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Communication

Long-Jawed Spider Moves across Water with and without the Use of Silk

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Abstract: Among spiders, movement in aquatic environments, including below the water's surface or on the surface film, is completed using a variety of techniques that do not involve the use of silk, including swimming, walking, and rowing. The use of silk to assist with aquatic locomotion has been explored only to a limited extent. In this study, we report on observations of a long-jawed spider (Family: Tetragnathidae) from Australia, *Tetragnatha nitens*, moving across the surface film in two different manners, one of which involves the use of silk. The first observation was of a female *T. nitens* walking across the water's surface when prompted by a predation attempt: the spider used its front three pairs of legs for propulsion while the back pair remained motionless on the water, likely for stabilization. The second observation featured a male *T. nitens* utilizing a silk line to reel itself towards emergent vegetation while gliding across the water. Our findings support work on other long-jawed spiders, revealing that individual species can exploit several strategies for moving across water, including those that involve the use of silk. This study sheds light on the remarkable adaptability of spider silk and its potential use in aquatic systems.

Keywords: arachnid; locomotion; spider silk; surface film

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1. Introduction

Spiders exhibit a remarkable diversity in the utilization of silk beyond the construction of prey-catching webs [1,2]. For example, spiders also rely on silk for terrestrial dispersal and movement. Noticeable examples include silk lines that (i) act as security 'lifelines' in case of falls while navigating structures off the ground and for abseiling [1], (ii) are picked up by air currents, allowing individuals to momentarily glide ('ballooning') [3], and (iii) allow for the bridging of wide gaps [4]. While the functions of silk for navigating terrestrial environments is well documented, its use in aquatic environments remains a relatively understudied aspect of spider biology.

As spiders venture into aquatic environments they encounter a range of challenges and potential opportunities associated with the presence of water. For example, long-jawed spiders (Family: Tetragnathidae) and species in the *Wendilgarda* genus lay silk that physically contacts water to ensnare prey moving over the surface film [5–7], while the 'diving bell' spider, *Argyroneta aquatica*, has evolved the ability to create air bubbles around themselves to breathe underwater [8]. Spiders move through the water column by diving, swimming, or walking along submerged vegetation, while movement across the water's surface (referred to as surface film locomotion) is achieved by actively walking, rowing, or galloping, as well as passively using wind [9–12]. While silk serves a variety of functions for spiders in aquatic environments [8,13], there is currently limited evidence that it is used by spiders when moving on or through the water. An exception is the use of silk as an anchor to slow movement while on water, which has been recorded in some spiders [14]. Nonetheless, further investigation is warranted to uncover the potential contributions of silk to the ways in which spiders move in aquatic habitats. Herein, we report on a long-jawed spider from Australia using silk to assist with surface film locomotion and how this may be advantageous for a species that only facultatively moves across water. Additionally, we compare this behaviour to observations of surface film locomotion occurring without the assistance of silk to show the diversity of locomotion styles used by a single species.

2. Observations

During fieldwork on Kooragang Island, NSW, Australia, we observed long-jawed spiders in the genus *Tetragnatha* (Family: Tetragnathidae) completing surface film locomotion. The first observation occurred in April 2022 at a permanent pond (32.86652° S, 151.74914° E) in which an adult female, *Tetragnatha nitens*, was found on the water's surface approximately 100 cm away from the nearest emergent vegetation (*Typha orientalis*). The spider was initially at rest on the surface, with the tip of each leg (tarsus) contacting the water and the entire body lifted off the water at a 45° angle. The spider suffered a predatory attack from an eastern mosquitofish, *Gambusia holbrooki*, which attempted to grab one of its legs with its mouth. This triggered the spider to start rapidly walking across the water's surface using what appeared to be an alternating tripod gait, whereby the first three pairs of legs were used for walking, while the fourth pair of legs were kept extended and permanently on the water behind the body (Supplementary Video S1). While walking, the spider's body remained raised in the air and did not contact the water, remaining at a 45° angle similar to when it was at rest previously (Figure 1a).

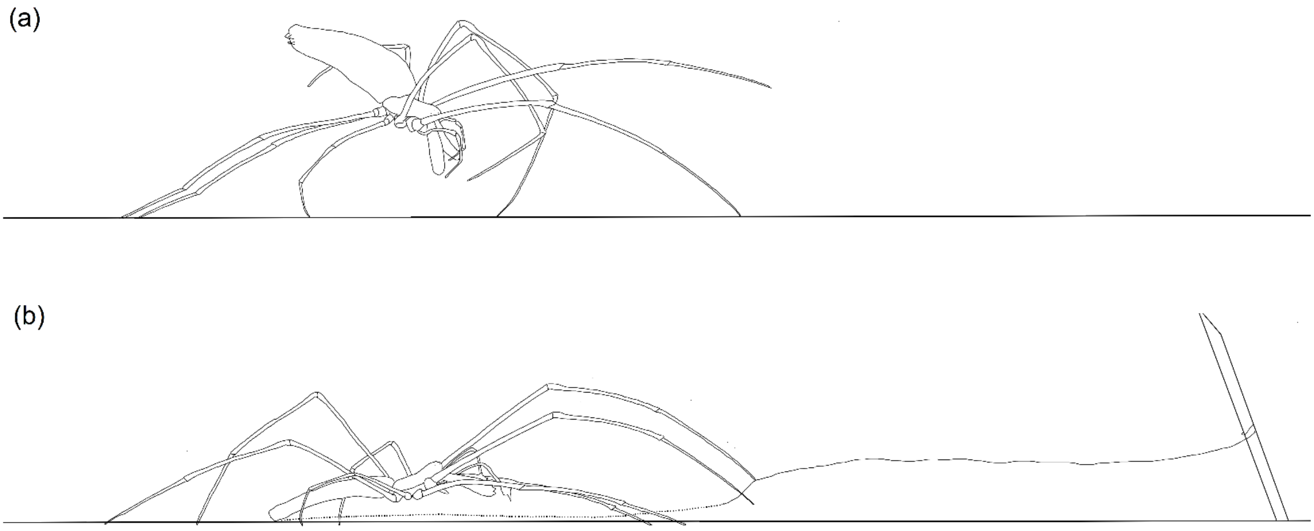

Figure 1. Illustration of *Tetragnatha nitens* individuals moving across the water using two different locomotion techniques: (**a**) female running without the assistance of silk lines, and (**b**) male pulling on silk lines while simultaneously walking. A dotted silk line has been extending from the front pair of legs towards the male's abdomen to represent the possibility of attachment to the spinnerets, although not directly observed.

The second observation occurred in May 2023 at a different permanent pond (32.87451° S, 151.74501° E) in which an adult male, also *T. nitens*, was found on the water's surface approximately 50 cm away from an emergent stand of *Bolboschoenus* sp. The spider was moving towards the emergent vegetation, following a line of silk that appeared to be connecting the spider to the vegetation. The spider held the line with the first pair of legs, which remained taught at all times, suggesting that the spider was reeling itself closer to the vegetation (Supplementary Video S2). The first pair of legs contacted the silk in an alternating fashion, one after the other, as opposed to together at the same time. The second pair of legs contacted the water and were used for walking. The third and fourth pair of legs remained extended, primarily motionless, and continuously contacting the water. During locomotion, the body remained relatively parallel with the water, with the end of the abdomen making contact with the surface. The spider made its way to the vegetation stand, at which point it lifted itself off the water's surface using the silk line that was attached to the vegetation at the other end (Figure 1b). It is possible that one end of the silk line was attached to the individual's spinnerets throughout this period, although this was not directly observed.

3. Discussion

We show that *T. nitens* can move across water surfaces in multiple ways, including walking without the assistance of silk lines and pulling on silk lines while gliding. The former shows that *T. nitens* possesses the necessary hydrophobicity, posture, and gait to both rest and move across water. The latter shows evidence of silk being exploited during locomotion on water. Our observations support work on *Tetragnatha extensa* [14], which suggests that water-trapped spiders may use silk as draglines once anchored to floating vegetation. Our findings highlight the adaptability of silk in aquatic systems.

There are few species that habitually associate with water, but many may interact with this surface inadvertently or momentarily due to flooding or dropping from nearby vegetation [12]. Our observations indicate that *T. nitens* individuals do walk on water, at least when prompted by predation attempts. This is in contrast to other species in the Tetragnathidae family that do not attempt locomotion when on water, instead waving their front legs in the air to increase the chance of contacting nearby structures in order to rescue themselves [12]. The active movement of long-jawed spiders on water is not surprising considering their close association with riparian habitats [15,16], and their interaction with water surfaces for various activities such as prey manipulation, web attachment, and water collection [5,17,18]. Several traits may support surface film rest and locomotion in *T. nitens*, such as hydrophobic surfaces, hair-like projections, and increased hair density to prevent the breaking of surface tension [12,19,20]. As seen among terrestrial spiders during locomotion on a solid substrate, only the leg tips of the *T. nitens* individual we observed supported the body by contacting the water, with the body relatively high off the water [10]. This contrasts with semi-aquatic fishing spiders which sit low on the water, with the ventral surface placed against the water and the legs extended much more horizontally to distribute weight over a wider surface area [10]. Yet, similar to fishing spiders that row on water, we hypothesise that *T. nitens* used the back legs for stabilization rather than propulsion while walking on water, resembling the function of a rudder [10]. This differs from the alternating tetrapod gait used by terrestrial spiders when walking on water, whereby all legs are involved in propulsion [10]. Walking on water in *T. nitens* appears to be intermediate to the locomotion behaviour exhibited by terrestrial and semi-aquatic species.

Silk-assisted movement on water involves several behavioural and morphological components. Similar to surface film walking exhibited by this species, the fourth pair of legs are never contracted but instead remain extended outwards, which we hypothesise is involved in stabilising the spider as it moves. This appears to also be the role of the third pair of legs and back portion of the abdomen, which are covered in hair-like projections and thus likely to be hydrophobic, allowing the spider to remain above the water by helping to disperse body weight and prevent the breaking of surface tension. Instead of reaching out in the air, the front pair of legs repeatedly grip and move along the silk line, pulling the spider forward across the water as it reels itself closer to the opposing end of the line. The second pair of legs are simultaneously used for walking to provide additional forward momentum as it glides over the water. Additionally, the placement of the tip of the abdomen against the water's surface may act to reduce drag as it is covered in hairs that may trap a layer of air, as seen in fishing spiders which ride over the water on their ventral surface [10]. Silk-assisted movement on water may not in itself be a distinct technique, but rather the exploitation of silk whilst using behaviours used for surface film walking and gliding.

It is apparent that *T. nitens* is less efficient at moving on water compared to spiders that habitually use this surface, such as fishing spiders [11,21]. Silk lines may thus assist in surface film locomotion by acting as a safety line to return to nearby vegetation [14]. These lines may (i) allow for more targeted movement towards a desired destination and provide a guide without the need for continuous orienting, and (ii) reduce disruption to the surface film that occurs with leg movements during water walking [10]. These benefits may enable more rapid and efficient surface film locomotion than would be possible by walking alone. However, it remains to be determined the circumstances that led the spider we observed to be in open water with a silk line at its disposal. It is possible that the individual was in the midst of laying a silk line between vegetation stands but decided to return to its previous location, repurposing the silk already secreted and still attached to the spinnerets to do so. Further investigation is required to fully understand the benefits of silk-assisted locomotion on water.

This study demonstrates that some long-jawed spiders, such as *T. nitens*, can effectively exploit silk lines to navigate across water surfaces. This silk-assisted locomotion provides an efficient means of movement for species not naturally adapted for frequent water walking. By examining the multifunctional nature of silk in both terrestrial and aquatic environments, it is possible to gain insights into the extraordinary adaptability of this fibre and how it has helped facilitate the ability of spiders to thrive in a diversity of habitats.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/arthropoda1040017/s1, Video S1: Video recording of a *Tetragnatha nitens* female walking across the surface film of a freshwater pond after a predation attempt by *Gambusia holbrooki* on Kooragang Island, NSW, Australia. Video S2: Video recording of a *Tetragnatha nitens* male using a silk line to reel itself towards emergent vegetation while it walks across the surface film of a freshwater pond on Kooragang Island, NSW, Australia.

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