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OVERLAND DISPERSAL AND DROUGHT-ESCAPE BEHAVIOR IN A FLIGHTLESS AQUATIC INSECT, *ABEDUS HERBERTI* (HEMIPTERA: BELOSTOMATIDAE)

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Abstract—We report an observation of overland dispersal in a flightless aquatic insect during a period of drought-induced stream-drying. We observed an adult giant water bug, *Abedus herberti* (Hemiptera: Belostomatidae), crawling at 4.6 m/min along a dry stream channel in the Galiuro Mountains, Arizona. We tracked the individual for 130 m and estimate that it moved 240 m from the nearest remaining aquatic habitat. Additionally, we conducted behavioral experiments that confirm that *A. herberti* can use drying as a cue to initiate movement.

Resumen—Se reporta la observación de la dispersión por tierra de un insecto acuático no volador durante un periodo de sequía intensa en un arroyo. Se observó un adulto de *Abedus herberti* (Hemiptera: Belostomatidae) arrastrándose a 4.6 m/min a través del lecho seco de un arroyo en las montañas Galiuro, Arizona. Se rastreó al individuo por 130 m y se estima que se trasladó 240 m desde el hábitat acuático restante más cercano. También se condujeron experimentos de comportamiento que confirman que *A. herberti* puede usar la sequía total como estímulo para iniciar su movimiento.

Aquatic communities in aridland streams are often separated by harsh intervening terrain that can act as a dispersal barrier. However, genetic evidence suggests that populations of several obligatory aquatic taxa exhibit some genetic connectivity, indicating that at least a few individuals move between locations, however infrequently (Finn et al., 2007). Long-distance dispersal events can be essential for the persistence of highly isolated populations because they provide genetic connectivity and can serve as mechanisms for recolonization following local extinctions, but they are rare due to the high risks incurred by dispersing individuals (Lowe, 2010). Rapid changes in the suitability of the local aquatic environment, such as stream-drying, might trigger such rare dispersal events in aquatic taxa. We report a direct observation of what we believe to be the first documented case of overland drought-escape behavior in a flightless aquatic insect.

In the early afternoon of 8 April 2009, we observed a giant water bug, *Abedus herberti* (Hemiptera: Belostomatidae), crawling along a dry stream reach in High Creek, Galiuro Mountains, Arizona (UTM 12S 569134, 3603989; elevation of 622 m). High Creek is a spring-fed stream that runs through Madrean evergreen woodland and fragments annually to a series of pools separated by dry reaches lined with cobble and boulders. On the day of the observation, the sky was overcast, with an air temperature of ca. 20°C and palpable humidity, although we found no evidence of recent rainfall. The dispersing giant water bug was an adult male (ca. 3 cm in length) moving downslope (15–20° incline) in the dry stream channel and climbing over cobbles >10 cm in diameter as it went. We followed it for 130 m and estimated its movement rate at 4.6 m/min (see video at http://hdl.handle.net/1957/28659). The nearest wetted aquatic habitat was 110 m upstream; therefore, this individual traveled at least 240 m over dry land. Interestingly, the startle response of the insect was completely stifled, and it continued its pace despite observation by the authors. While remaining habitat was upstream, it moved down the canyon in a positively geotactic manner and remained oriented in the stream channel even when climbing over and around obstructions such as cobbles and woody debris. On several occasions during its navigation around debris, the individual landed upside down. Each time, it righted itself and resumed movement in a downstream direction. This unique behavior is analogous to the rainfall-response behavior that is well documented for *A. herberti* and other belostomatids, where individuals use heavy rainfall as a cue to escape flash floods by moving uphill and away from the active stream channel (Lytle and Smith, 2004). Unlike rainfall-response behavior, however, the dispersal behavior we observed was uniformly downhill rather than uphill, consistently within the stream channel rather than perpendicular to it, and required no rainfall-cue to initiate.

Although adult and juvenile *A. herberti* were abundant during a previous visit to High Creek on 9 June 2008, *A. herberti* were scarce on 8 April 2009 and the wetted-stream habitat had fragmented to a series of small pools due to below-average winter precipitation (rainfall during January–March only 55% of the 30-year mean; National Oceanic and Atmospheric Administration weather station, Willcox, Arizona). A few pools (15.8 m^2 in total surface area) remained 110 m upstream of the observation site, with another suitable reach 750 m further upstream. We extensively sampled the limited upstream aquatic habitat and found only five adult females, four of which were gravid, and no males or juveniles. Upon a return visit in March 2010, we found more pool habitat but only three giant water bugs, this time all adult males. Thorough sampling of all pool habitats on 3 April 2011 yielded only a single gravid female. These observations suggest that the population at High Creek is highly vulnerable to local extinction, especially given that this species has already been extirpated from other streams in the region by similar drying events (Bogan and Lytle, 2011).

To explore a possible mechanism behind our fortuitous observation, we conducted laboratory experiments to determine if *A. herberti* can use stream pool-drying as a cue to initiate movement. We collected *A. herberti* from East Turkey Creek, Chiricahua Mountains, Arizona, and acclimated them to tanks in the laboratory at the Southwestern Research Station, Portal, Arizona. Each experimental unit consisted of a small opaque inner tank (10.9 L) nested within a larger outer tank (29.1 L). The outer tanks contained water, and the inner tanks were either wet or dry, representing our two treatments. Inner tanks were lined with screen to allow individuals to crawl from inner to outer tanks, whereas the high, smooth walls of the outer tanks prevented the insects from moving back to the inner tanks or escaping the experiment altogether. Inner tanks contained cobbles (mean diameter of 8–20 cm) to provide substrate similar to that found in natural habitat of the insects. To begin each trial, a single adult giant water bug was placed in each of 12 inner tanks. We returned after 12 and 24 h and recorded the movement of individuals from inner to outer tanks. We found that dryness was a strong predictor of movement in this species. In fact, insects were 10 times more likely to leave a dry tank than a wet one (Fisher's exact test, one-sided $P < 0.0001$). This simple experiment supports stream-drying as a possible mechanism behind our observation of overland dispersal.

While *A. herberti* is an air-breathing aquatic insect and is known to move distances of a few meters along fragmented streams, overland dispersal in response to drought had not previously been observed in this species. We suggest that drought escape behavior might occasionally result in long-distance dispersal of *A. herberti* and thus might allow for recolonization of areas where populations have been extirpated, or provide the genetic diversity necessary for small extant populations to avoid extinction altogether. The surprising distance and speed of the observed individual makes dispersal between aquatic habitats in the Galiuro Mountains a possibility. If an individual giant water bug were to continue for 24 h at the rate we recorded, it would travel over 6.5 km, which would put it within several days of perennial habitats in adjacent stream basins. Although this scale of movement is unlikely, our observation provides some evidence that populations of *A. herberti* could persist despite projected stream-drying in the southwestern United States (Seager et al., 2007).

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