclopoid	
	Copepoda	Harpacticoid	
	Diptera	Chironomidae Orthocladiinae	
	Diptera	Chironomidae Tanypodinae	
	Diptera	Chironomidae Tanytarsini	
	Diptera	Empididae	Clinocera
	Diptera	Ephydridae	Unknown 3
	Diptera	Ptychopteridae	Ptychoptera

APPENDIX 2 (Continued)

Spring	Order	Family/Tribe	Genus/species
Finucane	Diptera	Simulidae	Simulium
	Diptera	Tipulidae	Dicranota
	Ephemeroptera	Baetidae	Labiobaetis
	Hemiptera	Corixidae	Hesperocorixa
	Hemiptera	Notonectidae	Notonecta
	Nematoda		
	Odonata	Lestidae	Lestes
	Oligochaeta		
	Ostracoda		
	Trichoptera	Limnephilidae	Unknown 3
Hopper	Acari		
	Coleoptera	Dytiscidae	Agabini
	Coleoptera	Dytiscidae	Colymbetini
	Coleoptera	Dytiscidae	Hydroporini
	Coleoptera	Helophoridae	Helophorus
	Coleoptera	Hydrophilidae	Hydrobius
	Coleoptera	Hydrophilidae	Laccobius
	Copepoda	Harpacticoid	
	Diptera	Chironomidae Orthocladiinae	
	Diptera	Chironomidae Tanypodinae	
	Diptera	Chironomidae Tanytarsini	
	Diptera	Tipulidae	Dicranota
	Diptera	Tipulidae	Limonia
	Diptera	Unknown 4	
	Ephemeroptera	Baetidae	Labiobaetis
	Nematoda		
	Oligochaeta		
	Ostracoda		
Falls	Acari		
	Annelida	Hirudinoidae	
	Annelida	Planariidae	
	Coleoptera	Hydrophilidae	Cymbiodyta
	Coleoptera	Hydrophilidae	Laccobius
	Collembola		
	Copepoda	Harpacticoid	
	Diptera	Ceratopogonidae	Stilobezzia
	Diptera	Chironomidae Chironomini	
	Diptera	Chironomidae Orthocladiinae	

APPENDIX 2 (Continued)

Spring	Order	Family/Tribe	Genus/species
Falls	Diptera	Chironomidae Tanypodinae	
	Diptera	Chironomidae Tanytarsini	
	Diptera	Dixidae	Dixa
	Gastropoda	Lymnaeidae	Fossaria
	Hemiptera	Mesoveliidae	Mesovelia
	Nematoda		
	Odonata	Coenagrionidae	Argia
	Oligochaeta		
	Ostracoda		
	Pelecypoda	Sphaeriidae	
Crackle	Acari		
	Coleoptera	Dytiscidae	Agabini
	Coleoptera	Dytiscidae	Colymbetini
	Coleoptera	Dytiscidae	Hydroporini
	Coleoptera	Helophoridae	Helophorus
	Coleoptera	Hydrophilidae	Hydrobius
	Collembola		
	Copepoda	Cyclopoid	
	Copepoda	Harpacticoid	
	Diptera	Chironomidae Chironomini	
	Diptera	Chironomidae Orthocladiinae	
	Diptera	Chironomidae Tanytarsini	
	Diptera	Culicidae	Culiseta
	Diptera	Dixidae	Dixa
	Diptera	Dixidae	Dixella
	Diptera	Ephydridae	Notiphila
	Diptera	Psychodidae	Pericoma/Telmatoscopus
	Diptera	Ptychopteridae	Ptychoptera
	Gastropoda	Lymnaeidae	Fossaria
	Nematoda		
	Oligochaeta		
	Ostracoda		
	Trichoptera	Limnephilidae	Unknown 2
Pope	Acari		
	Coleoptera	Dytiscidae	Colymbetini
	Coleoptera	Dytiscidae	Hydroporini
	Coleoptera	Hydrophilidae	Unknown 2
	Copepoda	Cyclopoid	

APPENDIX 2 (Continued)

Spring	Order	Family/Tribe	Genus/species
Pope	Copepoda	Harpacticoid	
	Diptera	Chironomidae Chironomini	
	Diptera	Chironomidae Orthocladiinae	
	Diptera	Chironomidae Tanypodinae	
	Diptera	Chironomidae Tanytarsini	
	Diptera	Dixidae	Dixa
	Diptera	Tipulidae	Dicranota
	Nematoda		
	Oligochaeta		
Stockade	Acari		
	Amphipoda		
	Coleoptera	Dytiscidae	Colymbetini
	Coleoptera	Dytiscidae	Hydroporini
	Coleoptera	Helophoridae	Helophorus
	Collembola		
	Copepoda	Cyclopoid	
	Copepoda	Harpacticoid	
	Diptera	Chironomidae Orthocladiinae	
	Diptera	Chironomidae Tanypodinae	
	Diptera	Chironomidae Tanytarsini	
	Diptera	Empididae	Clinocera
	Diptera	Ptychopteridae	Ptychoptera
	Diptera	Tipulidae	Dicranota
	Diptera	Tipulidae	Limonia
	Diptera	Tipulidae	Pedicia
	Diptera	Tipulidae	Tipula
	Diptera	Unknown 1	
	Nematoda		
	Oligochaeta		
	Trichoptera	Limnephilidae	Hesperophylax
Goat	Acari		
	Amphipoda		
	Annelida	Planariidae	
	Coleoptera	Dytiscidae	Agabini
	Coleoptera	Dytiscidae	Hydroporini
	Coleoptera	Helophoridae	Helophorus
	Collembola		
	Copepoda	Cyclopoid	

APPENDIX 2 (Continued)

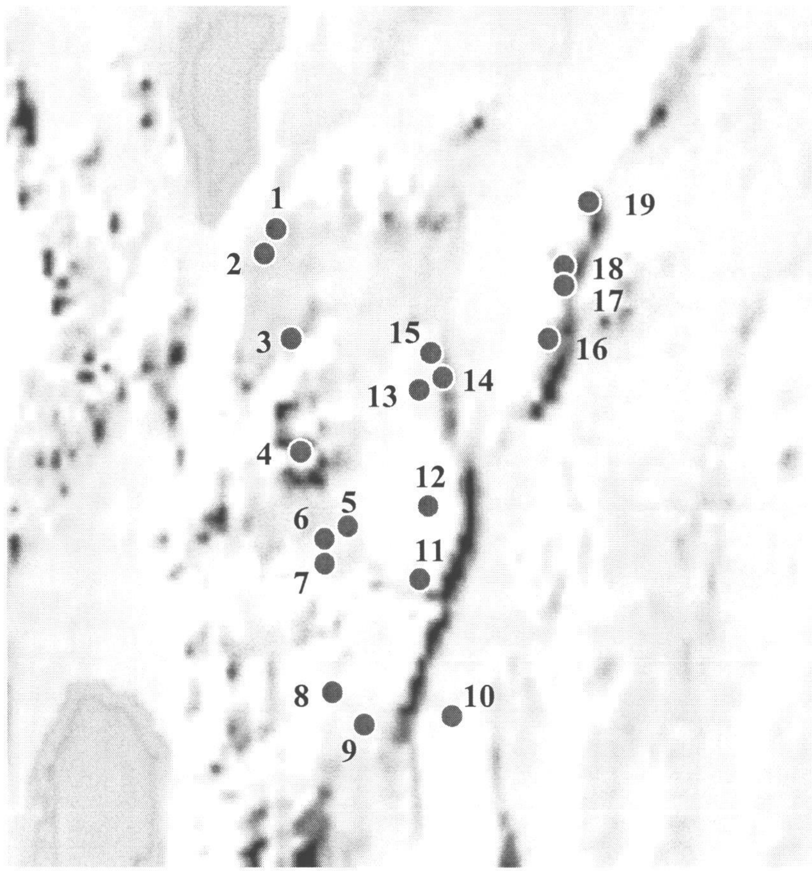
Spring	Order	Family/Tribe	Genus/species
Goat	Copepoda	Harpacticoid	
	Diptera	Chironomidae Orthocladiinae	
	Diptera	Chironomidae Tanypodinae	
	Diptera	Chironomidae Tanytarsini	
	Diptera	Tipulidae	Dicranota
	Diptera	Tipulidae	Pedicia
	Diptera	Unknown 3	
	Ephemeroptera	Ameletidae	Ameletus
	Nematoda		
	Oligochaeta		
	Ostracoda		
	Pelecypoda	Sphaeriidae	
	Plecoptera	Nemouridae	Zapada
	Trichoptera	Limnephilidae	Hesperophylax
Basque	Acari		
	Coleoptera	Dytiscidae	Colymbetini
	Coleoptera	Dytiscidae	Hydroporini
	Coleoptera	Elmidae	Optioservus
	Coleoptera	Hydrophilidae	Hydrobius
	Coleoptera	Hydrophilidae	Tropisternus
	Copepoda	Harpacticoid	
	Diptera	Chironomidae Orthocladiinae	
	Diptera	Chironomidae Tanytarsini	
	Diptera	Empididae	Clinocera
	Diptera	Ptychopteridae	Ptychoptera
	Diptera	Tipulidae	Dicranota
	Diptera	Unknown 8	
	Ephemeroptera	Ameletidae	Ameletus
	Ephemeroptera	Baetidae	Labiobaetis
	Ephemeroptera	Heptageniidae	Cinygmula
	Nematoda		
	Oligochaeta		
	Ostracoda		
	Plecoptera	Chloroperlidae	Triznaka
	Plecoptera	Nemouridae	Zapada
	Trichoptera	Limnephilidae	Limnephilus
	Trichoptera	Rhyacophilidae	Rhyacophila

APPENDIX 2 (Continued)

Spring	Order	Family/Tribe	Genus/species
Hidden	Acari		
	Coleoptera	Dytiscidae	Colymbetini
	Coleoptera	Dytiscidae	Hydroporini
	Collembola		
	Copepoda	Harpacticoid	
	Diptera	Ceratopogonidae	Forcipomyia
	Diptera	Chironomidae Chironomini	
	Diptera	Chironomidae Orthocladiinae	
	Diptera	Chironomidae Tanytarsini	
	Diptera	Dixidae	Dixa
	Diptera	Empididae	Clinocera
	Diptera	Psychodidae	Pericoma/Telmatoscopus
	Diptera	Tipulidae	Dicranota
	Diptera	Tipulidae	Pedicia
	Diptera	Unknown 4	
	Nematoda		
	Oligochaeta		
	Ostracoda		
	Trichoptera	Limnephilidae	Hesperophylax
	Trichoptera	Limnephilidae	Limnephilus
	Trichoptera	Limnephilidae	Unknown 1

APPENDIX 3

Names and locations of nineteen Warner Basin springs sampled in this study.



1	Clover Spring
2	Thunder Spring
3	Can Spring
4	Drake Spring
5	Matilda Spring
6	LOP Spring
7	Juniper Spring
8	Pope Spring
9	Spot Creek Spring
10	Foskett Spring
11	Falls Spring
12	Crackle Spring
13	Cricket Spring
14	Hopper Spring
15	Finucane Spring
16	Hidden Spring
17	Goat Spring
18	Stockade Spring
19	Basque Spring

Appendix 4

Plant assemblages and percent dominance within spring areas for nineteen Warner Basin springs sampled in July - August, 1998.

Spring Name	Family	Genus	Species	% Dominance
LOP:	Compositae	Achillea	millefolium	0.3
	Cyperaceae	Carex	sp.	9.1
	Gramineae	Poa	sp.	25.3
	Gramineae	Phleum	sp.	2.0
	Gramineae	Torreyochloa	sp.	2.0
	Gramineae	Agrostis	sp.	5.5
	Leguminosae	Trifolium	wormskjoldii	0.8
	Polygonaceae	Rumex	salicifolius	4.2
	Scrophulariaceae	Mimulus	guttatus	29.8
	Scrophulariaceae	Veronica	americana	1.8
Cricket:	Cyperaceae	Eleocharis	sp.	24.9
	Gramineae	Hordeum	sp.	10.0
	Gramineae	Poa	sp.	10.0
	Gramineae	Agrostis	sp.	6.6
	Juncaceae	Juncus	sp.	31.5
	Scrophulariaceae	Mimulus	guttatus	0.8
Foskett:	Compositae	Cirsium	vulgare	3.1
	Cyperaceae	Eleocharis	sp.	4.2
	Cyperaceae	Scirpus	sp.	36.3
	Cyperaceae	Carex	sp.	1.4
	Gramineae	Polypogon	sp.	0.2
	Juncaceae	Juncus	sp.	5.5
	Onagraceae	Epilobium	ciliatum	5.6
	Polygonaceae	Rumex	occidentalis	3.2
	Scrophulariaceae	Mimulus	guttatus	6.8
	Typhaceae	Typha	latifolia	2.4
	Umbelliferae	Berula	erecta	11.0
Spot:	Compositae	Cirsium	vulgare	1.8
	Compositae	Artemesia	sp.	1.7
	Cyperaceae	Carex	sp.	6.2
	Cyperaceae	Eleocharis	sp.	7.8
	Gramineae	Agrostis	sp.	2.5
	Gramineae	Poa	sp.	7.8
	Gramineae	Deschampsia	sp.	1.7
	Gramineae	Phalaris	sp.	1.4
	Juncaceae	Juncus	sp.	4.8
	Lemnaceae	Lemna	minor	0.4
	Onagraceae	Epilobium	ciliatum	7.7
	Rosaceae	Rosa	nutkana	3.5
	Scrophulariaceae	Mimulus	guttatus	29.2
	Urticaceae	Urtica	dioica	2.6

Appendix 4 (cont.)

Spring Name	Family	Genus	Species	% Dominance
Drake:	Brachytheciaceae	Brachythecium	frigidum	3.3
	Brassicaceae	Cardamine	breweri	1.7
	Compositae	Senecio	triangularis	30.6
	Cyperaceae	Carex	sp.	2.2
	Gramineae	Elymus	sp.	2.4
	Gramineae	Glyceria	sp.	7.7
	Gramineae	Torreyochloa	sp.	7.1
	Liliaceae	Veratrum	californicum	1.1
	Onagraceae	Circaea	alpina	1.1
	Onagraceae	Epilobium	glaberrimum	1.5
	Orchidaceae	Habenaria	dilatata	1.1
	Portulacaceae	Montia	fontana	1.1
	Ranunculaceae	Aconitum	columbianum	0.5
	Rubiaceae	Galium	triflorum	1.1
	Scrophulariaceae	Mimulus	guttatus	6.4
Can:	Brachytheciaceae	Brachythecium	frigidum	1.3
	Compositae	Achillea	millefolium	0.7
	Cyperaceae	Carex	sp.	3.1
	Gramineae	Poa	sp.	7.2
	Gramineae	Hordeum	sp.	0.7
	Leguminosae	Trifolium	wormskjoldii	1.3
	Onagraceae	Epilobium	ciliatum	5.8
	Orchidaceae	Habenaria	dilatata	1.3
	Saxifragaceae	Saxifraga	oregana	1.7
	Scrophulariaceae	Mimulus	guttatus	40.5
	Scrophulariaceae	Veronica	americana	3.0
Matilda:	Compositae	Achillea	millefolium	1.4
	Compositae	Conyza	canadensis	0.6
	Cyperaceae	Carex	sp.	1.2
	Gramineae	Phleum	sp.	6.6
	Gramineae	Agrostis	sp.	6.4
	Leguminosae	Trifolium	wormskjoldii	0.6
	Onagraceae	Epilobium	ciliatum	5.0
	Polygonaceae	Rumex	salicifolius	4.0
	Scrophulariaceae	Mimulus	guttatus	68.0
	Scrophulariaceae	Veronica	americana	1.4
	Urticaceae	Urtica	dioica	4.0

Appendix 4 (cont.)

Spring Name	Family	Genus	Species	% Dominance
Juniper:	Compositae	Achillea	millefolium	0.6
	Cyperaceae	Carex	sp.	16.7
	Gramineae	Poa	sp.	4.4
	Gramineae	Deschampsia	sp.	8.1
	Gramineae	Phleum	sp.	3.9
	Gramineae	Agrostis	sp.	7.4
	Juncaceae	Juncus	sp.	6.0
	Leguminosae	Trifolium	wormskjoldii	18.9
	Onagraceae	Epilobium	ciliatum	1.6
	Polygonaceae	Rumex	salicifolius	1.0
	Ranunculaceae	Aquilegia	formosa	1.2
	Scrophulariaceae	Mimulus	guttatus	21.6
	Urticaceae	Urtica	dioica	0.6
Clover:	Caryophyllaceae	Stellaria	longipes	0.9
	Cyperaceae	Carex	sp.	6.8
	Gramineae	Agrostis	sp.	1.7
	Gramineae	Poa	sp.	0.9
	Gramineae	Phleum	sp.	0.5
	Gramineae	Hordeum	sp.	1.4
	Juncaceae	Juncus	sp.	19.8
	Leguminosae	Trifolium	wormskjoldii	13.7
	Portulacaceae	Montia	chamissoi	1.4
	Ranunculaceae	Ranunculus	aquatilis	12.5
	Rosaceae	Potentilla	gracilis	0.2
	Scrophulariaceae	Veronica	americana	4.0
	Scrophulariaceae	Mimulus	guttatus	7.2
	Umbelliferae	Perideridia	gairdneri	2.6
Thunder:	Compositae	Achillea	millefolium	1.8
	Compositae	Artemesia	sp.	8.9
	Cyperaceae	Carex	sp.	3.0
	Gramineae	Agrostis	sp.	0.7
	Gramineae	Poa	sp.	1.6
	Gramineae	Phleum	sp.	3.7
	Juncaceae	Juncus	sp.	17.5
	Leguminosae	Trifolium	wormskjoldii	1.0
	Onagraceae	Epilobium	ciliatum	7.5
	Portulacaceae	Montia	fontana	1.9
	Rosaceae	Potentilla	gracilis	1.8
	Scrophulariaceae	Mimulus	guttatus	9.5
	Umbelliferae	Perideridia	gairdneri	1.8

Appendix 4 (cont.)

Spring Name	Family	Genus	Species	% Dominance
Finucane:	Caryophyllaceae	Stellaria	longipes	0.6
	Compositae	Achillea	millefolium	0.6
	Cyperaceae	Carex	sp.	10.9
	Cyperaceae	Eleocharis	sp.	3.7
	Gramineae	Hordeum	sp.	7.5
	Gramineae	Poa	sp.	11.6
	Gramineae	Agrostis	sp.	4.6
	Gramineae	Bromus	sp.	1.5
	Gramineae	Alopecurus	sp.	2.2
	Gramineae	Deschampsia	sp.	0.6
	Juncaceae	Juncus	sp.	9.3
	Onagraceae	Epilobium	ciliatum	6.9
	Polygonaceae	Rumex	salicifolius	2.6
	Scrophulariaceae	Mimulus	guttatus	7.2
	Urticaceae	Urtica	dioica	1.2
Falls:	Compositae	Cirsium	vulgare	3
	Compositae	Aster	eatonii	30
	Cruciferae	Rorippa	nasturtium-aquaticum	50
	Cyperaceae	Carex	sp.	2
	Juncaceae	Juncus	sp.	4
	Onagraceae	Epilobium	ciliatum	8
	Scrophulariaceae	Mimulus	guttatus	3
Hopper:	Compositae	Aster	occidentalis	1
	Cyperaceae	Carex	sp.	8
	Gramineae	Hordeum	sp.	5
	Gramineae	Agrostis	sp.	5
	Gramineae	Poa	sp.	3
	Gramineae	Alopecurus	sp.	3
	Juncaceae	Juncus	sp.	8
	Leguminosae	Trifolium	wormskjoldii	1
	Onagraceae	Epilobium	ciliatum	3
	Polygonaceae	Rumex	salicifolius	14
	Ranunculaceae	Ranunculus	aquatilis	1
	Scrophulariaceae	Mimulus	guttatus	20
Crackle:	Caryophyllaceae	Stellaria	longipes	0.7
	Compositae	Aster	sp.	1.5
	Cyperaceae	Carex	sp.	14.2
	Gramineae	Agrostis	sp.	4.5
	Juncaceae	Juncus	sp.	37.6
	Leguminosae	Trifolium	wormskjoldii	6.5
	Onagraceae	Epilobium	ciliatum	10.3
	Portulacaceae	Montia	chamassoi	7.4
	Scrophulariaceae	Mimulus	guttatus	16.5

Appendix 4 (cont.)

Spring Name	Family	Genus	Species	% Dominance
Pope:	Compositae	Achillea	millefolium	1.1
	Cyperaceae	Carex	sp.	11.2
	Gramineae	Alopecurus	sp.	5.0
	Gramineae	Agrostis	sp.	13.4
	Gramineae	Hordeum	sp.	9.1
	Gramineae	Deschampsia	sp.	4.2
	Gramineae	Poa	sp.	1.6
	Juncaceae	Juncus	sp.	13.6
	Onagraceae	Epilobium	ciliatum	14.7
	Onagraceae	Epilobium	densiflorum	1.1
	Polygonaceae	Rumex	salicifolium	1.6
	Scrophulariaceae	Veronica	americana	17.8
	Scrophulariaceae	Mimulus	guttatus	0.9
Stockade:	Caryophyllaceae	Stellaria	longipes	0.5
	Compositae	Aster	foliaceus	2.6
	Cruciferae	Barbarea	orthoceras	1.0
	Cyperaceae	Carex	sp.	15.7
	Gramineae	Agrostis	sp.	1.5
	Gramineae	Poa	sp.	2.6
	Gramineae	Agropyron	sp.	2.6
	Gramineae	Phleum	sp.	1.0
	Juncaceae	Juncus	sp.	7.6
	Liliaceae	Veratrum	californicum	15.4
	Onagraceae	Epilobium	ciliatum	20.2
	Portulacaceae	Montia	chamissoi	1.0
	Scrophulariaceae	Mimulus	guttatus	21.0
	Urticaceae	Urtica	dioica	3.4
Goat:	Bartramiaceae	Philonotis	fontana	6.0
	Caryophyllaceae	Stellaria	longipes	2.8
	Compositae	Achillea	millefolium	0.3
	Cyperaceae	Carex	sp.	8.5
	Gramineae	Poa	sp.	2.9
	Gramineae	Agrostis	sp.	3.0
	Gramineae	Phleum	sp.	1.0
	Gramineae	Agropyron	sp.	1.0
	Gramineae	Torreyochloa	sp.	3.8
	Juncaceae	Juncus	sp.	16.5
	Leguminosae	Trifolium	wormskjoldii	3.5
	Onagraceae	Epilobium	ciliatum	30.0
	Portulacaceae	Montia	fontana	1.5
	Scrophulariaceae	Mimulus	guttatus	18.5

Appendix 4 (cont.)

Spring Name	Family	Genus	Species	% Dominance
Basque:	Caryophyllaceae	Stellaria	longipes	1.0
	Compositae	Achillea	millefolium	0.6
	Cyperaceae	Carex	sp.	19.5
	Gramineae	Phleum	sp.	2.0
	Gramineae	Poa	sp.	3.0
	Gramineae	Hordeum	sp.	1.3
	Gramineae	Agrostis	sp.	2.0
	Gramineae	Glyceria	sp.	4.0
	Juncaceae	Juncus	sp.	5.1
	Onagraceae	Epilobium	ciliatum	7.7
	Portulacaceae	Montia	fontana	1.3
	Scrophulariaceae	Mimulus	guttatus	39.9
	Scrophulariaceae	Veronica	americana	1.3
Hidden:	Compositae	Cirsium	vulgare	11.3
	Compositae	Cirsium	arvense	16.2
	Cyperaceae	Carex	sp.	6.0
	Gramineae	Poa	sp.	1.5
	Onagraceae	Epilobium	ciliatum	3.8
	Scrophulariaceae	Mimulus	guttatus	48.7
	Urticaceae	Urtica	dioica	12.5

APPENDIX 5

Plant taxonomic names, wetland indicator status, and frequency of occurrence in nineteen Warner Basin springs sampled in July - August, 1998.

Family	Genus	Species	Wetland Indicator status*	# of springs
Scrophulariaceae	Mimulus	guttatus	OBL	19
Cyperaceae	Carex	sp.	FACW	18
Onagraceae	Epilobium	ciliatum	FACW	16
Gramineae	Poa	sp.	FAC	15
Gramineae	Agrostis	sp.	FAC	14
Juncaceae	Juncus	sp.	FACW	14
Compositae	Achillea	millefolium	UP	9
Leguminosae	Trifolium	wormskjoldii	FACW	9
Gramineae	Phleum	sp.	FAC	8
Gramineae	Hordeum	sp.	FACW	7
Caryophyllaceae	Stellaria	longipes	UP	6
Polygonaceae	Rumex	salicifolius	FACW	6
Scrophulariaceae	Veronica	americana	OBL	6
Urticaceae	Urtica	dioica	FAC	6
Portulacaceae	Montia	fontana	OBL	5
Compositae	Cirsium	vulgare	UP	4
Cyperaceae	Eleocharis	sp.	OBL	4
Gramineae	Deschampsia	sp.	FACW	4
Portulacaceae	Montia	chamissoi	OBL	4
Gramineae	Alopecurus	sp.	FACW	3
Gramineae	Torreyochloa	sp.	FAC	3
Ranunculaceae	Ranunculus	aquatilis	OBL	3
Brachytheciaceae	Brachythecium	frigidum	FACW	2
Compositae	Artemesia	sp.	UP	2
Gramineae	Agropyron	sp.	UP	2
Gramineae	Glyceria	sp.	OBL	2
Liliaceae	Veratrum	californicum	FACW	2
Orchidaceae	Habenaria	dilatata	UP	2
Rosaceae	Potentilla	gracilis	FAC	2
Umbelliferae	Perideria	gairdneri	UP	2

* OBL = obligate wetland , FACW = facultative wetland, FAC = facultative, UP = obligate upland (Reed 1988)

APPENDIX 5 (continued)

Family	Genus	Species	Wetland Indicator status*	# of springs
Amblystegiaceae	Leptodictyum	riparium	FACW	1
Bartramiaceae	Philonotis	fontana	FAC	1
Brassicaceae	Cardamine	breweri	OBL	1
Compositae	Aster	occidentalis	UP	1
Compositae	Aster	eatonii	UP	1
Compositae	Aster	sp.	UP	1
Compositae	Aster	foliaceus	UP	1
Compositae	Cirsium	arvense	UP	1
Compositae	Conyza	canadensis	UP	1
Compositae	Senecio	triangularis	UP	1
Cruciferae	Barbarea	orthoceras	FAC	1
Cruciferae	Rorippa	nasturtium-aquaticum	OBL	1
Cyperaceae	Scirpus	sp.	OBL	1
Gramineae	Bromus	sp.	UP	1
Gramineae	Elymus	sp.	UP	1
Gramineae	Phalaris	sp.	FAC	1
Gramineae	Polypogon	sp.	FAC	1
Lemnaceae	Lemna	minor	OBL	1
Onagraceae	Circaea	alpina	UP	1
Onagraceae	Epilobium	glaberrimum	FACW	1
Onagraceae	Epilobium	densiflorum	FACW	1
Polygonaceae	Polygonum	aviculare	UP	1
Polygonaceae	Rumex	occidentalis	UP	1
Ranunculaceae	Aconitum	columbianum	UP	1
Ranunculaceae	Aquilegia	formosa	UP	1
Rosaceae	Rosa	nutkana	FAC	1
Rubiaceae	Galium	triflorum	UP	1
Saxifragaceae	Saxifraga	oregana	FACW	1
Typhaceae	Typha	latifolia	OBL	1
Umbelliferae	Berula	erecta	UP	1

* OBL = obligate wetland , FACW = facultative wetland, FAC = facultative, UP = obligate upland (Reed 1988)

APPENDIX 6

Benthic invertebrates in Warner Basin springs and frequency of occurrence in Warner Basin streams. Frequency based on taxa presence in 81 samples from nine Warner Basin streams in Vinson, 1995. Very abundant >75%, abundant = 50-74%, common = 30-49%, rare = 10-24%, very rare <10% of samples contained the taxon.

TAXA IDENTIFIED IN 1998:

Order	Family/Tribe	Genus/species	Frequency in streams
Acari			very abundant
Amphipoda			rare
Annelida	Hirudinoidae		very rare
Annelida	Planariidae		rare
Coleoptera	Dytiscidae	Agabini	very rare
Coleoptera	Dytiscidae	Colymbetini	very rare
Coleoptera	Dytiscidae	Hydroporini	very rare
Coleoptera	Dytiscidae	Laccophilus	not found
Coleoptera	Dytiscidae	Bidessini	not found
Coleoptera	Elmidae	Heterlimnius	very rare
Coleoptera	Elmidae	Optioservus	very abundant
Coleoptera	Elmidae	Zaitzevia	abundant
Coleoptera	Helophoridae Helophorinae		very rare
Coleoptera	Helophoridae	Helophorus	very rare
Coleoptera	Hydraenidae	Hydraena	not found
Coleoptera	Hydrophilidae	Ametor	not found
Coleoptera	Hydrophilidae	Cymbiodyta	not found
Coleoptera	Hydrophilidae	Hydrobius	not found
Coleoptera	Hydrophilidae	Laccobius	not found
Coleoptera	Hydrophilidae	Paracymus	not found
Coleoptera	Hydrophilidae	Tropisternus	very rare
Coleoptera	Hydrophilidae	Unknown 1	unknown
Coleoptera	Hydrophilidae	Unknown 2	unknown
Collembola			very rare
Copepoda	Cyclopoid		rare
Copepoda	Harpacticoid		rare
Diptera	Ceratopogonidae	Forcipomyia	very rare
Diptera	Ceratopogonidae	Stilobezzia	not found
Diptera	Chironomidae Chironomini		abundant
Diptera	Chironomidae Orthocladiinae		abundant
Diptera	Chironomidae Prodiamesinae	Prodiamesa	abundant
Diptera	Chironomidae Tanypodinae		abundant
Diptera	Chironomidae Tanytarsini		abundant
Diptera	Culicidae	Culiseta	not found
Diptera	Dixidae	Dixa	not found
Diptera	Dixidae	Dixella	not found
Diptera	Empididae	Clinocera	very rare
Diptera	Ephydridae	Notiphila	not found
Diptera	Ephydridae	Discocerina	not found
Diptera	Ephydridae	Unknown 1	unknown
Diptera	Ephydridae	Unknown 2	unknown

APPENDIX 6 (Continued)

Order	Family/Tribe	Genus/species	Frequency in streams
Diptera	Ephydridae	Unknown 3	unknown
Diptera	Psychodidae	Pericoma/Telmatoscopus	very rare
Diptera	Psychodidae	Psychoda	not found
Diptera	Ptychopteridae	Ptychoptera	not found
Diptera	Simulidae	Prosimilium	very rare
Diptera	Simulidae	Simulium	common
Diptera	Stratiomyidae	Odontomyia	not found
Diptera	Tabanidae	Tabanus	very rare
Diptera	Thaumaleidae		not found
Diptera	Tipulidae	Dicranota	very rare
Diptera	Tipulidae	Limonia	not found
Diptera	Tipulidae	Pedicia	not found
Diptera	Tipulidae	Tipula	very rare
Diptera	Unknown 1		unknown
Diptera	Unknown 3		unknown
Diptera	Unknown 4		unknown
Diptera	Unknown 5		unknown
Diptera	Unknown 6		unknown
Diptera	Unknown 7		unknown
Diptera	Unknown 8		unknown
Ephemeroptera	Ameletidae	Ameletus	very rare
Ephemeroptera	Baetidae	Callibaetis	very rare
Ephemeroptera	Baetidae	Labiobaetis	very abundant
Ephemeroptera	Ephemerellidae	Ephemerella	rare
Ephemeroptera	Ephemerellidae	Serratella	rare
Ephemeroptera	Heptageniidae	Cinygmula	rare
Gastropoda	Hydrobiidae		not found
Gastropoda	Physidae	Physa/Physella	very rare
Gastropoda	Planorbidae	Gyraulus	very rare
Gastropoda	Pleuroceridae	Juga	not found
Gastropoda	Lymnaeidae	Fossaria	very rare
Gastropoda	Lymnaeidae	Stagnicola	not found
Hemiptera	Corixidae	Hesperocorixa	very rare
Hemiptera	Gerridae	Gerris	not found
Hemiptera	Gerridae	Limnoporus	not found
Hemiptera	Macroveliidae	Macrovelia	not found
Hemiptera	Mesoveliidae	Mesovelia	not found
Hemiptera	Notonectidae	Notonecta	not found
Nematoda			common
Odonata	Anisoptera		very rare
Odonata	Coenagrionidae	Argia	common
Odonata	Lestidae	Lestes	not found
Oligochaeta			common
Ostracoda			common
Pelecypoda	Sphaeriidae		very rare
Plecoptera	Chloroperlidae	Haploperla	very rare
Plecoptera	Chloroperlidae	Triznaka	not found

APPENDIX 6 (Continued)

Order	Family/Tribe	Genus/species	Frequency in streams
Plecoptera	Nemouridae	Malenka	rare
Plecoptera	Nemouridae	Zapada	very rare
Plecoptera	Peltoperlidae	Yoroperla	not found
Plecoptera	Perlidae	Hesperoperla	very rare
Plecoptera	Perlodidae	Rickera/Kogotus	not found
Plecoptera	Perlodidae	Skwala	common
Trichoptera	Brachycentridae	Micrasema	very rare
Trichoptera	Glossosomatidae	Glossosoma	rare
Trichoptera	Hydropsychidae	Arctopsyche	very rare
Trichoptera	Hydropsychidae	Parapsyche	very rare
Trichoptera	Hydroptilidae	Hydroptila	rare
Trichoptera	Lepidostomatidae	Lepidostoma	very rare
Trichoptera	Limnephilidae	Clostoeca	not found
Trichoptera	Limnephilidae	Hesperophylax	not found
Trichoptera	Limnephilidae	Limnephilus	not found
Trichoptera	Limnephilidae	Pseudostenophylax edwarsii	not found
Trichoptera	Limnephilidae	Psychoglypha	very rare
Trichoptera	Limnephilidae	Unknown 1	unknown
Trichoptera	Limnephilidae	Unknown 2	unknown
Trichoptera	Limnephilidae	Unknown 3	unknown
Trichoptera	Philopotamidae	Wormaldia	very rare
Trichoptera	Rhyacophilidae	Rhyacophila	very rare

ADDITIONAL TAXA IDENTIFIED IN 1999:

Coleoptera	Hydrophilidae	Enochrus	not found
Coleoptera	Hydrophilidae	Sperchopsis	not found
Diptera	Ceratopogonidae	Atrichopogon	rare
Diptera	Ceratopogonidae	Bezzia/Palpomyia	very rare
Diptera	Ceratopogonidae	Ceratopogon	not found
Diptera	Ceratopogonidae	Culicoides	not found
Diptera	Chironomidae Diamesinae		abundant
Diptera	Dixidae	Meringodixa	not found
Diptera	Tipulidae	Unknown 1	unknown
Diptera	Tipulidae	Unknown 2	unknown
Diptera	Unknown 9		unknown
Diptera	Unknown 10		unknown
Diptera	Unknown 12		unknown
Ephemeroptera	Heptageniidae	Ironodes	not found
Ephemeroptera	Leptophlebiidae	Paraleptophlebia	very abundant
Ephemeroptera	Tricorythidae	Tricorythodes	abundant
Neuroptera	Unknown 1		unknown
Trichoptera	Apataniidae	Apatania	not found
Trichoptera	Unknown 6		unknown
Trichoptera	Limnephilidae	Unknown 7	unknown
Trichoptera	Philopotamidae	Chimarra	very rare
Trichoptera	Unknown 4		unknown
Trichoptera	Unknown 5		unknown
Trichoptera	Uenoidea	Neophylax	very rare