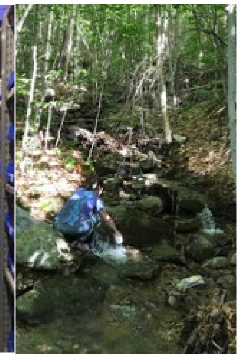
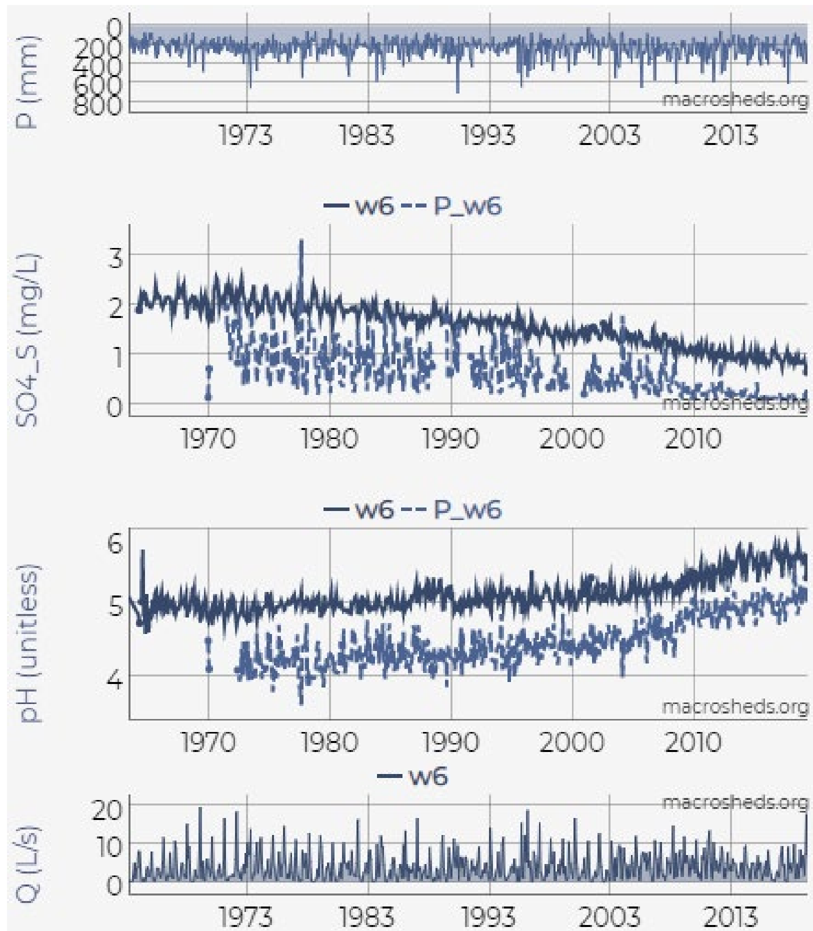
Hubbard Brook Watershed Report - 2019



What is HBWatER? The **H**ubbard **B**rook **Wat**ershed **E**cosystem **R**ecord is a dataset of chemical concentration data for precipitation and streamwater samples that have been collected weekly since the summer of 1963 from streams and precipitation gauges throughout the Hubbard Brook Experimental Forest, a research forest in the White Mountains of New Hampshire. HBWatER currently collects weekly samples from nine gauged watersheds, the mainstem of the Hubbard Brook into which each small stream drains, and two long-term precipitation collection sites.

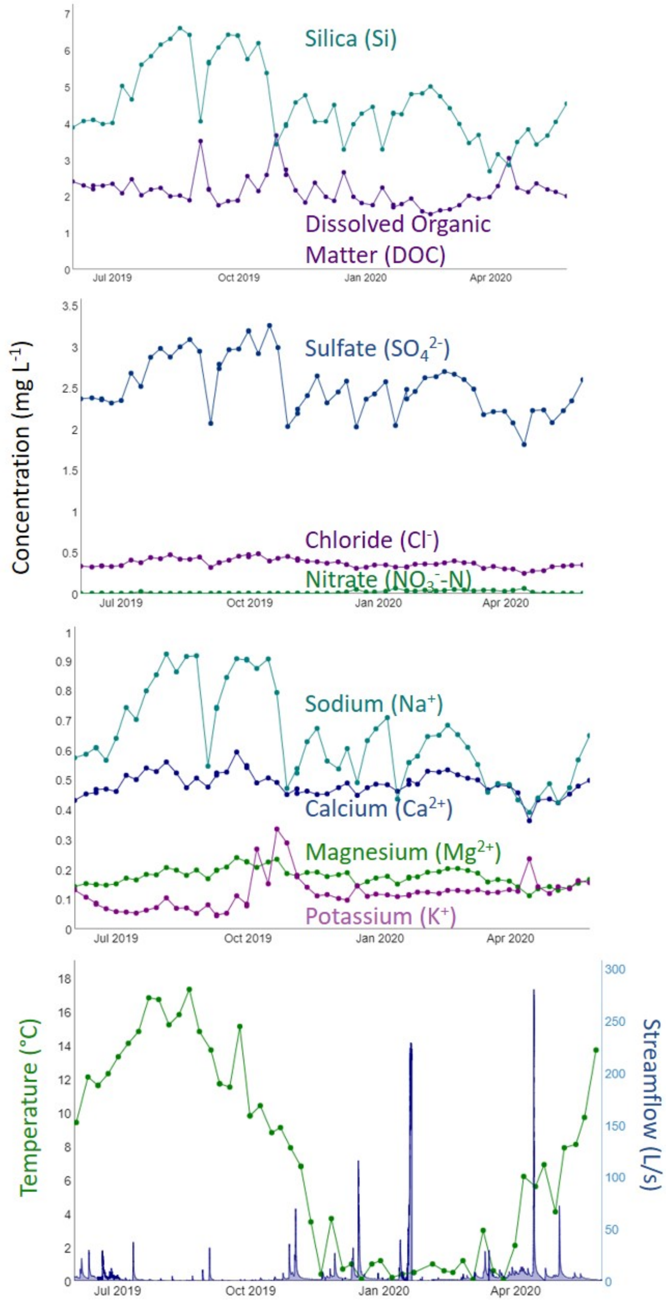
A brief history: In 1963, 4 visionary scientists (Gene E. Likens, F. Herbert Bormann, Robert S. Pierce, and Noye M. Johnson) began collecting and analyzing stream and precipitation (rain and snow) at a Forest Service property in the White Mountains of New Hampshire. They had a simple idea, that by comparing watershed inputs in rain and snow to watershed outputs from streams, they could measure the behavior of entire ecosystems in response to atmospheric pollution or forestry practices. The record they began in 1963 has been added to every week up to the present day. Insights gained from studying this long-term chemical record led to the discovery of acid rain in North America and documented the effectiveness of federal clean air legislation in reducing coal-fired power plant emissions **see the Figure on the right →**. This long-term record has become one of the most iconic and influential environmental data sets, featured in hundreds of scientific and popular press articles.



These graphs show us: (1) the amount of weekly precipitation as rain or snow; (2) the concentration of sulfates in streamwater (navy) and precipitation (blue); (3) the pH of streamwater (navy) and precipitation (blue); and (4) the total streamflow every week for the last 54 years. Notice that precipitation and streamwater has become less acidic and lower in sulfates over time.

The collection and analysis of HBWatER samples is currently sustained by Tammy Wooster (Cary IES) and Jeff Merriam (USFS) and the dataset is curated and maintained by a team of researchers: Emma Rosi (Cary IES), Emily Bernhardt (Duke), Lindsey Rustad (USFS), John Campbell (USFS), Bill McDowell (UNH), Charley Driscoll (Syracuse U.), Mark Green (Case Western), Scott Bailey (USFS). Current Financial Support for HBWatER is provided by NSF LTREB # 1907683 and the USDA Forest Service Northern Research Station.

You can listen to some of the stories about the HBWatER record and the people that have helped keep it going by listening to the podcast [Gather, Share, Teach] created by Duke student Tyler Edwards in summer 2020

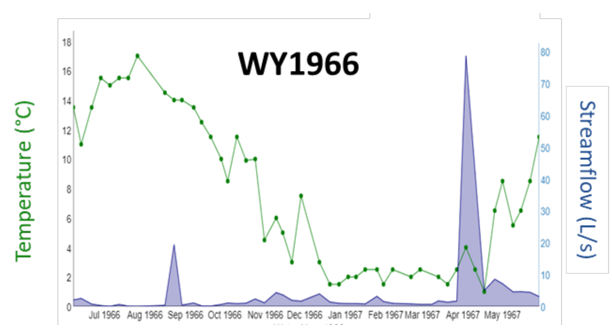


What can we learn from measuring the chemistry of a river? The graphs on the left side of the page show how the chemistry of one stream at Hubbard Brook changes over the course of a full year. First, check out the bottom axis. Our 'water year' begins on June 1, and is determined as the twelve-month period with the most consistent relationship between precipitation and streamflow across years. We use this water year because it minimizes variation due to catchment water storage (including water stored as snow) and evapotranspiration, and is therefore more hydrologically relevant than the calendar year.

In the top graph, note the opposing patterns of Silicon (Si) and Dissolved Organic Carbon (DOC). Silica is slowly released from granitic bedrock wherever rock is in contact with water. DOC is organic matter that is leached out of soil and leaves into soil solution (much like the flavor and color that leaches out when you put tea leaves or coffee grounds in water). Note that DOC goes up and Si goes down whenever stream flows are high (check navy line in the bottom graph). This graph shows us that at low flows, water in the stream is dominated by groundwater that has been in contact with rocks deeper in the soil. In contrast, during storms, more water is coming from the organic rich surface soils where leaves and roots accumulate. We can learn where water is coming from at any given time because of its different chemical signals.

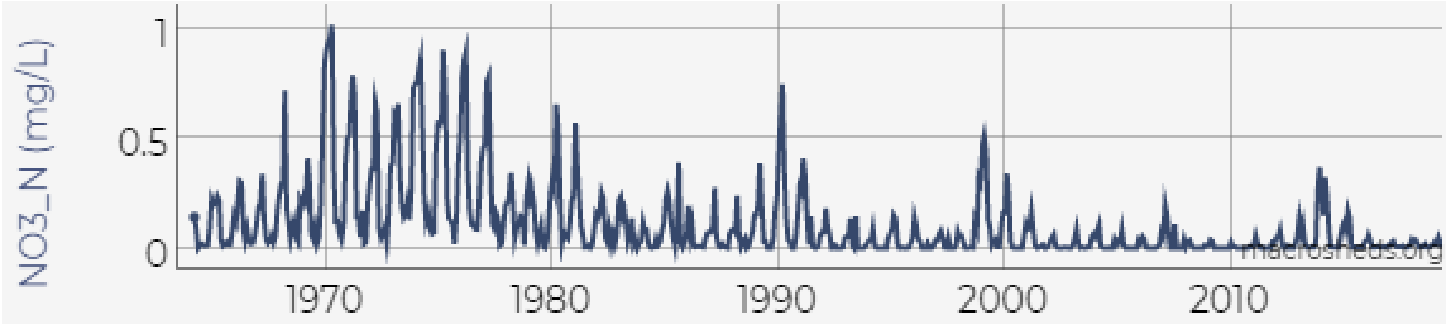
Now that you have noticed this, you can see that some other solutes, like Sulfate and Sodium, are also lower in concentration whenever there are high flows. In contrast, Chloride, Calcium and Magnesium concentrations stay the same no matter what the flow. Check out that spike in Potassium that occurs in late Autumn. We see that most years, and it's the result of Potassium ions being leached from all the leaves that fall from the trees into and alongside the stream.

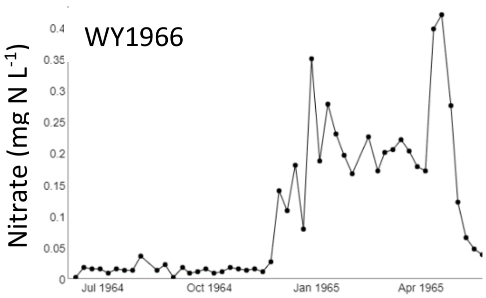
The final graph in this series shows us the temperature of stream water every Monday throughout the 2019 water year and the continuous rate of streamflow. You won't be surprised to see that these streams are warmer in the summer and colder in the winter. You can see the highest flow occurring as the stream warms up in April, that's the peak of snowmelt, as precipitation received throughout the winter melts and exits the watershed as streamflow. In WY2019 we also had a big flood in January. That's a phenomenon that doesn't happen every year in these New England mountain streams, but one that may become more common as the climate of Northeastern forests warms. For comparison, we show the same graph of temperature and streamflow for 1966. Here we again see that big snowmelt flood in April. If your eyes are sharp, you might notice that the winter stream temperatures in WY1966 were warmer than what we are showing for WY2019 (?!). That's because snow is a great insulator. As our snowpack gets thinner and less permanent, New England soils and stream waters may actually be getting colder during some winters!



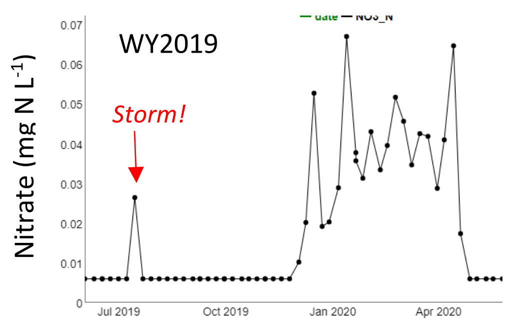
In WY2019, nitrate concentrations (2nd panel above, in green) are extremely low and barely change over the course of a year. We know that seems BORING but it wasn't always that way. Head to page three to learn more.

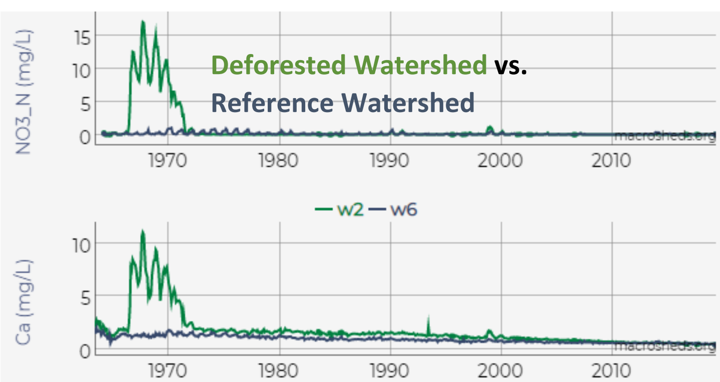
This next graph shows average monthly nitrate concentrations from the same reference watershed as we showed you on the previous page. But this time we're showing the data all the way back to 1963. Note that every year of the record is marked by a peak in stream water NO_3^- and that those peaks have declined over time.



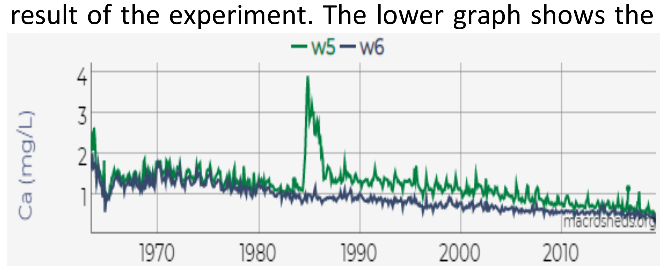


When we zoom into a single year, you can see that nitrate concentrations rise and stay higher throughout the winter and drop during the summer. During the summer, there are lots of plants and microbes that need that nutrient, and it is only when it gets cold that nitrogen can 'escape' biological demand and be exported from the watershed in stream water. That's true in both WY1966 and WY2019 at left. BUT look closely and you can see a couple of things. First, check the y axis - peak nitrate concentrations back in the 1960s exceeded 0.4 mg N/L while in WY2019 they were more than 5X lower (always below 0.07 mg N /L. Second, note that in the earlier year, nitrate concentrations stayed higher in the summer (for the last two decades we usually are unable to detect nitrate in the stream during the summer unless there's a *storm*). Third, check out how much earlier in the year the nitrate drops from its winter peak, in the later graph this happens in late April rather than June. That's probably because both snowmelt and canopy leaf out have been getting earlier and earlier over time.



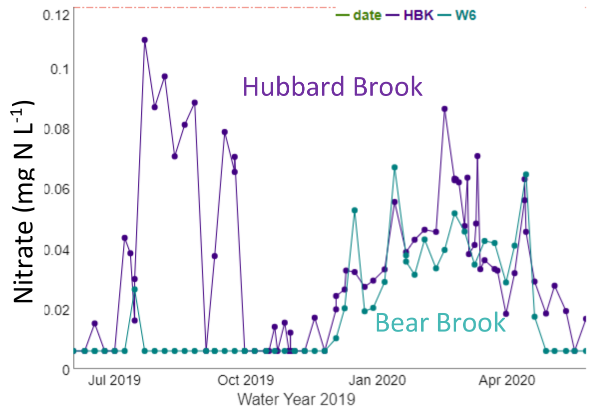


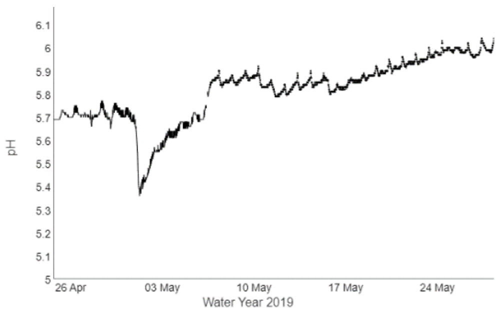
Ecosystem Experiments: One of the other things we learn from stream water chemistry is that clearcutting and many kinds of natural disturbances (e.g., ice storms, gypsy moth infestations, soil freezing events) lead to the loss of critical nutrients. Hubbard Brook first became 'scientifically famous' for a whole watershed clearcutting experiment done in the late 1960s. In subsequent experiments an entire watershed was stripcut in the 1970's, another was commercially clearcut in the 1980's, and a fourth watershed had helicopters drop tons of pulverized calcium silicate to fertilize the forests and mitigate soil acidification in the 1990's. All four of these experiments led to significantly enhanced watershed exports of nitrate and calcium. The graph just above shows this for the first watershed experiment. The green line is the average monthly nitrate (upper) and calcium (lower) concentrations for that first deforestation experiment that happened in 1965. The dark line in the top graph is the same data you see at the top of this page. That should give you some appreciation for just how much nitrate was lost from this forested watershed as a result of the experiment. The lower graph shows the same result for calcium, an important plant nutrient. Note that after the experiment there continued to be higher calcium coming out of the deforested watershed for 30 more years!! On the right → we can see the same result for the 1985 clearcut experiment - a dramatic loss of calcium for 3 years following the forest harvest followed by several decades of elevated calcium loss.



Watershed Year Curiosities: This final page of fun graphs, notes and photos is for the true watershed science junkies. Here are a few interesting observations from the 2019 water year dataset. We hope they will inspire your curiosity!

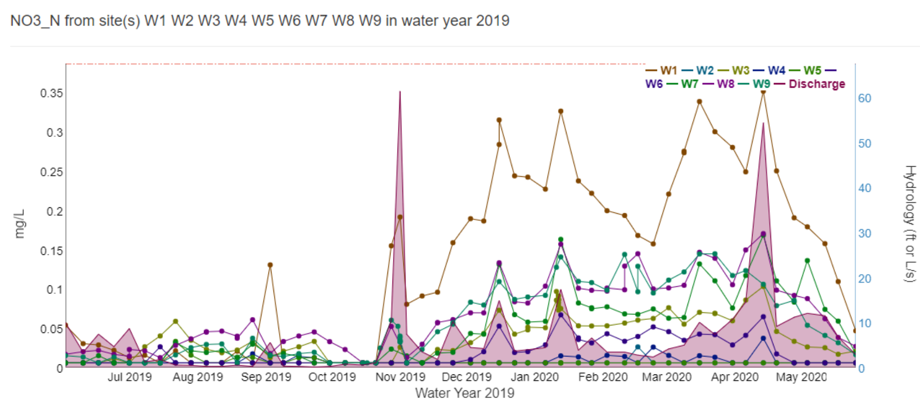
Nitrogen Fixation or Enhanced N Mineralization in the mainstem? For the last several years we've been seeing peak annual nitrate in the mainstem of Hubbard Brook just as its about to flow past the Forest Service boundaries. The concentrations are higher in the mainstem than in any of its nine monitored headwaters. If you look at the data for the last decade, this does seem to be a new phenomenon. *What's happening here?* We don't know yet. We've been collaborating with folks who have attempted to measure in situ rates of nitrogen fixation by algae in the mainstem. No clear answers yet but we would love your ideas!





Acid Flashes? In WY2019 we got a NSF LTREB supplement to install real time sensors in W6. We just caught the late Spring and early summer of the water year, but already this continuous data is providing useful insights. In the graph at left we see a substantial dip in pH associated with a high flow event on May 3, 2020. At peak flow the streamwater pH drops from 5.7 to 5.4. Our weekly sampling completely misses this quick phenomenon. For organisms living in these streams, we wonder how these acid pulses affect them.

Which Watershed Is Worst at Holding onto its Nitrogen? When we compare the seasonal nitrate concentrations across all 9 of our headwater sites for WY2019, We see that Watershed one has the highest peak nitrate concentrations.



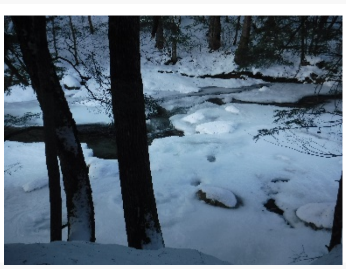
Field Notes Highlight: Tammy Wooster notes "What stood out for me in WY2019 was the period between mid-November through mid-January. There was icing and re-icing, with rain and warm temperatures leading to melting in between. The streams didn't stay ice/snow covered until late January. Here are some shots of the main Hubbard documenting this progression and weather whiplash! Note the 1/13/20 pic showing ice shelving."

November 18th

November 25th

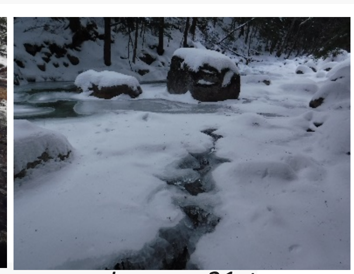
December 9th

December 16th



December 23rd

January 13th



January 21st

To explore all of these data (and so much more) using our HBWater online data visualization dashboard

Visit → http://hbwater.org:3838/watershed_exploration/

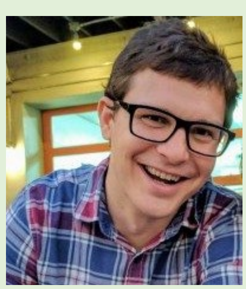
We welcome collaborators and we encourage you to use the HBWatER dataset. The entire record is available for download We only ask that you credit the source of the data by citing the record.

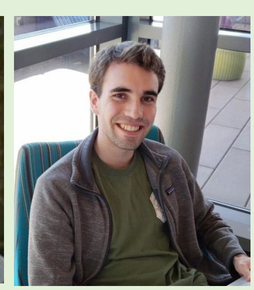
Hubbard Brook Watershed Ecosystem Record (HBWatER). 2021. Continuous precipitation and stream chemistry data, Hubbard Brook Ecosystem Study, 1963 – present. ver 4. Environmental Data Initiative.
https://doi.org/10.6073/pasta/0e79917db6bc3d70aa625f45f8bb226c

We encourage you to use figures straight from our data platform in talks and presentations, but if you please credit HBWatER and the MacroSHEDS project if you use these graphs straight in your talks.

Feel free to let us know what would make it easier for you to make use of the dataset in your research, your classrooms and your own independent learning.





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