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Habitat differences between *Drosera anglica* and *Drosera rotundifolia* in Sierra Nevada fens

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ABSTRACT

Interspecific competition for limited resources reduces fitness, and natural selection can favor divergence in resource use that allows species to coexist. *Drosera anglica* and *Drosera rotundifolia* are two closely related sundew species with distinct global ranges that co-occur in fens at Sagehen Creek Field Station in Nevada County, California. To determine how they are distributed on a local scale, we recorded *Drosera* presence across five fens, and measured temperature, water availability, and pH. *D. rotundifolia* occurred in all five fens and was more frequent than *D. anglica,* which was absent from the two warmest fens. We found temperature, net water availability, and pH all differed among fens, and the occurrence of both species was associated with fen differences in temperature and net water availability. Higher pH was associated with *D. anglica* occurrence among fens, but not with *D. rotundifolia* occurrence among fens. Within fens, however, only *D. rotundifolia* responded to local gradients, occurring more frequently in warmer and wetter sampled quadrats, while *D. anglica* occurrence was unrelated to any of the three environmental variables measured. Despite this, *D. anglica* occurred more frequently in the centers of fens than at their edges, whereas *D. rotundifolia* showed no positional preference. These results indicate that the environmental differences among fens had an influence on where the two species occur, while local fen gradients were associated primarily with the distribution of *D. rotundifolia.*

Keywords: *Drosera anglica* (English sundew), *Drosera rotundifolia* (Round-leaved sundew), competitive displacement, local distribution, subalpine fens

INTRODUCTION

Closely related species often occur in similar environments, raising the question of how they avoid competitive exclusion. Niche partitioning is one mechanism in which species reduce competition by differing in their use of resources or ecological conditions (MacArthur and Levins 1967). A species' ecological niche encompasses abiotic and biotic factors, and an important component of this is habitat partitioning, where species occupy different physical environments within the same ecosystem.

Plants can partition resources and environmental conditions that are essential for growth and survival, including soil moisture, nutrient availability, and water availability. Differences in these resources can allow closely related species to occupy different habitats within the same

ecosystem, reducing competition while promoting coexistence (Silvertown 2004; Silvertown et al. 2015). One example of this occurs in California serpentine plant communities, where *Mimulus guttatus* and *Mimulus nudatus*, two closely related monkeyflowers, coexist within northern California but occupy different microhabitats. *M. guttatus* occurs more widely in wet stream habitats while *M. nudatus* occurs in drier serpentine seeps (Sobel 2014; Toll and Willis 2018). This example illustrates how environmental variation can structure the distribution of species on a landscape. Such partitioning is likely in ecosystems that have heterogeneous environmental conditions.

Groundwater-fed fens are a prime example of an ecosystem with varied conditions because of their natural gradient in temperature, water table depth, and water chemistry across small spatial scales. Fens are peat-forming wetlands, characterized by their persistently water-saturated soil throughout the year and nutrient poor conditions, which support specialized plant communities (USDA Forest Service 2022; Weixelman 2009). Fen pH varies with the nutrients provided by their water source and surrounding vegetation type (Hájek et al. 2006). Water delivery is impacted by its geomorphic settings; as fens form on slopes, they require continuous groundwater inflow because downhill drainage is rapid (Wolf and Cooper 2015). Temperature also varies within fens, and shallow soil temperatures can differ by several degrees among locations across even a small mountain fen (Moore and Evans 2022). Within a fen, the peat is generally thinner near the margins than in the center (Andre et al. 2024). These conditions create distinct microhabitats, allowing different species to grow close together while occupying their own environment (Wolf and Cooper, 2015; Silvertown et al., 2015). Variation in temperature, water availability, and pH influences nutrient availability, and plant growth (Millett et al., 2018).

Among the plants adapted to the unique conditions found in fens are species of *Drosera*, commonly known as sundews. These carnivorous plants have specialized leaf structures that allow them to supplement essential nutrients like nitrogen and phosphorus by capturing and digesting small insects (Adamec 2013; Crowder et al. 1990; Ellison and Gotelli 2009). This adaptation allows sundews to persist in the low-nutrient soils that characterize fens.

Two sundew species, *Drosera anglica* (English sundew) and *Drosera rotundifolia* (Round-leaved sundew) are closely related and may co-occur within wetlands. Despite their ability to grow together, they have different geographic distributions. *D. anglica* is less common and reaches the southern extent of its range in the Sierra Nevada, while *D. rotundifolia* ranges across much of North America (GBIF 2026). In California, *D. anglica* is considered rare, whereas *D. rotundifolia* is classified as a species of least concern (California Native Plant Society 2026). This variation in global occurrence suggests that environmental factors may impact species distribution on a smaller, local scale where *D. anglica* and *D. rotundifolia* co-occur.

To further understand how fen microhabitat differences affect partitioning between two co-occurring sundew species, we compared where each species occurred and where they co-occurred against three environmental factors: temperature, water availability, and pH. This research was conducted at Sagehen Creek Field Station,

within five different fens. We hypothesized that *D. anglica* and *D. rotundifolia* partition their resources and occupy different positions along the environmental gradients. We predicted that *D. anglica* would be restricted to colder temperatures and narrower ranges for water availability and pH both across and within fens based on its global distribution. We predicted that *D. rotundifolia* would occur in a broader environmental range and would have a wider distribution across and within the fens. Understanding these relationships may help explain the ecological patterns that allow these species to coexist in a spatially variable fen.

METHODS

We conducted our research at Sagehen Creek Field Station from July 31, 2026 to August 2, 2026. Sagehen is located in the northeastern Sierra Nevada Mountains in California, USA, and consists of montane conifer forests, and subalpine meadows, wetlands, and fens. Sagehen Creek Basin contains multiple minerotrophic peatlands (fens) that are associated with perennial springs and occur within the same watershed (Erman and Erman 1975). The five fens sampled in this study therefore provided ecologically comparable sites within a shared basin while retaining variation in temperature, water-table hydrology, and water chemistry. This combination allowed us to compare abiotic conditions and *Drosera spp.* distribution across fens with similar environmental origins while examining variation among individual sites.

D. anglica and *D. rotundifolia* reproduce both vegetatively and sexually, with sexual pseudo-chasmogamous flowers that bud around July, and bloom in August (Baranyai & Joosten, 2016; Hoyo and Tsuyuzaki 2015). *D. anglica* has narrow, elongated leaves, while *D. rotundifolia* has more circular leaves. Despite differences in morphology, the average leaf area is relatively similar between the two species (Hoyo 2013).

We sampled from five fens: Bottomless Fen, Lower Kiln, Upper Kiln, Mason Fen, and 1/2 Fen (Table 1). Kiln Fen contains an upper and lower portion, which we sampled as separate fens due to a bottleneck with shrub growth and a steep incline in between the two sections. It should be noted that they are the same fen as they share a water source. Within each fen, the boundary was defined as where the moss-dominated substrate transitioned to woody vegetation, or when grasses exceeded 0.5 m in height. We mapped the fens by walking around the determined edge and used GPS tracking on eBird (version 3.6.2) to create a spatial outline. We overlaid the outline on Google Earth Pro (version 7.3.7) to create a map of where our transects would be placed. Each fen was divided into 6 horizontal sections from top to bottom, and sampled along the 5 dividing transect lines, which were between 17 m and 28 m apart depending on the size of the fen. The length of each transect was proportional to total fen size and ranged from 12–62 m long. Along each transect we sampled within a 0.25 m^2 (0.5 x 0.5 m) quadrat starting at the determined edge and at a minimum of 2 m between each sample. Quadrats were categorized as at the edge, intermediate, or center within the fen, proportional to the total length of the transect. Each transect had a minimum of two quadrats on the edge and one in the center. Intermediate quadrats were designated depending on length of transect and total number of quadrats measured along the length.

Table 1. Location, area, mean pH and net water availability measured across five fens in Sagehen Creek Field Station. These values characterize the environmental conditions associated with each fen and provide context to examine patterns of habitat partitioning between *D. anglica* and *D. rotundifolia*.

Fen Name	Coordinates	Area (m^2)	Mean Temperature (°C)	Mean Net Water Availability (g)	Mean pH
Bottomless	39.433067°, -120.280889°	2791	19.6	2.37	7.26
Lower Kiln	39.432069°, -120.259078°	4078	20.9	1.86	7.51
Upper Kiln	39.431275°, -120.259431°	2116	23.9	4.74	7.44
Mason	39.428586°, -120.244069°	5481	21.9	7.55	7.64
1/2	39.428986°, -120.237147°	1514	24.1	7.10	7.25

We measured three environmental factors across the five fens: temperature, pH, and net water availability. We collected temperature by submerging the probe just below the fen surface, using a Vivosun LCD digital aquarium thermometer and a HM Digital Com-80 meter. Water availability was measured at each sampling point by having the same individual stand on one foot on the fen substrate for 10 seconds. A cut kitchen sponge (5.5 cm x 6 cm) was then placed in the depression with the abrasive side up to absorb any available water for 20 seconds. The sponge was weighed before and after being placed on the moss using a Weigh gram TOP-100 digital scale, and the sponge was wrung out between each sample. This measurement allowed us to quantify excess water that could be absorbed from the fen surface beyond the saturation capacity of the moss. For pH measurements we subsampled along the transect, ensuring collection from the edges and center of the fen. The only exceptions occurred where water flow was too low to collect a sample. A minimum of 12 water samples were collected at each fen. The water samples were taken back to the lab and measured using a Milwaukee MW101 PRO pH meter.

We used point intercepts in our gridded quadrat to estimate the percent coverage. At the 16 intersection points, we recorded which species were present. Each sundew at an intersection point represented 6.25% cover (1/16). If there were no sundews at the intersection points but they were observed within the quadrat, we quantified it as a 1% coverage to represent their occurrence at that location in the fen.

All statistical analyses were performed in JMP (Student Edition, version 18. JMP Statistical Discovery LLC, Cary, NC.). Differences in temperature, water availability, and pH among fens were analyzed using three one-way ANOVAs followed by Tukey HSD tests for pairwise comparisons. Species composition among fens was analyzed with a chi-square test, as was the association between species occurrence and position within the fen

(edge, intermediate, or center). To test whether each environmental variable predicted species occurrence, we ran logistic regressions between the occurrence of each species and each environmental variable. We also ran nested logistic regressions that partitioned temperature, water availability, and pH into among-fen and within-fen components, allowing us to distinguish whether the relationships reflected broad differences among fens or local environmental gradients within an individual fen. Temperature and net water availability were recorded in all 164 quadrats, and pH was measured in a subsample of 72. Finally, we created temperature, net water availability, and species spatial maps of Mason Fen, Bottomless Fen and Lower Kiln Fen–the three fens in which both species occurred–using ArcGIS Pro version 3.6.

RESULTS

We found that species composition differed among the five study fens (N = 164, χ^2 = 60.172, P = 0.0001279; Fig. 1). *D. rotundifolia* occurred across all study fens, whereas *D. anglica* was only present in Bottomless, Mason, and Lower Kiln fens. Of these fens, *D. anglica* occurred most frequently in Bottomless Fen, where 28.1% of quadrats contained *D. anglica* alone. In contrast, *D. rotundifolia* occurred most frequently in 50.0% of quadrats in Upper Kiln and 38.9% of quadrats in Mason Fen. Co-occurrence was greatest in Mason Fen, where 30.6% of quadrats contained both species. Across all five fens, 58.5% of quadrats contained neither species.

The environmental conditions also varied across the fens. Temperature differed among the five study sites (N = 164, one-way ANOVA= 11.1280, P = 0.0001; Fig. 2). Bottomless Fen had the lowest mean temperature (19.57°C), while 1/2 Fen and Upper Kiln had the highest mean temperatures (24.07°C and 23.93°C). A Tukey HSD showed Bottomless Fen was cooler than Upper Kiln, Mason, and 1/2 Fen. It also showed that Lower Kiln was cooler than Upper Kiln and 1/2 Fen. Net water availability differed across the five fens (N = 164, one-way ANOVA: F = 4.28, P = 0.0025; Fig. 3). Mason Fen had the highest mean net water availability (7.55 g), and Lower Kiln had the lowest (1.86 g). Tukey HSD showed that Mason Fen had a greater net water availability than Bottomless Fen and Lower Kiln, with Upper Kiln and 1/2 Fen having intermediate values. Finally, pH also showed variance (one-way ANOVA: F = 3.75, P = 0.0082; Fig. 4). Mason Fen had the highest mean pH (7.64) and 1/2 Fen had the lowest mean pH (7.25). Tukey's HSD showed that Mason Fen had higher pH than Bottomless and 1/2 Fen, while Lower Kiln and Upper Kiln overlapped with both groups.

Across the fens, the environmental conditions also showed relationships with the occurrences of the two *Drosera* species. Temperature was associated with the occurrence of *D. rotundifolia*, but not *D. anglica*. *D. rotundifolia* was more frequently present in quadrats with higher temperature, which predicted a greater occurrence of the species (N = 164, χ^2 = 13.87217, P = 0.0002; Fig. 5). In comparison, the temperature distributions of quadrats with and without *D. anglica* overlapped, and temperature did not predict its occurrence (N = 164, χ^2 = 0.03678, P = 0.8479; Fig. 5). Overall, *D. anglica* was found in a narrower temperature range (14.6–28.2°C) than *D. rotundifolia* (13.9–29.8°C). Net water availability predicted the occurrence of *D. rotundifolia* (N = 164, χ^2 = 4.931324, P =

0.0264; Fig. 6) but not *D. anglica* (N=164, χ^2 = 2.242808, P = 0.1342; Fig. 6). Both species showed similar ranges in net water availability, with *D. rotundifolia* (0–31.2 g) only slightly broader than *D. anglica* (0–30.9 g). Higher pH was associated with the occurrence of both species. Quadrats containing *D. rotundifolia* tended to have high pH, and pH predicted greater occurrence (N = 72, χ^2 = 10.16763, P = 0.0014; Fig. 7). A similar pattern was observed for *D. anglica*, which was more frequently present in quadrats with higher pH (N = 72, χ^2 = 7.959241, P = 0.0048; Fig. 7). *D. rotundifolia* had a broader range of pH values (8.18–6.88) than *D. anglica* (8.18–7.06). To determine whether these environmental relationships differed depending on spatial scale, species occurrence was compared with temperature, net water availability, and pH both among and within fens (Table 2). Among fens, both *D. rotundifolia* and *D. anglica* showed relationships with temperature and water availability. There was an effect of pH on *D. anglica* presence but not *D. rotundifolia*. At the within-fen scale, however, *D. rotundifolia* occurrence continued to vary with temperature and net water availability. This was not true for *D. anglica* occurrence which did not vary with any of the three environmental conditions. The association between pH and *D. rotundifolia* occurrence did not persist once fen identity was accounted for.

At a finer spatial scale, the occurrence of each species was examined in relation to position within the fens. *D. rotundifolia* was present in 50.8% of center quadrats (n = 59), 50.0% of intermediate quadrats (n = 56) and 38.7% of edge quadrats (n = 49). However, position was not associated with *D. rotundifolia* occurrence (N = 164, χ^2 = 1.884, P = 0.3899; Fig. 8). *D. anglica* occurrence was highest in center quadrats (30.51%), followed by the intermediate quadrats (21.43%), and the lowest at the edge of the fen (10.20%). Position within the fen was associated with *D. anglica* occurrence, with a lower proportion of edge quadrats containing *D. anglica* (N = 164, χ^2 = 6.574, P = 0.0374; Fig. 9).

To further visualize patterns of species distribution and environmental gradients, heat maps were created for Bottomless, Mason, and Lower Kiln–the three fens in which both *D. anglica* and *D. rotundifolia* co-occurred (Fig. 10). The maps display the spatial distribution of species occurrence, alongside the spatial distribution of temperature and water availability. Species occurrence was spatially variable within all three fens, with areas of both separation and overlap between *D. anglica* and *D. rotundifolia*. Temperature and net water availability also varied spatially within each fen, although direction and strength of these gradients varied among fens.

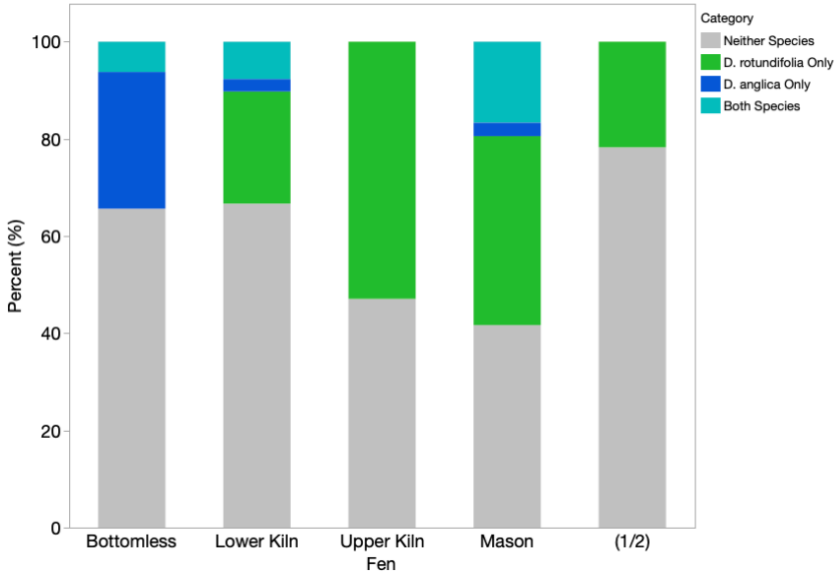


Figure 1. Species composition of Drosera among five fens. Stacked bars represent the percentage of sampled quadrats within five fens in the Sagehen Creek Field Station containing only *Drosera rotundifolia*, only *Drosera anglica*, both species, or neither species. Values representing percentage were calculated relative to the total number of quadrats sampled within each fen to illustrate the co-occurrence and occupancy among the fen sites. Species composition differed among fens (N=164, Pearson χ^2 = 60.172289, p < 0.0001279).

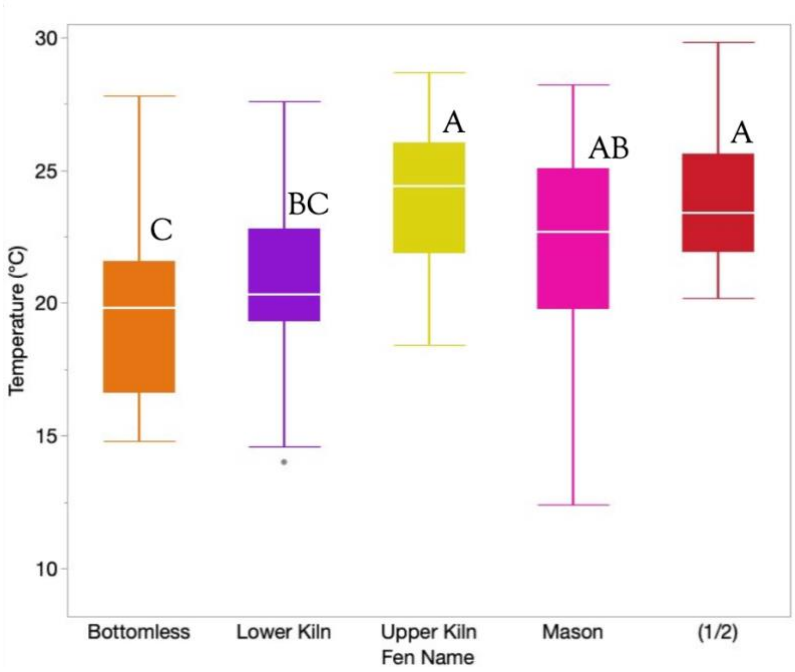


Figure 2. Temperature distributions across the five study fens. The boxplots show the temperatures measured at the quadrats within each fens. Temperature differences were taken at five different fens in the Sagehen Creek Field Station. Temperature differed among the fens (one-way ANOVA: $F_{4,159}$ = 11.1280, P < 0.0001). Tukey's HSD indicated that Bottomless Fen was cooler than 1/2 Fen, Upper Kiln, and Mason Fen, while Lower Kiln was cooler than Upper Kiln and 1/2 Fen.

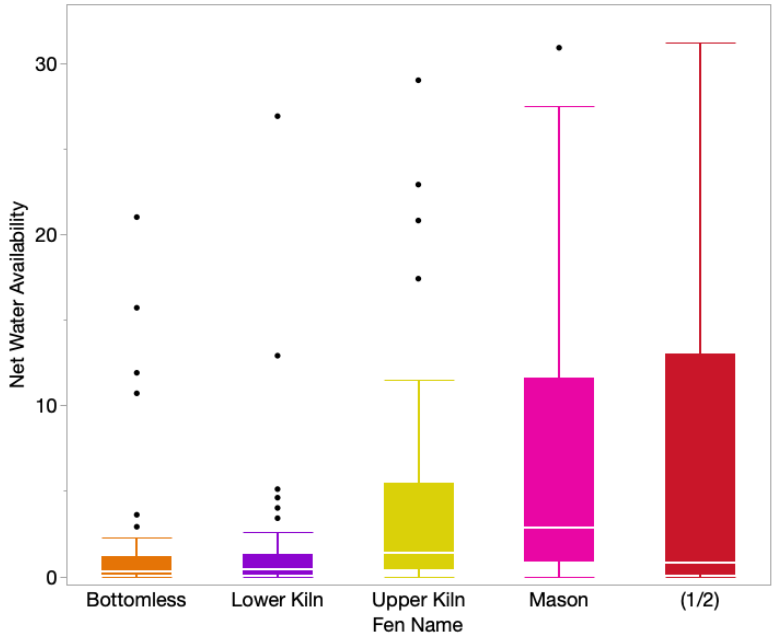


Figure 3. Net water availability across the five study fens. Net water availability was calculated by subtracting sponge dry weight from wet weight from plots in fens at Sagehen Creek Field Station from July 31, 2026 to August 2, 2026. Water availability differed at each fen (one-way ANOVA: F= 4.28, P < 0.0025). Tukey's HSD indicated that Mason Fen had greater net water availability than Bottomless Fen and Lower Kiln Fen, while Upper Kiln and 1/2 Fen were intermediate.

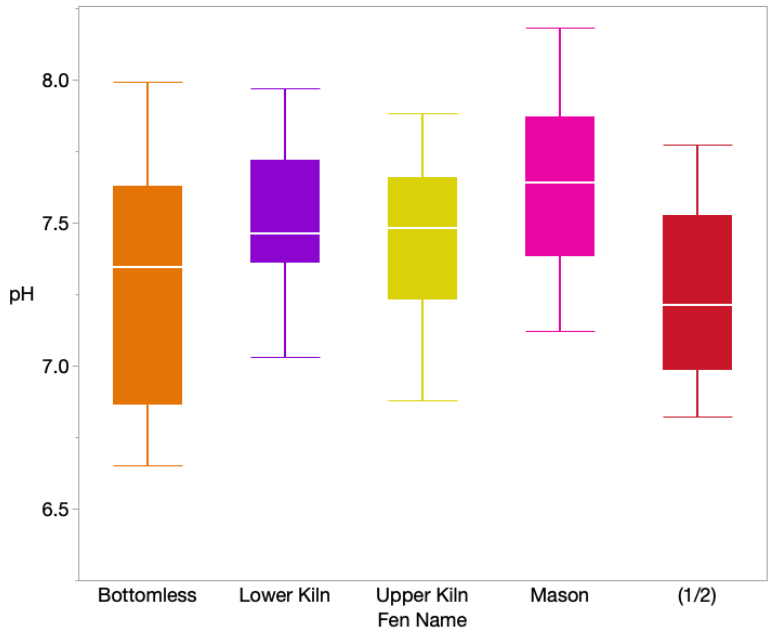


Figure 4. pH distributions across the five study fens. The box plots show the pH measured from water samples at random sub sampled quadrats at each fen at Sagehen Creek Field Station from July 31, 2026 to August 2, 2026. pH differed among fens, (one-way ANOVA: F= 3.75, P < 0.0082). Tukey's HSD indicated that Mason was the most basic, while Lower Kiln and Upper Kiln were intermediate and Bottomless and 1/2 Fen were the most acidic.

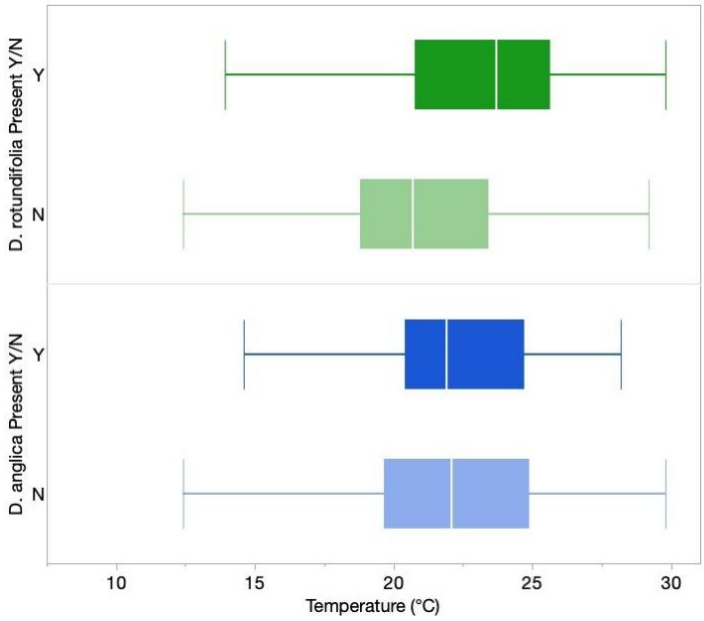


Figure 5. Temperature distributions associated with the presence (Y) and absence (N) of *D. anglica* and *D. rotundifolia* across sampled quadrats. Temperature differences were taken at five different fens in the Sagehen Creek Field Station from July 31, 2026 to August 2, 2026. A logistic regression showed that temperature did not predict the occurrence of *D. anglica* (N=164, χ^2 = 0.03678, P = 0.8479). Higher temperatures were a predictor for increased *D. rotundifolia* presence (N=164, χ^2 = 13.87217, P = 0.0002).

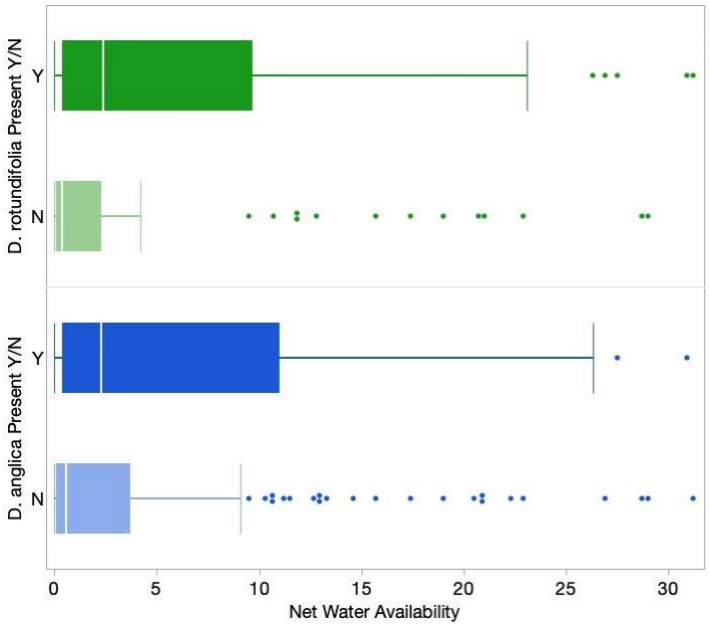


Figure 6. Net water availability associated with the presence (Y) and absence (N) of *D. rotundifolia* and *D. anglica* across sampled quadrats. Net water availability was calculated by subtracting dry sponge weight from wet sponge weight from plots in fens at Sagehen Creek Field Station from July 31, 2026 to August 2, 2026. Greater water availability had an effect on *D. rotundifolia* presence (N=164, χ^2 = 4.931324, P = 0.0264) but not *D. anglica* presence (N=164, χ^2 = 2.242808, P = 0.1342).

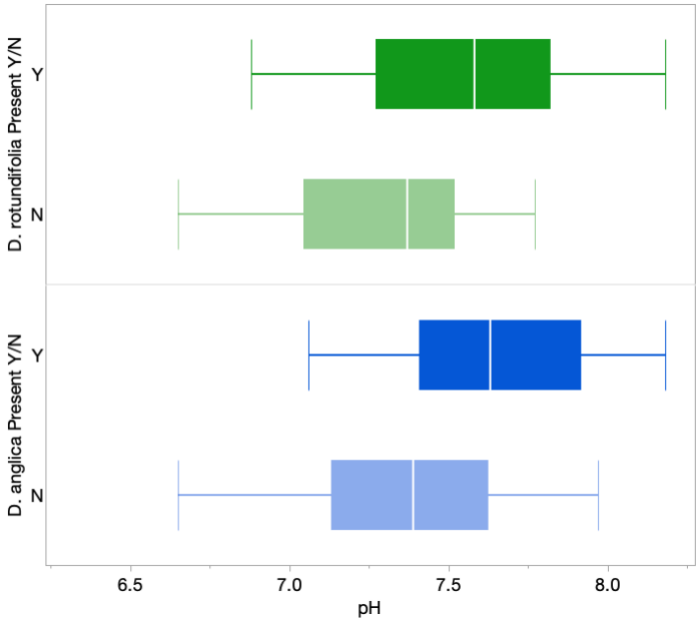


Figure 7. pH distributions associated with the presence (Y) and absence (N) of *D. rotundifolia* and *D. anglica* across sampled quadrats. Water samples were taken at 5 different fens in Sagehen Creek Field Station to measure pH from July 31, 2026 to August 2, 2026. A logistic regression showed that higher pH predicted presence for both *D. anglica* (N=72, χ^2 = 7.959241, P = 0.0048) and *D. rotundifolia* (N=72, χ^2 = 10.16763, P = 0.0014).

Table 2. Results of logistic regression models examining the nested effects of temperature, water availability, pH, and the presence of *D. anglica* and *D. rotundifolia* across and within five fens in Sagehen Creek Basin. Chi-square statistics from nested logistic regression models show whether temperature, net water availability, and pH were associated with species presence among fens and within individual fens. Temperature and water availability were associated with *D. rotundifolia* presence both among and within fens, while *D. anglica* presence was associated with differences among fens but not with these factors within fens. pH was associated with *D. anglica* presence among fens but not within fens, and was not significantly associated with *D. rotundifolia* presence at either scale. For temperature and water availability, N = 164; for pH, N = 72.

Species	Abiotic factor	Scale of effect	Chi squared	p value	Meaning
D.rotundifolia	temperature (◦C)	among fens	29.865	0.0001	presence was affected by fen
		within fens	16.651	0.0052	presence was higher in warmer temperatures in fen
D.anglica	temperature(◦C)	among fens	39.333	0.0001	presence was affected by fen
		within fens	6.659	0.2473	presence was not affected by temp within fen
D.rotunfidolia	water availability (g)	among fens	41.861	0.0001	presence was affected by fen
		within fens	26.478	0.0001	presence was higher in wetter areas in fens
D.anglica	water availability (g)	among fens	37.492	0.0001	presence was affected by fen
		within fens	5.216	0.3901	presence was not affected by wetter areas within fen
D.rotundifolia	pH	among fens	8.487	0.0753	presence was not affected by fen
		within fens	9.527	0.0898	presence was not affected by ph within fens
D.anglica	pH	among fens	17.252	0.0017	presence was affected by fen
		within fens	7.156	0.2093	presence was not affected by ph within fen

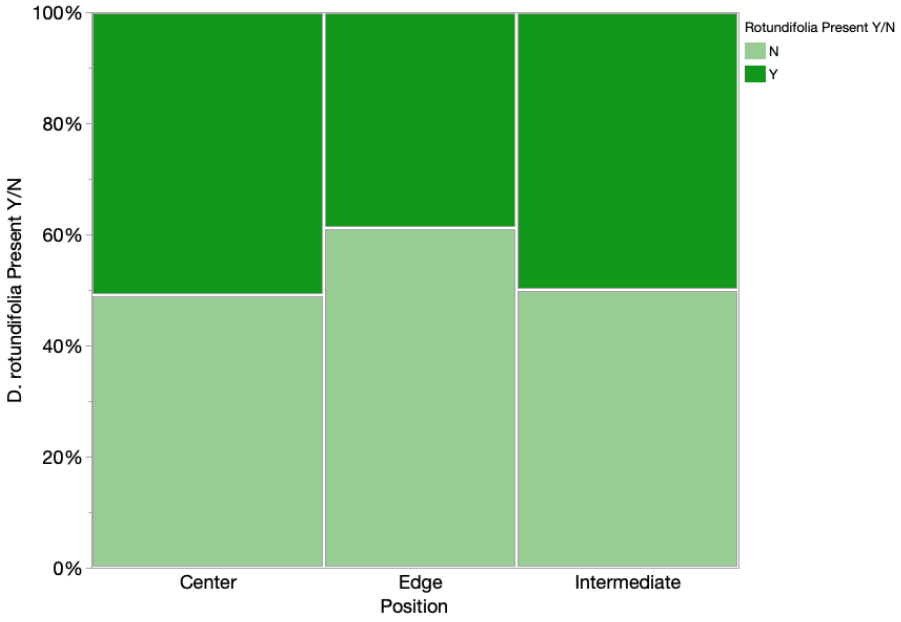


Figure 8. Position in fen does not correlate to *D. rotundifolia* presence (Y) and absence (N) across sampled quadrats at Sagehen Creek Field Station. Position was categorized as edge, intermediate and center determined proportionally to the number of quadrats across the fen and species present was recorded from July 31, 2026 to August 2, 2026. *D. rotundifolia* was present in 50.8% of center quadrats, 50.0% of intermediate quadrats and 38.7% of edge quadrats (Fig. 8). Position inside fen was not associated with *D. rotundifolia* occurrence (N = 164, $\chi^2 = 1.884$, P = 0.3899).

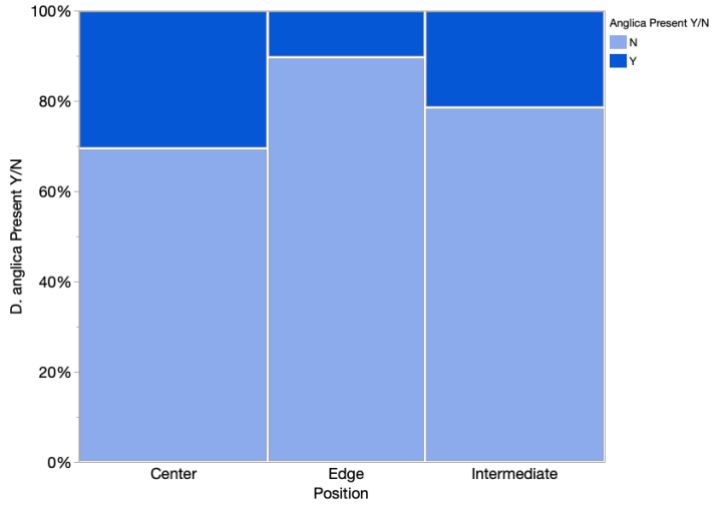


Figure 9. Position in fen correlates to *D. anglica* presence (Y) and absence (N) across sampled quadrats at Sagehen Creek Field Station. Position was categorized as edge, intermediate and center determined proportionally to the number of quadrats across the fen and species present was recorded from July 31, 2026 to August 2, 2026. *D. anglica* occurrence was associated with position and was highest in center quadrats (30.51%), followed by the intermediate quadrats (21.43%), and the lowest at the edge of the fen with 10.20%) (Fig. 9). Position within the fen was associated with *D. anglica* occurrence, with a lower proportion of individuals occupying the edge of the fen (N = 164, $\chi^2 = 6.574$, P = 0.0374).

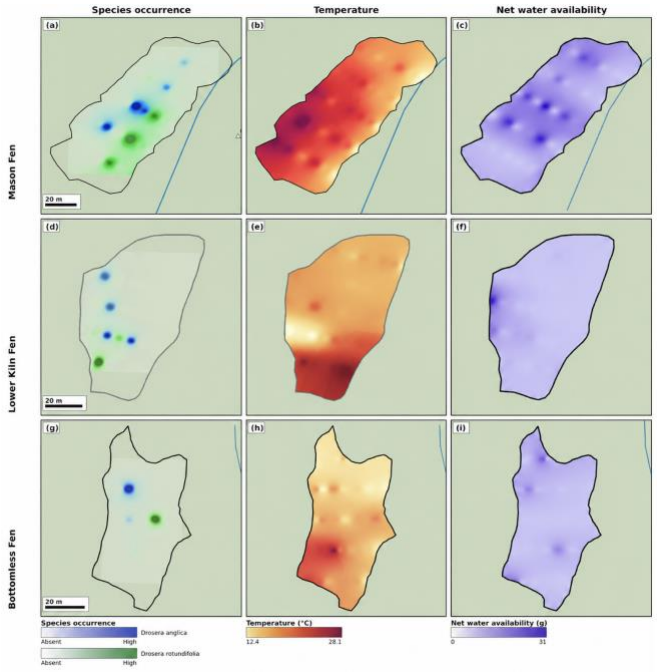


Figure 10: Spatial distributions of *Drosera anglica*, *D. rotundifolia*, temperature, and net water availability within Bottomless, Mason, and Lower Kiln fens. Heat maps were created for the three study fens in which both *Drosera* species occurred. Species distributions, temperature, and net water availability variation are shown across sampled locations within each fen using edge, intermediate, and center classifications based on relative position within the fen. Mason Fen (a-c), Lower Kiln Fen (d-f), and Bottomless Fen (g-i). Species occurrence maps (a, d, g) show relative spatial occurrence of *D. anglica* (blue) and *D. rotundifolia* (green). Temperature maps (b, e, h) show interpolated temperature across each fen, and net water availability maps (c, f, i) show interpolated surface water availability.

DISCUSSION

D. rotundifolia exhibited a broader range of tolerance for temperature and pH than *D. anglica*, supporting our hypothesis that it has a broader environmental distribution. However, the two species occupied very similar ranges of net water availability, which did not support our hypothesis that *D. rotundifolia* would occupy a broader water availability range. We found that temperature influenced the distribution of the two *Drosera* differently. *D. anglica* was absent from fens with the highest average temperature, but temperature variation within individual fens did not predict where *D. anglica* occurred. Temperature was associated with D. rotundifolia occurrence at both spatial scales: occurrence differed among fens with different temperature conditions and was greater in warmer quadrats within individual fens. In contrast, *D. anglica* occurrence was associated with temperature differences among fens, but not within individual fens. We found *D. rotundifolia* present in all the fens, which also aligned with our hypothesis, as we predicted they would be able to tolerate a wider range of temperatures than *D. anglica.* Despite this, there was a lower abundance of *D. rotundifolia* in Bottomless Fen, which had the lowest temperature. These results showed that the two species responded differently to temperature across the spatial scales. *D. anglica* occurrence was associated primarily with differences among fens rather than local temperature gradients within them, whereas *D. rotundifolia* responded to

temperature at both the among-fen and within-fen scales.

Our results from five study fens within Sagehen showed a range of water availability differences across the fens, despite their geographic proximity. Surface level discharge can vary in groundwater fens due to the size of a recharge zone of their water source. (Amon et al. 2002). The small-scale hydrology of the fens may help explain some of the environmental differences observed among sites. Within Sagehen peatlands, water can enter through springs along upslope edges and move through the peatland as small streams or laterally through the peat, creating local differences in water movement. Several springs along the upslope edge of Mason Fen form small streams that provide a continuous water supply, while groundwater remains at or near the surface (Erman 1973). Net water availability was associated with the occurrence of both species among fens, but only *D. rotundifolia* had an association with water availability within fens. Our measure of net water availability represented the amount of water that could be absorbed by the moss beyond its saturation capacity, providing an estimate of excess water potentially available to *Drosera*. Thus, while local hydrology may contribute to environmental differences among fens, water availability alone did not differentiate the habitats of the two species among fen, although local variation in water availability appeared to influence *D. rotundifolia* within individual fens.

Changes in groundwater levels can influence the spatial extent and vegetation of fens. Recent observations from the Sagehen Creek Basin found that the spatial extent of Kiln Fen, Mason Fen, and 1/2 Fen decreased between 2005 and 2022 due to a major drought from 2011–2016 (University of the Pacific et al. 2025). Because reduced groundwater recharge can cause fens to contract, changes in hydrologic conditions may also alter the vegetation communities supported by these systems. In our study, water availability was associated with *D. rotundifolia* presence within fens, indicating that water availability may influence its site-level distribution. This suggests that local hydrology could alter the areas of the fen suitable for *D. rotundifolia,* and potentially shift broader habitat suitability for both species.

Of the three environmental variables measured, pH was the only variable that showed the clearest pattern of *D. anglica* occurrence. *D. anglica* occurrence was associated with pH differences among fens only, while *D. rotundifolia* showed no association among or within fens. The pH of the fen reflects the chemistry of the groundwater supplying each site (Hájek et al. 2006). This pattern suggests that *D. anglica* may occupy a narrower range of water chemistry than *D. rotundifolia*, and it is more sensitive to water chemistry fluctuations.

D. anglica occurrence was also associated with position within the fen. *D. anglica* was most frequent in center quadrats and least frequent in along fen edges. However, *D. rotundifolia* showed no association with fen position. Fen centers and margins can differ in characteristics not measured in this study, such as peat depth. (Andre et al 2024) The characteristics that differentiate the center from the edge may help explain why *D. anglica* showed higher frequency in fen centers, despite showing no relationship with local temperature, pH, or net water availability that were measured in this study.

Drosera occurred in concentrated areas of each fen, but another factor that may have

influenced the observed distributions is that *Drosera* species use gravity dispersal or barochory dispersal to scatter their seeds. *Drosera* seeds typically do not travel very far. Rather they grow near or under their parent plant, except when secondarily facilitated by other factors like water or animals (Walck et al. 2001). This could have contributed to the irregular species distribution, as *Drosera* would typically reproduce within a small portion of a fen rather than being widely dispersed from wind or pollinators.

Our findings demonstrate that environmental variation among Sierra Nevada fens play an important role in structuring the distribution and coexistence of *D. anglica* and *D. rotundifolia*. The two species responded at different spatial scales: *D. anglica* occurrence had differences between fens but was unrelated to any environmental gradients within them, whereas *D. rotundifolia* responded to temperature and water availability at both scales. *D. rotundifolia* occupied a broader range and occurred more frequently, while *D. anglica* was not present in all the fens and occurred less frequently in the Sagehen Experimental Forest. This pattern suggests that *D. rotundifolia* may have a more generalist strategy with wider abiotic tolerances than its counterpart, *D. anglica*, consistent with our predictions.

As climate change and continued habitat degradation alter the hydrology and extent of Sierra Nevada fens, maintaining the environmental heterogeneity of these wetlands will likely be essential for conserving both *Drosera* spp. and the specialized plant communities they support. Water table depths are at risk of dropping due to rising global temperatures (Gorham 1991), which could create environments unsuitable for *Drosera spp.* to persist. Specialized communities in fens that are dependent on specific abiotic factors like temperature, water availability, and pH are at risk when there is habitat alteration or loss. Environmental changes are making it increasingly more important to maintain variation in hydrologic and chemical conditions across Sierra Nevada fens to conserve both *Drosera* species.

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