Table 1. List of Utah cold water preference taxa. Distribution and abundance information is also included. Sum_Individuals=the total number of individuals from that taxon in the Utah database; Pct_Abund=percent of total individuals in the database comprised of that taxon; Num_Stations=number of stations in the database that the taxon occurred at; Pct_Stations=percent of stations in the database at which the taxon occurred.

Type	Order	Family	FinalID	Sum_Individs	Pct_Abund	Num_Stations	Pct_Stations
cold	Ephemeroptera	Ameletidae	Ameletus	13157.6	0.03	137	21.57
cold	Trichoptera	Glossosomatidae	Anagapetus	42	0	2	0.31
cold	Trichoptera	Apataniidae	Apatania	20154.3	0.04	39	6.14
cold	Diptera	Ceratopogonidae	Bezzia	109267.1	0.23	232	36.54
cold	Diptera	Blephariceridae	Bibiocephala	2257	0	15	2.36
cold	Plecoptera	Capniidae	Capniidae	113578.8	0.24	228	35.91
cold	Diptera	Empididae	Chelifera	94014.1	0.2	261	41.1
cold	Plecoptera	Chloroperlidae	Chloroperlidae	203579.9	0.44	309	48.66
cold	Ephemeroptera	Heptageniidae	Cinygma	606.2	0	6	0.94
cold	Ephemeroptera	Heptageniidae	Cinygmula	479866.5	1.03	278	43.78
cold	Plecoptera	Perlodidae	Cultus	20419.7	0.04	97	15.28
cold	Diptera	Tipulidae	Dicranota	35439.2	0.08	220	34.65
cold	Trichoptera	Limnephilidae	Ecclisomyia	1262.8	0	14	2.2
cold	Ephemeroptera	Ephemerellidae	Ephemerella	859335.8	1.85	292	45.98
cold	Plecoptera	Pelecorhynchidae	Glutops	91	0	4	0.63
cold	Coleoptera	Elmidae	Heterlimnius	16463	0.04	50	7.87
cold	Ephemeroptera	Heptageniidae	Ironodes	551.6	0	6	0.94
cold	Plecoptera	Perlodidae	Kogotus	1288.7	0	14	2.2
cold	Trichoptera	Lepidostomatidae	Lepidostoma	353679.8	0.76	240	37.8
cold	Plecoptera	Leuctridae	Leuctridae	21176.5	0.05	106	16.69
cold	Plecoptera	Perlodidae	Megarcys	7129.9	0.02	65	10.24
cold	Dorylaimida	Dorylaimidae	Nematoda	141425.3	0.3	249	39.21
cold	Trichoptera	Uenoidae	Neothremma	129853.8	0.28	100	15.75
cold	Trichoptera	Uenoidae	Oligophlebodes	147256.9	0.32	101	15.91
cold	Diptera	Empididae	Oreogeton	228.5	0	13	2.05

Table 1. continued…

Type	Order	Family	FinalID	Sum_Individs	Pct_Abund	Num_Stations	Pct_Stations
cold	Trichoptera	Hydropsychidae	Parapsyche	3552.5	0.01	40	6.3
cold	Diptera	Psychodidae	Pericoma	145582.7	0.31	210	33.07
cold	Diptera	Tipulidae	Rhabdomastix	8	0	1	0.16
cold	Ephemeroptera	Heptageniidae	Rhithrogena	198501.8	0.43	243	38.27
cold	Plecoptera	Taeniopterygidae	Taenionema	79949.8	0.17	87	13.7
cold	Plecoptera	Nemouridae	Visoka	50	0	1	0.16
cold	Diptera	Empididae	Wiedemannia	458	0	13	2.05
cold	Plecoptera	Peltoperlidae	Yoraperla	72.7	0	5	0.79

Table 2. List of Utah warm water preference taxa. Distribution and abundance information is also included. Sum_Individuals=the total number of individuals from that taxon in the Utah database; Pct_Abund=percent of total individuals in the database comprised of that taxon; Num_Stations=number of stations in the database that the taxon occurred at; Pct_Stations=percent of stations in the database at which the taxon occurred.

Type	Order	Family	FinalID	Sum_Individs	Pct_Abund	Num_Stations	Pct_Stations
warm	Hemiptera	Naucoridae	Ambrysus	25879.7	0.06	39	6.14
warm	Isopoda	Asellidae	Asellidae	1450840.4	3.12	81	12.76
warm	Ephemeroptera	Caenidae	Caenis	567	0	11	1.73
warm	Plecoptera	Perlidae	Calineuria	245	0	9	1.42
warm	Diptera	Stratiomyidae	Caloparyphus	9652	0.02	26	4.09
warm	Trichoptera	Hydropsychidae	Cheumatopsyche	172233.9	0.37	105	16.54
warm	Odonata	Coenagrionidae	Coenagrionidae	45144.1	0.1	117	18.43
warm	Ephemeroptera	Leptohyphidae	Leptohyphidae	659670.3	1.42	197	31.02
warm	Diptera	Psychodidae	Maruina	1140.2	0	16	2.52
warm	Coleoptera	Elmidae	Microcylloepus	114016	0.24	50	7.87
warm	Trichoptera	Leptoceridae	Nectopsyche	8434.7	0.02	35	5.51
warm	Trichoptera	Hydroptilidae	Ochrotrichia	6768.2	0.01	29	4.57
warm	Trichoptera	Leptoceridae	Oecetis	28993.3	0.06	90	14.17
warm	Coleoptera	Elmidae	Ordobrevia	360	0	5	0.79
warm	Coleoptera	Psephenidae	Psephenus	65.8	0	4	0.63
warm	Trichoptera	Psychomyiidae	Tinodes	12774.6	0.03	34	5.35

Development of the Utah cold and warm water preference lists

Sources. The Utah cold and warm water taxa lists were developed using several different sources: 1. weighted average calculations based on a subset of the Utah biomonitoring database (done by Lei Zheng of Tetra Tech, using fall samples (sample size=572); 2. the thermal preference trait from the Poff et al. 2006 traits matrix; 3. the thermal preference trait from the USGS traits database (Vieira et al. 2006); 4. the thermal preference trait from the compilation of EPA Environmental Requirements and Pollution Tolerance series from the late 1970's (Beck et al. 1977, Harris et al. 1978, Hubbard et al. 1978, Surdick et al. 1978); and 5. best professional judgment of the Utah Climate Change feedback group.

Cold water designation. Taxa were placed on the Utah cold water taxa list if they met the following criteria: 1. They received a rank temperature optima value of 1 or 2 or 3 (the rank optima value is based on percentiles of the dataset; for these taxa, the weighted average optima value was less than the 0.4 percentile value of the dataset it was derived from); or 2. the thermal preference in the Poff et al. 2006 traits matrix was 'cold_cool'; or 3. The thermal preference in the USGS traits database (Vieira et al. 2006) was 'cold stenothermal' or 'cold-cool eurythermal' (temperature preference of less than 15°C); or 4. The thermal preference in the EPA Environmental Requirements and Pollution Tolerance series (which were interpreted by Jen Stamp) was 'oligothermal' or 'stenothermal' or 'metathermal' (temperature preference of less than 15°C); or 5. If anyone in the Utah Climate Change feedback group felt a taxa should be added to this list.

Warm water designation. Taxa were placed on the Utah warm water taxa list if they met the following criteria: 1. They received a rank temperature optima value of 5 or 6 or 7 (the rank optima value is based on percentiles of the dataset; for these taxa, the weighted average optima value was greater than the 0.6 percentile value of the dataset it was derived from); or 2. the thermal preference in the Poff et al. 2006 traits matrix was 'warm'; or 3. The thermal preference in the USGS traits database (Vieira et al. 2006) was 'hot euthermal' or 'warm eurythermal' (temperature preference of greater than 15°C); or 4. The thermal preference in the EPA Environmental Requirements and Pollution Tolerance series (which were interpreted by Jen Stamp) was 'euthermal' or 'eurythermal' or 'mesothermal' (temperature preference of greater than 15°C); or 5. If anyone in the Utah Climate Change feedback group felt a taxa should be added to this list.

Limitations. These lists were developed using the best information available, but it should be noted that the available information is limited. The weighted average calculations are based on instantaneous water temperature measurements that were taken at the time of the sampling event. Ideally continuous water temperature data could have been used, since this would provide more information about the thermal regime, especially during times of greatest thermal stress (i.e. summer baseflow conditions). The weighted average calculations also have limitations. One of the main concerns is that the analysis does not take into account the confounding factors ('noise') that are not related to temperature. However, with a sufficient amount of data, the noise essentially cancels itself out. Another limitation is that the operational taxonomic unit (OTU) that was most appropriate for this analysis is at the genus-level (in some instances, family-level

was most appropriate). Within certain genera in particular, the thermal preference among species varies, so the assigned thermal preference may not be appropriate for all species within a genera. Attempts were made to note these genera. Also worth noting is that in Utah, due to taxonomic issues in the long-term dataset, a family-level OTU had to be used for Chironomidae, which may partly account for the relatively low number of taxa on the warm water list (in Maine and North Carolina, a number of midge genera were on the warm water lists).

We want to reiterate that when we developed these lists, we did the best we could with the data that was available. These lists should be viewed as a first step, not a final product. It would be very helpful if future research included a combination of short and long-term field and experimental studies designed to better evaluate climate change effects on freshwater ecosystems.

Initial Results. Initially there were 76 taxa on the cold water list and 53 taxa on the warm water list. These lists were based on weighted average calculations and literature. These lists were further refined through the evaluation of additional evidence. This evidence included analyses of other datasets, case studies, and best professional judgment. Taxa with the greatest amount of evidence were assigned cold or warm water designations. More detailed information about the steps that were used to develop these lists is summarized below:

Considerations

A. Results from weighted average or maximum likelihood thermal optima and tolerance calculations were a major consideration. Results from the following eight analyses were used:

- California - Herbst and Silldorff (2007)
- Idaho - Brandt (2001)
- Maine – EPA GCRP Maine (2010) (based on site average temperature values (July-September) from 616 sites in the Maine biomonitoring database)
- North Carolina - EPA GCRP North Carolina (2010) (based on maximum likelihood calculations for the North Carolina biomonitoring database, full-scale collection method only)
- Ohio – Rankin and Yoder (2009)
- Oregon - Oregon DEQ (2008)
- Utah - EPA GCRP Utah (2010) (based on 572 fall samples from the Utah biomonitoring database)
- Western EMAP - Yuan (2006) (Estimation and Application of Macroinvertebrate Tolerance Values. Report No. EPA/600/P-04/116F)

A scoring system was developed to summarize results from the eight different analyses. It takes into account thermal preference, thermal tolerance and sample size. Scores were assigned (for each of the eight analyses) as follows:

COLD WATER TAXA

- 2=cold stenotherm (rank optima of 1 or 2 or 3 and rank tolerance of 1 or 2 or 3), adequate sample size (20 or more counts)
- 1=cold preference (rank optima of 1 or 2 or 3), adequate sample size (20 or more counts)
- 1=cold stenotherm (rank optima of 1 or 2 or 3 and rank tolerance of 1 or 2 or 3), low sample size (less than 20 counts)
- 0.5=cold preference (rank optima of 1 or 2 or 3), low sample size (less than 20 counts)

WARM WATER TAXA

- 2=warm eurythermal (rank optima of 5 or 6 or 7 and rank tolerance of 5 or 6 or 7), adequate sample size (20 or more counts)
- 1=warm preference (rank optima of 5 or 6 or 7), adequate sample size (20 or more counts)
- 1= warm eurythermal (rank optima of 5 or 6 or 7 and rank tolerance of 5 or 6 or 7), low sample size (less than 20 counts)
- 0.5=warm preference (rank optima of 5 or 6 or 7), low sample size (less than 20 counts)

In addition to the weighted average and maximum likelihood results, information on thermal preferences was also derived from literature. The taxon received a score of 1 if it was cited as a cold or warm water taxon in at least one of the following sources: Poff et al. 2006 traits matrix; or USGS traits database (Vieira et al. 2006); or EPA Environmental Requirements and Pollution Tolerance series from the late 1970's (Beck et al. 1977, Harris et al. 1978, Hubbard et al. 1978, Surdick et al. 1978). If the weighted average results showed the taxon to have a preference for cold or warm water but the literature showed conflicting results (i.e. based on the weighted average results, the taxon was a cold water taxa, but the literature showed it to be a warm water taxa), then the taxon was not included on the cold or water water list.

After scores were assigned as described above, they were summed so that each taxon received a total score. The higher the total score, the more evidence there was in the eight analyses and the literature that supported the designation of the cold or warm water taxa.

B. A subset of the scores that included only the western states (California, Oregon, Idaho, Utah, Yuan Western EMAP) was also evaluated. The reasoning behind this is that the data from these states is more similar and therefore more comparable to Utah than data from Ohio, North Carolina and Maine. Therefore it was given more weight in the consideration process. Taxa that received higher scores had more evidence supporting their inclusion on the list. Cold and warm water taxa lists from these western states were also evaluated for conflicting evidence. If a taxon showed a preference for cold or warm water in Utah but was shown to have the opposite preference in the California, Oregon, Idaho or Yuan Western EMAP analyses (i.e. cold water taxon in Utah was listed as a warm water taxon in Oregon), it was not included on the list.

C. Several 'case studies' were performed to see whether the cold or warm water taxa occurred at sites in Utah that had the warmest or coldest water temperatures (June-September). The following case studies were performed:

> **a. Cold Water Case Study #1**. Taxa lists from 4 sites in the Wasatch and Uinta Mountains level 3 ecoregion that had the coldest average water temperatures (using June-September samples) and that had <2% urban and <10% agricultural land use/land cover within a 1 km buffer were evaluated. Sites include: Station 4938910 (avg temp 5.75°C, 0% urban, 0% agricultural), Station 4936700 (avg temp 9.1°C, 0.74% urban, 0% agricultural), Station 4935970 (avg temp 9.5°C, 0% urban, 0% agricultural), and Station 4995830 (avg temp 9.6°C, 0% urban, 0% agricultural).
>
> **b. Cold Water Case Study #2**. Taxa lists from 4 sites in the Colorado Plateaus level 3 ecoregion that had the coldest average water temperatures (using June-September samples) and that had <2% urban and <10% agricultural land use/land cover within a 1 km buffer were evaluated. Sites include: Station 4937720 (avg temp 10.9°C, 0.17% urban, 1.4% agricultural), Station 4936200 (avg temp 12.5°C, 0.11% urban, 0% agricultural), Station 4954140 (avg temp 14.1°C, 0% urban, 0% agricultural), and Station 4956480 (avg temp 14.2°C, 0% urban, 0% agricultural).
>
> **c. Warm Water Case Study #1**. Taxa lists from two sites in the Colorado Plateaus level 3 ecoregion that had the warmest average water temperatures (using June-September samples) and that had <2% urban and <10% agricultural land use/land cover within a 1 km buffer were evaluated. Sites include: Station 4933120 (avg temp 32°C, 1.6% urban, 3.4% agricultural) and Station 4950790 (avg temp 26.2°C, 0% urban, 0% agricultural).

D. In addition to the case studies, best professional judgment from the Utah Climate Change group[1] was taken into account.

[1] Utah Climate Change group: Jeff Ostermiller (Utah DEQ), Mark Vinson and Eric Dinger (formerly Utah State University Bug Lab), David Herbst (Sierra Nevada Aquatic Research Laboratory – University of California), Eric Hargett (Wyoming DEQ), Dan Mosely (Pyramid Lake Paiute Tribe), Shann Stringer (formerly New Mexico Env. Dept.)

Development of the Cold Water Taxa List. Taxa were placed on the cold water list if the following criteria were met:

1. The taxon was NOT present at the warm water case study site.
2. The taxon (and no species within the genera) was NOT on the warm water lists derived from the California, Oregon, Idaho and Yuan Western EMAP datasets.
3. The Utah Climate Change feedback group did not specify that they did not think the taxon should be on the list (based on best professional judgment).
4. The taxon had to be on the cold water taxa list in at least two of the western datasets, or if it was only listed in one dataset, it also had to be present at one or more of the cold water case study sites.

Development of the Warm Water Taxa List. Taxa were placed on the warm water list if the following criteria were met:

1. The taxon was NOT present at the cold water case study sites.
2. The taxon (and no species within the genera) was NOT on the cold water lists derived from the California, Oregon, Idaho and Yuan Western EMAP datasets.
3. The Utah Climate Change feedback group did not specify that they did not think the taxon should be on the list (based on best professional judgment).
4. The taxon had to be on the warm water taxa list in at least two of the western datasets, or if it was only listed in one dataset, it also had to be present at the warm water case study sites.

Cold and Warm Water Lists. The cold water taxa list was comprised of 33 taxa and the warm water taxa list was comprised of 16 taxa. Lists can be found in Tables 1 & 2.

Important Notes – variation within genera. Some noteworthy genera were left off the Utah cold water taxa list. These include Zapada, Epeorus, Drunella, Brachycentrus and Rhyacophila. The reason they were not included is because there is variation in temperature preferences among species within these genera. For example, *Zapada cinctipes* is on the warm water taxa lists in the Oregon and Idaho datasets, but the other species within this genus are listed as cold water taxa. *Epeorus albertae* is on the warm water list in the Oregon dataset, but other species within this genus are generally listed as cold water taxa. *Drunella grandis* is listed as a warm water taxa (barely – it received a rank optima score of 5) in the Oregon and Idaho datasets, but other species

within this genus are generally listed as cold water taxa. Within the family Rhyacophilidae, there are a few taxa that are listed as warm water taxa and several that are listed as cold water taxa. There is similar variation within the genus Brachycentrus.

Abundance and Distribution. Those taxa that are widespread and common are likely to have greater genetic diversity and greater chance of adapting than rare taxa that only occur in isolated, localized populations (Sweeney et al. 1992). Moreover, the more abundant taxa are more likely to affect the state biomonitoring assessments.

Abundance and distribution information for the cold and warm water taxa can be found in Tables 1 & 2. The most abundant cold water preference taxa are two Ephemeropterans, *Ephemerella* and *Cinygmula*, which comprise 1.85 and 1.03 percent of the total individuals, respectively. Twenty of the cold water taxa have overall abundances of less than 0.1%. Asellidae and Leptohyphidae are the most abundant warm water taxa, with overall abundances of 3.12 and 1.42%. Eleven of the warm water taxa have overall abundances of less than 0.1%. Of the cold water taxa, Chloroperlidae occurs at the highest percentage of sites (49%), followed by two Ephemeropterans (*Ephemerella* and *Cinygmula*), which occur at 44 and 46% of the sites, respectively. Fifteen of the cold water taxa occur at less than 10% of the sites. Among the warm water taxa, Leptohyphidae occurs at the highest percentage of sites (31%), followed by Coenagrionidae (18%) and *Cheumatopsyche* (17%). Eleven of the warm water taxa occur at less than 10% of the sites.

Additional information – Cold Water Taxa. Ten of the cold water taxa are Plecopterans, eight are Dipterans, seven are Trichopterans and six are Ephemeropterans (Table 3a). The families with the most number of taxa on the cold water list are Heptageniidae, Empididae and Perlodidae (Table 3b).

Additional information – Warm Water Taxa. Five of the warm water taxa are Trichopterans, three are Coleopterans, and two are Dipterans and Ephemeropterans (Table 4a). The families with the most number of taxa on the warm water list are Elmidae and Leptoceridae (Table 4b).

Table 3a. Number of cold water taxa in each order.

Order	Total
Plecoptera	10
Diptera	8
Trichoptera	7
Ephemeroptera	6
Coleoptera	1
Dorylaimida	1

Table 3b. Number of cold water taxa in each family.

Family	Total
Heptageniidae	4
Empididae	3
Perlodidae	3
Tipulidae	2
Uenoidae	2
Ameletidae	1
Apataniidae	1
Blephariceridae	1
Capniidae	1
Ceratopogonidae	1
Chloroperlidae	1
Dorylaimidae	1
Elmidae	1
Ephemerellidae	1
Glossosomatidae	1
Hydropsychidae	1
Lepidostomatidae	1
Leuctridae	1
Limnephilidae	1
Nemouridae	1
Pelecorhynchidae	1
Peltoperlidae	1
Psychodidae	1
Taeniopterygidae	1

Table 4a. Number of warm water taxa in each order.

Order	Total
Trichoptera	5
Coleoptera	3
Diptera	2
Ephemeroptera	2
Hemiptera	1
Isopoda	1
Odonata	1
Plecoptera	1

Table 4b. Number of warm water taxa in each family.

Family	Total
Elmidae	2
Leptoceridae	2
Asellidae	1
Caenidae	1
Coenagrionidae	1
Hydropsychidae	1
Hydroptilidae	1
Leptohyphidae	1
Naucoridae	1
Perlidae	1
Psephenidae	1
Psychodidae	1
Psychomyiidae	1
Stratiomyidae	1

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