Functional Ecology

APPENDIX S1 : Details on parameter estimation.

Assumptions

We assume there is 45% of Carbon in the detritus and the predators (Sterner and Elser 2002). We have placed protozoa and rotifer as the same compartment in the model since we estimate their biomasses to be in the same range (the parameter characteristic of this compartment will be the average of protozoa and rotifer parameters). We consider the ratio C/N = 6.625 for bacteria (Thingstad 1987). By extension we will use the same value for other compartments.

Pitcher

V (volume)	The volume per pitcher is variable, depending on rain and temperature. We have used 20 ml, which is slightly above the mean, but typical of healthy young pitchers (Miller unpublished data 2004). V = 0.020 l.

Detritus

θ_A (input)	The capture rate of the pitcher varies significantly depending on the age of the leaf (Fish and Hall 1978) and the region considered. Cresswell (1991) found 2.66 mg of dry biomass per leaf per 55 days that is θ_A = (2.66*0.45/55)/0.02 = 1.08 mg C $l^{-1}.d^{-1}$. Chapin and Pastor (1995) found 12.3 mg dry biomass of insect captured per leaf and per season (110 days) that is θ_A = (12.3*0.45/110)/0.02 = 2.51 mg C $l^{-1}.d^{-1}$. Newell and Nastase found 0.07 ants captured per leaf per day that is (0.07*1.1*0.45)/0.02) = 1.73 mg.$l^{-1}.d^{-1}$.

	Our estimate in Florida (Apalachicola National Forest, USA) gives 2.56 ants per day in young leaves and 0.218 ants per day across all leaf ages. The dry biomass per ant is 1.1 mg (Miller unpublished data). That result in a maximum of θ_A = (2.56 * 1.1 * 0.45) / 0.02 = 63.36 mg C $l^{-1}.d^{-1}$ and an average of θ_A = (0.218 * 1.1 * 0.45) / 0.02 = 5.39 mg C $l^{-1}.d^{-1}$. We have chosen θ_A = 5.39 mg.$l^{-1}.d^{-1}$ as a good approximation of the prey C input in North Florida.
D (carbon)	The number of ants found decomposing per pitcher leaf is, on average, 15 (J. Kneitel unpublished data). D = (15 * 1.1 * 0.45) / V = 371.25 mg.l^{-1}
Bacteria	
B (carbon)	The mean bacteria density is 5.E7 per ml (T. Miller unpublished data). Troussellier et al (1997) have found an average of 20.E-15 g of carbon per bacteria in aquatic media. Their estimation was done in open system and it is likely that the bacteria incubated in the pitcher will be much larger. We have chosen 100.E-15 g as a good approximation. B = 5.E7 * 1000 * 100.E-15*1000 = 5 mg.l^{-1}
u_B (uptake)	We have at equilibrium: $u_B = (\theta_A + m_B B + m_P P - sD) / BD$ = 0.00105 d^{-1}
r_B (respiration)	Thingstad and Pengerud (1985) assume that 50 % of carbon ingested by bacteria is lost through respiration. On this basis the model gives: $r_B = 0.5 \times u_B$ = 0.00053 d^{-1}
m_B	We could not find accurate data for bacterial mortality rate. It is

(mortality)	probably very low compared to uptake by bacterivores. We have fixed m_B = 0.001 d^{-1}
Nitrogen fixation by bacteria (not included in our model)	Prankevicius and Cameron (1991) have found that the maximum nitrogen yield in a leaf (due to bacterial dinitrogen fixation) was 0.3149 g of N produced by year and by plant. They assumed that a plant produced 5.6 leaves during a season (138 days). Converted into our units this yields: ((0.3149*1000))/(5.6*138)/0.02= 20.37 mg of N fixed by day and by liter.
Bacterivores	
P (carbon)	*Protozoa:* We have estimated the dry weight per cell from values in the literature, as the protozoa found in pitcher plants appear to be representative of protozoa communities found elsewhere, in terms of diversity and sizes. These dry weight estimates are highly variable, from 1.0 to 1000 E-9 g. (Laybourn-Parry 1984). We have used 100. E-9 g per cell. The protozoa mean cell density is approximately 500 cells per ml (T. Miller unpublished data). P_P = 100.E-9 * 500* 1000 * 0.45*1000 = 22. 5 mg.l^{-1} *Rotifer:* The rotifer dry weight per individual is 0.119 μg (Bledzki and Ellison 1998). A reasonable average is approximately 100 rotifers per ml (T. Miller unpublished data). Rotifer density can be highly variable in the field but we have shown that our results are robust to strong variation in rotifer density (data not shown). P_R = 0.119.E-6*100*1000*0.45*1000 = 5.355 mg.l^{-1} Thus $P = P_P + P_R$ = 27.855 mg.l-1

u_P (uptake)	We have at equilibrium: $u_P = (u_B D - m_B - r_B)/P$ = 0.014 d^{-1}
r_P (respiration)	We have fixed the respiration to 10% of what is ingested by bacterivores (REF) : r_P = 0.1 * u_P = 0.0014 d^{-1}
m_P (mortality)	We have no data on bacterivores mortality rate. We have assumed m_P = 0.01 d^{-1}
Mosquitoes	
M (carbon)	Dry weight is about 0.9 mg per individual and we have estimated an average of 15 mosquitoes per pitcher (T. Miller unpublished result). We encapsulate all the instars into the same box. M = (15 * 0.9*1000*0.45)/ 0.02 = 303.75 $mg.l^{-1}$
u_M (uptake)	We have at equilibrium: $u_M = u_P B - m_P - r_P$ = 0.0587 d^{-1}
r_M (respiration)	We have chosen arbitrarily r_M = 0.05 d^{-1}
Plant	
N (nitrogen)	The concentration of NH_4 in *S. purpurea* is 1 $mg.l^{-1}$ (Miller unpublished data). Concentration of NO_{3-} has been found to be 0.16 $mg.l^{-1}$ (Wakefield et al. 2005) N = 1*0.78 + 0.16*0.23 = 0.817 $mg.l^{-1}$
y	From the model the input and the output of nitrogen are at equilibrium:

(uptake)

$$y = \frac{\theta_N + \frac{r_B B + r_P P + r_M u_M P}{\alpha}}{N_i} = 0.1026 \text{ d}^{-1}$$

θ_N (input)

Sarracenia purpurea can receive inorganic nutrients input through precipitation. Precipitation is standardized by the active period for the pitcher plant community: for example, we estimated that pitchers are active for 10 months in N. Florida (Apalachicola National Forest, USA) giving a total 1390 mm of precipitation and four month in Minnesota, USA (where Chapin and Pastor (1995) have done their experiments) giving a total of 370 mm of precipitation (US National Weather Service http://www.nws.noaa.gov). Approximately 50% of the rain that falls on a pitcher goes inside (T. Miller personal observation) and pitchers have an aperture of approximately 7cm^2. That gives 139*0.5*7/(10*30)=1.62 ml.pitcher^{-1}.d^{-1} for a Florida sites and 37*0.5*7/(4*30)=1.07 ml.pitcher^{-1}.d^{-1} for a Minnesota sites.

From Ollinger et al (1993) we can estimate the amount NO_3- and NH_4^+ deposition based on field longitude: respectively 84° (NO_3- = 2.66 mg.l^{-1} and NH_4^+ = 0.41 mg.l^{-1}) for the Apalachicola site and 92° (NO_3- = 3.58 mg.l^{-1} and NH_4^+ = 0.56 mg.l^{-1}) for the Minnesota site. Converting into the amount of nutrients that go into the pitcher, we have (we assume there is 78% of N in NH4 and 23% of N in NO3) :

Florida :

((2.66 /1000)*1.62)/0.02 = 0.215 mg.l^{-1}.d^{-1} of NO_3-

((0.41 /1000)*1.62)/0.02 = 0.033 mg.l^{-1}.d^{-1} of NH_4^+

θ_N = (0.215*0.23+0.033*0.78) = 0.0751 mg.l^{-1}.d^{-1}

Minnesota :

$((3.58 /1000)* 1.07)/0.02 = 0.191$ mg.l^{-1}.d^{-1} of NO_3-

$((0.56 /1000)* 1.07)/0.02 = 0.030$ mg.l^{-1}.d^{-1} of NH_4^+

$\theta_N = (0.191*0.23+0.030*0.78) = 0.0673$ mg.l^{-1}.d^{-1}

These two values are of the same order of magnitude; we have chosen to use the values found for the Florida site in our simulations : $\theta_N = 0.0751$ mg.l^{-1}.d^{-1}

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