Population ecology of the round-leaved sundew

Simran Aujla

Saujla1@sheffield.ac.uk

@EvoEcoSim

ACCE
Doctoral Training Partnership

The Alice McCOSH TRUST

The University Of Sheffield.

Background

Carnivorous plants fascinated Charles Darwin, who included results from many experiments on the round-leaved sundew (*Drosera rotundifolia*) in his book Insectivorous Plants. In a letter to Charles Lyell, Darwin wrote 'I care more about *Drosera* than the origin of all the species in the world'. Historically, these carnivores have been regarded as biological oddities, but it is now understood that carnivorous plants make ideal systems to test many evolutionary and ecological questions.

D. rotundifolia growing amongst *Sphagnum* moss at Rocher Bog in the Peak District.

D. rotundifolia can be found in peatlands, which are near constantly waterlogged ecosystems with little belowground oxygen. These anaerobic conditions hinder decomposition, resulting in the build up of thousands of year of organic material. Consequently, peatlands account for 30% of terrestrially stored carbon despite occupying a mere 3% of the worlds land surface. However, the biodiversity and carbon storage potential of peatlands are threatened – nitrogen pollution being of particular concern. Nitrogen limited plants will dominate peatland communities, change the hydrology and increase decomposition, releasing carbon dioxide and methane into the atmosphere.

Previous studies have documented how peatland species composition changes with nitrogen, but by the time these community level changes occur conditions may be irrecoverable. *D. rotundifolia* could be a key indicator of peatland health and provide insights in how other species respond to environmental change. *D. rotundifolia* is an ideal study species because it has reduced root systems, as its leaves take the role of nutrient acquisition. Therefore, we can measure individual investment in survival, growth and reproduction aboveground, over time and non-invasively, without the need to address belowground dynamics.




Peatlands have their own unique communities. On the left are mating *Cordulegaster boltonii* at the Ben Lomond field site; the female laid eggs in a small pool the following day. Captured on the right: at the Llyndy Isaf Mountain site a dragonfly emerges in the shadow of Snowdon and spreads its wings for the first time. Note the presence of *Drosera* in both bottom pictures.

Fieldwork

I investigated how *D. rotundifolia* responded to nitrogen pollution and varied by region. The population study involved tracking individual plants in different locations over time. I gave half of the plants doses of ammonium nitrate annually to simulate double current levels of nitrogen deposition at their location (based on Air Pollution Information System records). Individuals were measured every year, including various size metrics, whether individuals reproduced, the number of seed capsules produced, and their survival status.

Population studies are time and resource intensive. These studies are useful because they allow us to link observations of individual plants to large-scale ecological processes, in natural settings. Moreover, spatial replication allows us to see how effects of experiments vary by site, and think about the reasons for those differences.

Data from four fieldsites is presented in this report. Clockwise from top left: 1) Inversnaid – Loch Lomond and the Trossachs. A manmade rockface kept moist from water travelling down nearby mountains. *D. rotundifolia* is one of few plants that can establish themselves on such shallow soil. 2) Llyndy Isaf Mountain – Snowdonia. A small pool is surrounded by *Sphagnum* moss. The pool is little more than a puddle early in the year but accumulated rainfall triggers growth in early summer. 3) Llyn Barfog – Snowdonia. This lakeside habitat is covered in *Sphagnum*, but larger vascular plants like grasses, forbs and heather are distributed throughout. Sheep also graze here 4) Rocher Bog – Peak District. A small area with a central pool is surrounded by sphagnum moss. The ground is boggy, but further away from the pool the mosses appear more desiccated and vegetation is drier.

Analysis

I ran statistical models to test whether there was variation in *D. rotundifolia* performance between sites and under the experimental treatment of nitrogen.

Individuals at Snowdonia 1 had statistically significant higher rates of growth than other sites, with Loch Lomond 1 plants having the lowest rates of growth. The addition of nitrogen had a significant negative effect on *D. rotundifolia* growth (Fig. 1).

Larger individuals produced more flowers/ seed capsules, but site was also important. Individuals at Loch Lomond 1 were capable of reproducing at smaller sizes, and a plant of a given size at Loch Lomond 1 was more productive than equivalently sized plants at Snowdonia 2 or Peak District 1. Model selection suggested that nitrogen was not a significant determinant of reproductive output. *D. rotundifolia* produce flowering stalks, and some of these stalks bifurcate (fork). Model selection showed that producing bifurcating flower stalks significantly increases reproductive output regardless of size (Fig. 2).

Survival depended upon size, and was significantly lower at Peak District 1. However, there was a considerable amount of error around Snowdonia 2 due to smaller sample sizes (due to livestock interference), hence large confidence intervals in Fig. 3. There was a notable nitrogen-site interaction, with nitrogen having a significantly harmful effect on *D. rotundifolia* survival only at Snowdonia 1.

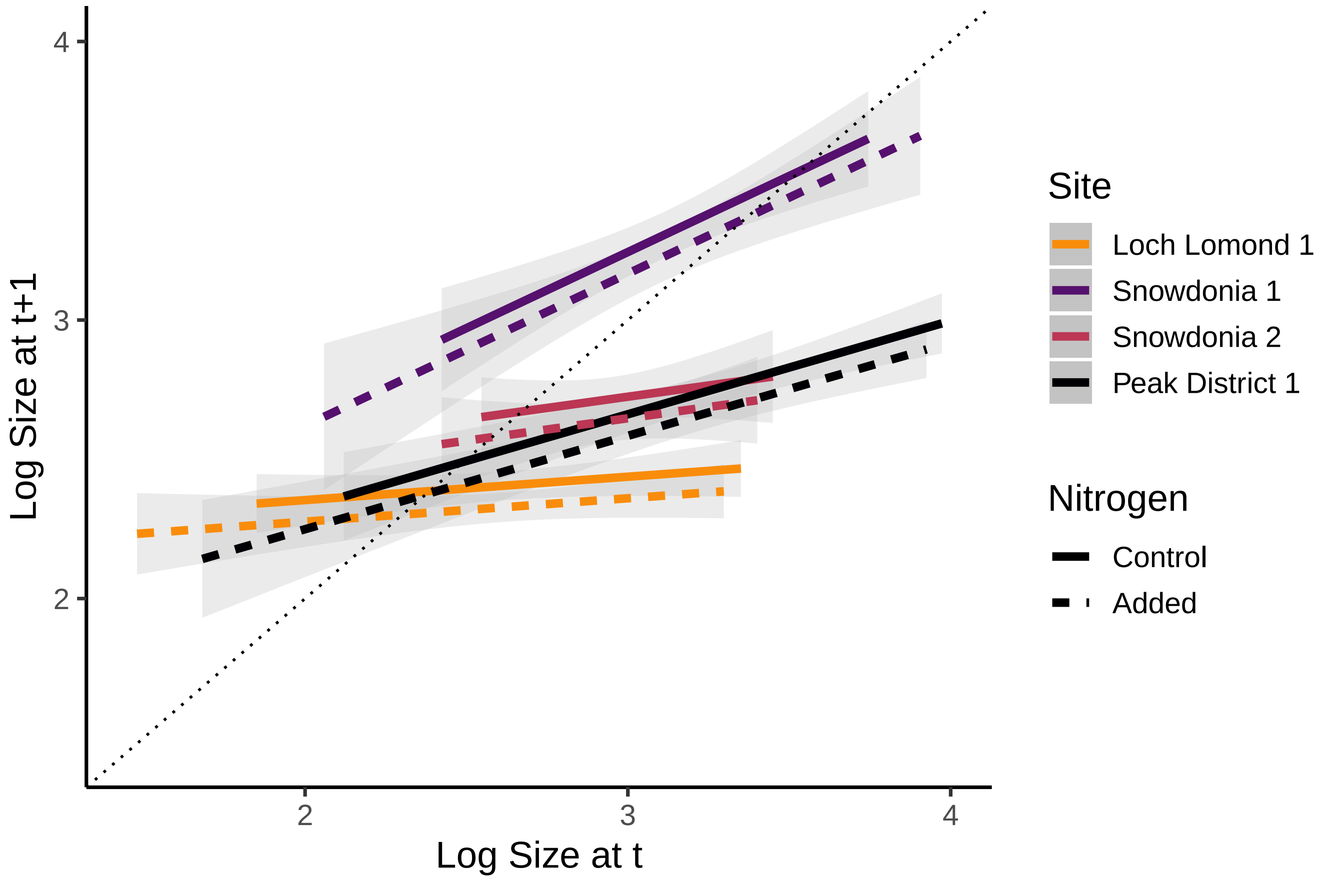

Figure 1. *Drosera rotundifolia* changes in natural logged size over a year, categorised by site and experimental addition of nitrogen. The fitted lines correspond to a general linear model. The shaded area around regression lines represent 95% confidence intervals (a measure of confidence of fit). The dotted line has a slope of 1, and so points above this indicate individuals tended to grow.

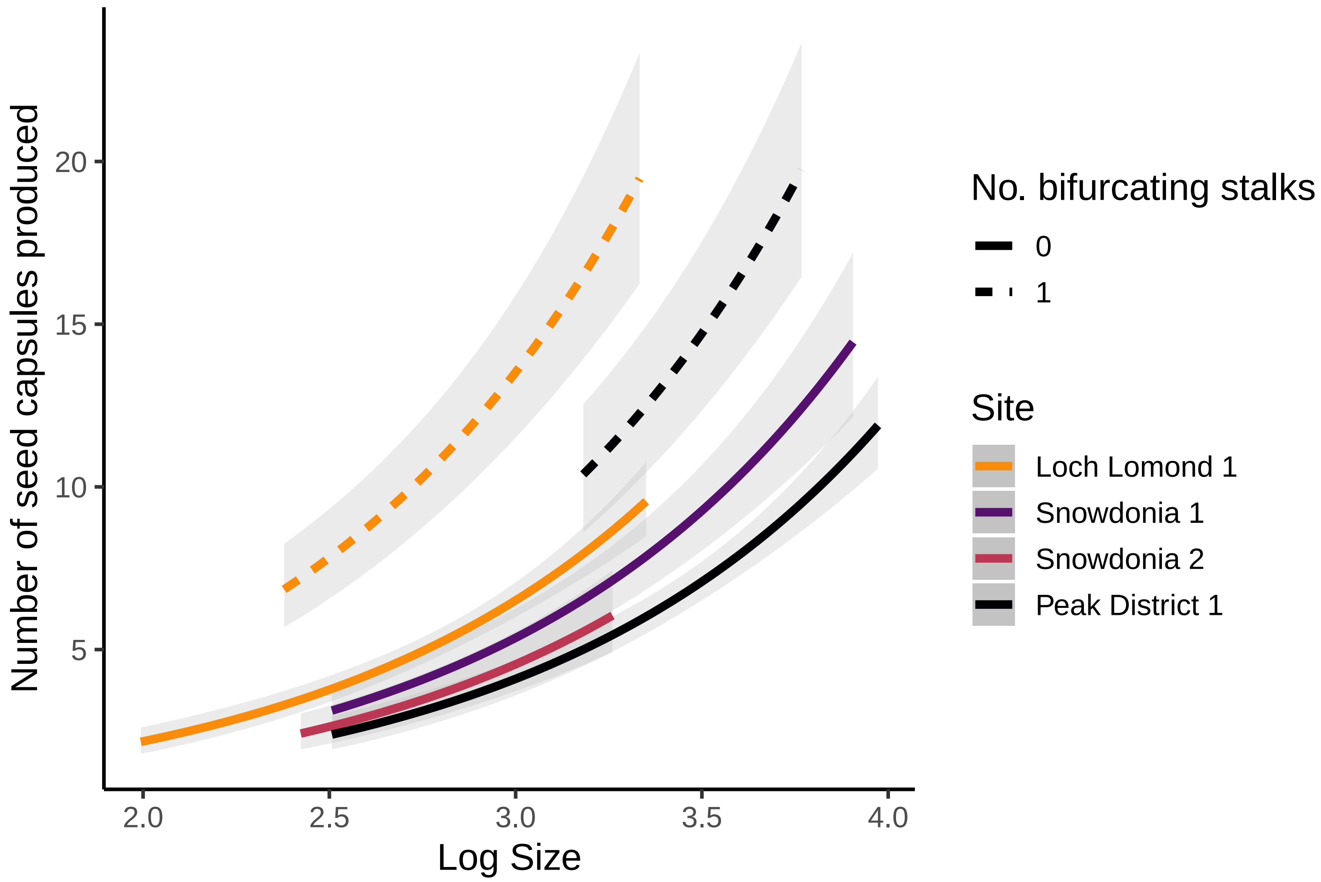

Figure 2. *Drosera rotundifolia* reproductive output varying by natural logged size categorised by site and whether an individual produced a bifurcating flowering stalk. The fitted lines correspond to a negative binomial generalised linear model. The shaded area around regression lines represent 95% confidence intervals (a measure of confidence of fit).

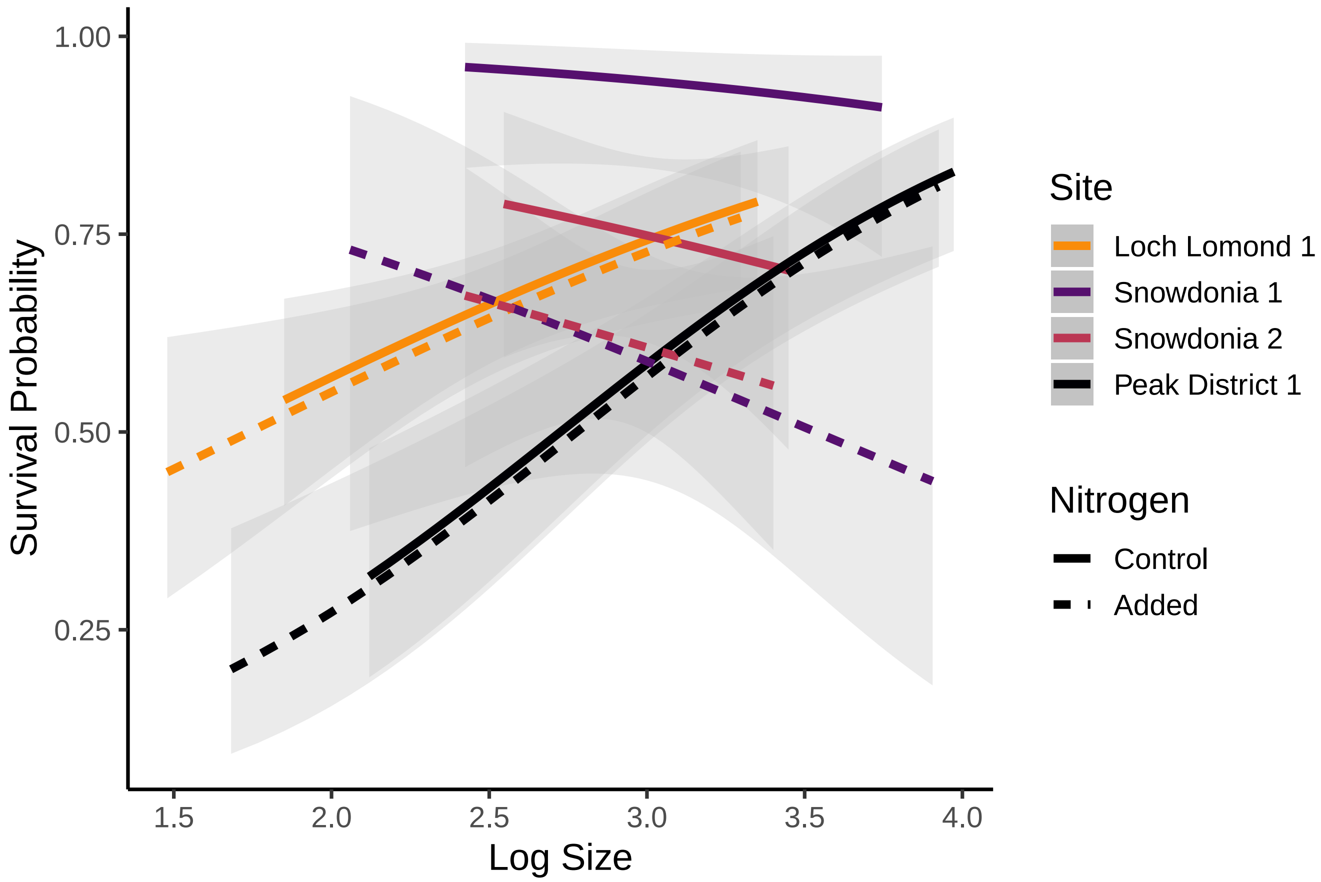

Figure 3. *Drosera rotundifolia* survival probability varying by natural logged size categorised by site and experimental addition of nitrogen. The fitted lines correspond to a binomial generalised linear model. The shaded area around regression lines represent 95% confidence intervals (a measure of confidence of fit).

Interpretation

Nitrogen had a negative effect on plant growth (Fig. 1) and this could be due to increased growth of competitors that are better able to utilise it. We did not see significant effects of nitrogen on reproduction, but reproduction is size dependent (Fig 2.). Therefore, nitrogen may have indirect negative effects on reproductive output by retarding growth. Moreover, our nitrogen treatment was based on rainfall-based deposition – runoff from agriculture is a much greater source of nitrogen deposition. Therefore, we have detected that even small changes in nutrient availability may change performance and competitive interactions between plants.

Site becomes particularly important when considering reproductive output and mortality. At Loch Lomond 1 plants have relatively high reproductive output given their size. A likely explanation is that individuals can invest more in reproduction due to a lack of competition on the rock face habitat. *D. rotundifolia* leaves are comprised of a thin tubes beginning at the centre of the plant (petiole) and end in a carnivorous disc shaped portion. The petiole lengthens when there is little light availability, so with little competition established *D. rotundifolia* individuals can remain compact (Fig.4).

D. rotundifolia at Snowdonia 1 had lower survival when exposed to nitrogen. Peak District 1 and Snowdonia 1 field sites appeared similar, but the differences in nitrogen effects on survival may be due to water availability. Mosses at Snowdonia 1 were constantly saturated, whereas at Peak District 1 the top layer of *Sphagnum* was often desiccated (Fig 4). It could be that the drier conditions buffer *Drosera* mortality, as the mosses are incapable of exploiting the added resources while desiccated.

Figure 4. Field site differences. From the left: 1) *Drosera rotundifolia* growing at Peak District 1 (Rocher Bog) amongst very dry moss; 2) *D. rotundifolia* at Peak District 1 in damper conditions – moss is saturated; 3) *D. rotundifolia* at Loch Lomond 1 (Inversnaid). Plants are growing in bare soil rather than moss, and are small with limited competition.

Future Work

I have presented how reproductive output varies depending on a number of factors, but we may also be interested in what determines probability of reproduction. Additionally, recruitment of new individuals into the population has not been assessed here. I monitored new recruits at Loch Lomond 1 and I grew seeds in *Sphagnum* moss at The University of Sheffield. I will analyse recruitment and reproductive probability and use this information to parameterise size structured population models later in the year.

D. rotundifolia goes into dormancy in the cold, and so individuals need to produce new leaves and flowering stalks when they emerge in spring. We may also be able to assess trade offs by considering how size in one year and survival depend upon reproductive investment in the previous year.

Acknowledgements

This project was made possible thanks to funding from ACCE and The Alice McCosh Trust. I would also like to thank Dafydd Roberts, Alasdair Eckersall, Fraser Lamont, Angus Hunter, and Sabine Nouvet in their great help finding suitable field sites, and the National Trusts for England and Scotland, RSPB and Sheffield City Council for granting site access for this study.