Editorial

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Editorial: Threatened aquatic gems: freshwater springs and groundwater-dependent ecosystems

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Editorial on the Research Topic
Threatened aquatic gems: freshwater springs and groundwater-dependent ecosystems

Groundwater constitutes the Earth's largest liquid freshwater reserve (Stephens et al., 2020). Although awareness is growing that human water demands threaten finite groundwater resources worldwide (Bierkens and Wada, 2019), there remains a dearth of information on how those water demands impact terrestrial and aquatic groundwater-dependent ecosystems (GDEs), including springs. Groundwater withdrawals have reduced inputs to GDEs even in high rainfall areas (Work, 2020), but the threat of groundwater extraction on GDE persistence and condition is especially acute in arid zones where globally, groundwater extraction already exceeds recharge (Aeschback-Hertig and Gleeson, 2012). Worldwide, springs often contain high endemism and can be biodiversity hotspots that contribute to regional biodiversity disproportionate to their size, so ecological consequences of groundwater extraction are potentially severe (Davis et al., 2017).

The Research Topic "*Threatened Aquatic Gems: Freshwater Springs and Groundwater-dependent Ecosystems*" advances our knowledge of the critical role that GDEs play in maintaining biodiversity, and highlights research and conservation strategies needed to protect GDEs, especially in a warming climate.

Arid-zone springs have been called "precious jewels of the desert", a reflection of their vulnerability and ecologic importance (Box et al., 2008). The arid spring ecosystems investigated by Fensham et al. in Australia, the southwestern US and Mexico exemplify this vulnerability, as they harbor some of the highest documented concentrations of endemic species in the world. The high endemism of these systems highlights the importance of stability and permanence over evolutionary timescales (up to 47 MYA, Murphy et al., 2015) in producing and maintaining biodiversity. To preserve these biodiversity hotspots will require recognition of their importance and the specific land and water uses that affect their persistence.

Globally, climate change will significantly stress GDE health, in part due to groundwater recharge reductions in regions with annual rainfall declines (Wu et al., 2020; Schenk and Stevens, 2022). An investigation of Copepoda from karst springs in Italy by Cerasoli et al.

revealed high diversity within and between springs. They suggested the preservation of copepod diversity may require conservation of entire spring complexes, given the variability in assemblages between microhabitats along multiple spatial, temporal and environmental axes. Predicted decreases in groundwater recharge with climate change could negatively impact microhabitats and therefore faunal diversity. Preservation of meiofauna diversity in these spring systems will require innovative conservation strategies that recognize the high species turnover within and between springs and the importance of unique microhabitats.

Similarly, the Mojave and Sonoran deserts support high biodiversity in a diverse array of GDEs. Using ecological and hydrological characteristics, Love et al. found little commonality across desert springs. Instead, they argued that each spring represented a unique ecosystem and therefore spring conservation should not rely on mitigation and re-creation of these irreplaceable sites. Worldwide, the endemism, ecosystem services and aquatic biodiversity of GDEs are not easily replaced or substituted, a theme that has recurred in past literature (e.g., Cantonati et al., 2020) and in this Research Topic.

Groundwater extraction in Australia has doubled in the past 40 years (Cook et al., 2022), yet how groundwater extraction affects GDEs is poorly understood, particularly in areas of Australia away from population centres (e.g., Brim Box et al., 2022). To fill this information gap Davis et al. sampled fish populations in an area of northern Australia undergoing development of multiple and large-scale groundwater-intensive industries. The highest freshwater fish richness occurred at sites with flow augmented by groundwater discharge. Therefore, industrial groundwater abstraction could reduce fish assemblage diversity in rivers, often not recognized as GDEs, through reduced baseflows and loss of aquatic refugia during dry seasons.

Global groundwater depletion has been well documented (e.g., Famiglietti, 2014; Thomas and Famiglietti, 2019), but the ecological implications of depletion have not, especially for terrestrial GDEs (e.g., groundwater-dependent vegetation). By analysing groundwater level trends in monitoring wells in Oregon and Nevada, Saito et al. showed that almost half of springs and 25% of phreatophyte communities were in areas with declining groundwater levels. Going forward, monitoring spring discharge and phreatophyte community condition will be imperative to understand the impacts of groundwater level declines on an array of ecosystem types.

The ecosystem services provided by both terrestrial and aquatic GDEs in California were explored in Howard et al. They concluded that GDEs provide significant benefits to people through three critical ecosystems services - pollination, water quality and carbon sequestration. In California, over 30% of California's pollinator-dependent crops may benefit from GDEs, and total carbon storage of GDEs was equivalent to 790 million tons, twice the annual emissions from California. As elsewhere, domestic, agricultural and industrial groundwater overuse is in direct conflict with protection of these systems and the ecosystem services they provide.

Protection of GDEs from climate change and continued groundwater extraction will require data, particularly for ecosystems that historically have been poorly represented in monitoring programs (Jungens et al., 2016). Thousands of springs are dotted across the US and, like other regions of the world, often harbor endemic plants and animals. By analysing the US national dataset of spring resources, the US Geological Survey National Water Information System, Work, 2020 found that the database was out of date with many springs sampled once and over 50 years ago. Time series of discharge data available for only 126 springs suggested that discharge has decreased for half of these springs. Work concluded that springs rank relatively low on the conservation priority scale of the US, despite their importance in landscapes, and called for a concerted national effort to more broadly monitor and protect US GDEs.

Threats of climate change and continued/expanding global groundwater extraction are likely to continue to increase for GDEs. To address these threats, Beasley-Hall et al. recommended improved biodiversity assessment and monitoring of South Australia's springs fed by waters of the iconic Great Artesian Basin, along with enhanced legal protection and coordinated management among the many stakeholders responsible for both land and water conservation. If followed, their recommendations, as well as those presented by other contributions to this Research Topic and insights from the broader literature (e.g., Cantonati et al., 2020; Cartwright et al., 2020; Rossini et al., 2020) could ensure that the unique flora and fauna found in GDEs globally are protected in the face of ever-increasing threats.

Author contributions

JB: Writing–original draft. JD: Writing–review and editing. JH: Writing–review and editing. KW: Writing–review and editing.

Conflict of interest

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References

Aeschback-Hertig, W., and Gleeson, T. (2012). Regional strategies for the accelerating global problem of groundwater depletion. *Nat. Geosci.* 5, 853–861. doi:10.1038/ngeo1617

Bierkens, M. F. P., and Wada, Y. (2019). Non-renewable groundwater use and groundwater depletion: A review. *Env. Res. Lett.* 14, 063002. doi:10.1088/1748-9326/ab1a5f

Box, J. B., Duguid, A., Read, R. E., Kimber, R. G., Knapton, A., Davis, J., et al. (2008). Central Australian waterbodies: The importance of permanence in a desert landscape. *J. Arid. Environ.* 72 (8), 1395–1413. doi:10.1016/j.jaridenv.2008.02.022

Brim Box, J., Leiper, I., Nano, C., Stokeld, D., Jobson, P., Tomlinson, A., et al. (2022). Mapping terrestrial groundwater-dependent ecosystems in arid Australia using Landsat-8 time-series data and singular value decomposition. *Remote Sens. Ecol. Conserv.* 8 (4), 464–476. doi:10.1002/rse2.254

Cantonati, M., Fensham, R. J., Stevens, L. E., Gerecke, R., Glazier, D. S., Goldscheider, N., et al. (2020). Urgent plea for global protection of springs. *Conserv. Biol.* 35 (1), 378–382. doi:10.1111/cobi.13576

Cartwright, J. M., Dwire, K. A., Freed, Z., Hammer, S. J., McLaughlin, B., Misztal, L. W., et al. (2020). Oases of the future? Springs as potential hydrologic refugia in drying climates. *Front. Ecol. Environ.* 18 (5), 245–253. doi:10.1002/fee.2191

Cook, P., Shanafield, M., Andersen, M., Bourke, S., Cartwright, I., Cleverly, J., et al. (2022). Sustainable management of groundwater extraction: An Australian perspective on current challenges. *J. Hydrol. Reg. Stud.* 44, 101262. doi:10.1016/j.ejrh.2022.101262

Davis, J. A., Kerezy, A., and Nicol, S. (2017). Springs: Conserving perennial water is critical in arid landscapes. *Biol. Conserv.* 211, 30–35. doi:10.1016/j.biocon.2016.12.036

Famiglietti, J. (2014). The global groundwater crisis. *Nat. Clim. Change* 4, 945–948. doi:10.1038/nclimate2425

Jungens, K., Springer, A. E., Stevens, L. E., and Ledbetter, J. D. (2016). Springs ecosystem distribution and density for improving stewardship. *Freshw. Sci.* 35 (4), 1330–1339. doi:10.1086/689182

Murphy, N. P., Guzik, M. T., Cooper, S. J. B., and Austin, A. D. (2015). Desert spring refugia: Museums of diversity or evolutionary cradles? *R. Swed. Acad. Sci.* 44 (6), 693–701. doi:10.1111/zsc.12129

Rossini, R. A., Arthington, A. H., Jackson, S. E., Tomlinson, M., Walton, C. S., and Flook, S. C. (2020). Springs of the Great Artesian Basin – knowledge gaps and future directions for research, management and conservation. *Proc. R. Soc. Qld.* 126, 305–321. doi:10.5962/p.357852

Schenk, E. R., and Stevens, L. E. (2022). Declines in an aridland river's base flow due to increasing air temperature: Implications for springs ecosystems. *J. Arizona-Nevada Acad. Sci.* 49, 92–98. doi:10.2181/036.049.0206

Stephens, G. L., Slingo, J. M., Rignot, R., Reager, J. T., Hakuba, M. Z., Durack, P. J., et al. (2020). Earth's water reservoirs in a changing climate. *Proc. R. Soc. A* 476, 20190458. doi:10.1098/rspa.2019.0458

Thomas, B., and Famiglietti, J. (2019). Identifying climate-induced groundwater depletion in GRACE observations. *Sci. Rep.* 9, 4124. doi:10.1038/s41598-019-40155-y

Work, K. (2020). Not just an arid landscape problem: Springflow declines in a region with high rainfall. *Limnologica* 82, 125766. doi:10.1016/j.limno.2020.125766

Wu, W. Y., Lo, M. H., Wada, Y., Famiglietti, J. S., Reager, J. T., Yeh, P. J-F., et al. (2020). Divergent effects of climate change on future groundwater availability in key mid-latitude aquifers. *Nat. Commun.* 11, 3710. doi:10.1038/s41467-020-17581-y