Environmental Profile of *Drunella grandis* Eaton (Ephemeroptera: Ephemerellidae) in the Western United States

Frederick A. Mangum
Intermountain Region, USDA, Forest Service
Federal Bldg. 324-25th St. ,Ogden, UT 84401
and
Robert N. Winget
MSC Division, 55-220 Kulanui St.
Brigham Young Univ.-Hawaii, Laie, HI 96762

ABSTRACT

In 898 stream stations in 11 western states, *Drunella grandis* Eaton exhibited broad physical habitat niche dimensions but moderate to narrow water quality niche dimensions. Nymphs were found over a wide range of channel gradients and substrate types, with tolerance to fine substrates as long as there were some rocky substrates. Occurrence was mostly random in relation to riparian vegetation. Nymphs were found in waters with a wide range of alkalinities, but frequency was low when alkalinity exceeded 250 mg/l. *Drunella grandis* commonly inhabited streams with conductivity over 400 µmhos/cm but was rarely found when it exceeded 800 µmhos/cm. Nymphs were found in higher than expected frequencies when sulfates were less than 50 mg/l, lower than expected when sulfates are 75-250 mg/l, and were not found in waters with sulfates over 250 mg/l. Distribution was near random over all states sampled with occurrence higher than expected at elevations between 6,000 and 8,000 feet.

INTRODUCTION

The diversity of aquatic invertebrates in the earth's surface waters and their specific physiological, morphological and behavioral adaptations provide a multidimensional tool for evaluation of environmental quality. Many benthic taxa have considerable tolerance to the perturbations man or nature imposes upon aquatic ecosystems (Winget and Mangum 1991) and thus have a wide "niche breadth" (Colwell and Futuyma 1971, Pielou 1972). Other taxa are more limited in the kinds and intensities of environmental factors they can tolerate and have a narrow "niche breadth" (Mangum and Winget 1991). This paper describes niche dimensions of *D. grandis* in 898 stream stations in 11 western states (Figure 1).

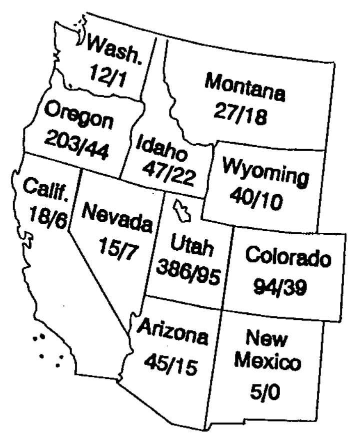

Figure 1. Number of stream sampling stations per state/number of stations *Drunella grandis* was collected.

METHODS

Methods used are presented in detail in Winget and Mangum (1991).

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RESULTS AND DISCUSSION

Merritt and Cummins (1984) characterized *D. grandis* as being widespread, exhibiting scraper and possibly predator feeding modes, and with clinging and sprawling habits. Edmunds et al. (1976) established that *D. grandis* is found in the southwestern and northwestern United States with a Neartic range extending from Alaska, British Columbia and Alberta in the north to Baja, California and New Mexico in the south. Adults mostly emerge from early June to early July but emergence may continue until late August at higher altitudes. Eggs hatch in September and young nymphs are found in streams through the winter. Growth is rapid in spring and early summer. In this study *D. grandis* Eaton was found in streams in ten of eleven western states sampled (Figure 1). This species was not found in any of the five streams sampled in New Mexico but this could be a result of small sample size. *Drunella grandis* occurred in more Colorado (p=0.01) and Idaho (p=.025) streams than was expected, but distribution in the other eight states was not significantly different from random.

Table 1. Occurrence of *Drunella grandis* according to elevation, minimum stream flows and percent stream channel gradient. ns = not significant; - = less than expected; + = more than expected; * = 0.1; ** = 0.01; * = 0.0001**

Station Variable	Total No. of Stns. No.	\ Rel. Freq.	Stns. with *D. grandis* No.	\ Rel. Freq.	Chi-Square Values
Elevation in Feet Above Sea Level					
≤2000 ft	52	0.067	9	0.043	1.789ns
-4000 ft	131	0.169	12	0.057	15.364-***
-5000 ft	108	0.139	24	0.115	0.890ns
-6000 ft	135	0.135	26	0.124	2.952-*
-7000 ft	114	0.147	44	0.211	5.758+**
-8000 ft	107	0.138	48	0.230	12.768+***
-9000 ft	78	0.100	30	0.144	3.849+*
>9000 ft	51	0.066	16	0.077	0.373ns
Minimum Stream Flows - cfs					
≤ 0.5 cfs	49	0.113	8	0.074	1.442ns
- 1 cfs	64	0.147	13	0.120	0.538ns
- 2 cfs	49	0.113	8	0.074	1.442ns
- 5 cfs	106	0.244	31	0.287	0.810ns
- 15 cfs	79	0.182	22	0.204	0.279ns
> 15 cfs	87	0.200	26	0.241	2.037ns
Percent Stream Channel Gradient					
≤ 1%	225	0.309	44	0.206	7.462-**
- 2%	215	0.296	86	0.402	8.151+**
- 3%	135	0.186	44	0.206	0.457ns
- 4%	72	0.099	21	0.098	0.002ns
- 5%	49	0.067	14	0.065	0.012ns
> 5%	31	0.043	5	0.023	3.495-*

Drunella grandis exhibited tolerance to low flows as shown by near random distribution at streams with low annual minimum flows (Table 1). This would indicate a moderate tolerance, at least for short periods of time, to conditions related to low stream flows. The strong avoidance of *D. grandis* of streams with channel gradients less than one percent indicates that slow water velocities and often related low dissolved oxygen levels are not tolerated well by this species. Low flow is not an important limiting factor to the distribution of *D. grandis* as long as gradient is great enough to guarantee adequate water velocities and the associated energy needed to keep some of the substrates clean.Allen and Edmunds (1962) recorded that nymphs of *D. grandis* were collected at elevations from 1,300 to 3,250 meters (4,000 to 10,000 feet) but were most common in streams near 2,300 meters (7,000 feet). In our study, *D. grandis* was collected from elevations between just above sea level to over 9,000 ft (Table 1). Nymphs were found more often than expected between 6,000 to 8,000 ft elevation and less than expected at from 2,000 to 6,000 ft elevation.

Drunella grandis was commonly found at stream gradients between one and five percent but strongly avoided gradients greater than five percent. Gradient is directly related with conditions important to survival of aquatic insects. DeMarch (1976) reported that measurement of current velocity at any single point is essentially meaningless in relation to describing the ecology of a stream stretch. He recommended a close examination of sediments as a better indicator of present and past stream current conditions. As stream gradient increases: velocity, substrate coarseness, dissolved oxygen, and recovery rate following physical or chemical perturbations all increase; and water depth per volume of discharge decreases.

Distribution of *D. grandis* nymphs was near random for all substrate composition categories except when boulders or sand/silt were first in dominance, and even then the difference was not highly significant (Table 2). This confirms a tolerance to low gradient streams with abundant sand/silt substrates as long as rocky substrates are also present. This is shown by the non-significant difference between frequency of stations occupied and total stations available when fine substrates were either fourth, third or even second in dominance of area covered, but frequency of occurrence was significantly less when fine substrates were first in dominance. Brusven and Rose (1981) found that *D. grandis* was a victim of predation 95-100% of the time when on a sandy substrate, but predation was less when different combinations of cobbles and pebbles were present. Rabeni and Minshall (1977) found that *D. grandis* was most successful in riffle substrates or in pools which included rock substrates. As Robinson and Minshall (1986) reported, absolute densities of *D. grandis* nymphs were not only related to substrate composition but also to stability of substrates. They reported that densities decreased in direct proportion to the frequency of substrate disturbances. Gilpin and Brusven (1970) reported that *D. grandis* was found occupying all substrates except ooze and silt, commonly found on organic debris in substrate interstices.

Many specific aspects of organism-substrate relationships have been studied in streams. Sheldon and Haick (1981) discovered strong separation of five species of *Ephemerella [Drunella]* by habitat differences, especially substrate composition. Hawkins (1984) suggested that for twelve species of Ephemerellidae, adaptive radiation of species and patterns of longitudinal distribution of these species resulted from specificity for different substrates. This is obvious for *Drunella doddsi* (Mangum and Winget 1991) that selected strongly for clean coarse substrates with little tolerance to sand or silt. A closely related mayfly, *Tricorythodes minutus*, selected for just the opposite, fines with little coarse substrates (Winget and Mangum 1991).

Table 2. Occurrence of *Drunella grandis* at stations classified according to dominance (first through fourth) of substrate components. - = less than expected; + = more than expected; ns = not significant; * = 0.1; ** = 0.01; *** = 0.001

Station Variable	Total No. of Stns. No.	Rel. Freq.	Stns. with *D. grandis* No.	Rel. Freq.	Chi-Square Values
Boulder Substrate					
1	62	0.076	9	0.041	3.660-*
2	142	0.175	43	0.195	0.501ns
3	130	0.160	35	0.158	0.003ns
4	479	0.589	134	0.606	0.110ns
Rubble Substrate					
1	372	0.458	116	0.525	2.189ns
2	213	0.262	49	0.222	1.368ns
3	154	0.189	36	0.163	0.821ns
4	74	0.091	20	0.090	0.001ns
Gravel Substrate					
1	218	0.268	64	0.290	0.379ns
2	298	0.367	84	0.380	0.111ns
3	224	0.276	58	0.262	0.137ns
4	73	0.090	15	0.068	1.182ns
Fine-Sized (Sand, Silt & Clay) Substrates					
1	154	0.189	29	0.131	3.811-*
2	165	0.203	41	0.186	0.027ns
3	235	0.289	78	0.353	1.662ns
4	259	0.319	73	0.330	0.013ns

Occurrence of *D. grandis* relative to riparian vegetation composition or percent cover was mostly random (Table 3). The few associations that were not entirely random were only slightly different (p=0.1). *Drunella grandis* shows broad niche dimensions for riparian vegetation types and stream substrates occupied. This in agreement with a generalist strategy for physical habitat occupancy. As reported by Mangum and Winget (1991), a related species, *Drunella doddsi,* selected a specialist strategy and is found in very specific substrate types and in streams with dense riparian vegetation, usually containing numerous trees. Winget and Mangum (1991) also reported on another related species, *Tricorythodes minutus,* that is also a specialist but is found in streams dominated by fine substrates and with sparse riparian vegetation with few, if any trees.

Results of this study show *D. grandis* inhabited streams with a broad range of alkalinities, but exhibited a preference for streams with 50 to 200 mg/l alkalinity. Occurrence at stations with alkalinity between 200 and 250 mg/l was random with no preference or avoidance. *Drunella grandis* was found significantly less than expected at stations with alkalinities over 250 mg/l (Table 4). These findings are in agreement with those of Osborne (1981). He reported productivity of *D. grandis* was significantly higher when alkalinities were 150 mg/l or higher than when they were less than 50 mg/l. Andrews and Minshall (1979) reported *D. grandis* was found in six of the "Lost Streams" of Idaho with a wide range of alkalinities, 100 to 250 mg/l. They did not report on streams with alkalinities over 250 mg/l.

Table 3. Occurrence of *Drunella grandis* according to cover dominance (first to fourth) of stream bank vegetation. ns = not significant; * = 0.1; ** = 0.01; * = 0.001**

Station	Total No. of Stns.		Stns. with *grandis* No.		Chi-Square
Riparian Vegetation Lacking					
1	106	0.137	18	0.084	4.472-*
2	106	0.137	28	0.130	0.075ns
3	109	0.141	31	0.144	0.015ns
4	102	0.132	33	0.153	0.756ns
5	350	0.453	105	0.488	0.601ns
Grass Vegetation					
1	277	0.358	76	0.353	0.014ns
2	151	0.195	47	0.219	0.596ns
3	153	0.198	52	0.242	2.096ns
4	133	0.172	25	0.116	3.888-*
5	59	0.076	15	0.070	0.121ns
Brush Vegetation					
1	209	0.270	68	0.316	1.676ns
2	300	0.388	66	0.307	3.646-*
3	166	0.215	47	0.219	0.015ns
4	31	0.040	7	0.033	0.305ns
5	67	0.087	27	0.126	3.755+*
Deciduous Tree Vegetation					
1	111	0.144	33	0.153	0.147ns
2	124	0.160	44	0.205	2.623ns
3	145	0.188	29	0.135	3.183-*
4	143	0.185	37	0.172	0.193ns
5	250	0.323	72	0.335	0.087ns
Coniferous Tree Vegetation					
1	63	0.082	18	0.084	0.013ns
2	82	0.106	23	0.107	0.002ns
3	119	0.154	28	0.130	0.785ns
4	102	0.132	26	0.121	0.198ns
5	407	0.527	120	0.558	0.408ns

Drunella grandis commonly inhabited streams with conductivities up to 600 µmhos/cm but strongly avoided streams with conductivities over 800 µhos/cm (Table 4). This, and the broad range of alkalinities *D. grandis* inhabits, indicates a moderate tolerance to water quality conditions, but *D. grandis* showed an intolerance to water sulfate concentrations, a narrow water quality niche dimension. Nymphs were found in higher than expected frequencies when sulfates were less than 25 mg/l. Most were found in streams with less than 10 mg/l sulfates. Frequency of occurrence was less than expected when waters had over 75 mg/l sulfates, and *D. grandis* nymphs were not found in waters with sulfates over 250 mg/l. Mangum and Winget (1991) reported that *Drunella doddsi*, a related mayfly species, has even narrower water quality niche dimensions than *D. grandis.*

Table 4. Occurrence of *Drunella grandis* at stations according to alkalinity, sulfate, and specific conductance levels. ns = not significant; * = 0.1; ** = 0.01; *** = 0.001

Station Variable	Total Number of Stations No. \ Rel. Freq.		Stations with *D. grandis* No. \ Rel. Freq.		Chi-Square Values
Total Alkalinity as mg/l $CaCO_3$					
≤ 50	206	0.276	57	0.291	0.153ns
- 100	145	0.194	52	0.265	5.074-*
- 150	111	0.149	33	0.168	0.505ns
- 200	94	0.126	30	0.153	1.139ns
- 250	67	0.090	18	0.092	0.009ns
- 300	48	0.064	3	0.015	7.325-**
- 350	47	0.063	3	0.015	7.077-**
> 350	28	0.038	0	0.000	7.357-*
Sulfate as mg/l					
≤ 10	315	0.467	96	0.508	8.406+**
- 25	126	0.187	57	0.302	6.124+*
- 50	57	0.084	15	0.079	0.699ns
- 75	40	0.059	15	0.079	0.289ns
> 75	137	0.203	6	0.032	27.338-***
Specific Conductance as mhos/cm					
≤ 100	150	0.238	40	0.255	0.175ns
- 200	124	0.197	43	0.274	4.691+*
- 300	64	0.102	26	0.166	6.292+*
- 400	60	0.095	22	0.140	3.294+*
- 600	86	0.137	18	0.115	0.560ns
- 800	47	0.075	6	0.038	2.800-*
> 800	98	0.156	2	0.013	20.653-***

Rader and Ward (1989) reported that *D. grandis* populations above a deep release reservoir was detritivorous but consumed mostly diatoms below the reservoir. Short (1983) had observed that the main diet of *D. grandis* in a Colorado trout stream was detritus. The fact that *D. grandis* fed almost entirely upon diatoms below the reservoir illustrates the opportunistic feeding habits of this mayfly species. Hawkins (1985) discovered that members of the family Ephemerellidae had undergone significant adaptive radiation in diet; closely related species did not group together by traditional feeding categories. He reported that *D. grandis* ate almost anything that came along, including animal material (predator) and coarse organic particulate material (shredder). *Drunella grandis* has selected a generalist strategy for coping with the challenge of acquiring adequate food. Instead of acquiring highly effective specialist food acquiring skills, this species has opted for moderate skills for acquiring a wider range of food items. Rader and Ward (1987) reported that peaks in temporal food resource utilization by several species of aquatic macroinvertebrates in a mountain stream were aggregated. Rader (1987) also was unable to demonstrate that food was commonly a limiting resource in the upper Colorado River, at least for Ephemerellidae species. Even if food is not always a major limiting resource in mountain streams, a wide array of foods utilized by a single species would contribute to that species' niche breadth and increase its options when food is limiting. Thus, the ability of *D. grandis* to be a detritivore and diatom grazer coupled with its tolerance to fine sediments helps explain its broad physical habitat niche dimensions.

In the 898 stations sampled, the niche hypervolume of *D. grandis* had broad physical habitat dimensions but moderate to narrow water quality dimensions. *Drunella grandis* is moderately tolerant to environmental conditions when compared with *Drunella doddsi,* an environmentally intolerant mayfly with narrow physical and chemical niche width dimensions and the obviously tolerant mayfly, *Tricorythodes minutus*, two closely related species.

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