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ARE ROTIFERS THE BASIS OF FUNCTIONING OF THE PITCHER PLANT TRAP MICROECOSYSTEMS?

The water-filled leaves of carnivorous pitcher plants are peculiar and simple ecosystems. This passive trap can capture invertebrates attracted by means of nectar and coloration of the pitcher. Each trap containing the water has almost the same simple community. There are no primary producers but only secondary consumers and decomposers. The food chain is very short and simple.The consumers consist of a highly productive group of one species of rotifer Habrotrocha rosa, Donner, 1949 and voracious larvae of Culicidae and Chironomidae. We hypothesize that the contributions of the infaunal microecosystem to plant nutrition are dissolved organic matter (mostly produced by the existing community) and phosphorus that is released by the rotifers in immediately available form. We tested this hypothesis by measuring the temperature, amount of oxygen, pH, nitrogen and phosphorus within the water of the pitcher plant traps, and related these measurements to the faunal composition.

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DIAGENESIS OF MERCURY AND METHYL MERCURY IN LAVACA BAY (TX) SEDIMENTS

The distributions of Hg species, Fe, and Mn were investigated in 15 cores taken in Lavaca Bay, Texas. Hg in the solid phase generally increased with depth, to a maximum located at 20-30 cm, corresponding to historic discharges to the bay. MMHg in the solid phase was found to be highest in the upper 0-3 cm of the cores, decreasing rapidly with depth. The MMHg content of the surface sediment was found to be a narrowly constrained function of the total Hg concentration (0.65 (0.33%) over a wide range of sediment types. Pore waters exhibited trends similar to, but more exaggerated than in the solid phase. The distribution coefficients (log Kd) for inorganic Hg were similar at all sites and depths, averaging 5.0 (0.2 despite total Hg ranging from 5 to 1000 ug/g. The observed log Kd for MMHg, on the other hand exhibited a pronounced subsurface minimum in most cores at near the point of the maximum in dissolved Fe. The MMHg Kd at the surface also showed a between-site variability over the range of 2.5 to 4 which was positively correlated with the total organic carbon in the sediments. A time course series showed a maximum in both solid phase and pore water MMHg during the early spring, followed by a decrease throughout the summer. These findings indicate that the surface sediment is a dynamic region of MMHg production and mobility, and that such activity decreases dramatically over the next 10 cm of depth.

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THE IMPACT OF COLORED DISSOLVED ORGANIC MATTER (CDOM) ON THE OPTICAL PROPERTIES AND BIOGEOCHEMISTRY OF SURFACE MARINE WATERS

Over the past ten years, it has become increasingly evident that colored (or chromophoric) dissolved organic matter (CDOM) plays an essential role in a variety of important processes in surface waters. Through its absorption of ultraviolet and visible light, CDOM affects significantly the aquatic light field, especially in coastal water and in oceanic regions experiencing major freshwater inputs. This light absorption by CDOM is likely to alter primary productivity and affect ecosystem structure, as well as complicate the determination of chlorophyll concentration by ocean color satellite sensors. Light absorption by CDOM further leads to the photochemical production of a variety of intermediates and products including biologically-labile low molecular weight organic compounds and nutrients, which may significantly influence the structure of the microheterotrophic community in the upper ocean. The photooxidative reactions giving rise to these products ultimately lead to the degradation of the CDOM and the bleaching of its absorption and emission bands, thus acting as a feedback to the aquatic light field. This presentation will provide an overview and integration of recent work in this area, highlighting the importance of CDOM in upper ocean processes.

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FISH PREDATION EFFECTS ON PREY SIZE DISTRIBUTION IN LAKE BENTHOS

Although effects of size-selective predation are often strong in pelagic habitats, size-structuring of prey communities by predation is less well understood for benthos. Several studies suggest that common omnivorous fish in temperate lakes are size selective, obtain much of their energy from benthic prey, and that growth rates are affected by the abundance of large, energetically profitable prey. We used normalized size-spectra analysis, originally developed in the study of pelagic communities, to examine whether omnivorous bass affect the size structure of benthic prey. Benthic size-spectra data over four years from three lakes in which fish were experimentally manipulated shows that the proportion of larger prey is negatively related to the consumption rates of fish as estimated from bioenergetics models. Changes in prey size distribution have implications for energetic transfer efficiencies both within and among benthic and pelagic habitats, and may limit the potential for production of fish populations.

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Abstract
The water-filled leaves of carnivorous pitcher plants (*Sarracenia purpurea* L.) are peculiar and simple ecosystems. This passive trap captures invertebrates attracted by means of nectar and coloration of the pitcher. Each trap containing the water has almost the same simple community. There are no primary producers but only secondary consumers and decomposers. The food chain is very short and simple. The consumers consist of a highly productive group of one species of rotifer, *Habrotrocha rosa* Donner (1949), and voracious larvae of Culicidae and Chironomidae. The pitcher plant community provides an example of a processing chain commensalism, where consumers specialize on food at different stages of processing (Heard 1994). *Sarracenia purpurea* does not possess digestive glands but relies on autolytic enzymes of the prey and bacterial decomposition of the organic matter (Plummer & Kethley 1964, Bradshaw & Creelman 1984), as well as nutrient excretion especially by abundant rotifers, which is underestimated but much faster than bacterial regeneration. We hypothesize that the contributions of the infaunal microecosystem to plant nutrition are dissolved organic matter (mostly produced by the existing community), nitrogen, and phosphorus that are rapidly released by the rotifers in immediately available form. We tested this hypothesis by measuring the temperature, amount of oxygen, pH, nitrogen and phosphorus within the water of the pitcher plant traps, and related these measurements to the faunal composition.

IMPORT

Nitrogen input.

The inputs of nitrogen from atmospheric sources average approximately 1.69 mg N (NO_3 and NH_4^+) dm^{-3} yr^{-1} over, Hubbard Brook Experimental Forest, New Hampshire (Likens and Bormann 1995). The average water volume inside pitchers is 12 cm^{-3}, so maximal average input to pitchers of nitrogen with precipitation could be approximately 5.56×10^{-2} µg N d^{-1}. Likens and Bormann (1995) indicated close similarities between Hubbard Brook experimental and others regional watersheds of Northern New England, but since the average precipitation in Western Massachusetts is lower by 25%, than at Hubbard Brook Experimental Forest, the nitrogen input could be closer to 1.5×10^{-2} µg (NO_3- N & NH_4^+-N)d^{-1} per pitcher leaf.

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Phosphorus input.

The inputs of phosphorus from atmospheric sources are about 8.0×10^{-3} mg PO_4 dm^{-3} yr^{-1} over Hubbard Brook Experimental Forest (Likens and Bormann 1995), and because of lower precipitation, the phosphorus input per pitcher at our site is approximately 8.6×10^{-5} µg PO_4-P d^{-1}

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These data do not account for organic matter and prey so existing import should be greater.

UPTAKE BY PLANT

Nitrogen uptake.

Ammonium ions, NH_4^+, released by living organisms can be taken up directly by plants or

heterotrophic microorganisms (Hutchinson 1957, Perry 1994), but it is still unclear whether plants take up ammonium or nitrate more rapidly.
Average values of nitrogen uptake by *Urtica dioica* and *Plantago lanceolata*, (calculated from Woldendorp 1983), are approximately 2.23×10^{-2} µg NO_3-N d^{-1}g DW^{-1} (range: 1.3×10^{-2} - 3.2×10^{-2}), for *Sarracenia purpurea*, where one leaf has approximately 1 - 2 g dry mass it could be approximately 3.3×10^{-2} µg NO_3-N d^{-1} $leaf^{1}$.

Phosphorus uptake.
The uptake of reactive soluble orthophosphate PO_4^{-3} is extremely high and dynamic. Algae can uptake 2.0×10^{-3} µg dm^{-3} min^{-1} (Wetzel 1975),or 2.88 µg dm^{-3} d^{1}, and we estimate that each pitcher could take up 1.2×10^{-2} µg d^{-1}. Since we have found an average concentration of orthophosphate in pitcher plants as high as 187.63 µg PO_4-P dm^{-3} (2.313 µg PO_4-P per leaf), phosphorus uptake by pitchers should be much faster. According to Fish and Hall (1978), *Sarracenia purpurea* in Massachusetts produces new leaves at an average interval of 20 days. New leaves are constantly replacing older ones, so the total numbers of leaves on a single plant remain, relatively constant (5 - 8 pitchers/plant). However, we observed that only 2 - 3 younger leaves per plant contained water.

EXCRETION
Nitrogen and Phosphorus.
Rotifers as well as other groups of zooplankton and invertebrates release nitrogen mostly as ammonia, NH_3 (Nogrady et al. 1993). In aquatic environments, NH_3 molecules immediately react with water, especially at lower pH values, to produce ammonium ions, NH_4^+. The substantial nitrogen and phosphorus excretion rates of the zooplankton community are well known (Gulati et al. 1995). Observed density of rotifers in pitchers (mean: 210 specimens, range 0 - 1240) is much higher than other invertebrates (respectively: Chironomidae 3.8 & 0 - 14; Culicidae 2.1 & 0 - 12; Acaridae 17.8, & 0 - 128). Mean individual dry weight of rotifers (0.017 µg) are some orders of magnitude lower than that of the other invertebrates. The mean excretion rate of rotifers is 2.5 - 5 times higher than the rates of crustaceans (Ejsmont-Karabin 1984, Gulati et al. 1989) and should be much higher than that of other invertebrates. According to Galled et al. (1989) and Ejsmont-Karabin (1983) possible excretion of phosphorus and nitrogen by rotifers in pitcher leaves could be as high as 0.01 µg PO_4-P d^{-1} $leaf^{1}$ and 0.04 µg NO_3-N d^{-1} $leaf^{1}$ for observed mean biomass, and 0.06 µg PO_4-P d^{-1} $leaf^{1}$ and 0.26 µg NO_3-N d^{-1} $leaf^{-1}$ for observed maximum biomass.

CONCLUSION
Relationships among water characteristics and abundance of bdelloid rotifers is significantly correlated with pH and volume of water inside pitcher leaves, but the correlation among inquiline abundances is only significant between bdelloids and culicids. This is related to the observed processing chain commensalism and resource partitioning (Heard 1994, Beaver 1983). Rotifers are the main source of food for culicids, and one of the primary and fastest sources of regenerated nitrogen and phosphorus for the plant, which was underestimated in previous papers. Phosphorus released by rotifers probably is sufficient to meet the nutritional needs of the pitchers during the vegetative growing season. Nitrogen is taken up by plants more rapidly (Bradshaw 1983), so the observed concentration inside leaves was lower and sufficient for a shorter period of time.

We draw the following conclusion about rotifers in pitcher plants:

rotifers are:
- one of the main sources of food for culicids
- a huge and rapid sources of regenerated N and P for use by plant leaves
- an important component of the phosphorus cycle
- one of the first and highly productive colonizers that can easily sustain microecosystem processes
- underestimated in previous research

Pitcher plants benefit from their inquiline community and do not actively kill invertebrates (so their "carnivory" is controversial). The small size of the pitchers, the ease with which their community can be manipulated, and the simplicity of the whole system are great advantages for studies of community ecology.

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