The distribution of *Hygrotus diversipes* during 2013 and 2014

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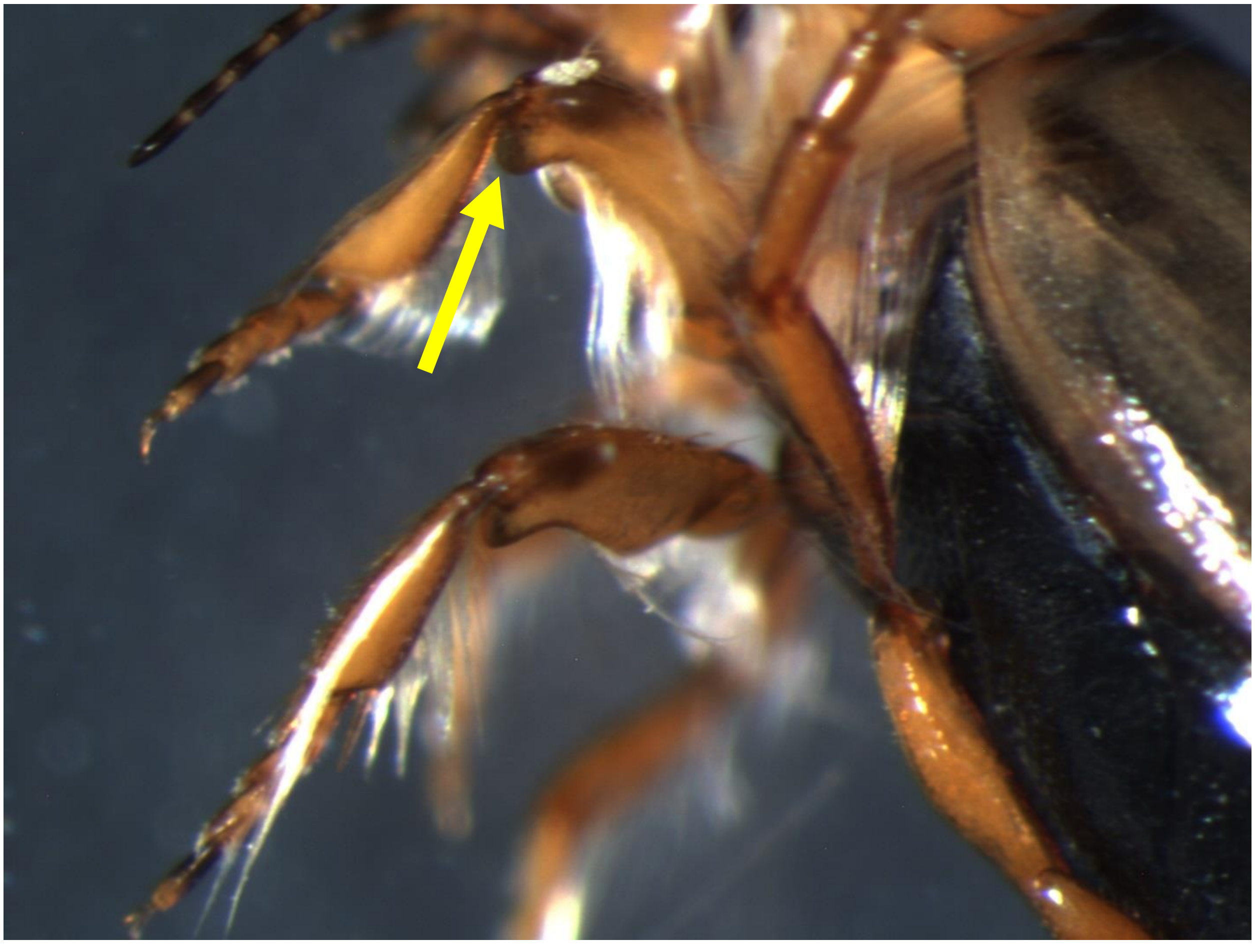
Cover photo by Lusha Tronstad showing Dead Horse Creek where *Hygrotus diversipes* (inset photo) is known from.

Photo below by Lusha Tronstad showing the unique front leg structure of *Hygrotus diversipes*.



Introduction

Predaceous diving beetles (Dytiscidae) are the most diverse aquatic beetle family in the world, with over 3900 species described in 175 genera that live on all continents (Jach and Balke 2008). Dytiscid larvae and adults live in a variety of aquatic habitats, including lakes, ponds, streams and wetlands. Eggs typically hatch in ~1 week (Larson et al. 2000) and beetles go through 3 life stages after hatching (holometabolus; larvae, pupae and adult). Before pupating, larvae go through 3 instars. Larval development time likely depends on water temperature and final instar size. Pupation is a relatively short stage where the beetle makes a cell under an object (e.g., rock or log) along the margin of the water body. The adult stage generally lasts the longest and is the stage where predaceous diving beetles can disperse by flying among habitats. Dytiscids are generally good flyers that disperse to colonize new habitats, find overwintering areas, or leave less desirable habitats (e.g., drying ponds).

Hygrotus is a genus in the family Dytiscidae. *Hygrotus* are small beetles (2.1-5.6 mm length) typically collected in standing water (i.e., lakes and ponds; Larson et al. 2000). Beetles in this genus occur from Alaska to Florida, but are most diverse on the prairies of British Columbia. Most *Hygrotus* beetles are thought to live one year (univoltine) with adults overwintering and mating the following spring and early summer. Many members of the genus live in unique habitats and may have special adaptations to do so. For example, *H. salinarius* has osmoregulatory adaptions for living in waters with high concentrations of salts (Tones 1978). The *Hygrotus pedalis*-group consists of five species that live in unique habitats or restricted areas (Anderson 1983). For example, *H. pedalis* is known from only 6 counties in California, *H. thermarum* and *H. fontinalis* live in hot springs, *H. curvipes* occupies temporary habitats in southern California and *H. diversipes* is known only from intermittent streams with relatively high conductivity in central Wyoming.

Hygrotus diversipes was first collected from Dugout Creek northwest of Midwest, Wyoming (Figure 1) by Hugh Leech in 1964 who published a paper describing the new *Hygrotus* species (Leech 1966). Anderson (1971, 1976, 1983) revised the genus and provided a key to distinguish species of *Hygrotus*. *Hygrotus diversipes* fits within the *pedalis*-group (group IV), because of the modified profemora, mesofemora and mesotibia on males (photo on 2nd page), and the shape of the aedeagus (male reproductive organ). *Hygrotus diversipes* was a Category II Candidate Species under the Endangered Species Act (ESA) from 1984 to 1996 and the beetle has been petitioned for listing under the Endangered Species Act (ESA) 3 times since 2007. *Hygrotus diversipes* is currently being reviewed for ESA listing by the US Fish and Wildlife Service (WildEarth Guardian 2013). I collected aquatic invertebrates from streams where *H. diversipes* is known from during 2013 and 2014 to provide information about the current distribution of the predaceous diving beetle.

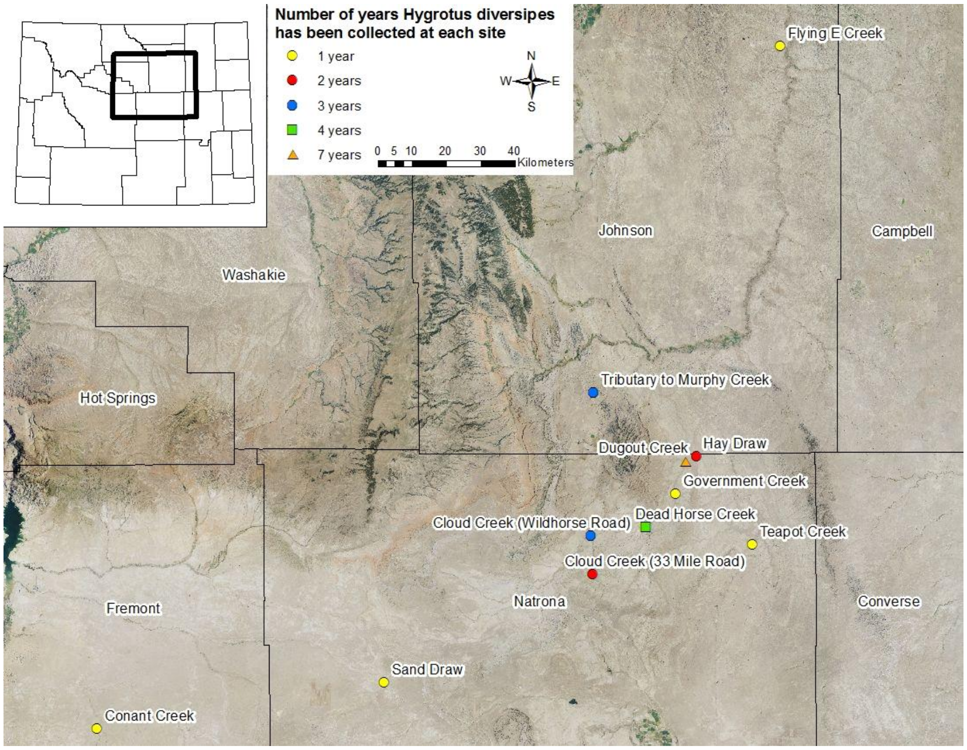


Figure 1. *Hygrotus diversipes* is known from 12 sites in central Wyoming (see inset map). Most *H. diversipes* specimens have been collected near the type location, Dugout Creek.

Methods

I visited sites on public land where *H. diversipes* had been previous collected and I sampled sites that had water (Appendix A). I collected aquatic invertebrates from pools with water using a dip net (250 µm mesh). I measured dissolved oxygen, water temperature, conductivity, oxidation-reduction potential and pH with a YSI Professional Plus Multiprobe calibrated daily. I recorded location and elevation with a GPS unit, described and photographed the habitat and noted the riparian (vegetation at margin of water) and landscape vegetation, primary land use and dominant stream substrate. Invertebrates were preserved in ~75% ethanol and returned to the laboratory for identification. I identified adult beetles using Merritt et al. (2008) and the family Dytiscidae using Larson et al. (2000).

Results

I visited 5 sites in 2013 and I collected invertebrates at 4 sites (Cloud Creek at 33 Mile Road was dry; Figure 2). Tributary to Murphy Creek was the only stream where *H. diversipes* was collected. Basic water quality in the tributary to Murphy Creek was similar to the other streams that I sampled in 2013, except the tributary to Murphy Creek had the highest concentration of dissolved oxygen and the highest specific conductivity (Table 1). Most of the streams showed signs of flooding earlier in the year.

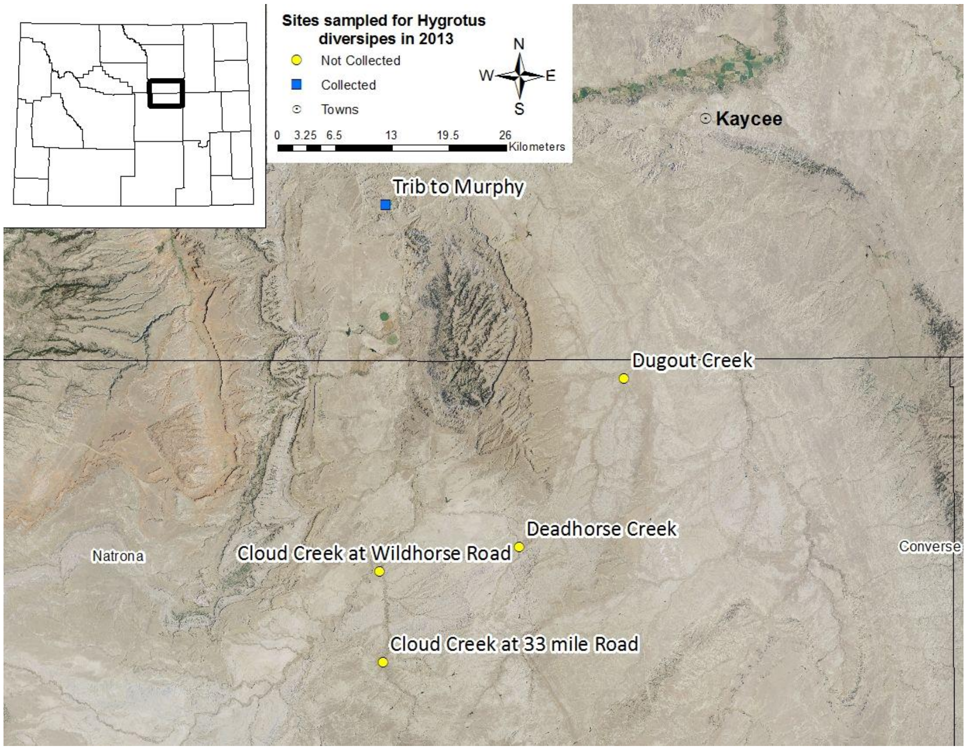


Figure 2. Sites sampled for *Hygrotus diversipes* in 2013. I collected *H. diversipes* in 1 stream. Inset map shows the location of the sampling sites in Wyoming.

Table 1. Basic water quality measured at sites sampled in 2013 and 2014. The mean and stream-specific water quality at sites where *Hygrotus diversipes* was collected are reported by year.

Stream	Temperature	Dissolved Oxygen		Specific Conductivity	pH	ORP
Units	°C	% saturation	mg/L	µS/cm		mV
2013						
Mean	23.7	121.5	10.1	7525	8.09	128.6
Tributary to Murphy	23.5	166.0	13.3	20,671	7.84	138.8
2014						
Mean	19.8	89.4	7.8	6430	8.05	127.2
Dugout Creek	19.1	71.0	6.6	2077	8.27	224.8
Cloud Creek	22.4	70.0	5.9	5881	7.96	86.4
Dead Horse Creek	12.8	55.0	5.7	5754	7.61	97.9
Tributary to Murphy	23.7	165.0	12.8	19,000	7.96	138.4

I visited nine sites in 2014 and I collected invertebrates from 7 streams (Cloud Creek at 33 Mile Road was dry and Teapot Creek was inaccessible; Figure 3). *Hygrotus diversipes* was collected at 4 sites (Dugout Creek, Cloud Creek at Wildhorse Road, Dead Horse Creek and tributary to Murphy Creek). Basic water quality was similar between sites with and without *H. diversipes*; however, tributary to Murphy Creek had higher dissolved oxygen and specific conductivity (Table 1). Hygrotus diversipes was more abundant in 2014 compared to 2013 (found at more sites and individuals were more abundant at sites).

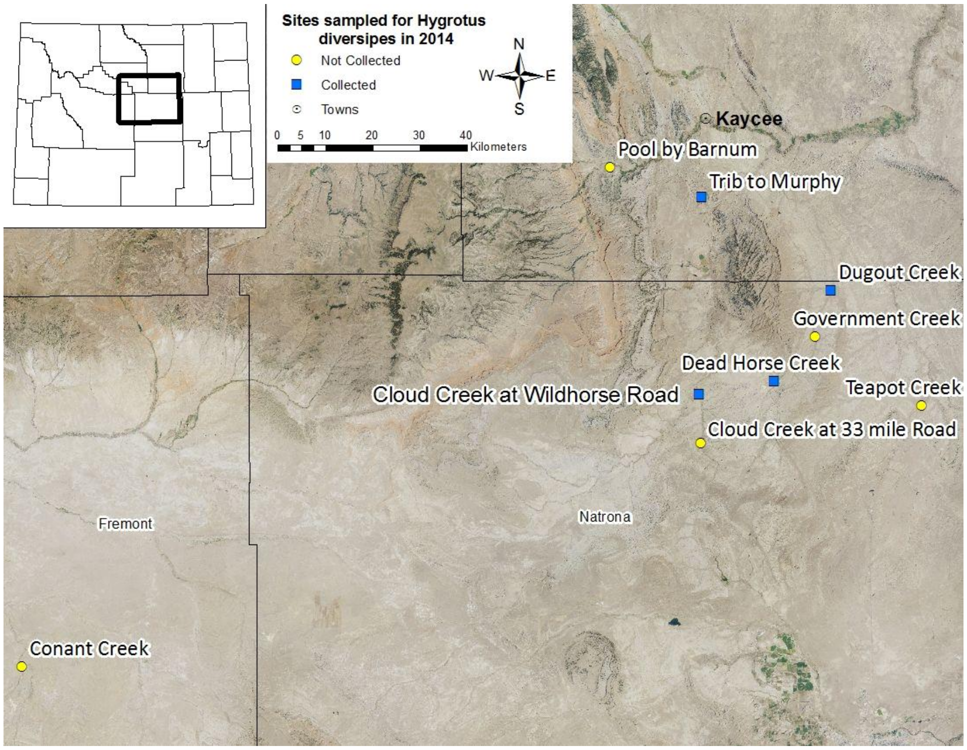


Figure 3. Sites sampled for *Hygrotus diversipes* in 2014. I collected the beetle from 4 sites. Inset map shows the location of the sampling sites in Wyoming.

Discussion

Hygrotus diversipes appears to be restricted to only a relatively small portion of central Wyoming. Currently, *H. diversipes* is known from 11 locations within the Powder River Basin and 1 location in the Wind River Basin (Figure 1; Table 2; Tronstad 2014). These 12 sites have been discovered over the past 50 years since the beetle was discovered by Hugh Leech in 1964 (Table 2). *Hygrotus diversipes* is not found at the same sites every year; in fact, *H. diversipes* has only been collected from 5 of these sites during a single year (Figure 1). The sites where the beetle has been collected multiple times appear to surround Dugout Creek and Dead Horse Creek.

Spring precipitation is probably vital to *H. diversipes*' habitat quality, because such precipitation recharges the shallow groundwater that is necessary to maintain these streams throughout the summer. Predictive distribution models suggested that *H. diversipes* inhabited streams with shallow ground water (Tronstad et al. 2011). More water likely percolates into the ground during spring because of lower temperatures and thus lower evaporation rates compared to summer. Precipitation in the form of snow probably recharges groundwater to a larger degree than rain, because a blanket of snow protects the melting snow from evaporation. Additionally, drifted snow that accumulated in the gulch throughout the winter are probably an important source of water.

Table 2. All known sites, locations (Datum NAD 83), collectors and dates where *Hygrotus diversipes* has been collected since the beetle's discovery.

Sites and Collectors	Locations and Dates
Dugout Creek	43.47795N, -106.41210W
H. Leech, California Academy of Sciences	July 1964
G. Dahlem, BLM	June 1985
L. Keenan and T. Howard, PEST, Inc.	August 1992
L. Keenan and T. Howard, PEST, Inc.	August 1993
K. Miller, Cornell University	July 1995
K. Miller, Cornell University	August 2002
L. Tronstad, WYNDD	July 2014
Cloud Creek at 33 Mile Road	43.26375N, -106.65775W
G. Dahlem, BLM	June 1985
W. Fitzgerald, BLM	September 1992
Cloud Creek at Wild Horse Road	43.33211N, -106.65852W
W. Fitzgerald, BLM	September 1992
K. Swanson, University of Wyoming	July 2010
L. Tronstad, WYNDD	July 2014
Dead Horse Creek	43.35316N, -106.51888W
G. Dahlem, BLM	June 1985
K. Swanson, University of Wyoming	July 2010
L. Tronstad, C. Bish, and K. Brown, WYNDD	May 2011
L. Tronstad, WYNDD	July 2014
Hay Draw	43.48763N, -106.38641W
L. Keenan and T. Howard, PEST, Inc.	August 1992
L. Keenan and T. Howard, PEST, Inc.	August 1993
Government Creek	43.41602N, -106.43983W
K. Miller, Cornell University	August 1996
Unnamed pool by Barnum	43.64741N, -106.83006W
K. Miller, Cornell University	August 2002
Flying E Creek	44.25968N, -106.16591W
K. Miller, Cornell University	August 2002
Teapot Creek	43.32006N, -106.23851W
K. Miller, Cornell University	August 2002
Conant Creek	42.96911N, -107.95193W
K. Miller, Cornell University	August 2002
Sand Draw	43.05640N, -107.20176W
K. Miller, Cornell University	August 2002
Tributary to Murphy Creek	43.60800N, -106.65500W
L. Tronstad, C. Bish, and K. Hack, WYNDD	May 2012
L. Tronstad and B. Tronstad, WYNDD	July 2013
L. Tronstad, WYNDD	July 2014

To investigate the idea that spring precipitation may at least partially explain the distribution of *H. diversipes*, I plotted precipitation between March and May collected at Casper and Kaycee weather stations during the years when *H. diversipes* surveys occurred. I compared spring precipitation to the proportion of core sites where *H. diversipes* was collected that year (Figure 3). The proportion of core sites where *H. diversipes* was collected were higher during years with more spring precipitation. I considered core sites to be the sites where *H. diversipes* was known from at the time of sampling. Therefore, the distribution of *H. diversipes* appears positively correlated with spring precipitation.

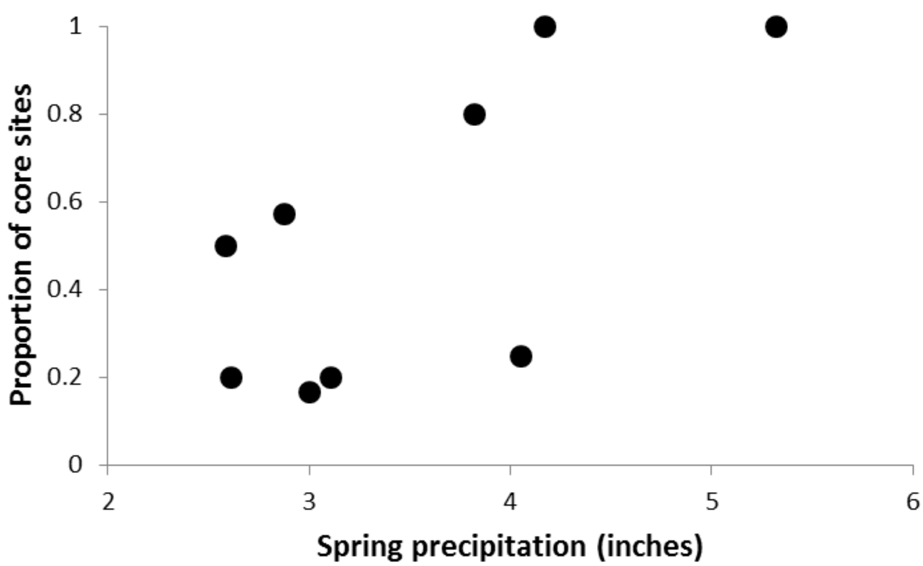


Figure 3. *Hygrotus diversipes* was collected at a higher proportion of core sites during years with more spring precipitation.

Hygrotus diversipes has only been collected in streams with relatively high concentrations of dissolved salts. *Hygrotus* beetles are thought to be lentic species (occur in standing water). Despite sampling in numerous ponds, *H. diversipes* has only been collected in intermittent streams. Most of these streams had dried to a series of disconnected pools when the beetles were collected. *Hygrotus diversipes* seems to specialize in small streams with little to no flow, a quality similar to ponds. Additionally, all the streams that *H. diversipes* lives in have white salts that precipitated around the margins. Salts in freshwater are primarily composed of the cations calcium, magnesium, sodium and potassium, and the anions bicarbonate, carbonate, sulfate and chloride (Wetzel 2001). Leech (1966) described the precipitated salts at Dugout Creek in 1964, and the 1985 BLM report stated that conditions at Dugout Creek, Cloud Creek and Dead Horse Creek all matched Leech's original description of Dugout Creek (BLM unpublished data). A high concentration of dissolved salts may at least partially explain the distribution of *H. diversipes*. Invertebrates must have special osmoregulatory adaptations to survive in waters with high concentrations of dissolved salts. For example, *H. salinarius* has osmoregulatory adaptations to survive higher concentrations of salts (Tones 1978). *Hygrotus diversipes* may select streams with higher conductivity, perhaps because these beetles have a competitive advantage in such environments.

Like most adult dytiscids, adult *H. diversipes* are probably good flyers that can readily disperse among habitats (Tronstad et al. 2007). Dytiscids may disperse for many reasons, such as to find overwintering habitat or escape a drying pond or stream. Dytiscids vary in their ability to disperse, with some taxa flying often to track available habitat (Hilsenhoff 1986). Due to the temporary nature of some habitats that *H. diversipes* has been collected in, we expect that *H. diversipes* readily disperses among streams. Available habitat is likely dynamic in time and space, possibly varying with patterns of local precipitation. *Hygrotus diversipes* often was not found in the same location each year (Table 2). For example, *H. diversipes* has not been collected at Cloud Creek (33 Mile Road) since 1992. I collected *H. diversipes* in Dugout Creek in 2014 for the first time since 2002, despite annual surveys during the last 5 years. Dugout Creek has held water during most of our visits, but water levels seemed to fluctuate more than other nearby streams. I have collected *H. diversipes* in the tributary to Murphy Creek each year since we discovered the site. The stream has the highest conductivity of known *H. diversipes* sites and the abundant floating algal mats increase dissolved oxygen concentrations.

The distribution of *H. diversipes* may retract during drought years. Dytiscid beetles are known to survive drought by aestivating (reduced metabolic rate and activity during warm and dry periods) in damp or dry sediments, or by the adults dispersing to new habitats (Paul 1980, Garcia et al. 1990, Velasco and Millan 1998, Robson et al. 2011). I am aware of studies that have found adult dytiscids aestivating in sediments (Boulton 1989), but I am not aware of any studies showing that larval dytiscids have strategies to survive drying. Dytiscids in an Arizona desert stream survived drought by ovipositing eggs in habitats that would likely stay inundated long enough (~6 weeks) to allow the larvae to develop to adults (Gray 1981). Most dytiscids collected in intermittent streams in Australia used receding pools as refugia, but some adult dytiscids were also found under leaf litter, in a lake, or in the sediments of dried pools (Boulton 1989). Shallow water (<1 cm depth; Velasco and Millan 1998) and higher beetle densities (Yee et al. 2009) triggered dytiscids to fly to new habitats. Garcia et al. (1990) postulated that *Agabus disintegratus* aestivated in sediments instead of dispersing to permanent water to avoid competition. Twenty-two percent of these dytiscid beetles survived aestivation in the laboratory for 5 months (Garcia and Hagen 1987). *Hygrotus diversipes* may aestivate in sediments, because of the limited range of the species and the relatively dry conditions in the area. We may have collected fewer adult *H. diversipes* during drought (e.g., 2012) because adults were aestivating (e.g., buried in sediments or under rocks). However, nothing is known about how *H. diversipes* copes with dry conditions. Future research should study the life cycle of the beetle and attempt to measure how *H. diversipes* copes with unsuitable conditions.

Hygrotus diversipes can only be identified in the adult stage. Although some species keys for *Hygrotus* larvae exist (Alarie et al. 1990, Barman 1999), *H. diversipes* larvae have not been paired with the adult stage. A number of important questions may be addressed once the larvae have been identified. For example, we currently do not know where *H. diversipes* lays eggs and rears larvae. We also do not know how long larval development lasts, what time of year larvae develop or the generation time for *H. diversipes*. Larvae cannot disperse among habitats, so larval rearing areas must remain inundated the entire larval development. Because larvae cannot move among habitats, protecting groundwater is probably vital to conserve the beetle. Larvae of *Hygrotus* can probably withstand higher concentrations of dissolved salts than adults (Tones 1978), so larval habitats may differ from adult habitats. We cannot learn more about the life cycle of *H. diversipes* until we identify the larval stage. Managing any species is exceptionally difficult when only a fraction of the life cycle is understood. Continued research into the basic biology of *H. diversipes* will yield important insights for resource managers.

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Appendix A. Photos of the sites where Hygrotus diversipes has been collected

Dead Horse Creek

Cloud Creek at Wildhorse Road

Pools by Barnum

Tributary to Murphy Creek


Government Creek


Conant Creek


Dugout Creek