

Bugs Below Zero: Communicating Science and Engaging the Public with Winter Active Aquatic Insects and Stream Food Webs

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Abstract

Winter is typically viewed as a time when insects are thought to be inactive; however, some aquatic insects (e.g., chironomid flies, stoneflies, and mayflies) have species which complete multiple life stages and emerge as active, terrestrial adults during winter. These insects have adaptations that permit survival at low temperatures and are known to occur in seasonally cold environments worldwide. However, awareness and education around these specialized insects are lacking partially due to the limited research and education centered around winter aquatic ecology. The *Bugs Below Zero* project, started in 2019, aims to enhance awareness and increase appreciation for winter-adapted aquatic insects, providing opportunities for the public to engage in community science efforts collecting data on these insect groups. The program has received positive reception in classroom and outreach settings and has successfully provided multimedia educational materials to hundreds of educators and data collection opportunities to numerous volunteer groups and classrooms. With the help of volunteers, the *Bugs Below Zero* team aims to add to the body of scientific knowledge about winter active insects and to continue educating students and community members about these organisms, their role in food webs, and their conservation needs.

Introduction

Aquatic insects that have recently completed their life cycle and emerged from water bodies are everywhere during the summer. However, relatively few people consider what happens to these insects during winter. Several groups of aquatic insects, including select Plecoptera, Ephemeroptera, Trichoptera, and Diptera (e.g., chironomids, craneflies) are adapted to emerge during winter (Lencioni 2004, Hågvar 2010, Soszyńska-Maj et al. 2016, Bouchard and Gelhaus 2020, Anderson et al. 2025/this issue). In particular, the temperature-modifying influence of groundwater springs keep groundwater-dominated stream sections “winter warm” and ice-free, permitting certain aquatic insects to complete their life cycle and emerge as reproductively active adults (Bouchard and Ferrington 2009, Anderson and Ferrington 2013, Baranov and Ferrington 2013, Nyquist et al. 2020). These winter-active species are well adapted to low temperatures, and exhibit behavioral, physiological, and biochemical adaptations that allow them to thrive during the cold winter season (e.g. Anderson et al. 2025/this issue).

The Chironomidae are among the most common winter-emerging aquatic insects, with over 220 taxa worldwide currently recorded as emerging during winter (Anderson et al. 2025/this issue). Chironomids are often seen walking or mating on snowbanks flanking ice-free groundwater-fed streams or even flying short distances. Research shows that these winter-emerging species are important components of winter food webs as a prey resource for certain fish (French et al. 2014, 2016, Anderson et al. 2016, Cochran-Biederman and Vondracek 2017) and birds (Braz et al. 2014).

Despite the long winter season in northern temperate regions, there is still limited awareness and understanding of cold-adapted insects and the role they play in groundwater-dominated streams. The *Bugs Below Zero* project (BBZ; www.bugsbelowzero.com), conceptualized by Dr. Len Ferrington, Jr. and a team of interdisciplinary, Minnesota-based researchers in 2019, aims to raise awareness and enhance the understanding of chironomids and other winter-active aquatic insects. BBZ strives to achieve this via a participatory science program that can guide research, along with offering classroom education and community outreach opportunities. Specific overarching goals of BBZ include: 1) raising awareness about the winter life of aquatic insects; 2) helping others to understand the value of chironomids and other aquatic insects and to appreciate their importance within stream food webs; and 3) gaining assistance from community scientists looking for and documenting winter-emerging insects.

BBZ includes resources on winter-active insect species and basic identification, kindergarten (K) to grade 16 classroom resources and activities, and information and directions for a community participatory science program where participants walk short sections of stream bank to collect and submit data about chironomids and other aquatic insects that are active on the snow (Fig 1). Volunteers are asked to count and identify insects they observe (chironomids, caddisflies, stoneflies, mayflies), differentiate sex when feasible (e.g., in chironomids), document behavior, and take pictures to help researchers verify identification. Participants are also encouraged to make observations related to weather, stream conditions, and habitat. Data are submitted via the *Aneccdata* community science app at: <https://www.aneccdata.org/projects/view/949>. Findings submitted via *Aneccdata* provide researchers, agencies, classrooms, and community volunteers with open access data on winter insect activity and winter stream conditions over time, with an additional underlying goal of allowing participants to directly engage with and appreciate winter insect activity.

While winters often feel long, the field season is short; enlisting help from community scientists allows researchers to better understand the winter insect community. The participatory science project has the potential to help scientists understand how variation in winter insect abundance and behavior differs among streams, sexes, taxa, under different air or water temperatures, and at different distances from the stream. This information may also inform natural resource managers as scientists are yet unsure how ecosystems, and the species within, will be impacted under scenarios of climate change.

Outreach and Reception

The BBZ project has garnered attention through its website, social media channels, blog posts, mailings, videos, podcasts, webinars, partner newsletters, media relations, and in-person outreach events. In 2023 and 2024 alone, the *Bugs Below Zero* team had more than 1,000 people attend in-person and live events and more than 2,000 unique visitors to the website.

The BBZ team has developed partnerships with natural history museums, nature centers, and nonprofit organizations like the Bell Museum, Belwin Conservancy, and Minnesota Valley National Wildlife Refuge to host interactive and educational programs for families, community members, and K–grade 12 classrooms. These programs offer an opportunity to handle insects, practice identifying them, and to participate in educational games that build knowledge of winter stream ecology and stream food webs (Figs 2 & 3). The team



Figure 1. Dr. Len Ferrington (left) and students searching for and collecting winter-active Chironomidae from a spring-fed stream in Minnesota, USA.

has also created supporting educational resources for K–grade 12 teachers, higher education classrooms, informal educators, and families, which are available on the website. For example, the team created an ethogram activity focused on documenting insect behavior in the field, instructions on how to use training datasets, videos that introduce stream environments and insects, and guides to support participants interested in collecting field data. These resources have been shared with over 500 educators, and BBZ activities have also been featured in multiple media interviews. Research conducted by the BBZ team shows there is growing interest and motivation to participate in winter community science, and educators are interested in involving classrooms in data collection (Swenson and Nyquist 2024). Specifically, educators view BBZ as an opportunity to break routine and provide students with relevant, hands-on experience in the field that creates enthusiasm for environmental issues, enhances connections and community, and contributes to meaningful science. Yet, barriers to participation exist, such as time constraints, access to field sites particularly during winter which presents additional field-safety concerns, and equity across the classroom, including mobility at stream sites and access to appropriate outerwear (Swenson and Nyquist 2024).

Conclusion

So far, the BBZ program has had positive reception from participants of its various activities with some sharing that they have learned about winter-active insects for the first time and have gained more confidence in identifying them. While BBZ is based in Minnesota, the team welcomes participants from northern-temperate states and countries around the world with the goal of increasing community participation in collecting data on winter-active insects and furthering knowledge and conservation of these uniquely adapted insect groups.

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Figure 2. Live aquatic insects used in demonstrations and workshops.



Figure 3. Middle school students learning about winter stream ecology and the importance of aquatic insects.

References

- Anderson, A.M., Nyquist, C., Bodmer, H., Bouchard Jr., R.W., Durnin, T. and Vondracek, B. 2025. Midges below zero: A review of hibernation emergence of Chironomidae in temperate regions. - *CHIRONOMUS: Journal of Chironomidae Research* 40: 37-63. DOI: <https://doi.org/10.5324/cjcr.v0i40.6298>
- Anderson, A.M. and Ferrington, L.C. 2013. Resistance and resilience of winter-emerging Chironomidae (Diptera) to a flood event: Implications for Minnesota trout streams. - *Hydrobiologia* 707: 59-71. DOI: <https://doi.org/10.1007/s10750-012-1406-4>
- Anderson, A.M., Mittag, E., Middleton, B., Vondracek, B. and Ferrington, L.C. 2016. Winter diets of brown trout populations in southeastern Minnesota and the significance of winter-emerging invertebrates. - *Transactions of the American Fisheries Society* 145: 206-220. DOI: <https://doi.org/10.1080/00028487.2015.1111258>
- Baranov, V. and Ferrington Jr., L.C. 2013. Hibernation Emergence of Chironomidae in Ukraine. - *CHIRONOMUS Journal of Chironomidae Research* 26: 33-40. DOI: <https://doi.org/10.5324/cjcr.v0i26.1616>
- Bouchard, R.W. and Ferrington, L.C. 2009. Winter Growth, Development, and Emergence of *Diamesa mendotae* (Diptera: Chironomidae) in Minnesota Streams. - *Environmental Entomology* 38: 250-259. DOI: <https://doi.org/10.1603/022.038.0131>
- Braz, L.F.P., Oliveira, B. and Hughes, S.J. 2014. The Importance of emerging chironomids as a food resource for overwintering passerines in an Iberian high altitude lake. - *CHIRONOMUS Journal of Chironomidae Research* 27: 48-50
- Cochran-Biederman, J.L. and Vondracek, B. 2017. Seasonal feeding selectivity of brown trout *Salmo trutta* in five groundwater-dominated streams. - *Journal of Freshwater Ecology* 32: 653-673. DOI: <https://doi.org/10.1080/02705060.2017.1386595>
- French, W.E., Vondracek, B., Ferrington, L.C., Finlay, J.C. and Dieterman, D.J. 2014. Winter feeding, growth and condition of brown trout *Salmo trutta* in a groundwater-dominated stream. - *Journal of Freshwater Ecology* 29: 187-200. DOI: <https://doi.org/10.1080/02705060.2013.847868>
- French, W.E., Vondracek, B., Ferrington, L.C., Finlay, J.C. and Dieterman, D.J. 2016. Winter diet of brown trout *Salmo trutta* in groundwater-dominated streams: influence of environmental factors on spatial and temporal variation. - *Journal of Fish Biology* 89: 2449-2464. DOI: <https://doi.org/10.1111/jfb.13128>

Nyquist, C., Vondracek, B. and Ferrington, L. 2020. The influence of an in-stream thermal gradient on chironomid emergence during winter. - *Hydrobiologia* 847: 3153–3167: DOI: <https://doi.org/10.1007/s10750-020-04281-3>

Swenson, R. and Nyquist, C. 2024. Studying K-12 and post-secondary teachers' reflections on the value of a citizen science project for fostering learning: The case of a winter stream project. - *Interdisciplinary Journal of Environmental and Science Education* 20: e2410: DOI: <https://doi.org/10.29333/ijese/14636>

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