

Plant Biology

Aquatic plants are influenced by the surrounding landscape

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ABSTRACT

Have you ever had an aquarium with plants and failed to make it flourish? In this recent study published in Science, we show that the mineral composition of the soils in the surrounding landscape controls the aquatic vegetation in adjacent lakes, but not in streams, and there are lessons to be also learned for the hobbyist.



Photo of submerged vegetation in a Norwegian lobelia lake. Lobelia lakes contain minimal amounts of dissolved minerals (the water is soft), and plants that are capable of using bicarbonate (present in high amounts in hard water) are virtually absent. Image credits: Ole Pedersen ©

Flowering plants living submerged in lakes or streams evolved from terrestrial ancestors. However, successful adaptations to living submerged required several adjustments in anatomy, morphology, and physiology. Nevertheless, all aquatic plants utilize CO_2 in their photosynthesis to produce carbohydrates and release O_2 as a waste product. However, gases move 10,000-fold slower in water compared to in the air. Thus CO_2 in water often becomes depleted since the resupply from the atmosphere above is slow. Many aquatic plants, including several groups of algae, can tap into an alternative source or inorganic carbon and use it in their photosynthesis when CO_2 becomes scarce. The

alternative source of CO_2 is bicarbonate (HCO_3^-). In most lakes and streams, bicarbonate is present in much higher concentrations than CO_2 . Hence, plants capable of using bicarbonate have a tremendous competitive advantage. They can continue to photosynthesize when CO_2 is depleted and where many competitors give in. The ability to utilize bicarbonate comes at a cost; it requires a unique set of enzymes. Therefore, bicarbonate users are weak competitors in situations where CO_2 is not limiting photosynthesis.

Bicarbonate derives from the weathering of calcium carbonate in the soils where groundwater forms.

When groundwater seeps into streams and lakes from the terrestrial systems, it carries dissolved CO₂ generated by bacteria in the mineralization processes in addition to bicarbonate. However, if there is little calcium carbonate in the soils, the amounts of bicarbonate are low. Therefore, we tested an idea. Lakes and streams situated in landscapes where the soils are rich in calcium carbonate would support few plant species of bicarbonate users. Plants capable of only using CO₂ would dominate. In contrast, carbonate-rich soils would generate a high amount of bicarbonate so that bicarbonate users would dominate lakes and streams in such landscapes. We tested the hypotheses by diagnosing 131 species of aquatic plants for their ability to use bicarbonate. Then, we created a global map with information on bicarbonate concentrations in lakes and streams. We overlaid this with more than 1 million global observations of the occurrences of the 131 species with known preferences for bicarbonate versus CO₂ use in photosynthesis.

Our analyses confirmed that bicarbonate use is indeed more prevalent among submerged aquatic freshwater plants in lakes with hard water (high amounts of bicarbonate) compared to softwater lakes (low amounts of bicarbonate). In other words, the competitive advantage of using bicarbonate as a source of inorganic carbon also leads to the dominance of plant species with this ability in lakes where the bicarbonate concentration is high. But in

softwater lakes with low amounts of bicarbonate, there is no competitive advantage. In fact, quite the opposite because of the cost associated with this trait. Hence, CO₂ users dominate in softwater lakes. However, this relationship does not exist in streams and rivers! We have a good explanation for the lack of coupling to bicarbonate concentrations in streams. Streams are inherently high in CO₂, so the aquatic plants rarely experience CO₂ shortage in streams since these are continuously fed with fresh supplies of CO₂ rich groundwater.

The findings of our study are significant because the bicarbonate content of freshwaters changes globally. Human land-use of the catchments (the areas that deliver water to a stream or a lake) results in higher concentrations of bicarbonate favoring bicarbonate users. Bicarbonate users are typically tall and ramifying plants that are also strong competitors. Thus we predict that the much smaller CO₂ users will lose the battle. This will change the 3D structure underwater, which is used by fish and crustaceans, particularly in juvenile stages. Therefore we predict a cascading effect at the ecosystem level. These changes are not caused by climate but by eutrophication and liming of agricultural use making intervention possible and tangible. Anglers may see their favorite fish disappear as the underwater landscape is changing.