Assessment of microhabitat differences between *Drosera rotundifolia* and *Drosera intermedia* in a northern Michigan bog

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Abstract

The purpose of this study was to investigate microhabitat differences between two species of sundews, *Drosera rotundifolia* and *Drosera intermedia*. I tested several hypotheses: *D. rotundifolia* density increases with increasing height above a fixed low point, while *D. intermedia* density decreases with height; *D. rotundifolia* grows primarily on red *Sphagnum* moss, while *D. intermedia* grows primarily on green *Sphagnum*; the densities of both *Drosera* species increase with decreasing pH; the density of neither *Drosera* species is affected by water conductivity or dissolved oxygen content. At Mud Lake Bog in Cheboygan County, Michigan, I recorded the species of *Drosera* plants, as well as the height of the plants above a fixed low point and the color of *Sphagnum* moss on which they were growing. I also measured the pH, conductivity, and dissolved oxygen content of the water in which the plants were growing. Densities of both *Drosera* species decreased with increasing height, though the trend was stronger for *D. intermedia*. *D. rotundifolia* grew significantly more on red *Sphagnum* than did *D. intermedia*, while *D. intermedia* grew significantly more on green *Sphagnum* than did *D. rotundifolia*. *D. rotundifolia* density varied significantly with neither pH, conductivity, nor dissolved oxygen. *D. intermedia* density increased significantly with decreasing pH and increasing conductivity, but not with dissolved oxygen. My results were consistent with past research, and conclusively illustrated the differences in microhabitat preferences between the two *Drosera* species.

INTRODUCTION

Carnivory in plants has long been a topic of interest in the field of ecology, likely because it is such a unique and fascinating adaptation that goes against the normal, photosynthetic manner in which most plants acquire nutrients. It is an adaptation that allows certain species of plants to occupy habitats deficient in nutrients to the degree that survival would otherwise be impossible; the ability to catch and digest insects allows for nutrients to be acquired from sources other than soil, so when conditions are especially poor, particularly when soil is deficient in nitrogen, these species of plants can still survive (Ellison and Gotelli 2001). Due to this adaptation, we see carnivorous plants in highest numbers and diversity in bright, low-nutrient environments, such as bogs (Ellison and Gotelli 2001), which occur when bodies of water are low in pH, nutrients, and dissolved oxygen, and are covered in large part by a floating mat of moss (*Sphagnum* spp.). Carnivorous plants are found in such environments because the development of carnivorous adaptations is energy intensive; one tradeoff is between carnivory and photosynthesis. Carnivorous plants tend to have comparatively low maximal photosynthetic rates (Ellison and Gotelli 2001), which explains the tendency to find them in areas with high light levels. In environments which are less nutrient-stressed, other plants would initially outcompete carnivorous plants because of the latter's lower photosynthetic rates, and then they would shade the area, further lowering the photosynthetic capabilities of the carnivorous plants and inhibiting their ability to grow (Ellison and Gotelli 2001).

One type of carnivorous plant found in northern Michigan bogs is the sundew (*Drosera* spp.). The individuals of this plant genus grow to a maximum size of around 6 cm tall, and they have basal rosettes of small leaves, sometimes modified to be active traps for insects or more frequently covered with irritable, mucilage-tipped tentacle-hairs called trichomes, which passively trap insects (Gleason and Cronquist 1991). A feeding experiment performed on sundews (Krafft and Handel 1991) showed positive correlations between increased insect feeding and both growth and reproductive rates of the plants, but no positive correlation between feeding via increased soil fertility and either growth or reproduction. The Krafft and Handel study (1991) demonstrates that this genus of plants is so highly adapted to surviving through carnivory that even when presented with advantageous soil conditions, the fitness of the plant is not improved.

A study of individual *Drosera* species showed that sundews are frequently found in unshaded areas where their photosynthetic rates can be maximized, lowering their necessary investment in carnivory (Thorén et al. 2003). They have also been shown to occur in fairly low densities because high rates of intraspecific competition for insects occur when the plants are in dense clusters (Gibson 1991). An experiment comparing two *Drosera* species (*D. rotundifolia* and *D. intermedia*) in a bog in Germany showed that both species survived with about equal fitness levels, based on their nearly-equivalent biomasses, but occupied different microhabitats within the bog (Thum 1986). It was observed that *D. rotundifolia* generally lived in drier areas of the bog, above the saturation point, on mounds of *Sphagnum* called hummocks, whereas *D. intermedia* tended to live in the more water-logged areas of *Sphagnum* between the hummocks, called hollows (Thum 1986). One reason for the microhabitat preferences of the different *Drosera* species is the *Sphagnum* on which they grow. In a study conducted by Svensson (1995), *Sphagnum* absorbed nitrogen that was introduced into the environment more effectively than did the sundews growing in the same area; *D. rotundifolia* plants responded by growing taller stems so as not to be shaded by the rapidly growing moss. The experiment showed that individual *Drosera* plants could cope with strong competition, but the spread of new sundews could be severely limited by the *Sphagnum* on which they grow (Svensson 1995). This means that the distribution of *Drosera* plants is often closely tied to the distribution of *Sphagnum*.

In addition to outcompeting other types of plants due to their ability to rapidly absorb nitrogen, *Sphagnum* species have a tendency to compete strongly with each other, and a species will often exist not where it would be most productive, but where it will be the strongest competitor (van Breemen 1995). In one experiment (Rydin 1993), *Sphagnum* species that normally grow on hummocks were switched with ones that normally grow in hollows. The hummock-adapted species thrived in the hollows, but eventually spread and returned to living primarily on the hummocks, where they outcompeted the species that had been transplanted there (Rydin 1993). Further, McQueen (1990) observed that most *Sphagnum* species show a strong wet-to-dry gradient in their relative abundances, and that they also have particular pH ranges where they will be most competitive; these preferences lead to sharp boundaries where two species meet. However, another study (Rydin 1985) showed that *Sphagnum* species that were prone to desiccation (and thus grew primarily in the wet hollows) could grow in drier areas if they were accompanied by *Sphagnum* species that retained water more effectively. This apparent commensalism suggests that the microhabitat boundaries of certain *Sphagnum* species may occasionally be blurred. In northern Michigan bogs, the two most common species of *Sphagnum* are *S. cupisdatum* and *S. fuscum*: *S. cupisdatum* appears green, prefers low pH values, and grows in the lower, wetter hollows; *S. fuscum* appears red, prefers slightly higher pH values, and grows primarily on the drier hummocks (Crum 2004).

The purpose of my research was to study the two aforementioned Drosera species, and investigate their distribution within bogs based on plant heights, *Sphagnum* color, and various abiotic factors. Because *D. rotundifolia* usually occurs on drier, more elevated sections of *Sphagnum* (Thum 1986), I expected that *D. rotundifolia* density would increase with increasing height up hummocks, and because *D. intermedia* usually occurs in wetter, lower sections of bogs (Thum 1986), I expected *D. intermedia* density to decrease with increasing height up hummocks. Based on the fact that *D. rotundifolia* and *S. fuscum* occur in similar areas and under similar conditions (higher on hummocks in drier areas with higher pH), and *D. intermedia* and *S. cupisdatum* occur under in similar areas and under similar conditions (lower in hollows in wetter areas with lower pH) (Thum 1986, Crum 2004), I predicted that *D. rotundifolia* would occur more on red *Sphagnum*, and that *D. intermedia* would occur more on green *Sphagnum*. I also predicted that *D. rotundifolia* and *D. intermedia* densities would be inversely related to pH, since both species prefer acidic conditions (Thum 1986). Since water conductivity is a good estimate of nutrient levels, and since Krafft and Handel (1991) showed that *Drosera* species do not respond to increased nutrients with increased growth, I predicted that there would be no relationship between densities of either *Drosera* species and either conductivity or dissolved oxygen. Finally, since *Drosera* plants have leaves capable of photosynthesis and take in the rest of their nutrients from captured insects, I predicted that there would be no relationship between densities of either *Drosera* species and the dissolved oxygen content of the water.

METHODS

I studied the microhabitat differences between *D. rotundifolia* and *D. intermedia* at Mud Lake Bog in northern Michigan's Cheboygan County. The bog contains areas of predominantly red *Sphagnum*, areas of predominantly green *Sphagnum*, and areas where both colors of moss appear in approximately equal proportions. I selected twelve hummocks, located away from foot traffic to avoid disturbances. The *Sphagnum* mat around six of the hummocks was predominantly red, while the *Sphagnum* mat around the other six was predominantly green. Around each hummock, I established a quadrat in which the area of the hummock was approximately equal to the area of flat terrain; the quadrats ranged in size from 2.25 to 4 m^2.

In each quadrat, I first estimated the percent covers of both red and green *Sphagnum*, and established the location of the lowest point on the mat. I then observed each sundew plant in the quadrat, recording its species, the color of *Sphagnum* on which it was growing, and its height above the quadrat low point, as measured from the bottom of its basal rosette. Finally, I formed a depression in a hollow in the middle of the quadrat so that a puddle of water formed around 10 cm deep. In this puddle, I measured the pH, conductivity, and dissolved oxygen content of the water.

To test how the distribution of each species varied with height above the low point of the quadrat, I divided the plant heights into categories (0 cm, 1-10 cm, 11-20 cm, and >20 cm). I then performed a 2-way ANOVA on the number of sundews, testing for effects of species, height category, and the interaction between species and height category. To test the difference in species abundance on the two *Sphagnum* colors, I used a Chi-Square Test. To test how the percent cover of red *Sphagnum* in a quadrat affected the density of each *Drosera* species, I used linear regression analyses. To test how the abiotic factors (pH, conductivity, and dissolved oxygen) affected the density of each species, I used linear regression analyses.

RESULTS

There was no significant difference in the number of sundews of each species, but there was a significant difference in the number of sundews growing in each height category: the number of plants decreased as the height increased (Figure 1). In addition, the number-height relationship was significantly different for both species (Table 1).

Of the *D. rotundifolia* plants observed, 94% were growing on red *Sphagnum*, compared to just 8% of the *D. intermedia* plants (Figure 2). This difference in species distribution was significant (χ^2=726, df=1, p<.001). In addition, there was a significant positive relationship between the percent cover of red *Sphagnum* and the density of *D. rotundifolia* (r^2=.446, N=12, p=.018), and a significant negative relationship between percent cover and *D. intermedia* density (r^2=.750, N=12, p<.001) (Figure 3).

There was no significant relationship between pH and *D. rotundifolia* density (Figure 4; r^2=.153, N=11, p=.235), while there was a significant negative relationship between pH and *D. intermedia* density (r^2=.286, N=11, p=.005). Figure 5 shows that there was no significant relationship between conductivity and *D. rotundifolia* density (r^2=.266, N=11, p=.104), while there was a significant positive relationship between conductivity and *D. intermedia* (r^2=.386, N=11, p=.018). There was no significant relationship between dissolved oxygen and *D. rotundifolia* density (Figure 6; r^2=.003, N=11, p=.864), nor was there a significant relationship between dissolved oxygen and *D. intermedia* density (r^2=.184, N=11, p=.188).

DISCUSSION

My results indicated a strong negative relationship between the number of each species of sundew and the height above the low point in the quadrat, contrary to my hypothesis that only *D. intermedia* would show this pattern. Still, it is worth noting that the pattern shown for *D. intermedia* was significantly stronger than that shown for *D. rotundifolia*. When forming my hypothesis, I neglected to take into account the fact that there is simply less *Sphagnum* area on which to grow as the height increases. It makes intuitive sense that even if a species prefers to grow higher up on a hummock, there will be more individuals growing at lower heights because of the greater area on which to grow. A more correct, though much more difficult, analysis would involve measuring the total area on the *Sphagnum* on which the sundews could grow, separated into height categories. In this way, one could obtain density measurements at each height above the quadrat low point, rather than numbers, which do not tell the full story. For this reason, my analysis of the relationship between *D. rotundifolia* density and height was incomplete. However, my hypothesis regarding *D. intermedia* was confirmed conclusively. An average of 55 plants per quadrat grew at the low point, compared to just 3.6 plants above the low point, showing this species' strong tendency to grow in hollows, in line with the research done by Thum (1986).

The data show a striking difference in the distribution of the two *Drosera* species on the two mat colors; *D. rotundifolia* grew on red *Sphagnum* nearly 20 times as often as it grew on green, and *D. intermedia* appeared on green *Sphagnum* 5 times as often as it appeared on red. These results are consistent with the significant increase in *D. rotundifolia* as the red *Sphagnum* percent cover increased, and the significant increase in *D. intermedia* as the green *Sphagnum* percent cover increased (Figure 3). Both of these results are consistent with the findings of Crum (2004) and Thum (1986), that *D. rotundifolia* and *D. intermedia* prefer similar microhabitats to those preferred by *S. fuscum* and *S. cupisdatum*, respectively. In addition, the fact that these distributions were significant on a plant-by-plant scale as well as on the quadrat scale serves to strengthen the conclusions that can be drawn about species abundance on different *Sphagnum* substrates, and makes it highly unlikely that my results were skewed by confounding variables such as uneven distributions of plants or moss.

The significant negative relationship between *D. intermedia* density and pH confirmed my hypothesis and makes sense in the context of Crum's (2004) and Thum's (1986) research and the mat color-species distribution found in this study; *S. cupisdatum* and *D. intermedia* both occur in low, wet, relatively acidic locations in bogs. I expected to find the opposite relationship between *D. rotundifolia* density and pH, but instead found no relationship at all. This can be explained in the context of Rydin's study (1993) of *Sphagnum* competition, in which moss that normally grew at the tops of hummocks grew successfully in hollows. Since *D. rotundifolia* and *S. fuscum* normally occur under the same conditions, and since that sundew species has been shown to successfully compete with *Sphagnum* moss (Svensson 1995), it is reasonable to assume that if the red

Sphagnum was able to colonize areas of relatively low pH, *D. rotundifolia* plants would not be far behind. Therefore, *D. rotundifolia* may be able to withstand a wider range of pH values than *D. intermedia*, preventing detection of a significant relationship.

Among the four relationships measured between both *Drosera* species and conductivity and dissolved oxygen, only one (between *D. intermedia* and conductivity) was significant. The remaining three agreed with my hypothesis, based on the findings of Krafft and Handel (1991) that added nutrients would not lead to more sundew growth. In light of that research, the three insignificant results, as well as the rest of the results in this survey, it seems very possible that conductivity was closely related to one or more variables in ways that I was unaware, which could give the appearance of a dependence on conductivity when none exists. If conductivity were even weakly associated with another variable, we would expect to see the same dependence on conductivity as with the other factor. Therefore, while it would be overly presumptuous to throw out the significant result completely, it is important to note the lack of evidence that supports a truly significant relationship between conductivity and *D. intermedia* density.

In this study, I demonstrated conclusively that there are microhabitat differences between *D. rotundifolia* and *D. intermedia*, and I linked those differences to the preferences of the *Sphagnum* moss on which they tend to grow. The common dependence on specific pH values and water levels is a clear example of the degree to which groups of organisms evolve to fill highly specialized niches within an ecosystem. Humans, animals, and carnivorous plants alike shape communities through dynamic interactions within species, between species, and among the myriad abiotic factors that shape our world.

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FIGURES AND TABLES

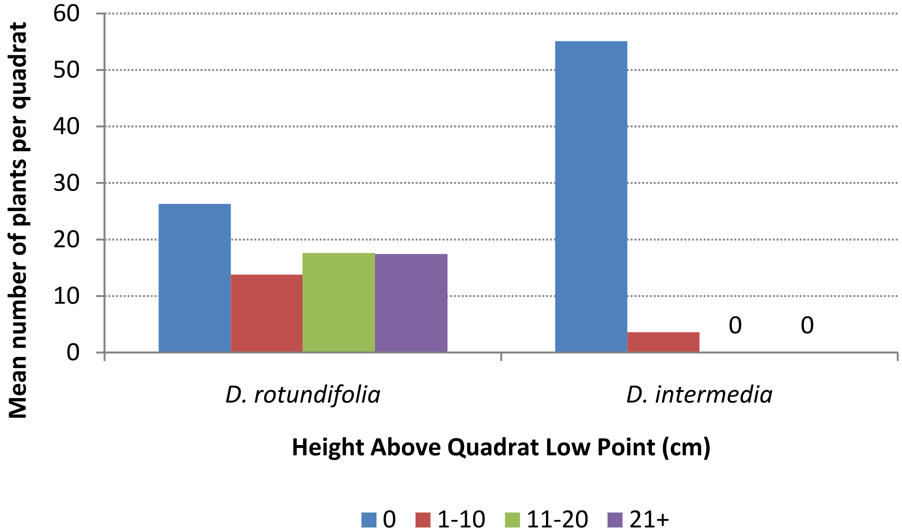

Figure 1. Number of *D. rotundifolia* and *D. intermedia* plants in the four height categories above quadrat low point. Both species showed a significant decrease in number as height increased, though their specific distributions were significantly different (see Table 1).

Table 1. Results from 2-Way ANOVA of the number of *Drosera* plants, testing for effects of species, height category, and the interaction between species and height category. There was no significant difference in the number of plants of each species, but there was a significant difference in the number of plants in each height category. In addition, there was a significant difference in the species-specific distribution of plant heights.

	F	df	p
Species	1.47	1, 42	.23
Height category	5.86	3, 42	.002
Species * height category	6.45	1, 42	.015

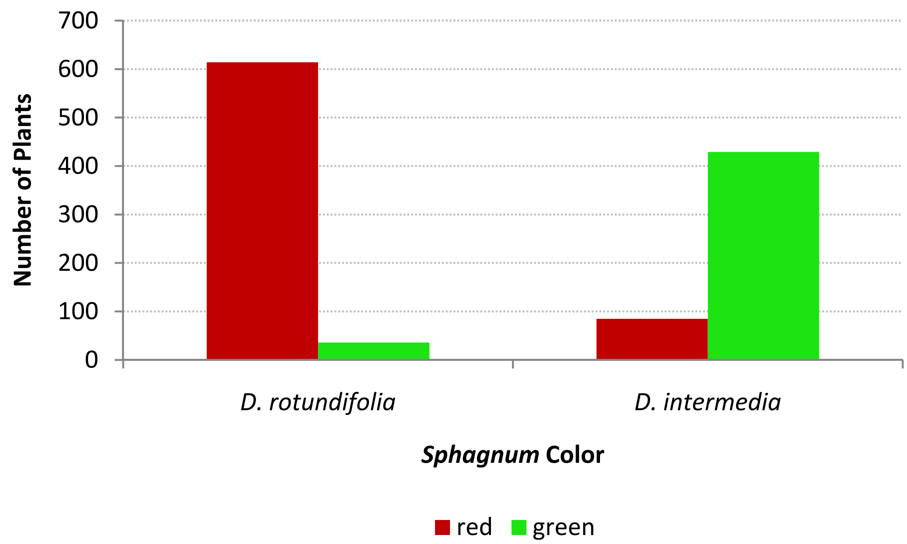

Figure 2. Number of *D. rotundifolia* and *D. intermedia* plants growing on red and green *Sphagnum*. There was a significant association between *Drosera* species and *Sphagnum* color (χ^2=726, df=1, p<.001).

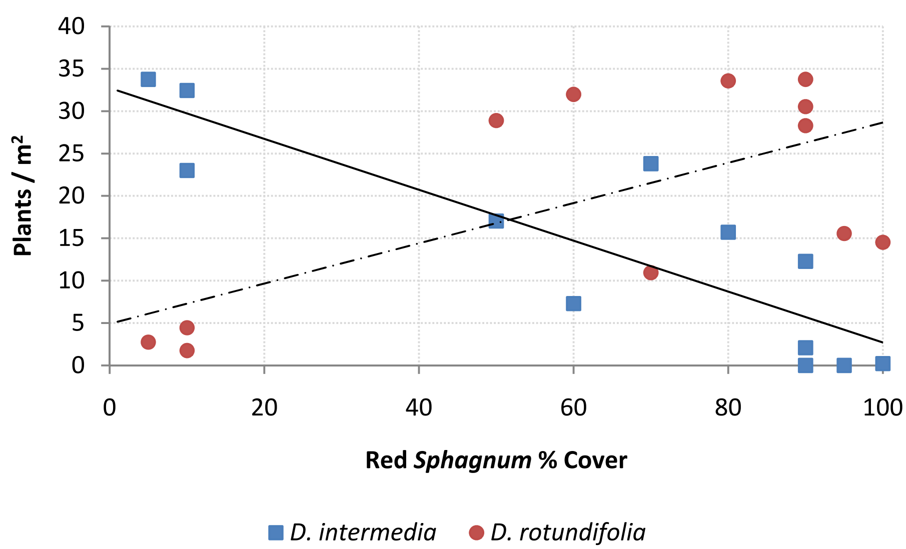

Figure 3. Densities of *D. rotundifolia* and *D. intermedia* as a function of the percent cover of red *Sphagnum* in each quadrat. There was a significant positive relationship between percent cover and *D. rotundifolia* density (r^2=.446, N=12, p=.018), and a significant negative relationship between percent cover and *D. intermedia* density (r^2=.750, N=12, p<.001).

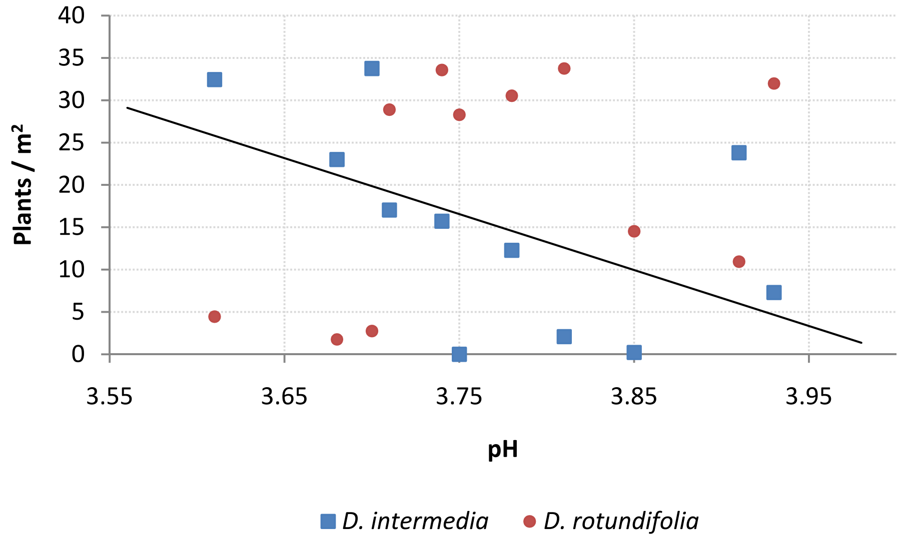

Figure 4. Densities of *D. rotundifolia* and *D. intermedia* as a function of quadrat pH. There was no significant relationship between pH and *D. rotundifolia* density (r^2=.153, N=11, p=.235), while there was a significant negative relationship between pH and *D. intermedia* density (r^2=.286, N=11, p=.005).

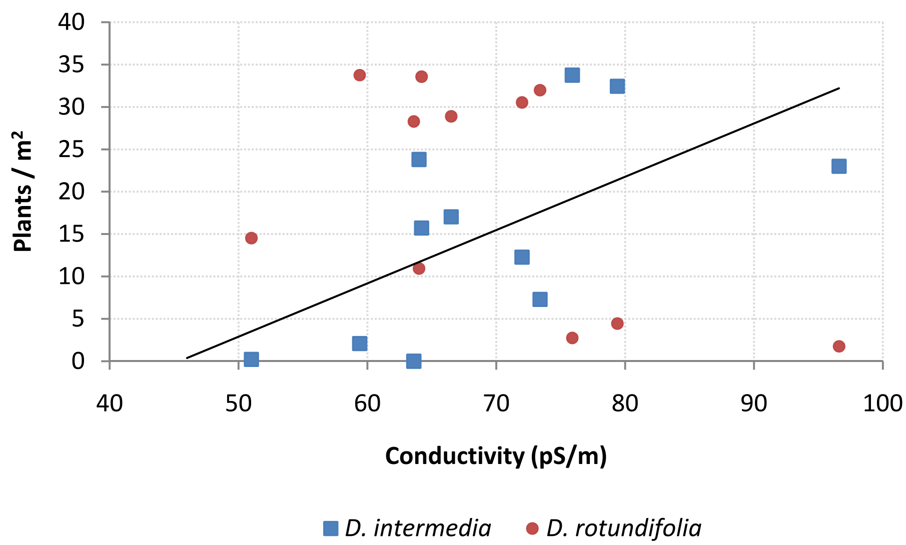

Figure 5. Densities of *D. rotundifolia* and *D. intermedia* as a function of quadrat conductivity. There was no significant relationship between conductivity and *D. rotundifolia* density (r^2=.266, N=11, p=.104), while there was a significant positive relationship between conductivity and *D. intermedia* (r^2=.386, N=11, p=.018).

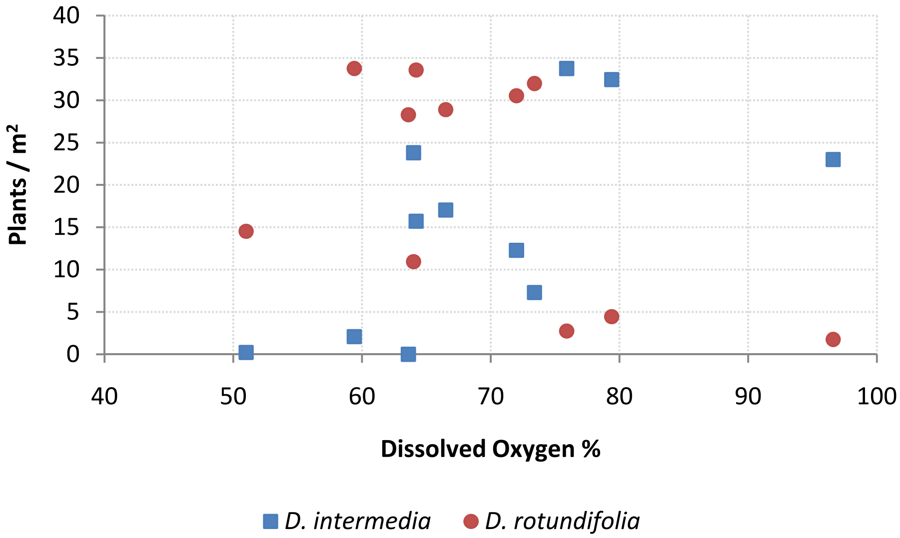

Figure 6. Densities of *D. rotundifolia* and *D. intermedia* as a function of dissolved oxygen content. There was no significant relationship between either *D. rotundifolia* density (r^2=.266, N=11, p=.864) or *D. intermedia* density (r^2=.386, N=11, p=.188).