UTAH DIVISION OF WATER QUALITY
195 North 1950 West
PO Box 144870
Salt Lake City, Utah 84114-4870

Willard Bay Project Proposal Form

Applicant Name: Dr. David C. Richards

Co-Applicant Name(s) (if applicable): Brett Marshall; Dr. Sam Rushforth, Dr. Heidi Hoven, and Dr. Theron Miller

Project Title: Of Midges and Snails: Assessing their Role in the Health and Resilience of Willard Bay in Response to Anthropogenic Impacts

Agency or Business Name (if applicable): OreoHelix Consulting: River Continuum Concepts; Rushforth Phycology LLC and Jordan River/Farmington Bay Water Quality Council

Mailing Address: P. O. Box 996 City: Moab State: UT Zip: 84532

Phone: (406) 580- 7816 E-mail: oreohelix@icloud.com

Individual Non-Profit Govt. Agency Academic **X** Commercial Other

1. Estimated Project Costs:

Labor	$160,000
Materials	$40,000
Equipment	$20,000
Administration	$10,000
Miscellaneous	$11,000
TOTAL	$241,000

Other sources of project funding:
Source: Jordan River/Farmington Bay Water Quality Council Amount: $75,000

Total project cost including other sources of funding: $316,000
(please include bids for labor, equipment, rentals, etc.)

2. Describe the purpose and need of the project:

The northeast section of Great Salt Lake includes approximately 74,000 acres of U.S. Fish and Wildlife Service Bear River Migratory Bird Refuge (Refuge); 41,000 of which are managed as wetland habitat. The Refuge attracts hundreds of thousands of migratory shorebirds and waterfowl each year as nesting and staging habitat. The Refuge is part of the Bear River Delta that extends into Willard Bay (Spur) of Great Salt Lake and has been identified by the National Audubon Society as an Important Bird Area because of its aquatic resources used by shorebirds and waterfowl. Willard Spur also provides additional invaluable ecosystem services including: water quality and storage, recreation, fish and wildlife habitat, aesthetics, etc. Very little is known about the ecology and health of Willard Spur (WS) in spite of its ecological and economic importance. Intensive ecological studies directed by the WS Science Panel (WSSP)(comprised of scientists and managers from state and federal agencies, water councils, and expert ecological consultants) were conducted on Willard Spur in 2012 and 2013 to help fill this knowledge gap. The consensus of the WSSP was that WS is a unique wetland and that maintaining its water quality, ecosystem services, ecosystem function, and resilience to anthropogenic perturbation is critical. The WSSP also agreed that epiphyton growth on submergent aquatic vegetation (SAV) could have deleterious effects on SAV health and condition and subsequently the WS ecosystem, and that a clear understanding of the top- down role of grazers (primarily macroinvertebrates) on epiphyton was lacking. In addition, how grazer taxa in WS respond to other impacts, including diesel fuel spills, remains unknown. Filling this missing piece of knowledge of the WS puzzle is critical to understanding its ecology and for the continued management of the health and resilience of this unique wetland.

The two most dominant secondary consumer taxa, both in numbers and biomass, in WS are midges (chironomids) and snails and both are extremely important in waterfowl diets, however in 2013, snail populations crashed in WS. These two taxa are also highly susceptible to oil spills and other human caused impacts. Monitoring their population trends and understanding their ecology, particularly their functional roles as top down consumers and susceptibility to anthropogenic impacts will allow managers to better protect WS.

A summary of the midge and snail study results in WS conducted by Hoven et al. 2013 is in Addendum 1. This addendum also summarizes the potential importance of midges and snails as top down regulators in WS.

3. Estimated time frame of the project with significant milestones (Note: Project must be completed with final reports filed by January 1, 2018):

July through September 2014: Macroinvertebrate and algae field sampling and processing
January 2015: Progress Report
June through September 2015: Macroinvertebrate and algae collection and processing
January 2016: Progress Report
June through September 2016: Macroinvertebrate and algae collection and processing
March 2017: Final Report, Formal Consultation

4. **Describe the location of the project with attached location map, including details on the total area that will be directly enhanced by the project:**

Macroinvertebrate and algae sampling will occur at several locations in Willard Spur.

5. Describe how the project will specifically enhance and protect waterways affected by the Willard Bay diesel release and improve the conditions of one or more of the following: wildlife, habitat, natural vegetation, water quality or emergency response:

The project will provide a deeper understanding of the ecology of two of the most dominant secondary taxa in WS and their importance to natural SAV health and water quality. This knowledge will help guide managers and regulators in future SAV enhancement projects and improved protection of WS and surrounding wetlands affected by human caused impacts, including diesel fuel release.

6. Describe project's connectivity to other natural areas or projects that further enhance wildlife, habitat, natural vegetation, water quality or emergency response:

Results of this study can be applied to all wetlands in eastern GSL.

7. Describe any additional social benefits of implementing this project:

Results of this study will be highly useful for assessing and monitoring water quality in WS and GSL wetlands to the benefit of all the citizens of UT

8. Project plans and details, including rights to work on specified piece of land:

We will address the following:

1. Relationships between midges and snail taxa with SAV die-off in WS, with a focus on algae and BDS on SAV. (e.g. why don't midges and snails control algae and BDS on SAV).
2. What is the relationship between snail and midge diets and *Cladophora* sp., a nuisance alga in WS?
3. Midge and snail habitat associations in WS. Are midges and snails primarily associated with bottom substrate (benthic, profundal) or SAV? What types of anthropogenic impacts are midges and snails susceptible to?
4. What environmental conditions cause snail populations to crash in WS? How do they recolonize?

METHODS

1. Monitor abundances, biomass, and diets of the following taxa at several locations in both SAV and benthic habitats in WS: *Chironomus* sp., Tanypodinae, *Stagnicola* sp., *Gyraulus* sp. and *Physa/Physella* sp. Dr. Larry Gray's research suggested spatial homogeneity in macroinvertebrate assemblages in WS, therefore only a few locations may be necessary for statistical power. We will collect samples every two weeks from July through September 2014 and from June through September 2015 and 2016.
2. Determine length, weights, biomass at several size classes for each sample (number of size classes to be determined).
3. Conduct midge and snail diet analysis by examining buccal cavity contents (snails), gut contents (midges) and feces (midges and snails). Diets will be analyzed by size class, sample location, and date collected. We will also compare ingested vs. egested, utilization, and energy transfer efficiencies by the midges and snails.
4. Collect epiphyte and periphyton samples for comparison with diets.
5. Conduct snail surveys in surrounding wetlands and streams and rivers, including literature review.
6. Evaluate midge and snail taxa in WS as water quality indicators to several stressors, focusing on oil spills and nutrient enrichment.

Specific taxa will be identified by the team member with the most pertinent experience. Dr. David Richards will work with the snails, Brett Marshall with the midges, Dr. Heidi Hoven with the SAV, and Dr. Sam Rushforth with the diatoms. We assume from prior studies that we can achieve a relatively high statistical power with relatively few sample replicates because the macroinvertebrate assemblages are relatively homogeneous in species composition (at the sample-scale) throughout the Willard Bay (Dr. Larry Gray report to Willard Spur Science Panel 2013). However, the basis for this study is the need to understand how feeding and food webs change seasonally. Therefore, although we will allocate very little replication towards each sampling period, we sample frequently to ensure seasonal shifts are well represented. We will visit the field sites bi-monthly (June-September), and collect 3-4 replicate samples from vegetated littoral zone habitat and 3-4 from benthic profundal zone habitat. We will also sample from an area that may have been most heavily impacted from the diesel fuel spill and a reference area outside of the fuel spill zone. Initially, we will examine ~20 randomly selected midges and 20 snails of each taxa for stomach content analysis. Depending on the richness of samples, we may have to add additional specimens to the survey to ensure we accurately reflect the predominant functional pathways in the community. Among the midge assemblages, we know that locally there are usually very two common Chironomini (*Glyptotendipes* and *Chironomus* (cf. *patens*)) and two very common Tanypodinae (*Tanypus* and *Procladius*). Although Tanypodinae are traditionally considered predators, we have found that *Tanypus*, often the most abundant tanypod in freshwater wetlands near Great Salt Lake, frequently have stomachs full of diatoms (Figure 1.). There are also some less-abundant midge taxa, which may become seasonally abundant—it may be the periodic/sporadic rise in some of these species which causes more dramatic community structure shifts later in the year.

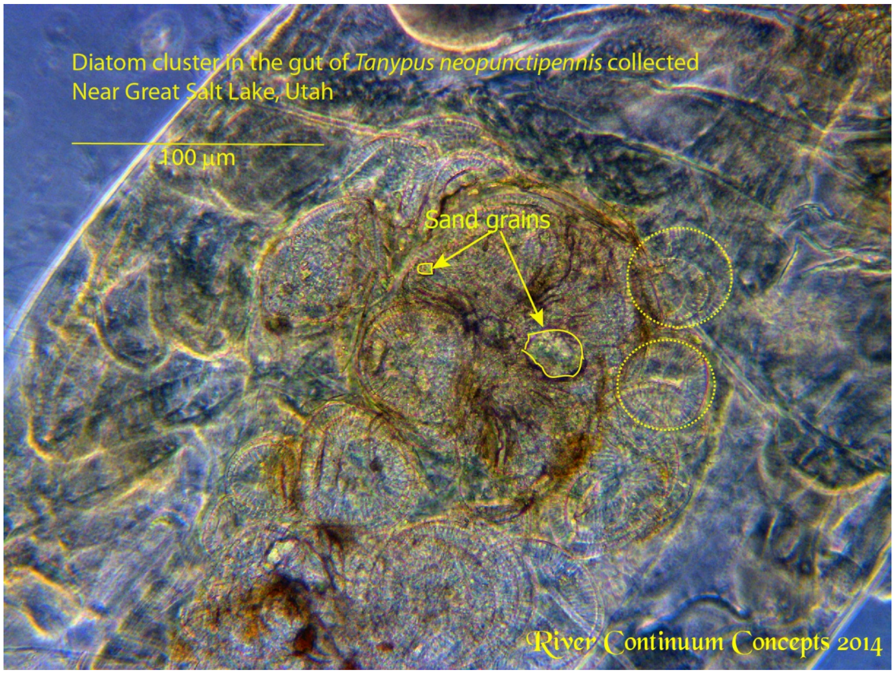

Figure 1. In this slide mounted *Tanypus* sp. midge, the individual diatom cells can be observed within the midges gut. We can measure the size of different food items to estimate the relative proportion of the diet comprised of diatoms, green algae, inorganic material or organic particles.

For the snails, stomach contents will be purged onto microscope slides and sent to the diatom laboratory for identification. For the midges, which must be slide mounted to be identified, the relative volume of different food items will be measured using digital image analysis within midges' slide mounted bodies. Numbered slides can then be sent to the diatom analyst for species determination of any algae within the midge's stomachs.

9. Describe your experience in implementing projects of similar scope and magnitude:
This consortium of scientists is highly experienced in these specific types of projects. Please review our resumes, C.V.s, and Statements of Qualifications that are attached.

10. Describe how ongoing maintenance of the project will be funded and carried out: NA

11. List consultants or agency partners that have participated in project development (below):
All of the applicants and co-applicants have participated in the project development. No additional consultants or agency partners were involved.

Signature: *David C. Richards* Date: April 24, 2014
Applicant

Signature *Brett Marshall* Date April 25, 2014
Co-Applicant (if applicable)

Signature *Sam Rushforth* Date April 25, 2014

Co-Applicant (if applicable)

Signature *Heidi Hoven* Date April 26, 2014
Co-Applicant (if applicable)

Signature *Theron Miller* Date April 27, 2014
Co-Applicant (if applicable)

March 2014

DAVID CHARLES RICHARDS
Director, OreoHelix Consulting
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Moab UT
Phone: 406.580.7816
Email: oreohelix@icloud.co

Research Interests: Ecological studies of freshwater ecosystems in desert regions; biological and ecological assessment and monitoring; post-secondary teaching

Professional Experiences:

2014 to present Director, OreoHelix Consulting, Moab, UT

2013- 2014	Aquatic Ecologist, Cramer Fish Sciences, West Sacramento, CA
1999-2012	Senior Research Ecologist, EcoAnalysts, Inc.
2009	Instructor. Introduction to Ecological Statistics. Northwest Environmental Training Center, Seattle WA.
2007-2009	Adjunct Assistant Professor, Department of Ecology, Montana State University, Bozeman, MT
2006-2008	Affiliate Assistant Professor, Land Resources and Environmental Sciences, Montana State University, Bozeman, MT
1997-1999	Biologist, USFWS/Puerto Rico Dept. Natural Resources, San Juan, Puerto Rico
1986-1997	Backcountry Ranger and Trail Crew Leader, Absaroka-Beartooth and Bob Marshal Wilderness, and Yellowstone and Glacier National Parks, fisheries technician Yellowstone National Park

Education

Ph.D.	2004	Montana State University; Biology (Dept. Ecology) with minor in Statistics
M. S.	1996	Montana State University; Entomology and Mountain Research Center
B. S.	1987	Montana State University; Biology, Fish and Wildlife Management Option

Awards, Achievements, and Certificates

2011	PADI Open Water Scuba Certification
1983-2004	Red Cross Advanced First Aid and CPR
1993	Montana Board of Regents Academic Scholarship
1993	Outstanding Biology Student of the Year, Flathead Valley Community College

Professional and Public Service Activities

2006-present Topic-Editor
- Encyclopedia of Earth, http://www.eoearth.org/

2001–present Peer-review referee:
- American Malacological Society Bulletin
- Journal of North American Benthological Society
- Western North American Naturalist

Southwest Naturalist
Biological Invasions
Northwest Science
North American Journal of Aquaculture

2001-2005 Initiated and organized 1st, 2nd, 3rd, 4th, and 5th Annual Conference on New Zealand Mudsnail in Western USA, July 9-10, 2001, August 26-28, 2002, August 26-27, 2003, 2005, Bozeman, MT and June 2007, Davis, CA

Field and classroom lecturer: Aquatic Ecology, Stream Ecology, Science Teachers Institute of the Rockies, Montana State University; and local grade schools

Professional Societies, Conservation Organizations, and Committees

American Malacological Society
Freshwater Mollusk Conservation Society
American Fisheries Society
Ecological Society of America
Montana Academy of Science
Society for Freshwater Science
PADI Diving Society
Snake River Snail Conservation Plan Technical Committee
Society for Conservation Biology
    Working Group for Ecological Economics and Sustainability Science
Western Regional Panel Aquatic Nuisance Species

Publications

Carling, G.T, Richards, D.C., Hoven, H., Miller, T., Fernandez, D.P., Rudd, A, Pazmino, E., and W. P. Johnson. 2013. Relationships of surface water, pore water, and sediment chemistry in wetlands adjacent to Great Salt Lake, Utah and potential impacts on plant community health. Science of the Total Environment.

Richards, D. C., T. Arrington, S. Sing, and B. L. Kerans. In revision. Competition and coexistence between an invasive aquatic snail and its threatened native congener. American Malacological Society Bulletin.

Richards, D. C. and T, Arrington. In review. Spatial and environmental relationships of three snail taxa in a freshwater spring: with estimates of their abundance. Journal North American Benthological Society.

Richards, D. C., C. M. Falter, G. T. Lester, and R. Myers. In revision. Mollusk survey of Hells Canyon reservoirs and free flowing Snake River, Idaho and Oregon, USA: with focus on rare and listed taxa, including a newly described Taylorconcha sp. American Malacological Society Bulletin.

Richards, D. C., P. O'Connell, and D. C. Shinn. In preparation. Growth Rates of the threatened Bliss Rapids Snail, Taylorconcha serpenticola and the invasive New Zealand mudsnail Potamopyrgus antipodarum at six temperatures.

Richards, D. C. 2010. Mollusk diversity and estimated predation rates by gastropod shell borehole drillers on Turritella spp. at Playa Grande, Las Baulas National Park, Costa Rica. American Malacological Society Newsletter. Vol. 41. No. 2. Pg 5-7.

Richards, D. C. and T. Arrington. 2008. Evaluation of Threatened Bliss Rapids Snail, Taylorconcha serpenticola susceptibility to exposure: potential impact of 'load following' from hydroelectric facilities. American Malacological Society Bulletin.
Richards, D. C. In review. Some life history studies of the threatened Bliss Rapids snail and invasive New Zealand mudsnail. Western North American Naturalist.
Richards, D. C. 2004. Competition between the threatened Bliss Rapids Snail, Taylorconcha serpenticola and the invader New Zealand Mud Snail, Potamopyrgus antipodarum. Ph D. Dissertation. Montana State University, Bozeman, Montana. 175 pp.
Richards, D. C. and D. C. Shinn. 2004. Intraspecific competition and development of size structure in the invasive snail, Potamopyrgus antipodarum. American Malacological Society Bulletin. 19. 1.2.
Richards, D. C., P. O'Connell, and D. C. Shinn. 2004. Simple control method for the New Zealand mudsnail, Potamopyrgus antipodarum. Journal North American Fisheries Management. 24:114-117.
Richards, D. C., L. D. Cazier, and G. T. Lester. 2001. Spatial distribution of three snail species, including the invader Potamopyrgus antipodarum, in a freshwater spring. Western North American Naturalist.61: 375-380.
Richards, D. C., M. Rolston, and F. V. Dunkel. 2000. Comparison of salmonfly densities upstream and downstream of Ennis Reservoir. Intermountain Journal of Sciences. Vol 1:1-7.
Dunkel F. V. and D. C. Richards. 1998. Effect of an azadirachtin formulation of six nontarget aquatic macroinvertebrates. Environmental Entomology. Vol. 27. no. 3. pp 667-674.
Richards, D. C. 1996. The use of aquatic macroinvertebrates as water quality indicators in mountain streams of Montana. Masters thesis. Montana State University. Bozeman, MT. 199 pp.
Sriharan, S., A. Wright, P. Singh, F. V. Dunkel, D. C. Richards, W. Bertsch, and C. Wells. 1994. Insecticidal activity of floral and root extracts of Tagetes minuta and Tagetes patula (marigold against the Mexican bean weevil, (Zabrotes subfasciatus), a non-target fish (Gambusia affinis), and the predatory warehouse pirate bug (Xylocoris flavipes). in D. L. Weigmann, ed. New directions in pesticide research, development, management, and policy. Proc. Fourth National Conference on Pesticides. Blacksburg, Virginia, November 1-3, 1993. pp. 542-556.
Weaver, D.K, F.V. Dunkel, L. Van Puyvelde, D.C. Richards, and G.W. Fitzgerald. 1996. Toxicity ad protectant potential of the essential oil of Tetradenia riparia (Lamiales: Lamiaceae) against Zabrotes subfasciatus (Coleoptera: Bruchidae) infesting dried pinto beans (Fabales: Leguminosae) J. App. Entomology. pp. 126-131.

Technical Reports

Richards, D. C. 2013. Arizona Intermittent Streams Macroinvertebrate Index of Biological Integrity. Developed for the *Arizona/New Mexico Mountain Ecoregion.* Final Report. Biocriteria Program Monitoring Unit, Water Quality Division, Arizona Department of Environmental Quality, Phoenix AZ. 59 pp.
Richards, D. C. 2013. Development of Idaho Macroinvertebrate Temperature Occurrence Models. Report to Dept. Water Quality, ID Department of Environmental Quality, Boise, ID. 32 pp.

Richards, D. C. 2012. Development of an Arizona Intermittent Streams Macroinvertebrate IBI. Final Draft Report to Arizona Department of Water Quality. 95pp.
Richards, D. C., J. Rensel, and Z. Siegrist. 2011. Rufus Woods Lake – Columbia River reservoir morphometrics, initial food web, and rainbow trout fishery studies. Report to Colville Confederated Tribes. Nespelem, WA. 138pp.
Miller, T. G., D. C. Richards, Hoven, H. M., Johnson, W. P., Hogset, M., and G. T. Carling. 2011. Macroinvertebrate communities in Great Salt Lake impounded wetlands and their relationship to water and sediment quality and plant communities. Preliminary report to: Jordan River / Farmington Bay Water Quality Council, Salt Lake City, UT. 67pp.
Hoven, H. M., D. Richards, W. P. Johnson, and G.T. Carling. 2011. Plant metric refinement for condition assessment of Great Salt Lake impounded wetlands. Preliminary report to: Jordan River / Farmington Bay Water Quality Council, Salt Lake City, UT. 44pp.
Johnson, W. P., G. T. Carling, and D. Richards. 2011. Chemistry of surface water, pore water, and sediment in seven impounded wetlands bordering Great Salt Lake. Preliminary report to: Jordan River / Farmington Bay Water Quality Council, Salt Lake City, UT. 31pp.
Richards, D. C., 2011. Colville streams fertilization study: Final report to: Colville Confederated Tribes, Fish and Wildlife Department, Nespelem, WA. 44pp.
Richards, D. C. 2010. Possible effects of selective withdrawal-temperature control at Hungry Horse Dam, nuisance growth of Didymosphenia geminata, and other factors, on benthic macroinvertebrate assemblages in the Flathead River. Final report to: Montana Fish, Wildlife & Parks, Kalispell, MT. 142pp.
Richards, D. C. 2010. Characterization of temperature, dissolved oxygen, and macroinvertebrate communities of targeted intermittent streams. Report to Idaho Department of Environmental Quality, Boise, Idaho. 189 pp.
Richards, D. C., W. VanWinkle, and T. Arrington. 2009. Metapopulation viability analysis of the threatened Bliss Rapids Snail, Taylorconcha serpenticola in the Snake River, Idaho: effects of load following. EcoAnalysts Center for Aquatic Studies. Bozeman, MT. 162 pp.
Stephenson, M., D. Bates, D. C. Richards, and T. Arrington. 2009. Risk Assessment of Hydroelectric Operations on the Bliss Rapids Snail in the Middle Snake River, Idaho with a Focus on Load Following. 63pp.
Richards, D. C. and T. Arrington. 2009. Bliss Rapids Snail abundance estimates in springs and tributaries of the Middle Snake River, Idaho. EcoAnalysts Center for Aquatic Studies. Bozeman, MT. 195pp.
Richards, D. C., W. Van Winkle, and T. Arrington. 2009. Estimates of Bliss Rapids Snail, Taylorconcha serpenticola, abundances in the Lower Salmon Falls Reach and Bliss Reach of the Snake River, Idaho. EcoAnalysts Center for Aquatic Studies. Bozeman, MT. 24pp.
Richards, D. C., W. Van Winkle, and T. Arrington. 2009.Spatial and temporal patterns of Bliss Rapids Snail, Taylorconcha serpenticola, in the Middle Snake River, Idaho in Relation to Population Viability Analysis. EcoAnalysts Center for Aquatic Studies. Bozeman, MT. 47 pp.
Richards, D. C., C. M. Falter, and K. Steinhorst. 2006. Status review of the Bliss Rapids snail, Taylorconcha serpenticola in the Mid-Snake River, Idaho. 170pp.

Richards, D. C., T. Veldhuizen, and G. Noda. 2004. The invasive New Zealand mudsnail reaches the Central Valley Watershed. Pices. Vol. 32. (4): 4-6.
Richards, D. C., C. M. Falter, G. T. Lester, and R. Myers. 2005. Listed Mollusks. Responses to FERC Additional Information Request AR-2. Hells Canyon Project. FERC No. P-1971-079. 180 pp.
Richards, D. C. 2004. Population dynamics of Taylorconcha serpenticola and Potamopyrgus antipodarum at Banbury Springs outlet: 1999 to 2004 using time series analysis. EcoAnalysts Inc. Moscow, Idaho. 16pp.
Richards, D. C. and G. T. Lester. 2003. Survey of the invasive New Zealand mudsnail, Potamopyrgus antipodarum in the Silver Creek drainage in and around The Nature Conservancy's Silver Creek Preserve, Idaho, USA. EcoAnalysts Inc, Moscow, Idaho. 19pp.
Richards, D. C., Gustafson, D.L., Kerans, B.L., and C. Cada. 2002. New Zealand mudsnail in the Western USA. Web site. www2.montana.edu/nzms
Richards, D. C. and G. T. Lester. 2002. Survey for the endangered Pyrgulopsis idahoensis at the Cove Recreation Site, CJ Strike Reservoir. Prepared for North Wind, Inc. Idaho Falls, Idaho. EcoAnalysts Inc., Moscow, Idaho. 12pp.
Richards, D. C. 2002. The New Zealand Mudsnail invades the Western United States. Aquatic Nuisance Species Digest. Vol. 4. (4): 42-44.
Richards, D. C. and L. D. Cazier Shinn. 2001. Intraspecific and interspecific competition between Taylorconcha serpenticola and Potamopyrgus antipodarum under laboratory conditions. EcoAnalysts Inc. Report. 14pp.
Richards, D. C., P. O'Connell, and L. D. Cazier Shinn. 2001. Growth rates of the Bliss Rapids Snail, Taylorconcha serpenticola and the New Zealand mudsnail, Potamopyrgus antipodarum at six temperatures. EcoAnalysts Inc. Report.10pp.
Richards, D. C. and L.D.Cazier Shinn. 2001. Distribution and abundance of the Bliss Rapids Snail, Taylorconcha serpenticola in Banbury Springs in relation to two hydrobiid snail species and eight environmental gradients. EcoAnalysts Inc. Report. 23pp.
Richards, D. C. and L.D. Cazier Shinn. 2001. Taylorconcha serpenticola densities at Banbury Springs 1999-2001. EcoAnalysts Inc. Report. 16pp.
Richards, D. C. and L.D.Cazier Shinn. 2001. Densities of Taylorconcha serpenticola and Potamopyrgus antipodarum in cobble habitat at the outlet of Banbury Springs 1999-2001. EcoAnalysts Inc. Report. 11pp.
Richards, D. C., L. D. Cazier, and G. T. Lester. 2001. Spatial distribution of three snail species, including the invader Potamopyrgus antipodarum, in Banbury Springs, Snake River Drainage, Southern Idaho, USA. EcoAnalysts Inc. Report.19 pp.
Richards, D. C. and D. L. Gustafson. 2001. Compilation workbook for Mollusk Identification Workshop: New Zealand mudsnail in Western USA . First Annual Conference. July 9 and 10, 2001. Montana State University, Bozeman, MT.
Richards, D. C. and G. T. Lester. 2000. Intraspecific competition of Potamopyrgus antipodarum (Gray) at different densities for a limiting resource under laboratory conditions. EcoAnalysts Inc. Report. 22 pp.
Richards, D. C. and G. T. Lester. 2000. Growth rates of the New Zealand Mud Snail, Potamopyrgus antipodarum (Gray) at five temperatures. EcoAnalysts Inc. Report.19 pp.
Richards, D. C. and G. T. Lester. 2000. Competition between two freshwater snail species: the invasive New Zealand Mud Snail, Potamopyrgus antipodarum and the native, threatened

Bliss Rapids Snail, Taylorconcha serpenticola in an enclosure study, 1999 and 2000. EcoAnalysts Inc. Report. 25 pp.
Richards, D. C. and G. T. Lester. 2000. Comparison of the number of Potamopyrgus antipodarum neonates produced seasonally, between habitats, and in two freshwater springs, Idaho and Montana: a preliminary investigation. EcoAnalysts Inc. Report. 18 pp.
Richards, D. C. and G. T. Lester. 1999. Seasonal changes in densities of three snail species at Banbury Springs, 1999. EcoAnalysts Inc. Moscow, Idaho. 9 pp.
Richards, D. C. and G. T. Lester. 1999. Exploratory population analysis of the Banbury Limpet (Lanx sp. undescribed) colony in Banbury Springs, Snake River drainage, southern Idaho. EcoAnalysts Inc. Moscow, Idaho. 7 pp.
Richards, D. C. and G. T. Lester. 1999. Evidence for competition between two freshwater snail species, the exotic, biological invader Potamopyrgus antipodarum and the native, threatened Taylorconcha serpenticola in an enclosure study. EcoAnalysts Inc. Moscow, Idaho. 30 pp.
Richards, D. C. and G. T. Lester. 1999. Abiotic and biotic factors influencing the distribution and abundance of three species of freshwater snails in Banbury Springs. EcoAnalysts Inc. 17 pp.
Richards, D. C. 1998. Assessment of the 1997 release of captive-reared Hispaniola amazons (Amazona ventralis) in the Dominican Republic as related to their training at the parent facility training cage (PFTC), Rio Abajo Aviary, Puerto Rico. Report to Puerto Rico Department of Natural Resources and Environment. San Juan. 14 pp.
Richards, D. C. 1996. Relationship of the number of taxa and the number of organisms in macroinvertebrate samples from mountain streams of Montana. Report to State of Montana, Water Quality Division Department of Environmental Quality. Helena, MT. 5pp.
Richards, D. C. 1996. Effects of an unbiased 300 organism subsample on macroinvertebrate samples from mountain streams of Montana. Report to State of Montana, Water Quality Division Department of Environmental Quality. Helena, MT 12pp.
Shannon, J. P., E. P. Benenati, H. Kloeppel, and D. C. Richards. 2003. Monitoring the aquatic food base in the Colorado River, Arizona during June and October 2002. Annual Report. Grand Canyon Monitoring and Research Center. USGS. Cooperative Agreement-02WRAG0028.
Kern, A., L. D. Cazier, G. T. Lester, and D. C. Richards. 2000. Determining genetic diversity within and between spatially isolated populations of the native Threatened freshwater snail, Taylorconcha serpenticola in the mid-Snake River drainage, Idaho. EcoAnalysts Inc. Report. 4pp.
Marcus, W. A., J. A. Stoughton, S. C. Ladd, and D. C. Richards. 1995. Trace metal concentrations in sediments and their ecological impacts in Soda Butte Creek, Montana and Wyoming. In: Meyer G (ed), 1995 Field conference guidebook, friends of the Pleistocene-Rocky Mountain cell: Late Pleistocene-Holocene evolution of the northeastern Yellowstone landscape, Middlebury College, Vermont, 9 pp.

<u>Invited Presentations</u>

Richards, D. C. and P. Spindler. 2013. Development of Arizona Intermittent Streams Macroinvertebrate Index of Biological Integrity. California Aquatic Bioassessment Workgroup Annual Meeting. Davis, CA.

Author and co-author of three talks on Salt Lake wetlands. 2013. Society for Wetland Scientists Annual Conference, Duluth, MN. May 2013. Need citations.

Richards, D. C., J. Rensel, and Z. Siegrist. 2012. Food web and fisheries studies: Rufus Woods Lake, Columbia River, WA. Large river ecology section moderator; Society for Freshwater Science Annual Meeting. Louisville, KT.

Richards, D. C. and T. Arrington. 2012. Predicting and monitoring the effects of a habitat restoration project on metapopulation viability of two federally listed species in a tributary of the Columbia River. Columbia River Estuary Conference. Astoria, OR. May 15-17.

Farley, J. and D. C. Richards. 2008. A critique of economic valuation of ecosystem services and its applicability to sustainable economic policy. Symposium on Economic Growth and Biodiversity: The Elemental Arguments. Society for Conservation Biology Annual Meeting. Chatonooga, TN. July 13-17.

Richards, D. C. and T. Arrington. 2007. Morgan Lake restoration project: Does Lanx sp. have a problem with that? Mid-Snake River Technical Work Group: Quarterly Meeting. September 19. Boise, ID.

Richards, D. C. and T. Arrington. 2007. Evolutionary consequences of a rapidly evolving invasive species to the viability of a native threatened species. Presented Poster. International Summit: Evolutionary Consequences of a Changing Environment. University of California. Los Angeles, CA. February, 2007.

T. Arrington and D. C. Richards. 2007. Predicting the effects of a habitat restoration project on the population viability of one threatened and one endangered lotic gastropod. Mid-Snake River Technical Work Group: Quarterly Meeting. September 19. Boise, ID.

T. Arrington and D. C. Richards. 2007. Predicting the effects of a habitat restoration project on the population viability of one threatened and one endangered lotic gastropod. World Malacological Congress Annual Meeting. Antwerp, Netherlands. July.

Richards, D. C. and T. Arrington. 2006. Empirical estimates of extinction and colonization rates of the threatened Bliss Rapids Snail for use in metapopulation viability analyses. Presented Paper. Snake River Snail Technical Committee Quarterly Meeting. December 12.

Richards, D. C., C. Smith, and B. Marshall. 2006. Effects of New Zealand mudsnail on water quality bioassessment metrics. Presented paper. California Water Quality Bioassessment Annual Meeting. Davis California. November 28-29th.

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Richards, D. C. 2004. Conducted New Zealand mudsnail identification workshop. Western Division American Fisheries Society Annual Meeting. Salt Lake City, Utah. March 1-4.

Richards, D. C. and D. C. Shinn. 2003. Spatial distribution of Bliss Rapids Snail and New Zealand mudsnail in a freshwater spring, Idaho, USA. Presented paper. North American Benthological Society Annual Meeting. Athens GA.

Richards, D. C. and D. C. Shinn. 2003. Intra and interspecific competition between Bliss Rapids Snail and New Zealand mudsnail. Presented paper. Society for Conservation Biology Annual Meeting. Duluth, MN.

Richards, D. C. 2002. The New Zealand Mudsnail in the Western USA. 2002. Presented paper. American Malacological Society Annual Conference. Charleston, SC. August 2002.

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Richards, D. C. 2002. New Zealand mudsnail in the western USA.. Invited paper. Western Regional Panel on Aquatic Nuisance Species Annual Meeting. Las Vegas, Nevada. January 9-10.

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Richards, D. C. 2001. Competition between the invader Potamopyrgus antipodarum and a threatened snail species in the Snake River. Presented paper. Aquatic Ecology Group, Montana State University, Bozeman, Montana.

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Richards, D. C., M. Rolston, and F.V. Dunkel. 1995. The distribution and abundance of Pteronarcys californica in the Madison River, MT. Poster presentation. Entomological Society of America. Las Vegas, Nevada.

Richards, D. C. and R. Bukantis. 1995. The use of aquatic insects as indicators of water quality in mountain streams in Montana using modified Rapid Bioassessment Protocols. Presented paper. Montana Academy of Sciences; Clark Fork Symposium, Missoula, MT.

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Rodriquez, D.C., F.V. Dunkel, D.C. Richards, and D.K Weaver. 1992. Fumigative, repellent, and oviposition deterrent properties of mountain sagebrush, Artemesia tridentata, for stored grain insects. Poster presentation. Entomological Society of America. Baltimore, MD.

River Continuum Concepts
502 E. Main Street
Manhattan, MT 59741
www.RiverContinuum.org
2/12/2013

Statement of Qualifications for: Benthic Macroinvertebrates of the Willard Bay Freshwater Wetland

Purpose

Each year we assist diverse people and organizations to develop, implement, and interpret ecological studies involving macroinvertebrate community structure and function. The purpose of this document is to demonstrate our unique qualifications to work on several environmental investigations of the Willard Bay near Great Salt Lake, Utah. The goal is to provide sufficient information to allow the Utah Division of Water Quality to make an informed decision without providing too much technical information. We invite feedback on the format and content of this document to make your job easier in the future.

Be sure to "Like" us on Facebook for frequent project updates!
http://www.Facebook.com/RiverContinuum

I. Project Specific Introduction:

River Continuum Concepts is partnering with several other investigators for several scientific investigations relating to the ecology of freshwater wetlands near the Great Salt Lake, Utah. We contribute to this team by providing several innovative laboratory capabilities in addition to standard invertebrate taxonomy. Our digital imaging microscopy will be used to generate more-accurate estimates of biomass and also measure the sizes of food items in the stomachs of even very small insects. We have developed a nested sieve invertebrate sorting procedure that allows data to be comparable with earlier efforts, while avoiding some of the pitfalls of fixed-count subsampling—this is especially important for ecological investigations concerned with invertebrate density, life history and biomass. Our museum collection (alcohol and slides) will be used to catalog and archive specimens as voucher organisms and for the eventual analysis of DNA bar codes.

II. Why Choose River Continuum?

Our principle investigator, Brett Marshall, has extensive experience working with macroinvertebrate ecology (q.v., resume and project list below). However, our experience is not only limited to our principle scientist. Our lab remains affiliated with the Academy of Natural Sciences as Adjunct Research Associates and we remain on call to the Academy as their go-to Aquatic Entomology Laboratory. Furthermore, River Continuum Concepts works with a consortium of professional aquatic scientists who work together on projects to ensure synergy and dynamic approaches to problem solving.

III. The Willard Bay Midge & Snail Top-Down Regulation Study: Similar Projects

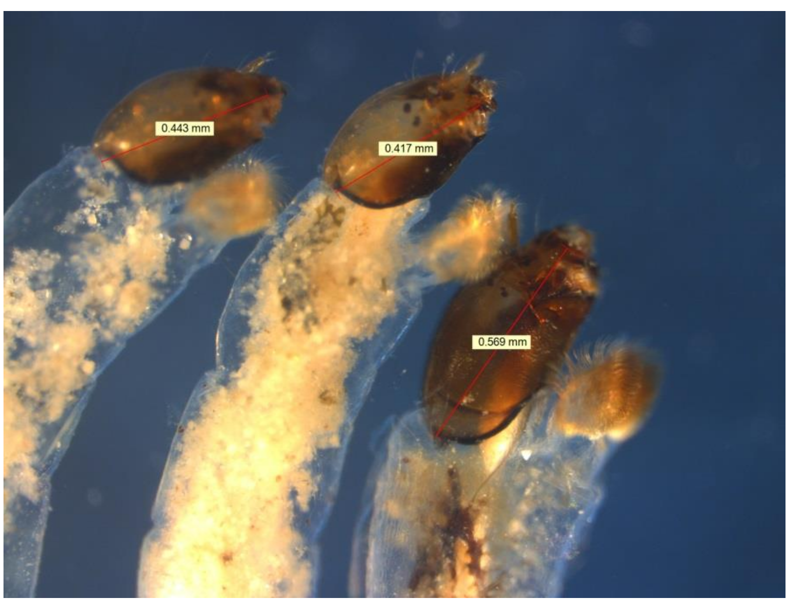
In this section we highlight several projects that demonstrate our success in projects similar to the current project from our extensive list of completed projects (Table 1). For this proposal we have selected a related wetland study near Great Salt Lake, a study of natural gas development in the upper Green River of Wyoming, and a study in which we modeled the relative abundance of certain macroinvertebrate groups relative to epilithic algae density.

Macroinvertebrates of Freshwater Wetlands near Great Salt Lake. (with T. Miller, D. Richards et al.)

In 2013, we identified macroinvertebrates from several freshwater wetlands near Great Salt Lake, Utah. We improved on the methods of other laboratories by implementing an altered subsampling protocol and by measuring head capsules using digital microscopy to measure the size of specimens before they were mounted. These methods were necessary to improve the study's ability to quantify potential changes in the food webs of wetlands.

We have found that many studies rely on rapid bioassessment field and laboratory methods which are based upon assumptions that are not necessarily valid for studies of population dynamics because of the effects of small, abundant species and the underlying assumptions of standard-unit-effort.[1] Alternatively, when large samples are collected, processing the whole sample can be cost-prohibitive. We developed a method of sieving that split the sample into fine and coarse portions and allocated subsampling effort proportionally. This circumvented some of the problems of errors-of-multiplication and violations of assumptions that accompanied applying bioassessment methodology to studies of ecosystem structure and function—while conserving some elements of comparable effort with earlier studies.

Often laboratories will combine all the insects after identification and bake them in an oven to estimate biomass as dry weight. This is always an underestimate of true biomass because (1) specimens are damaged in the field and lab (often missing legs, gills, or whole body sections), (2) lipids are leached into preservative resulting in a net loss of individual mass, and (3) slide mounted specimens are excluded from biomass. We used digital imaging to measure insect heads, then applied regression equations to estimate mean individual mass. Then, since specimens were not destroyed in the process, we were able to slide-mount them to ensure accurate and detailed taxonomy. Our adaptive approach to methods development for this study will improve its ability to accurately predict future changes in ecosystem structure and function.



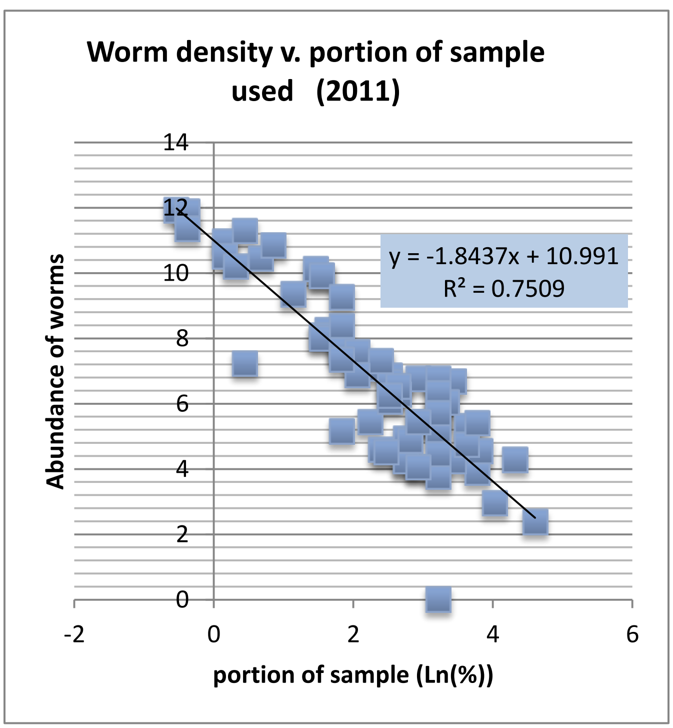
These midges from the Pintail freshwater wetland, adjacent to Great Salt Lake were measured (Head-capsule length, and head capsule width) to estimate biomass. A phase contrast microscope with imaging capability will be used to identify and quantify stomach contents.

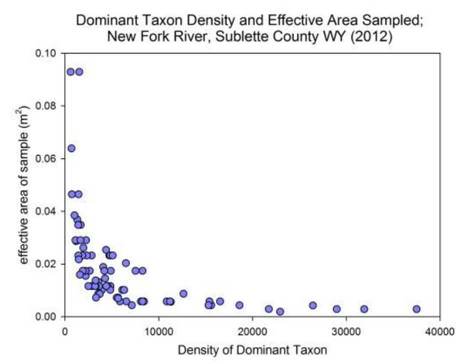
[1] See our presentation at the SFS/NABS 2014 meeting in Portland, OR.

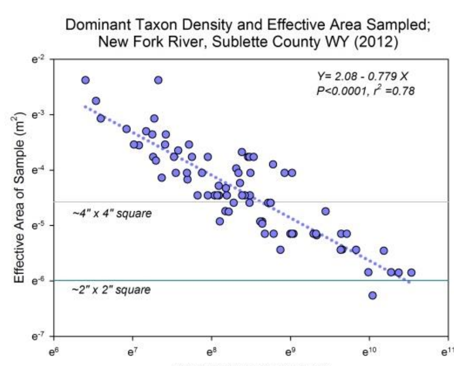
Effects of Natural Gas Development on Benthic Macroinvertebrate Assemblages of the New Fork River, Sublette County, Wyoming

We designed and implemented a study to assess the potential impacts of natural gas development on public lands in Sublette County, Wyoming. Each year, we complete this project with a detailed statistical analysis and report describing spatial and temporal changes in the New Fork River's benthic macroinvertebrates. The project had to meet the needs of diverse stakeholders and therefore, it needed a more-rigorous sampling design than possible using state's bioassessment protocols; we had to develop a nested sampling design which measured near-substrata flow and benthic substrata composition within the benthic sample area of each sample. Once established, we were able to elucidate when sedimentation caused shifts in macroinvertebrate assemblages, and when similar changes were due to increased plant growth. We did not want to unduly burden the natural gas developers with false positive impairment detections, but we also had to protect the public's interest by providing sufficient statistical power to detect ecologically relevant shifts in community structure; natural and anthropogenic.

After several years of analysis, we actually had sufficient data to quantify some of the assumptions of bioassessment field and laboratory methods, such as homogeneity of variance, and taxonomic completeness. More recently, we examined how the high abundance of some very small animals (~1mm) affects density estimates of larger animals. Understanding these limitations is paramount if data are to be interpreted intelligently—especially where density and biomass are more important than relative abundance.

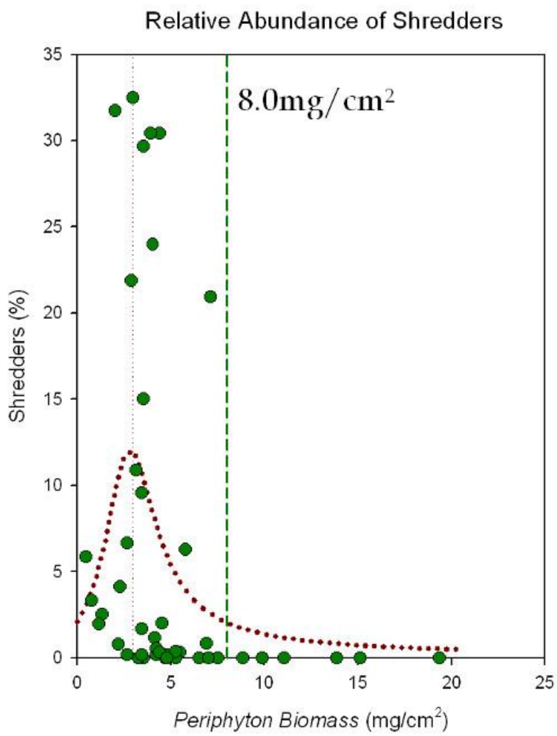


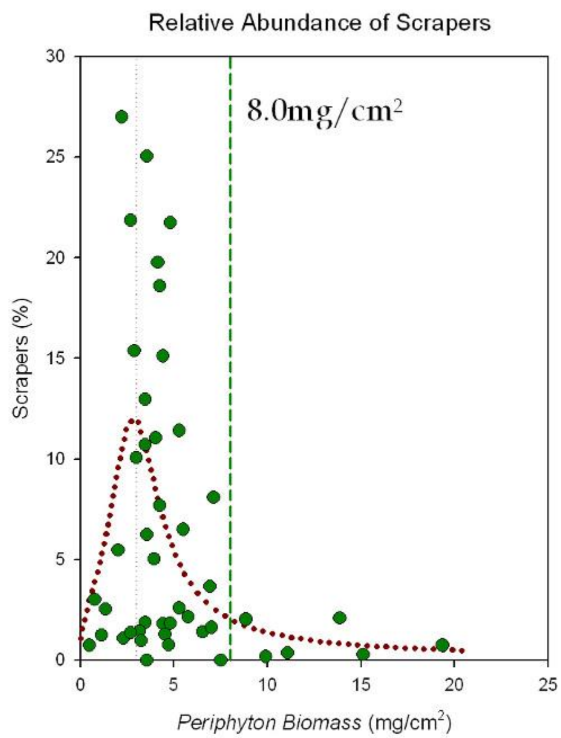




Effects of the nuisance algae *Didymosphenia geminata* on macroinvertebrate assemblages of the Kootenai River, below Libby dam, Montana Fish Wildlife and Parks, Libby Montana

This project examined benthic community structure along a longitudinal gradient on a large river below a dam. Its relevance for the Willard Bay Project is in the correlations macroinvertebrate communities with epilithic algae. We designed a study that was able quantify the response of invertebrate assemblages to changes in the density of algae films. The design used a nested sampling technique where algae samples were actually collected from within benthic macroinvertebrate samples, rather than elsewhere in the reach. This innovation combined with our statistical expertise, allowed us to use several non-linear regression techniques to model the response. Thus, we mathematically described the functional shifts in macroinvertebrate communities in response to algae films which allowed the testing of several hypotheses, but also allowed us to generate response thresholds that are used by the funding agency to manage the biota of the Kootenai River.





IV. Staff for this Project

Brett Marshall, Co-Principle Investigator

Our Principle Investigator (a Co-PI for this project), Brett Marshall has conducted studies of aquatic ecosystems since 1986, with a broad focus on macroinvertebrates, fish, primary producers, and water chemistry. Since 1990, his research focus has been on the effects of environmental variables on macroinvertebrate communities, and the methods where by environmental impacts can best be detected. His research on the effects of a riparian disturbance on the structure and function of benthic food webs of headwater streams earned him several awards from the Entomological Society of America, and from Virginia Tech. Furthermore, his role leading the Invertebrate Zoology Research Section at the Academy of Natural Sciences, America's first natural history institution (now the Academy of Natural Sciences of Drexel University), earned him the Patrick Center for Environmental Research's 1997 Award for Environmental Project Quality. His experience developing aquatic environmental monitoring programs in 27 U.S. States and ecological research goes into each and every study performed at River Continuum Concepts' laboratory in Manhattan, Montana. Brett's specific project experience is detailed in Section VIII of this document.

In addition to his award-winning Master's degree, Brett had completed the necessary course work for his Ph.D before a severe spinal injury and temporary paralysis preempted his education. He resumes work towards his doctorate in 2014, with a dissertation topic on the misuse and misapplication of bioassessment study designs in aquatic ecosystem studies. In addition to his extensive experience in invertebrate zoology, he has the credit-equivalent of an MS in statistics (39 graduate semester credits).

Today, he remains affiliated with the Academy of Natural Sciences as their adjunct researcher of Aquatic Invertebrate Zoology. We can accommodate clients needing to work with non-profit organizations through arrangements with the Academy[2] or through a consortium of local researchers. This also allows us to bring in experts in biogeochemistry, algae, fisheries, botany, engineering and geomorphology when multidisciplinary investigations are required.

Presentations, reports and other references are provided on our webpage and on our lab's Facebook Page.

HTTP://www.RiverContinuum.org

HTTP://www.facebook.com/RiverContinuum

[2] Due to the Academy's overhead, it is often more expensive to work through the Academy. This option is best when grants require oversight of a non-profit institution.

Brett Marshall's Resume Summary

Education:

Master of Science: Entomology, Virginia Tech. Honors. {see awards}

Bachelor of Science: Biology + Chemistry, Advanced Focus: Aquatic Population and Community Analysis. High honors.

Ph.D. Ecology: Montana State University. Incomplete.

Employers:

2007 – River Continuum Concepts. Founder. Principle Scientific Investigator.

2004-2007. EcoAnalysts, Inc. Statistical Design Consulting Scientist / Aquatic Ecologist

2003-2004. Rhithron Associates, Inc. Quality Assurance Officer/ Aquatic Ecologist

2002-2003. Inter-Mountain Laboratories: Aquatic Ecologist / Entomologist

2000-2002. Montana State University, Department of Ecology. Research Assistant, Ph.D.

1996-2000. Academy of Natural Sciences, Patrick Center of Environmental Research, Section Leader, Invertebrate Zoology.

1994-1996. National Park Service, New River Gorge National River, Biological Science Technician

1994: Independent Consultant to National Park Service, New River Gorge National River

1990-1994. Virginia Tech Department of Entomology. Graduate Research Assistant, Aquatic Entomology.
1987-1990. US Environmental Protection Agency, Biological Science Aide.

1986-1990. University of Wisconsin Superior. Biology Science Tech.

1983-1986. US ARMY. Tactical Communications.

Awards

1997. Academy of Natural Sciences. Patrick Center for Environmental Research.

1993. Virginia Tech Dept. of Entomology. James McDaniel Grayson Honorarium

1992. Entomological Society of America, Eastern Branch. Asa Fitch Memorial Award

1991. Entomological Society of America, National. Graduate Research Award: Ecology, Honorable Mention

1991-1993. Competitive Instructional Fee Scholarship (6x consecutive terms) (spring + fall semesters).

1990. University of Wisconsin Superior. Biology Student of the Year

1987-1990 National Deans List.

1986. US ARMY. Army Achievement Medal for meritorious service.

1985. US ARMY. Army Achievement Medal for meritorious service.

V. Support Staff for this project

Angel Lawellin, Senior Technician

Angel has been preparing slide mounts of chironomid midges for several years at River Continuum Concepts' Laboratory in Manhattan, Montana. She has helped develop methods to use digital image analysis and digital microscopy to measure midge parts; allowing biomass estimation for midges in freshwater wetlands, streams and rivers. This is more accurate than weighing animals after drying in ovens because insects are often damaged in the field or laboratory before biomass estimation. Angel also works in Data Quality Assurance activities.

Merle Roberts, Senior Technician

Merle is an advanced technician at RCC. He does some limited taxonomic identifications, sorts samples, and performs quality assurance checks on other technicians. He is also skilled at GPS/GIS applications and lends his expertise there when required. Merle also works in sorting and other laboratory Quality Assurance activities.

Esmeralda Ortiz, Technician

Esmeralda has been with River Continuum since the lab began operation in 2009. She has worked on projects from Tennessee to Texas, and north to Montana and many places in between. She is a versatile laboratory assistant, with experience in sorting, subsampling, fluid displacement, mounting midges, field work, and many other important activities.

VI. References

Our principle investigator has been a key promoter of optimum sampling theory, cost-benefits analysis, and adaptive sampling. But don't take our word for it; Please feel free to contact either of these two professional references that are familiar with our work on benthic sampling and study design.

Roger L. Thomas
Patrick Center for Environmental Research,
The Academy of Natural Sciences of Drexel University
1900 Benjamin Franklin Parkway,
Philadelphia PA, 19119
Telephone: (215) 299-1105

Kathy Raper,
Surface Water Monitoring Program Manager
Sublette County Conservation District
P.O. Box 647 / 1625 W. Pine St.
Pinedale, WY 82941
Telephone: (307) 367-2257 ext 102
kraper@sublettecd.com

VII. Price Schedule

Despite recent increases due to changes in operating costs and inflation, our price schedule is usually lower than the competitor's. The rates here are loaded for overhead expenses such as facilities, utilities, insurance, and taxes. There are no hidden fees on our invoices.

Principle scientist: $90/hr
Lab manager: $50/hr
Advanced Technician: $50/hr
Junior Technician: $40/hr
Junior Technician with high supply demand: $50 /hr

VIII. River Continuum Concepts Project Experience

Year	Agencies	Project Description	Duration
2013	Central Valley Reclamation / Jordan River	Analysis of macroinvertebrate assemblages of freshwater wetlands near Great Salt Lake, Utah	On going
2013	Greater Yellowstone Ecosystem Technical Workgroup	Ecology and life history of *Yoraperla brevis* (Plecoptera: Peltoperlidae)in the Greater Yellowstone Ecosystem	3
2013	R2 Resources Inc.	Macroinvertebrate identifications for FERC relicensing project on Deschutes River, Oregon	2 yr.
2013	National Forest Service	Analysis of 30-year trends of macroinvertebrate community structure with emphasis on the effects of increasing levels of atmospheric dry deposition of nitrogen	2 yr.
2013	Sublette County Conservation District	Effects of natural gas development on benthic macroinvertebrate assemblages of the New Fork River: 2012	2 yr.
2013	National Forest Service	Analysis of 30-year trends of macroinvertebrate community structure with emphasis on the effects of increasing levels of atmospheric dry deposition of nitrogen	1 yr.
2013	Sublette County Conservation District	10 year trend analysis of macroinvertebrate assemblages in the New Fork River basin of Sublette County Wyoming	1 yr.
2012	Sublette County Conservation District	Effects of natural gas development on benthic macroinvertebrate assemblages of the New Fork River: 2011	1 yr.
2011	Sublette County Conservation District	Effects of natural gas development on benthic macroinvertebrate assemblages of the New Fork River: 2010	1 yr.
2011	Sublette County Conservation District	Baseline biology of macroinvertebrate assemblages of the Hoback River, Sublette County, WY	1 yr.
2011	Sublette County Conservation District	Statistical design of environmental monitoring program	1 yr.
2011	RCC outreach	Effects of the Exxon pipeline rupture on macroinvertebrate assemblages of the Yellowstone River in Montana	3 yr.
2010	Sublette County Conservation District	Effects of natural gas development on benthic macroinvertebrate assemblages of the New Fork River: 2009	1 yr.
2010	Eastman Chemical Corp. / The Academy of Natural Sciences	Assessment of longitudinal and temporal changes in benthic community structure of the Holston River, Tennessee: the effects of industrial point source discharges relative to other land use effects.	1 yr.
2010	Eastman Chemical Corp. / The Academy of Natural Sciences	Assessment of longitudinal changes in benthic community structure of the Sabine River, Texas: the effects of industrial point source discharges relative to other land use effects.	2 Yr.
2009	Sublette County Conservation District	Effects of natural gas development on benthic macroinvertebrate assemblages of the New Fork River: 2008	1 yr.

2009	National Forest Service/ National Park Service / Bureau of Land Management	Greater Yellowstone Ecosystem Atmospheric Deposition Workgroup: Macroinvertebrate Ecology Expert	3 yr.
2009	US Forest Service / Sublette County Conservation District	Study Design for the assessment of long term patterns of macroinvertebrate community structure and function in Hoback River National Scenic River	1 yr.
2008	Montana Army National Guard / US BLM	Status of seven invertebrate species of conservation concern in the Limestone Hills National Guard Training area, Montana	1 yr.
2008	Sublette County Conservation District	Effects of natural gas development on benthic macroinvertebrate assemblages of the New Fork River: 2007	1 yr.
2008	Lincoln Conservation District	Analysis of water quality trends of the Hams Fork River over 10 years.	1 yr.
2007	Sublette County Conservation District	Effects of natural gas development on benthic macroinvertebrate assemblages of the New Fork River: 2006	1 yr.
2007	Sublette County Conservation District	Baseline water chemistry and biotic conditions of streams in the Green River Basin of Sublette County	1 yr.
2007	Oasis Environmental / PacifiCorp	Study design to describe the effects of changed flow regime and hydropower generation on macroinvertebrate ecology of the Bear River, ID	1 yr.
2006	Montana Department of Fish, Wildlife and Parks	Effects of the nuisance algae *Didymosphenia geminata* on benthic macroinvertebrate assemblages of the Kootenai River, MT and ID	2 yr.
2006	Sublette County Conservation District	Baseline water chemistry and biotic conditions of streams in the New Fork River Basin of Sublette County	1yr
2006	Natrona County Conservation District	Laboratory Analyses of macroinvertebrate samples	1 yr.
2006	Niobrara Conservation District	Cost-benefits analysis of floating artificial substrates to monitor the ecological health of prairie streams in Niobrara County, WY	1 yr.
2005	Sublette County Conservation District	Local short term effects of natural gas development on the Pinedale anticline project area of Sublette County: 2005	1 yr.
2004	EcoAnalysts	Development of an analytical relational database to store and process macroinvertebrate data	2 yr.
2004	Wyoming Association of Conservation Districts	Wyoming educational benthic imaging project: interactive imaging of macroinvertebrates and the integration of images into educational materials	1 yr.
2004	EcoAnalysts	Assessment of impacts on benthic assemblages of streams in Idaho	3 yr.
2003	Judith Gap Conservation District	Assessment of macroinvertebrates in restored and non-restored reaches of streams in Judith Gap Conservation District	1 yr.
2003	Niobrara Conservation District	Analysis of macroinvertebrates of prairie rivers of Niobrara County, WY	2 Yr.
2002	Montana State University / Montana DEQ	Alternative biocritera for the assessment of the ecological health of streams and rivers of Montana: a statistical power analysis approach.	1 yr.

2000	Montana State University / Montana DEQ	Critical assessment of biological assessment criteria of Montana	3 yr.
2000	National Park Service	Development and assessment of bioassessment criteria for small streams in New River Gorge National River	1 yr.
1999	Academy of Natural Sciences	Effects of seasonality on the statistical power of macroinvertebrate assessments in North Eastern North America	1 yr.
1999	Academy of Natural Sciences	Study design for assessment of the effects of low-head dam removal on macroinvertebrates of streams and rivers of Pennsylvania	1 yr.
1998	DuPont Chemical / The Academy of Natural Sciences	Recovery of macroinvertebrate communities of contaminated sediments of Pompton Lakes, New Jersey, after restoration: Analyses of community structure and bioaccumulated mercury.	1 yr.
1998	William Penn Foundation / The Academy of Natural Sciences	Biodiversity of Parks in Urban Watersheds of Philadelphia	2 yr.
1998	US EPA / The Academy of Natural Sciences	Ecological Benefits of Riparian Restoration in urbanizing watersheds: a multidisciplinary assessment of fish, invertebrates, algae, hydrology, biogeochemistry, and food webs	2 yr.
1997	Eastman Chemical Corp. / The Academy of Natural Sciences	Effects of industrial operations on community structure of snag-dwelling macroinvertebrates of the Congaree River, near Charleston, South Carolina.	1 yr.
1997	Eastman Chemical Corp. / The Academy of Natural Sciences	Effects of industrial operations on community structure of snag-dwelling macroinvertebrates of the White River, near Batesville, Arkansas	1 yr.
1997	National Park Service	Development of standard methods for the assessment of macroinvertebrate assemblages of Delaware Water Gap National Recreation Area, of PA, NJ, and NY.	2 yr.
1997	Eastman Chemical Corp. / The Academy of Natural Sciences	Assessment of longitudinal changes in benthic community structure of the Holston River, Tennessee: the effects of industrial point source discharges relative to other land use effects.	1 yr.
1996	Academy of Natural Sciences / US Dept. of Energy	Effects of Nuclear cooling water on the structure and function of benthic macroinvertebrates of the Savannah River, Georgia.	3 yr.
1996	DuPont Chemical / The Academy of Natural Sciences	Assessment of longitudinal changes in benthic community structure and production in the Guadalupe River, Texas: Evaluation of the ecological benefits of bioremediation	4 yr.
1995	Virginia Tech / National Park Service	Use of Aquatic insect community structure and life history to establish "perennial" vs. intermittent stream flow status to evaluate construction options of a proposed park way through New River Gorge National River	1 yr.
1995	National Park Service	Water /quality Monitoring and macroinvertebrate Ecology for New River Gorge National River	2 Yr.
1995	National Park Service	Longitudinal variation in benthic macroinvertebrate community structure of the New River below Bluestone Dam, West Virginia	1 yr.
1994	Virginia Tech / National Forest Service	Baseline bioassessment of George Washington National Forest and Thomas Jefferson National Forest, Virginia and Kentucky	1 yr.
1992	Virginia Tech	Aquatic Entomology of the New River, Virginia	3 yr.
1991	Virginia Tech / National Park Service	Effects of riparian defoliation by gypsy moth larvae (*Lymantria dispar*) on the ecology and secondary production of macroinvertebrates of Appalachian Headwater Streams	3 yr.
1990	US EPA	Use of Pypronyl butoxide as a metabolic inhibitor to block cytochrome P-450 detoxification pathways to improve predictive toxicology models for fat head minnow	1 yr.
1990	Virginia Tech	Assessment of different formulations on penetration of Octoborate into different wood species using gas chromatography	1 yr.

1990	Virginia Tech / National Park Service	Long-term Ecological Monitoring System (LTEMS) for Shenandoah National Park	4 yr.
1990	Whitmire Chemical Corp	Assessment of borate treated wood on the survival of wood boring beetles.	1 yr.
1989	UWS	Invertebrates of the Little Rock Lake experimental acidification long-term environmental research (LTER) site	1 yr.
1989	US EPA	Bioassay of static toxicity of organic compounds to planktonic invertebrates	3 yr.
1988	UWS	Effects of acidification on activity levels of planktonic organisms and potential indirect effects on foraging larval fishes of Little Rock Lake	1 yr.
1987	US EPA	Bioassay of toxicity of organic compounds to fat head minnows	3 yr.
1987	US EPA	Bioassay of toxicity and carcinogenesis of organic compounds to madaka.	3 yr.
1987	University of Wisconsin Superior	Aquatic Entomology of streams of the north shore of Lake Superior, Minnesota	1 yr.
1986	UWS	Curation of University Aquatic Entomology Museum Collection	4 yr.

UTDWQ Willard Bay Project

Proposal: Of Midges and Snails: Assessing their Role in the Health and Resilience of Willard Bay in Response to Anthropogenic Impacts

Investigators: Richards and Marshall et al.

ADDENDUM 1

BACKGROUND INFORMATION ABOUT MIDGES AND SNAILS IN WILLARD SPUR FROM HOVEN ET AL. 2013

Bottom up vs. top down regulation of primary producers

Ecosystem food webs, particularly primary producers (plants) are regulated by both bottom up and top down interactions. Examples of bottom up regulation can include interactions between water chemistry, substrate, climate, and even bacteria. Top down regulators include grazers, which in turn can be regulated by predators. Research conducted in 2012 and 2013 in Willard Spur (Bay) (Hoven et al. 2013, Gray 2013, Ostermiller et al. 2013, and others) focused mostly on bottom up controls including water chemistry and epiphyton on SAV health, and to a lesser extent top down regulation including macroinvertebrates and zooplankton. The reason for less emphasis on macroinvertebrates and zooplankton was because these taxonomic groups did not appear to respond to nutrient enrichment in the 2012 study; which was one of the primary goals of the collaborative research (Hoven et al. 2013). The WS Science Panel concluded that the two years of research provided a very good understanding of the bottom up regulation of SAV (i.e. water chemistry and epiphyton). However, the role of top-down regulation was unclear.

WS macroinvertebrate assemblages

Food web role of macroinvertebrates

Macroinvertebrates act as primary and secondary consumers and decomposers. Many macroinvertebrate taxa are herbivores (primary consumers), while others are predators (secondary consumers), omnivores, or detritivores. They are also the key link between primary producers (plants) and larger bodied predators such as fish and birds. Macroinvertebrates comprise the full range of food web roles: primary and secondary consumers, omnivores, and detritivores in WS, with at least 19 different taxa reported in WS in 2012 (Hoven et al. 2013, Gray 2013). Macroinvertebrate assemblages in WS are also a subset of the surrounding wetland ponds in GSL (Miller et al 2011). The WS ecosystem does not act in isolation and the resilience of WS to environmental changes is dependent on this connectivity to other wetlands and water sources in GSL. This connectivity includes dispersal and recolonization of macroinvertebrates from surrounding locations. Many of the macroinvertebrate taxa that occur in WS, including midges and snails, are the primary food items for migratory waterfowl and shorebirds.

Seasonality

Hoven et al. (2013) and Gray (2013) reported that macroinvertebrate assemblages in WS changed seasonally in 2012 (Figures 1 and 2). Macroinvertebrate grouped into three seasonal assemblages: 1) June/July, 2) August, and, 3) September/October based on biomass data from the Hoven et al. 2013 study (Figure 1), whereas assemblages grouped into two seasonal patterns: June/September and July/August based on abundance data from Gray (2013).

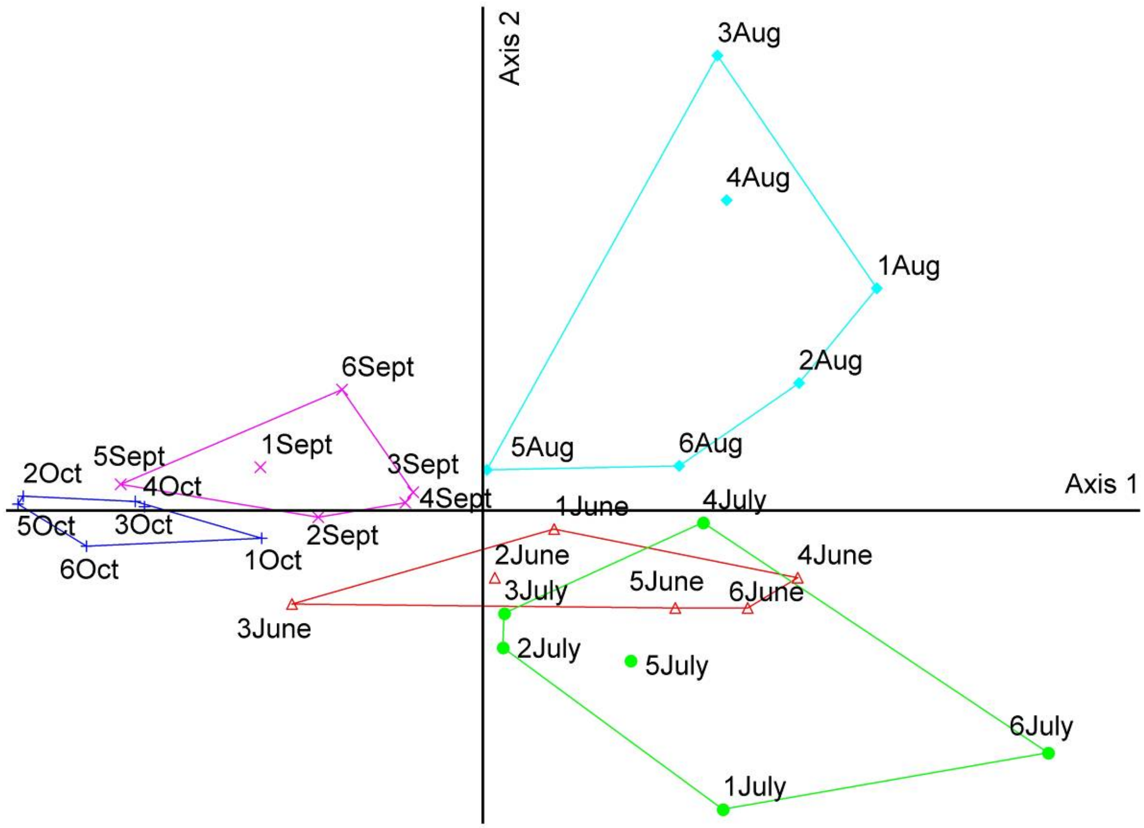


Figure 1. Non Metric Multidimensional Scaling ordination of the macroinvertebrate assemblages in the Willard Spur from Hoven et al. 2013. (the number before the month represents nutrient treatment codes not dates).

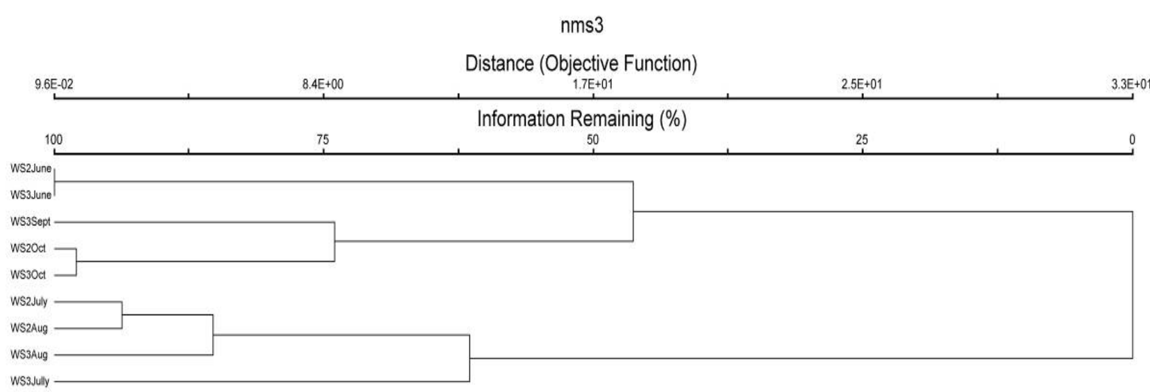


Figure 2. Cluster analysis of macroinvertebrate assemblages in 2012 from Gray 2013 data (from Hoven et al. 2013 report).

Many of the taxa in WS showed seasonal patterns in 2012 (Hoven et al. 2013). For example, biomass of the snail *Physa* sp. (synonymous with *Physella* sp.) was greatest in August and biomass of midges (Chironomidae) was greatest from August through October (Figure 3). The remaining taxa did not show major monthly trends or were uncommon (Hoven et al. 2013). The most abundant taxon, reported by Gray 2013, in WS in 2012 was the pulmonate snail *Gyraulus* sp. This snail occurred at very high abundances in July but low abundances in other months. *Physa* sp. and two midge taxa, *Chironomus* sp. and Tanypodinae had the highest biomasses reported by Hoven et al 2013 and their combined biomass was greater than all of the other taxa combined in all five months (Figure 4). From these studies it appears that midges and snails are by far the dominant herbivore taxa in WS and their roles in its function and food web structure are key.

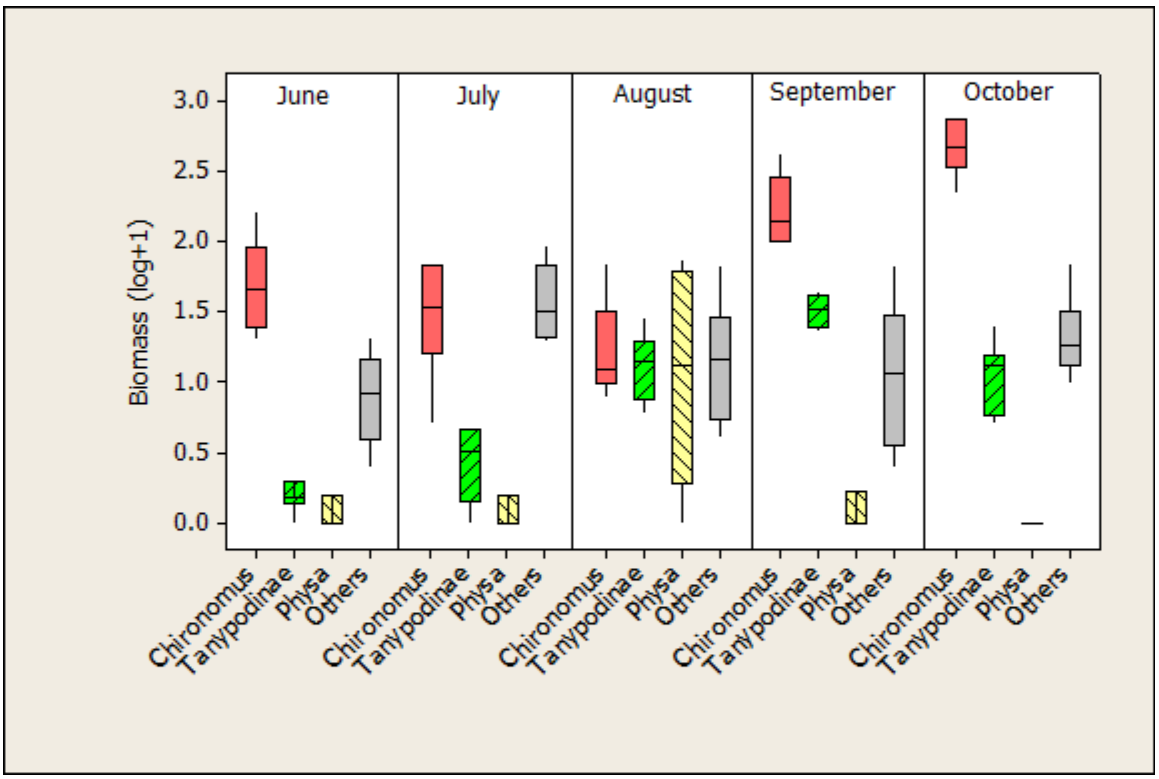


Figure 3. Biomass (log+1) of two midge taxa, *Chironomus* sp. and Tanypodinae and one snail taxon, *Physa* sp. vs. all other macroinvertebrate biomass combined (Others) at five months in a WS nutrient treatment study (Hoven et al. 2013).

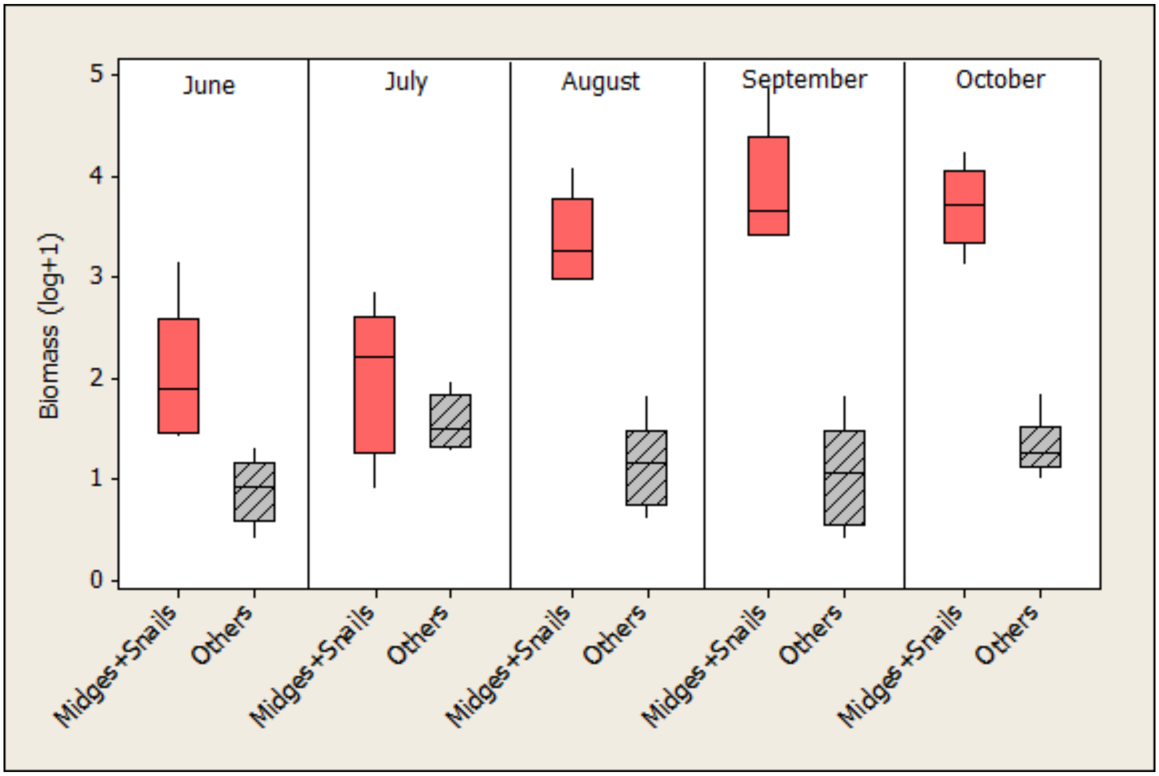


Figure 4. Combined biomass (log+1) of two midge taxa, *Chironomus* sp. and Tanypodinae and one snail taxon, *Physa* sp. (Midges + Snails) vs. all other macroinvertebrate biomass combined (Others) at five months in a WS nutrient treatment study (Hoven et al. 2013).

Scraper-grazer and collector-gatherer taxa relationships with SAV and epiphyton in WS

Hoven et al. (2013) reported that the major differences in macroinvertebrate assemblages and taxonomic diversity appeared to be mostly related to the presence and amount of SAV habitat and epiphyte food resources. Total vegetative abundance which included forageable and non-forageable SAV (as measured by percent cover) was: greatest in May and June, almost completely absent in July, increased substantially in August, decreased again in September and then increased in October (Figure 5). Percent Forageable SAV followed a somewhat similar pattern as did total vegetation cover: % Forageable SAV was greatest in May and June, and then there was a die off in July, and a slight rebound in August. However, forageable SAV did not recover as well as non-forageable SAV in September and October.

(Figure 5) The amount of algae (epiphyton) growing on SAV (as measured by percent) increased from May through August and was not recorded when standing SAV was absent in September and October (Figure 5).

Note: % Algae (epiphyton) was not measured on non-forageable SAV.

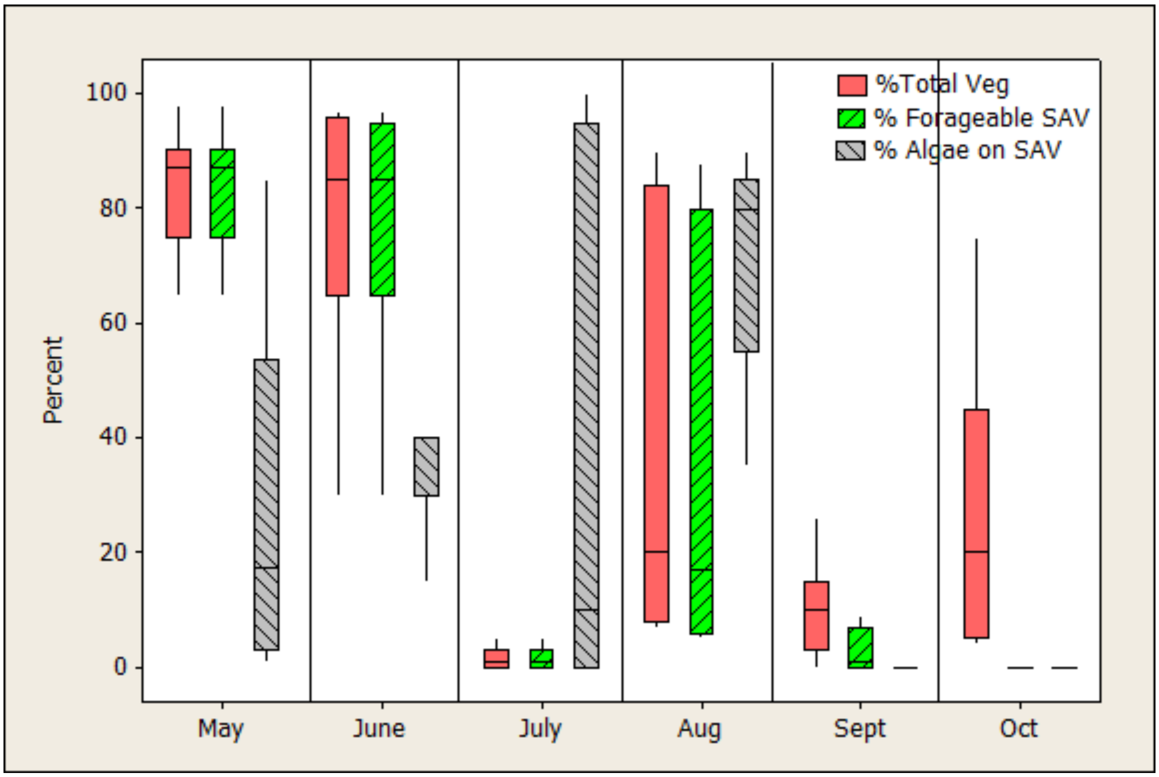


Figure 5. Percent total vegetation cover, % forageable SAV, and % algae on SAV for 6 months in the 2012 nutrient enrichment enclosure studies conducted by Hoven et al. 2013.

The increase in percent epiphytes (algae) on SAV corresponds with increases in abundances of *Gyraulus* sp. in July and biomass of *Physa* sp. in August (Figure 3). The loss of standing forageable SAV and reduced non-forageable SAV in September and October also corresponds with the very large increases in biomass of midges, particularly *Chironomus* sp. but also Tanypodinae (Figure 3).

Filamentous green algae, *Cladophora* sp. vs. BDS

The dominant epiphyton on SAV was by far the green algae, *Cladophora* sp. in 2012, whereas BDS dominated the epiphyton assemblage on SAV in 2013 (Hoven et al. 2013). BDS is a mixture of bacteria, diatoms, and sediment, exclusive of green algae. Reasons for this dramatic switch in epiphyton on SAV from 2012 to 2013 are unknown. However, *Cladophora* sp. is a poor food resource for most macroinvertebrate herbivores, including midges and snails and it is often selected against in their diets. In contrast, one of the most common epiphytic diatom taxon in WS is *Cocconeis* sp. (Rushforth personal communication). This species of diatom also happens to be a preferred food item of snails.

Functional Feeding Groups

Scrapers

The functional feeding group (FFG) *scrapers* is primarily associated with food resources such as algae, bacteria, detritus, etc. that grow on substrates, collectively generically known as *periphyton,* or as *epiphytes* when it occurs on plants. The FFG *collector/gatherers* also track periphyton but to a lesser extent. Scrapers can reduce and even alter periphyton assemblages via their grazing activities and food preferences (i.e. top down control). Some scraper taxa can remove long stalked algae, either by ingesting as a food source or by physical removal during grazing; other scrapers prefer short stalked algae as a food source (Richards 2004, Sommer 1999, Chase et al. 2001).

Two snail genera *Physa* sp. and *Gyraulus* sp. (Planorbidae) were the only scraper taxa collected in the Hoven et. al. 2013 and Gray 2013 WS studies. However, *Stagnicola* sp. (Lymnaeidae) likely occurs and frequents other nearby wetland ponds (Miller et al. 2013). In addition, a highly invasive snail, *Radix auricularia* (Family Lymnaeidae) has been reported in GSL wetlands (Miller et al. 2013).

The seemingly simple snail assemblage in WS represents three different families and therefore a range of niches, diversification, and convergent evolution. Although all three taxa are loosely clumped in the functional feeding group (FFG), *scrapers*; each taxon has different environmental requirements, life histories, spatial and temporal distributions, feeding habits, and ecologies. Thus the generalized FFG classification of 'scrapers' can be highly misleading. Scrapers are typically classified by their scraping mouthparts (e.g. snails have scraping, rasping, *radula* (teeth)) and are frequently assumed to be generalist herbivores. However, most studies of snail diets show that they are selective feeders.

Other factors affecting midge and snail seasonality

Members of the WS Science Panel postulated that the population crash of *Physa* sp. (Hoven et al. 2013 data), *Gyraulus* sp. (Gray 2013), the total disappearance of these snails in WS in 2013, and the increase in midges in mid/late summer may have been due to increased pH and/or decreased DO. However, many taxa also maintained populations during increased pH and decreased DO levels in 2012 including: *Callibaetis* sp. (Ephemeroptera), *Caenis* sp. (Ephemeroptera), *Ischnura* sp. (Odonata), *Corisella* sp. (Hymenoptera), *Notonecta* sp. (Hymenoptera), and *Hyallela* sp. (Amphipoda)(Hoven et al. 2013).

Although the absence of the most important grazer (scraper) taxon, snails, in WS in 2013 is alarming; we surmise that conditions in WS were likely suitable for snails for at least part of their growing season in 2013. All three snail taxa that occur in WS are tolerant of low DO levels and are known as 'air breathing lung snails' (former subclass Pulmonata) and have the ability to breathe atmospheric air under adverse conditions. However, these three taxa are intolerant of high pH. Increased pH may have been the ultimate cause of snail population crashes in 2012 but proximate causes may have resulted from increased pH stress including: low DO, low early season water temperatures that limited growth and reproduction, other water chemistry conditions, physiological responses, parasites, poor food quality (particularly *Cladophora* sp. in 2012), or reduced competitive ability (Dillan 2000). Snail taxa in WS are hermaphroditic, continuous breeders and reproducers and can have several generations per year depending on environmental conditions. These taxa are egg layers, not live- bearers, and their eggs are deposited in a gelatinous matrix that provides some protection from environmental conditions including:

desiccation, low DO, and increased pH. Resistant eggs can then hatch when conditions again become favorable (Dillan 2000). It is unknown if snails laid eggs in late 2012 or if they did whether the eggs were viable the following year, 2013.

Snail extinction, dispersal, and metapopulation dynamics

We also surmise that this snail 'extinction' event at the end of 2012 and into 2013 was in part a result of lack of dispersal and recolonization from surrounding suitable habitat in 2013. Snail population viability is dependent on dispersal and recolonization and is the cornerstone of metapopulation dynamics (Hanksi 1999). Snails are relatively poor active dispersers compared with aerial adult aquatic insects but rely mostly on passive dispersal such as drift or possibly via attachment to other more active dispersers such as fish, birds, humans, etc. Without recolonization events, snail populations in WS are not likely to become reestablished and their loss as the primary grazer of epiphyton on SAV could have adverse effect on WS ecosystem function.

Potential for Invasive snail taxa better suited to WS conditions

Native snails such as the three taxa that occur in WS are there because of the virtue of the relatively long period of time they have had to evolve and become established. They may not be the best suited macroinvertebrate grazers for the WS ecosystem but have adapted as well as possible given their evolutionary constraints and the physical, ecological, biological, bio- geological conditions in WS and because no other better suited grazers have had the opportunity to become established.

As stated earlier, the invasive *Radix auricularia* now occurs in nearby GSL wetlands and we expect it to spread throughout unoccupied habitats and quite possibly WS. The highly invasive New Zealand mudsnail, *Potamopyrgus antipodarum* (Family: Hydrobiidae) (NZMS) occurs in the Bear River, which empties into Willard Spur. Its ability to readily invade aquatic ecosystems is primarily due to several factors including; tolerance to freshwater and saline conditions, a wide range of temperature tolerance, an operculum that can be closed to seal itself from environmental conditions including desiccation, low DO, and even a fishes digestive system. NZMS are parthenogenic live- bearers that can reproduce without sex. It takes only one NZMS to start a population, which can then become a clonal population of several million within a few short years. Reasons why it has not been reported or become well established in WS are unknown but could be due to high pH. NZMS are a much poorer food resource to shorebirds and waterfowl than the native snails in WS because of their harder to digest shells and opercula.