Undergraduate Water Research at Smith College: Experiments, Field Work, and Modeling

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Abstract

In this presentation, we highlight undergraduate research approaches and projects at Smith College, the largest college for women in the United States. We share lessons learned along with current challenges to spark conversation and improvement. We comprise a hydrologist (Guswa), environmental engineer (Ismail), and aqueous geochemist (Rhodes), and we investigate the effects of landscape, land management, and natural infrastructure on water quality and water resources. Rhodes and her students carryout field work and laboratory analyses to determine the impacts of development on water chemistry, and a recent project investigates the fate and transport of road salt in a calcareous fen in western Massachusetts. Ismail and her students conduct laboratory experiments to assess the efficacy of filter-feeding organisms to improve water quality in natural systems. A recent project determined how environmental conditions affect the uptake of bacteria by zooplankton. Guswa and his students use models to understand the interactions among climate, landscape, and water resources, and a recent project explores the effects on peak flows of a set of plausible land-use futures for New England in 2060. As undergraduates, students join these projects with limited relevant coursework and research experience. We find that undergraduate engagement is best facilitated by activities that are skill- or technique-based (such as making careful measurements) rather than those based on a deep understanding of theory. Additionally, multiple scales of involvement (e.g., newer students attending group meetings and more senior students designing experiments and serving as peer mentors) allow students to explore potential interests and possibly persist to richer levels of involvement.

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As undergraduates, students join these projects with limited relevant coursework and research experience. We find that undergraduate engagement is best facilitated by activities that are skill- or technique-based (such as making careful measurements) rather than those based on a deep understanding of theory. Additionally, multiple scales of involvement (e.g., newer students attending group meetings and more senior students designing experiments and serving as peer mentors) allow students to explore potential interests and possibly persist to richer levels of involvement.

Smith College

Smith is a liberal arts college for women in Northampton, MA with an enrollment of 2600 and 40% of students majoring in STEM. Smith is a member of CUAHSI.

Students regularly work with faculty on research projects. During the semester, students may volunteer, be paid as research assistants, or earn course credit. Each summer, 150-200 students are funded to pursue research with faculty.

Water research is supported by equipment and that includes

High-performance liquid and gas chromatography

Liquid water isotope analyzer

TOC analyzer

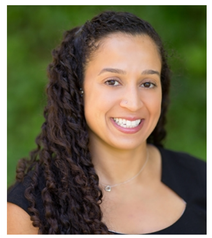
Graphite furnace AAS

Field hydrology instruments (rain gauges, pressure transducers, various sensors)

Drew Guswa

Civil Engineer, Ecohydrologist

- Plant-water interactions
- Effects of landscape change on hydrology
- Simple models to identify key drivers
- Place-based to tease out complexity



Niveen Ismail

Environmental Engineer

- Natural systems to improve water quality
- Zooplankton uptake of bacteria and viruses
- Uptake of silver nanoparticles by filter-feeding organisms

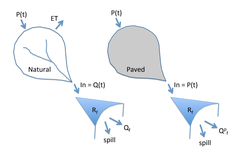
Amy Rhodes

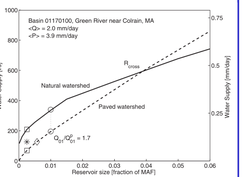
Aqueous Geochemist

- Effects of land-use on water chemistry
- Isotope geochemistry
- Fate and transport of road salt contamination
- Vegetation effects on soil chemistry

Modeling

Which attributes of natural landscapes are more important for water supply – infiltration and temporal regulation or evapotranspiration?

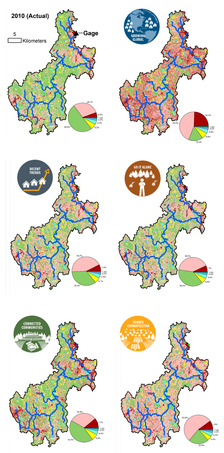




The importance of natural infrastructure decreases in the presence of gray infrastructure.

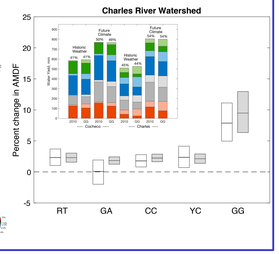
Temporal regulation is more important for seasonal climates and in areas of high topographic complexity.

How will development trajectories for New England affect water balances and high flows?



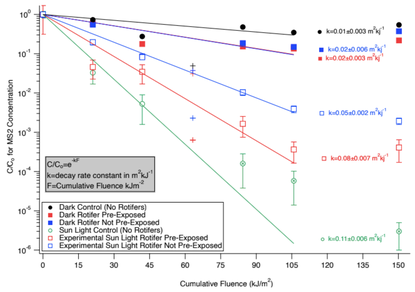
Stakeholder-informed land-use scenarios are modeled with SWAT.

Water yields are relatively unaffected by land use, though they are affected by climate. The Growing Global scenario, with the largest increase in impervious area, shows a substantive increase in the annual maximum daily flow.



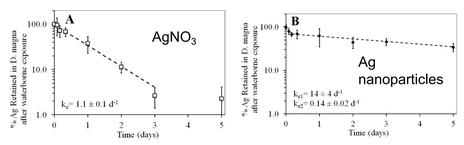
Experiments

Does uptake by rotifers protect viruses from UV inactivation?



Presence of rotifers (blue and red open symbols) shows reduced UV inactivation. The data from this figure were generated by students during summer research. Leading up to this experiment, students spent the prior semester learning experimental techniques. After completing the experiment students worked closely with the PI to learn about modeling to generate the inactivation rate constants.

How long do *Daphnia magna* retain silver?



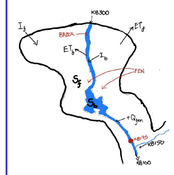
A significantly greater percentage of nanoparticles are retained vs nitrate in daphnids, which has implications for trophic transfer and highlights the difference in potential health effects of particulate versus dissolved forms of silver.

The data for these figures were generated by two students and a postdoctoral research fellow. Students worked closely with the PI to complete all modeling work and learn to use appropriate software to complete data and statistical analysis.

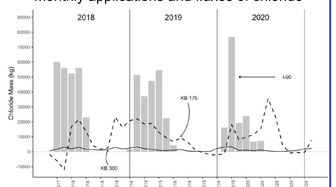
Field Work

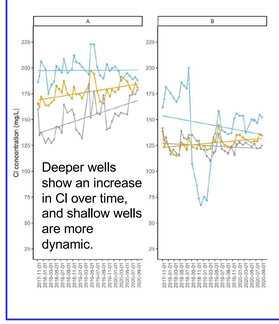
How much of the road salt applied to the Massachusetts Turnpike is retained each year in Kampoosa Bog?

Through field work, students learn to collect hydrologic data and water samples and improve their understanding of the context behind scientific questions. Students identify commonalities and differences across sites.



Monthly applications and fluxes of chloride





For her honor's thesis, Wayne Ndlovu combined field samples with a mass-balance model to calculate the amount of chloride added, released and potentially stored within the wetland. The model relied on stage, specific conductance, and water chemistry data collected in the field. Samples from wells assisted with interpretations of salt storage indicated by the model. This project combined this student's interests in geology, hydrology and data science and deepened her ability to make connections between these disciplines.

Ideas that Work

- More advanced students mentor newer members of the lab group – promotes collaboration and sense of belonging; everyone is learning.
- First semester: reading literature and attending group meetings; Second semester: shadowing another student and learning techniques; Third semester and beyond: engaging in a project.
- Match the scope and complexity of the project to student ability and interests; requires a range of possible projects and tasks.
- System of rotating lab maintenance and updating of methodological protocols – keeps students engaged and instills a sense of responsibility to the group.
- Activities for which the time to accomplish the task is long compared to the time is takes the PI to check that it has been done correctly (e.g., some experiments, building instruments)

Challenges

- Helping students manage their time, since research tasks rarely appear to be as urgent as coursework.
- Finding adequate time during the semester (amid teaching, advising, meetings, etc.) to engage with students on time-intensive efforts: a day in the field or training on a complex experimental analysis.
- Math and statistical background of students – makes it challenging to have them engage in modeling and data analysis tasks in a way that is productive and efficient (i.e., not duplicating work).
- Balancing long-term engagement that is often needed to make a meaningful contributions with encouraging student growth by exploring different scholarly avenues/interests outside of one research focus.
- Relatedly, balancing our own goals of research productivity with student mentoring.

Further Reading

Guswa, A.J., Hall, B., Cheng, C., Thompson, J. R., 2020. Co-designed land-use scenarios and their implications for storm runoff and streamflow in New England, *Environmental Management*, 66(5), 785-800, doi:10.1007/s00267-020-01342-0.

Guswa, Andrew J., P. Hamel, P.J. Dennedy-Frank, 2017. Potential effects of landscape change on water supplies in the presence of reservoir storage, *Water Resources Research*, doi:10.1002/2016WR019691.

Lesser, E.B., F.N. Sheikh, M. Sikder, M.N. Croteau, N. Franklin, M. Baalousha, N.S. Ismail, 2021. Water chemistry, exposure routes and metal forms determine the bioaccumulation dynamics of Ag (ionic and nanoparticulate) in *Daphnia magna*, *Environmental Toxicology and Chemistry*, 41(3), 726-738.

Ndlovu, W., 2022. Determining conditions for storage and release of road salt pollution in a calcareous fen: A hydrological and geochemical analysis of Kampoosa Bog, Stockbridge and Lee, MA. Honors Thesis, Smith College, Northampton, MA. 57p.

Ismail, N.S., M. Olive, X. Fernandez Cassi, V. Bachmann, T. Kohn, 2020. Viral transfer and inactivation through zooplankton trophic interactions, *Environmental Science and Technology*, 54(15), 9418-9426.

Rhodes, A.L. and Guswa, A.J., 2016. Storage and release of road-salt contamination from a calcareous lake-basin fen, western Massachusetts, USA. *Science of the Total Environment*, 545-546: 525-545. doi:10.1016/j.scitotenv.2015.12.060.