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SHORT COMMUNICATION

The importance of streamside sandbars to ground beetle (Coleoptera, Carabidae) communities in a deciduous forest

Scott Horn · Michael D. Ulyshen

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Abstract We used pitfall traps to sample ground beetles on sandbars along a small woodland stream and in the adjacent floodplain forest (Oglethorpe Co., GA, USA). We captured a total of 1,477 ground beetles representing 41 species. Twenty-two species were exclusive to sandbars, while eight were found only in the forested habitat. Ground beetles were captured in significantly greater numbers from sandbars, especially *Brachinus janthinipennis* and *Omophron americanum*. The *B. janthinipennis* record represents a new state record for the species. This study demonstrates that many unique species can be found in specialized microhabitats and emphasizes the need for biodiversity assessment surveys to include a wide range of these microhabitats within a survey area. In addition, it appears that many generalist forest species might use sandbars seasonally to exploit available resources.

Keywords Carabidae · Ground beetles · Psammophilous · Riparian beetles · Sandbars

Introduction

Riparian forests are dynamic systems that connect terrestrial and aquatic habitats. The transition zone created by these forests generates a patchwork of microhabitats influencing local biodiversity (Junk 2000; Tockner et al. 2000a; Robinson et al. 2002). The most obvious and dominant influence on floodplain forests is periodic inundation (Junk et al. 1989; Plachter and Reich 1998; Joyce and Wade 1998; Ward et al. 1999; Bonn et al. 2002) which results in higher productivity of riverine forests compared to adjacent uplands (Brinson 1990). These disturbances create microhabitats that may have unique species associated with them. Likewise, since many habitats are dependent on surrounding areas (Batzer 2004) this interface between terrestrial and aquatic systems may be especially important.

Sand and gravel bars are such transitional habitats occurring along streams and rivers worldwide. Flood events determine the development and abundance of sand and gravel bars along streams and also limit the growth of vegetation on them (Hering 1998). These unique habitats are often characterized by distinct faunas adapted to varying water levels or substrate types (Hering and Plachter 1997; Manderbach and Hering 2001; Framenau et al. 2002). Sandbars represent ever-changing habitats dependent on varying stream levels resulting from storm events. However, humans have caused a reduction of habitat heterogeneity in streamside habitats through the creation of dikes, dams, and river modification (Gunther and Assmann 2005 and sources therein). Such operations have been listed as potential threats to invertebrate diversity, especially along exposed riverine sediments that provide beetles a vast continuum of microhabitats (Bates et al. 2007). Thompson and Allen (1992) stated that insufficient ecological information exists on the effects of forest management activities on many plant and animal species. The same could be said for other activities such as agricultural practices, recreational activities, and human development along streams. Thus, riparian corridors may be an important focal point for detecting environmental degradation and change (LaBonte 1998).

S. Horn (✉) · M. D. Ulyshen
USDA Forest Service, 320 Green Street, Athens, GA 30602-2044, USA
e-mail: shorn01@fs.fed.us

Terrestrial arthropods can be useful bioindicators of the impacts of various factors on ecosystem function (Kremen et al. 1993) and ground beetles (Carabidae) have been frequently promoted as a good group for this purpose. For example, recent studies showed negative impacts of beach tourism (Arndt et al. 2005) and dam creation (Knisley and Fenster 2005) on tiger beetles. Ground beetles are promoted for environmental assessment studies because: (1) they have wide distributions, (2) specialized habitat preferences, (3) are very mobile, and (4) present in large numbers (Thompson and Allen 1992). Because ground beetles often utilize defined habitats (Thiele 1977) and are considered ecologically sensitive (Boscaini et al. 2000), they are good candidates for use in detecting changes to alluvial ecosystems (Sustek 1994). For example, Manderbach and Hering (2001) found that *Bembidion* spp. in Central Europe could be separated into groups based on substrate preference, some being more common on coarse gravel while others were more prevalent on fine sediments.

Numerous studies have inventoried carabid species occurring on sand and gravel bars in Europe, but little baseline information exists from North America. This is especially true for the southeastern United States so we initiated a study of ground beetles on sandbars along a small woodland stream in the Georgia Piedmont.

Study area

Falling Creek is a small (3–4 m) woodland stream with numerous sandbars which flows through the Oconee National Forest's Scull Shoals Experimental Forest in Oglethorpe County, GA, USA. The stream is within the Oconee River Watershed and is in an area that was heavily farmed until the land was incorporated into the national forest system and reforested in the 1940s and 1950s. The floodplain forest is now a mixed forest of mainly deciduous species such as willow oak (*Quercus phellos*), sycamore (*Platanus occidentalis*), sweetgum (*Liquidambar styraciflua*), loblolly pine (*Pinus taeda*), and yellow poplar (*Liriodendron tulipifera*). Understory species included spicebush (*Lindera benzoin*), Georgia buckeye (*Aesculus sylvatica*), Carolina silverbell (*Halesia carolina*), and the exotic Chinese privet (*Ligustrum sinense*).

Methods

To determine which ground beetles occurred on sandbar habitats and in the adjacent floodplain forest, we established trapping stations on five sandbars (13 traps) and at five corresponding locations 30 m into the forest (13 traps). Trapping stations had either two or three traps depending on the size of the sandbar and individual traps were located ~6 m apart. Corresponding forest locations had the same number of traps as the sandbar counterpart. The sandbars were made up entirely of fine sand with some leaf litter and fine woody debris present and were 25 m in length and 4 m wide on average. Some sandbars became increasingly vegetated but they were never completely covered during our trapping period.

Although pitfall traps have some disadvantages (see Ulyshen et al. 2005 and sources therein), they remain the most common method for sampling ground beetle communities, and are probably the best traps for targeting this group on sandbars. Our traps consisted of 480 ml plastic cups fitted with 8.4 cm diameter funnels that directed beetles into 120 ml specimen cups containing a saturated salt solution with 1% formaldehyde as a preservative and small amount of detergent to reduce surface tension. Samples were stored in 70% ethanol until they were identified using a regional key (Ceigler 2000). Specimens that could not be identified with confidence were sent to Harry Lee Jr. (HJLC-personal collection) for further taxonomic scrutiny. Voucher specimens are deposited at the University of Georgia Natural History Museum Arthropod Collection.

Traps were operated for five 7-day intervals in 2004 and collected on: 30 April, 14 May, 28 May, 17 June, and 16 July. During our study the area was undergoing a drought (4.98 cm/month below normal rainfall), so stream water levels remained low. Mean temperatures ranged from 16.4°C in April to 26.8°C during July.

Results

Pitfall traps caught a total of 5,243 arthropods at the two locations. Sandbars were most productive totaling 3,635 individuals, while forest traps totaled 1,608. The most common orders were Coleoptera (40.0%), Araneae (18.6%), Diptera (12.6%), and Hymenoptera (11.8%). Carabids accounted for 28.2% of the total catch. Following the overall trend, a paired *t*-test showed that ground beetles were significantly more abundant ($P = 0.001$) on sandbars than in forests. Table 1 lists all ground beetle species collected and the number from each location.

We collected 41 ground beetle species of which 22 species were trapped only on sandbars and eight species were only caught in the forest. The remaining 11 species were collected in both habitats. Species captured commonly ($n \geq 43$) and exclusively on sandbars include: *Agonum extensicolle*, *Bembidion inaequale*, *Brachinus janthinipennis*, *Cicindela repanda*, *Omophron americanum*, and *Schizogenius ferrigineus*. Several other species showed a propensity for sandbars, while few were more common in forested habitats (*Dicaelus* species and *Amara* species).

Table 1 Total number of specimens collected from pitfall traps of each ground beetle species caught in sandbar and forest habitats along Falling Creek, Oglethorpe County, GA, USA

Carabid taxon	Total number	
	Sandbar	Forest
Agonum extensicolle	62	0
Agonum ferreum	7	1
Agonum sp.	2	0
Amara cupreolata	2	6
Amara sp.	1	4
Anisodactylus furvus	0	1
Anisodactylus verticolis	17	5
Badister notatus	2	1
Bembidion aenulum	2	0
Bembidion inaequale	43	0
Bembidion nigrum	12	0
Bembidion plagiatum	1	0
Brachinus alternans	13	0
Brachinus janthinipennis	566	0
Chlaenius aestivus	54	8
Chlaenius impunctifrons	1	0
Cicindela repanda	44	0
Cicindela sexguttata	63	3
Clivina dentipes	14	0
Clivina ferrea	4	0
Dicaelus dilatatus	0	4
Dicaelus elongates	0	1
Dicaelus furvus	0	1
Dicaelus purpuratus	0	1
Dyschirius sp.	1	0
Elaphropus sp.	18	2
Elaphrus ruscarius	3	0
Galerita bicolor	0	2
Harpalus longicollis	2	0
Omophron americanum	391	0
Oodes brevis	1	0
Paratachys sp.	2	0
Platynus sp.	1	1
Pterostichus coracinus	2	2
Pterostichus sculptus	0	1
Scarites quadriceps	1	0
Scarites subterraneous	2	0
Schizogenius ferrigineus	44	0
Semiardistomis viridis	28	20
Sphaeroderus sternostomus	0	2
Stenolophus ochropeus	5	0

The most abundant species (accounting for 38.3% of the carabids collected), *B. janthinipennis* had not previously been reported within 800 km of our study based on distributional information provided by Erwin (1970b). However, a recent museum search showed that the species was collected in Pickens County, SC, USA (Clemson University Arthropod Museum) ~160 km from our study site. Lakeshores, riverbanks, and moist or wet sandy soils are listed as suitable habitat for *B. janthinipennis* by Larochelle and Lariviere (2003). They also list this nocturnal species as an ectoparasite of gyrinid (*Dineutes* spp.) and hydrophilid (*Tropisternus* spp.) pupae.

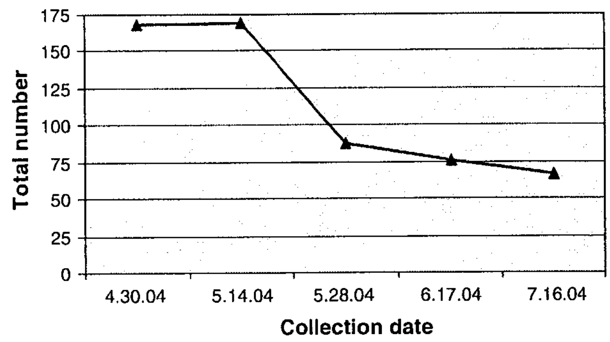

Fig. 1 Total number of *B. janthinipennis* collected for each of the five sampling dates

We caught 168 *B. janthinipennis* in April and 169 in May after which they declined to approximately half that number in June and remained low through the end of our study (Fig. 1). The high numbers we caught show that *B. janthinipennis* may not be rare, but rarely collected due to its specific habitat requirements and infrequent sampling of that habitat in southeastern forests. *B. janthinipennis* was caught on sandbars demonstrating that this species has explicit habitat requirements, likely related to its larval hosts. More research needs to be conducted to determine its ecology and distribution in the region.

Discussion

Our results show sandbars represent an important habitat for many species of ground beetles. While some of the more opportunistic species appear to regularly patrol sandbars, others seem to be largely restricted to this habitat. We collected significantly more beetles from sandbars than from forested traps. One explanation of this is that catch might be influenced by surrounding groundcover (Refseth 1980). Pitfall traps in the forest were surrounded by sparse vegetation and leaf litter, while sandbar traps were almost completely unobstructed. In such exposed habitat carabids may move more or move longer distances to avoid predators. Another explanation could be sandbar specialists were very abundant and restricted to small habitat patches resulting in more captures.

Ground beetles have adapted to fill many distinct ecological roles and often occur in narrowly defined habitats. The importance of some habitats, particularly those like sandbars that are ephemeral in nature have received little attention. Most studies of these habitats have been conducted in Europe where carabid communities are better known and the ecosystems have been greatly altered by humans for quite some time. Habitat alteration in the United States continues at a rapid rate, despite the fact that many unique environments remain unstudied and local communities unknown.

The most commonly collected ground beetle during our sampling was *B. janthinipennis*, greatly expanding its known range. Other ground beetle species were also captured exclusively on sandbars in high numbers. These include *O. americanum*, *A. extensicolle*, *C. repanda*, *S. ferrigineus*, and *B. inaequale*. These species might be considered sandbar specialists based on our collections, but they have also been recorded from other open, wet habitats such as shorelines, riverbanks, and related areas (see Larochelle and Lariviere 2003). However, others (*Anisodactylus verticolis*, *Brachinus alternans*, *Chlaenius aestivus*, and *Semiardistomis viridis*) are known to occur in forested settings (Ulyshen et al. 2006 and personal observations) so their occurrence on sandbars raises an interesting question: why are these typical forest species found on sandbars? Their presence likely reflects opportunistic resource exploitation. For example, Batzer (2004) observed that predatory invertebrates invade drying ponds to take advantage of stranded aquatic invertebrates. In our study area the winter and early spring months typically bring rising stream levels due to low evapotransporation by trees and greater rainfall. We hypothesize that as stream levels drop many forest species move with water levels to utilize resources available at the waters edge. Future work should test this hypothesis using methods such as exclusion cages (Batzer 2004) to determine the level to which aquatic resources are being utilized. Likewise, drift fences or similar barriers should be installed lengthwise along sandbars that allow "resident" sandbar carabids to be differentiated from those migrating in from forests. An experiment of this nature might shed light as to why so many forest species are found in sandbar habitats and how frequently they use this resource.

Several studies have shown that prey available to riparian beetle predators can come from varying habitats, but aquatic systems seem to be especially important. In Oregon, Hering (1998) showed that carabids were dependent on aquatic invertebrates such as fly larvae and caddisfly larvae. A similar study in Alpine floodplains found that larger ground beetles, such as *Nebria picicornis*, fed on emerging stoneflies, while smaller beetles (*Bembidion* spp.) preferred chironomid flies (Hering and Plachter 1997). Paetzold et al. (2005) found that some ground beetles fed entirely on aquatic insects and pointed out that the consumption of aquatic detritivores by riparian arthropods represented a return of energy to terrestrial systems. This phenomenon could be likened to a larger and better known example, that of Pacific salmon which contribute large amounts of nutrients back to terrestrial systems (Cederholm et al. 1999).

It is clear that sandbars create a "waterhole" situation that attract and/or strand many invertebrates, providing prey to ground beetles living there and possibly those more frequently found in forests. Future work focusing on ground beetle taxa present on sandbars in the United States would help determine their value as bioindicators of habitat change and document many unique species as well.

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