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Phenology of Kleptobiotic Sundew Bugs Tracks Peak Stickiness of Their Carnivorous Host Plants

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ABSTRACT

Drosera L. (Droseraceae) is a diverse genus of carnivorous plants that is cosmopolitan in distribution, with Australia its centre of diversity (ca. 160 species in Australia). Collectively known as sundews, their leaves are covered with mobile sticky hairs ("tentacles") that serve as active flypaper-type traps that catch small invertebrates. This prey is then digested with enzymes and absorbed as nutrition for the plant. Not all invertebrates fall prey to sundews, with sundew bug species of the genus *Setocoris* China & Carvalho, 1951 (Miridae) avoiding capture and stealing the plant's prey, in an unusual case of kleptobiosis. This specialised interaction suggests that the bug and host plant are highly co-adapted, although most aspects of the natural history of this interaction are poorly understood. In this study, field observations made over the course of 3 months show that the undescribed species *Setocoris* n.sp_BINA are first present on their host plants (*Drosera binata* Labill. and *Drosera peltata* Thunb.) when plants are sticky and catching prey. Sundew bugs are observed first on *D. peltata* and then *D. binata*, corresponding to the differing phenologies of each host plant species. These observations generated the following hypotheses for future testing: (1) *S.* n.sp_BINA move between host species to prioritise prey availability, and (2) *S.* n.sp_BINA eclosion is triggered by the same moisture and/or temperature cues as their hosts so that hatching coincides with prey availability.

1 | Introduction

The sundew bug genus *Setocoris* China & Carvalho 1951 of the family Miridae (Insecta: Hemiptera: Heteroptera) comprises at least 21 species, with only three formally described (Cassis and Gross 1995) (Figure 1). Many species of Miridae are associated with sticky-leaved plants, which offer protection and a food source of invertebrates captured by sticky hairs, referred to as "tentacles" (Wheeler and Krimmel 2015; Darwin 1875). *Setocoris* are affiliates of carnivorous plants, mostly species belonging to the genera *Drosera* L. and *Byblis* Salisb. (Droseraceae; Byblidaceae) (Figure 1), although they have also been reported on the non-carnivorous sticky plant *Stylidium* Sw. (Stylidiaceae; Nge and Lambers 2018). *Setocoris* are specialised to live among the extremely sticky and dangerous traps of these carnivorous plants at all their life stages and 'steal' the animal prey captured by them in an interaction known as kleptobiosis. *Drosera* is an iconic group of carnivorous plants, commonly known as sundews, that are adapted to low-nutrient soils. They use active flypaper-type traps to capture invertebrate prey, and secrete digestive enzymes including nucleases, proteinases and chitinase (Matušíková et al. 2018). Digested prey items are absorbed as supplemental nutrition (Dixon et al. 1980; Millett et al. 2003).

Many animal and carnivorous plant associations have been documented, for example the larvae of *Toxomerus basalis* Walker, 1836 flies have a kleptobiotic interaction with South American *Drosera* (Fleischmann et al. 2022). A few such associations have been shown to have co-diversified, for example Satler and Carstens (2019) show that *Sarracenia alata*

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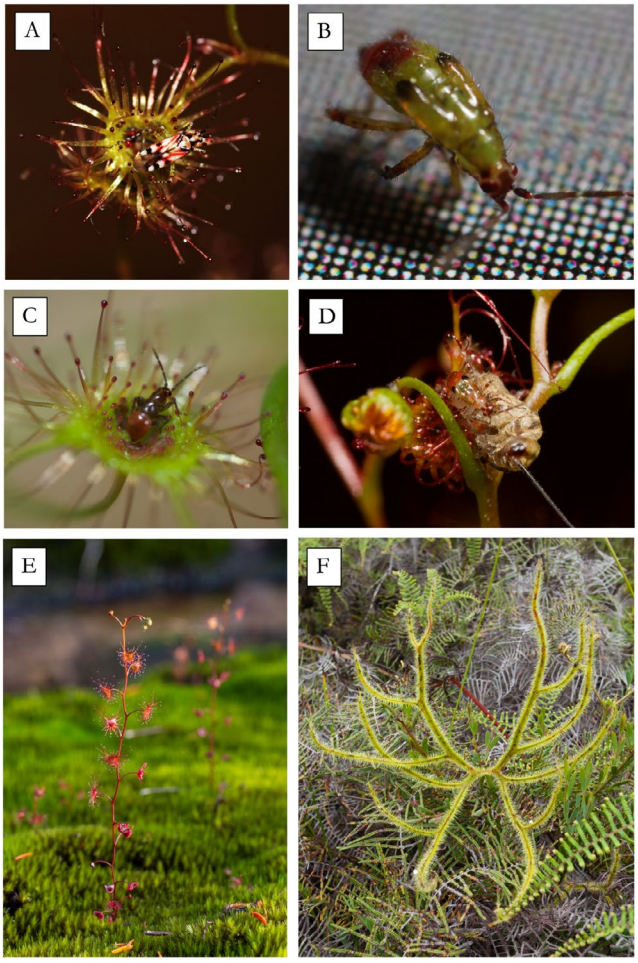


FIGURE 1 | (A) Adult *S*. n.sp_BINA on *D. auriculata*, a close relative of *D. peltata*; (B) late instar nymph of *S*. n.sp_BINA; (C) early instar *S*. n.sp_BINA nymph on *D. peltata*; (D) late instar nymph of *S*. n.sp_BINA feeding on a captured cricket; (E) *D. peltata*; (F) *D. binata* leaf lamina.

(Alph. Wood) Alph. Wood pitcher plants are co-diversifying with invertebrates living in their pitchers. Since the description of the genus *Setocoris* in 1951, the sundew bug-*Drosera* interaction has been known but there are few detailed records of the interaction, with most derived from casual observations (e.g., Dixon et al. 1980; Lamont 1994; Lowrie 1998, 2014; Rice 2010; Wheeler and Krimmel 2015; Lowrie et al. 2017; Skates 2021).

The absence of published studies documenting *Setocoris* and *Drosera* phenology and host use remains a major barrier to understanding the evolution and ecology of this association. The *Setocoris* bug lifecycle is theorised to be aligned with their host plants' lifecycle due to the close association (Bourke and Nunn 2012), however this has not been specifically investigated before. We do not know whether they use different hosts throughout their life span, when they emerge, and whether this coincides with prey availability. Australian *Drosera* have a seasonal period of dormancy, so the period that plants are suitable as habitat for *Setocoris* (i.e., catching prey for them to feed on) may be only a few weeks per year. *Setocoris* in Western Australia have been observed to overwinter in their host plants' tubers during host dormancy, or in surrounding soil (Lowrie 1998). However, this has not been observed in east coast species, therefore we conclude that they overwinter as eggs.

Royal National Park in the Sydney Basin area of New South Wales is home to several *Setocoris* and *Drosera* species. Two of these *Setocoris* species are host specific, while *S*. n.sp_BINA (Cassis & Cheng in preparation) has been recorded on five species of *Drosera*: *D. auriculata* Backh. ex Planchon, *D. binata* Labill., *D. gunniana* (Planch.) Mig.F.Salas, *D. hookeri* R.P.Gibson, B.J.Conn & Conran, and *D. peltata* Thunb., and has a wide inland and coastal distribution on the Australian east coast. *Setocoris* n.sp_BINA is new to science and is in preparation for publication; it is given a code as in Cassis et al. (2022) and is thereby unavailable in accordance the International Code of Zoological Nomenclature. In Royal National Park *Setocoris* n.sp_BINA uses two host species in different sections of the *Drosera* genus: *D. binata* (Section Phycopsis) and *D. peltata* (Section *Ergaleiun*). These are both upright forms of *Drosera* that have quite different morphology; *D. binata* has linear lobed leaves which emerge first as the non-carnivorous petiole, with the carnivorous lamina enfolding later in the year. *D. peltata* has numerous small round leaves which emerge first as a carnivorous rosette, then growing upright. *D. peltata* has a shorter window of prey capture that *D. binata* (Lowrie 1998). There have not been any studies on prey species of these species, however other studies show that other species with similar growth forms to *D. peltata* (upright with small leaves) capture mostly winged prey (Verbeek and Boasson 1993). We do not know whether *S*. n.sp_BINA is adapted to its different host plants, although specimens from different hosts cannot be distinguished via morphology. In this paper we describe aspects of the ecological association between an undescribed species—*Setocoris* n.sp_BINA and its host plants, in particular the timing of *S*. n.sp_BINA emergence and prey availability on host plant leaves.

2 | Methods

We studied *S*. n.sp_BINA associated with *D. binata* and *D. peltata* at four locations in Royal National Park, NSW. We selected two sites of *D. binata* and two of *D. peltata*, with between 10 and 50 plant individuals of only one of either *Drosera* species present per site. One *D. binata* site was in the northern part of the park and the rest were in the southern part. Some sites are very close; for example, *D. binata* #2 and *D. peltata* #2 were only 105 m apart. We visited sites every 2 weeks over 3 months in spring 2022.

When leaves first emerge they are covered with glandular tentacles that secrete drops of sticky mucilage. Tentacles shrink and stop producing mucilage after they trap prey and/or age (Figure 2). Less sticky mucilage means a lesser capacity for prey capture as well as less efficient digestion (Zamora et al. 1997, 1998; Thorén et al. 2003). We used the number (for *D. peltata*) or length (for *D. binata*) of sticky leaves as a proxy for the plant's capacity to catch prey, according to their differing morphology and since larger trap area has been shown to capture more prey (Krueger et al. 2020). Although these measurements cannot be compared directly, they identify when in the growing season each plant reaches its maximum prey capture capacity. A leaf where more than half the lamina was covered with actively mucilage-producing tentacles was characterised as "sticky". After capturing prey, tentacles can be "re-activated" and continue producing mucilage. For this study we considered leaves "non-sticky" when they appeared to have

already captured prey, were shrivelled and appeared senesced i.e., were not likely to re-activate following Watson et al. (1982).

The following observations were recorded:

1. For *D. binata*, the total length of sticky leaf lamina of three individuals at each of the two sites was recorded since it has large linear lobed leaves that may be partially or completely sticky.
2. For *D. peltata* the number of sticky leaves of three individuals at each of the two sites was recorded since it has numerous small leaves.
3. Every plant at each site was searched closely for *S.* n.sp_BINA and any bugs present were counted, and the developmental stage was recorded as early instar (without wing pads), late (with wing pads) or adult.

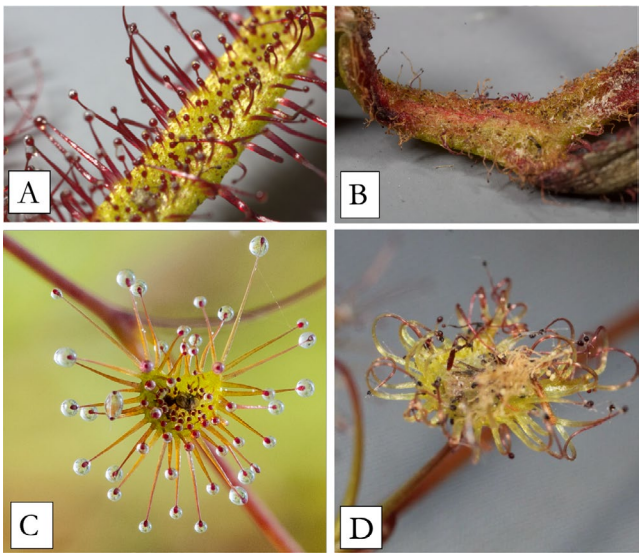


FIGURE 2 | (A) *Drosera binata* with sticky leaves, mucilage drops are visible; (B) *D. binata* with senescent, non-sticky leaves, trichomes are shrivelled with no mucilage; (C) *D. peltata* with sticky leaves; (D) *D. peltata* with senescent, non-sticky leaves.

3 | Results

Setocoris n.sp_BINA were observed at all sites, two at *D. peltata* #1, 14 at *D. peltata* #2, four at *D. binata* #1 and one at *D. binata* #2. Both nymphs and adults were observed at three of the sites, and initial *S.* n.sp_BINA presence coincided with a high number of sticky leaves (Figure 3). The first observations of *S.* n.sp_BINA were earlier in the year at both *D. peltata* sites (16-Sep and 4-Oct) than at *D. binata* sites (2-Nov and 16-Nov). *Drosera peltata* had the highest mean number of sticky leaves in early-October (9 and 15 leaves, $n = 3$) and *D. binata* had the greatest mean length of sticky leaves slightly later, peaking in early-October to early-November (42.6 cm and 27.3 cm, $n = 3$).

4 | Discussion

For both *D. peltata* and *D. binata*, *S.* n.sp_BINA were first observed at each site when host plants were at or near maximum number of sticky leaves, even though this timing varied between host species. Although the oviposition sites are not known for this species, like other Mirid species eggs are likely oviposited in host plant tissue, therefore we consider early instar nymph emergence as an indication of eclosion as in Abraços-Duarte et al. (2025). This implies that the bugs' eclosion is adapted to ensure suitable habitat (host plant) for foraging. It is possible that *S.* n.sp_BINA eclosion is triggered by the same environmental cues as their host species, and the timing varies depending on the host plant (i.e., *D. peltata* or *D. binata*). Temperature and moisture cues are known to trigger egg hatching in various

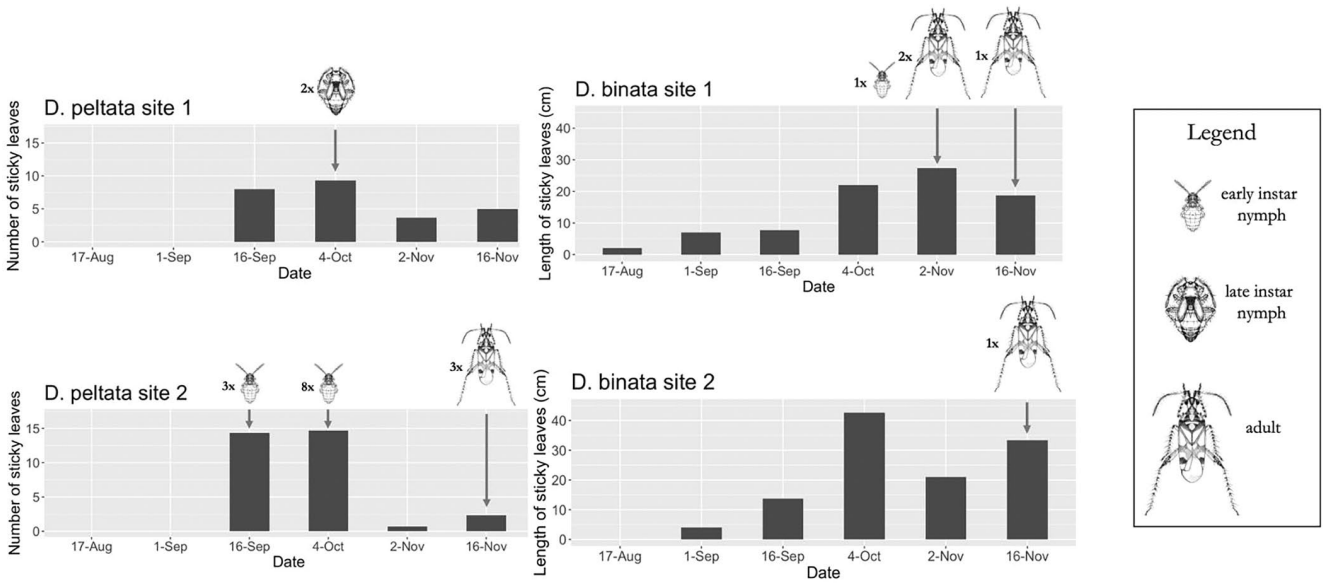


FIGURE 3 | Mean number/length of sticky leaves at each site of *D. peltata* (left) and *D. binata* (right) ($n = 3$). Observations of early instar nymph, late instar nymph and adult *S.* n.sp_BINA are shown with icons above the date of observation. Numbers indicate the number of individuals of *S.* n.sp_BINA that were observed.

Miridae species (e.g., Sakurai and Sakakibara 2008; Judd and McBrien 1994; Champlain and Butler JR 1967; Jin et al. 2016). Moisture cues can come from rainfall or the moisture levels of plant tissue at oviposition sites (Jin et al. 2016; Neal Jr and Haldemann 1992). Possibly the first emergence of nymphs on *D. binata* was delayed due to adaptation to different environmental cues, or response to varying plant tissue moisture between *D. peltata* and *D. binata*.

Use of multiple hosts throughout a season has been observed in other Miridae species (e.g., Pan et al. 2013) and may also be happening in this system. Nymphs may emerge first on *D. peltata* then move to *D. binata* when the *D. peltata* becomes unsuitable. Since *S*. n.sp_BINA has a wide distribution and multiple hosts, swapping hosts may be a useful alternative when, for instance, dry inland weather shortens the host plant's growing season. *S*. n.sp_BINA has been observed to fly a short distance (~1 m) and moving on foot between host plants via contacting vegetation or on the ground (pers. obs). Similar movement has been documented in the genus *Pameridea* Reuter, 1907, bugs also of the Dicyphini tribe which have a mutualism with carnivorous R*oridula* L. plants (Anderson et al. 2004). Some sites in this study are very close so moving between hosts is possible.

This study was affected by heavy rains in October 2022. Creek banks were flooded at some sites and as a result the *D. peltata* plants were mostly senesced; this is reflected in a reduced number of sticky leaves after October (Figure 2). The *D. binata* sites were not seriously affected by the rainfall.

5 | Conclusion

Our observations of the life history of *Setocoris* and *Drosera* revealed that the occurrence of *S*. n.sp_BINA nymphs at the study sites coincided with peak leaf stickiness on their *Drosera* hosts and varied between *Drosera* species. This information generates new avenues to investigate, for example determining the oviposition sites for *Setocoris* and the mechanism for eclosion, and whether these are triggered by the same environmental cues as *Drosera* emergence and/or stickiness. There are also questions of host use to investigate, for example whether *S*. n.sp_BINA move between host species which are suitable at different times of the year. Further studies will add to our understanding of the highly specialised interaction between these species, and ultimately an understanding of their shared evolutionary histories.

Author Contributions

Zoe Bloesch: writing – original draft, conceptualization, methodology, investigation, visualization, writing – review and editing. **Greg Bourke:** methodology, writing – review and editing. **Dieter Hochuli:** writing – review and editing, supervision. **Daniel J. Murphy:** funding acquisition, writing – review and editing, supervision. **Gerasimos Cassis:** funding acquisition, writing – review and editing, supervision.

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Disclosure

Research Permits: This work was conducted under the permit: NSW scientific licence SL101210.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon request.

References

Abraços-Duarte, G., F. Madeira, P. Souto, E. Borges da Silva, and E. Figueiredo. 2025. "*Dicyphus cerastii*: First Data on Development, Survival, and Reproduction." *PLoS One* 20, no. 4: e0320847.

Anderson, B., I. Olivieri, M. Lourmas, and B. A. Stewart. 2004. "Comparative Population Genetic Structures and Local Adaptation of Two Mutualists." *Evolution* 58, no. 8: 1730–1747.

Bourke, G., and R. Nunn. 2012. *Australian Carnivorous Plants*. Redfern Natural History Productions.

Cassis, G., and G. F. Gross. 1995. *Zoological Catalogue of Australia. Heteroptera. Volume 27.3A*. CSIRO.

Cassis, G., R. Shofner, S. Laffan, and M. Cheng. 2022. "Impact of Black Summer 2019/20 Wildfires on True Bug Priority Species (Insecta: Hemiptera: Heteroptera) in the Northeast Forests of New South Wales." *Australian Zoologist* 42, no. 2: 352–385.

Champlain, R. A., and G. D. Butler JR. 1967. "Temperature Effects on Development of the Egg and Nymphal Stages of *Lygus hesperus* (Hemiptera: Miridae)." *Annals of the Entomological Society of America* 60, no. 3: 519–521.

China, W. E., and J. C. Carvalho. 1951. "A New Ant-Like Mirid From Western Australia (Hemiptera, Miridae)." *Annals and Magazine of Natural History* 4, no. 39: 221–225.

Darwin, C. 1875. *Insectivorous Plants*. John Murray.

Dixon, K. W., J. S. Pate, and W. J. Bailey. 1980. "Nitrogen Nutrition of the Tuberous Sundew *Drosera erythrorhiza* Lindl. With Special Reference to Catch of Arthropod Fauna by Its Glandular Leaves." *Australian Journal of Botany* 28, no. 3: 283–297.

Fleischmann, A., P. M. Gonella, S. Rojo, and X. Mengual. 2022. "Attracted to Feed, Not To Be Fed Upon – On the Biology of *Toxomerus basalis* (Walker, 1836), the Kleptoparasitic 'Sundew Flower Fly' (Diptera: Syrphidae)." *Journal of Tropical Ecology* 38, no. 5: 241–253.

Jin, Y., P. Chen, Y. Zhang, G. Tian, H. Feng, and Y. Hou. 2016. "Effect of Water on Survival and Development of Diapausing Eggs of *Apolygus lucorum* (Hemiptera: Miridae)." *PLoS One* 11, no. 9: e0161657.

Judd, G. J. R., and H. L. McBrien. 1994. "Modelling Temperature-Dependent Development and Hatch of Overwintered Eggs of *Campylomma verbasci* (Heteroptera: Miridae)." *Environmental Entomology* 23, no. 5: 1224–1234.

Krueger, T., A. T. Cross, and A. Fleischmann. 2020. "Size Matters: Trap Size Primarily Determines Prey Spectra Differences Among Sympatric Species of Carnivorous Sundews." *Ecosphere* 11, no. 7: e03179.

Lamont, B. B. 1994. "Triangular Trophic Relationships in Mediterranean-Climate Western Australia." In *Plant-Animal Interactions in Mediterranean-Type Ecosystems*, edited by M. Arianoutsou and R. H. Groves, 83–89. Springer Science+Business Media.

Lowrie, A. 1998. *Carnivorous Plants of Australia*. University of Western Australia Press.

Lowrie, A. 2014. *Carnivorous Plants of Australia*. Redfern Natural History Productions.

Lowrie, A., R. Nunn, A. Robinson, G. Bourke, S. McPherson, and A. Fleischmann. 2017. *Drosera of the World Volume 1*. Redfern Natural History Productions.

Matušíková, I., A. Pavlovič, and T. Renner. 2018. "Biochemistry of Prey Digestion and Nutrient Absorption." In *Carnivorous Plants: Physiology, Ecology, and Evolution*, edited by A. Ellison and L. Adamec, 207–220. Oxford University Press.

Millett, J., R. I. Jones, and S. Waldron. 2003. "The Contribution of Insect Prey to the Total Nitrogen Content of Sundews (*Drosera* spp.) Determined In Situ by Stable Isotope Analysis." *New Phytologist* 158, no. 3: 527–534.

Neal, J. W., Jr., and R. L. Haldemann. 1992. "Regulation of Seasonal Egg Hatch by Plant Phenology in *Stethoconus japonicus* (Heteroptera: Miridae), a Specialist Predator of *Stephanitis pyrioides* (Heteroptera: Tingidae)." *Environmental Entomology* 21, no. 4: 793–798.

Nge, F. J., and H. Lambers. 2018. "Reassessing Protocarnivory—How Hungry Are Triggerplants?" *Australian Journal of Botany* 66, no. 4: 325–330.

Pan, H., Y. Lu, K. A. Wyckhuys, and K. Wu. 2013. "Preference of a Polyphagous Mirid Bug, *Apolygus lucorum* (Meyer-Dür) for Flowering Host Plants." *PLoS One* 8, no. 7: e68980.

Rice, B. A. 2010. "Reversing the Roles of Predator and Prey: A Review of Carnivory in the Botanical World." In *All Flesh Is Grass: Plant-Animal Interrelationships*, edited by J. Seckbach and Z. Dubinsky, 491–518. Springer.

Sakurai, T., and M. Sakakibara. 2008. "Exposure of Non-Diapause Eggs to Low Temperature: The Effects on Egg Hatching, Nymphal Survival, and Developmental Periods in *Trigonotylus caelestialium* (Heteroptera: Miridae)." *Applied Entomology and Zoology* 43, no. 3: 437–442.

Satler, J. D., and B. C. Carstens. 2019. "The *Sarracenia alata* Pitcher Plant System and Obligate Arthropod Inquilines Should Be Considered an Evolutionary Community." *Journal of Biogeography* 46, no. 2: 485–496.

Skates, L. 2021. "How Carnivorous Are Carnivorous Plants? Exploring Nutritional Rewards From Prey Using Stable Isotope Analysis." PhD Thesis, The University of Western Australia.

Thorén, L. M., J. Tuomi, T. Kämäräinen, and K. Laine. 2003. "Resource Availability Affects Investment in Carnivory in *Drosera rotundifolia*." *New Phytologist* 159, no. 2: 507–511.

Verbeek, N. A. M., and R. Boasson. 1993. "Relationship Between Types of Prey Captured and Growth Form in *Drosera* in Southwestern Australia." *Australian Journal of Ecology* 18, no. 2: 203–207.

Watson, A. P., J. N. Matthiessen, and B. P. Springett. 1982. "Arthropod Associates and Macronutrient Status of the Red-Ink Sundew (*Drosera erythrorhiza* Lindl.)." *Australian Journal of Ecology* 7, no. 1: 13–22.

Wheeler, A. G., Jr., and B. A. Krimmel. 2015. "Mirid (Hemiptera: Heteroptera) Specialists of Sticky Plants: Adaptations, Interactions, and Ecological Implications." *Annual Review of Entomology* 60: 393–414.

Zamora, R., J. M. Gómez, and J. A. Hódar. 1997. "Responses of a Carnivorous Plant to Prey and Inorganic Nutrients in a Mediterranean Environment." *Oecologia* 111: 443–451.

Zamora, R., J. M. Gómez, and J. A. Hódar. 1998. "Fitness Responses of a Carnivorous Plant in Contrasting Ecological Scenarios." *Ecology* 79: 1630–1644.