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Notes

Observations of cocooned *Hydrobaenus* (Diptera: Chironomidae) larvae in Lake Michigan

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ABSTRACT

Larvae of the family Chironomidae have developed a variety of ways to tolerate environmental stress, including the formation of cocoons, which allows larvae to avoid unfavorable temperature conditions, drought, or competition with other chironomids. Summer cocoon formation by younger instars of the genus *Hydrobaenus* Fries allows persistence through increased temperatures and/or intermittent dry periods in arid regions or temporary habitats, but this behavior was not observed in the Great Lakes until the current study. Cocoon-aestivating *Hydrobaenus* sp. larvae were found in benthic grab samples collected in 2010–2013 near Sleeping Bear Dunes National Lakeshore in northern Lake Michigan with densities up to 7329/m^2. The aestivating species was identified as *Hydrobaenus johannseni* (Sublette, 1967), and the associated chironomid community was typical for an oligotrophic nearshore system. *Hydrobaenus* cocoon formation in the Great Lakes was likely previously unnoticed due to the discrepancies between the genus' life history and typical benthos sampling procedures which has consequences for describing chironomid communities where *Hydrobaenus* is present.

Introduction

The development of different life history strategies allows aquatic organisms to persist in the face of environmental challenges (Verberk et al., 2008). Members of the family Chironomidae can tolerate a wide variety of adverse environmental conditions including pollution, hypoxia, drought, and extreme cold (Danell, 1981; Irons et al., 1993). Some chironomids survive inhospitable circumstances by simply leaving the area or by burrowing deeper into the sediment (Kornijów, 1992; Yamagishi and Fukuhara, 1972). Other chironomids aestivate/enter diapause, which has been observed in many other aquatic invertebrates including cladocerans, cyclopoid copepods, and asellid isopods (Dietz-Brantley et al., 2002). When entering diapause, some chironomids fashion silk cocoons with their salivary glands (Frouz et al., 2003; Tokeshi, 1995). Onset of winter cocoon formation may be due to lack of food or depleted oxygen (Sæther, 1962), and while the cocoon does not necessarily prevent the chironomid from freezing, it acts as protection against mechanical stress caused by freezing (Danks, 1971, 2004; Olsson, 1981). Drought-resistant species form cocoons to reduce water loss during dry spells and re-emerge when the soil is rehydrated (Benigno and Sommer, 2008; Grodhaus, 1980; Jones, 1975; Steinhart, 2000; Tronstad et al., 2005). Upon emergence, cocoon-aestivating chironomids gain earlier access to food resources and improved conditions, thereby potentially outcompeting their counterparts unable to survive drought (Frouz et al., 2003; Steinhart, 2000).

Cocoon-forming chironomids in the genus *Hydrobaenus* Fries are found in littoral areas of oligotrophic lotic and lentic northern waters (Sæther, 1976). Cocoon aestivation by *Hydrobaenus* has been observed in both temporary habitats (vernal pools and floodplains; Grodhaus, 1980; Steinhart, 2000) and permanent waterbodies (lakes and rivers; Hudson, 1971; Kondo, 1996). In the United States, cocoon aestivation has been observed in South Dakota (Hudson, 1971) and California (Grodhaus, 1980) with suspected aestivation reported near San Francisco Bay (Benigno and Sommer, 2008). Outside of the United States *Hydrobaenus* cocoons have been documented in Japan (Kondo, 1996), Europe (Steinhart, 2000), northern Germany (Mozley, 1970) and in the Northwest Territories, Canada (Sæther, 1976).

Cocoon formation in *Hydrobaenus* typically occurs in the summer during the second or third instar and diapause is terminated when temperatures begin to fall as winter approaches (Grodhaus, 1980; Hudson, 1971; Kondo, 1996; Steinhart, 2000). Hudson (1971) broke diapause by experimentally decreasing temperature from 23 °C to 3 °C and reducing daylight hours from 15.5 to 10.5. Grodhaus (1980) suggested that the summer cocoon may be an obligatory phase for early instars, but Steinhart (2000) found that 28% of *Hydrobaenus lugubris* larvae did not form cocoons under experimental temperature regimes (ranging from 5 to 20 °C) used to simulate seasonal changes. Delaying development until autumn has been hypothesized to reduce competition with

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and predation from other chironomids (Mozley, 1970), and may allow for multivoltinism (Kondo, 1996; Sæther, 1976; but see Steinhart, 2000).

Hydrobaenus has been found in most of the Laurentian Great Lakes (Winnell and White, 1985), but may be more common in rivers, wetlands, and inland ponds than in the lakes proper (Judd, 1964; Krieger and Klarer, 1992; Walther et al., 2006). Here we present the first known observation of aestivation and cocoon formation by *Hydrobaenus* in the Great Lakes with a review of its life history.

Methods

Sample collection

Benthic sediment samples were collected from offshore sites in northern Lake Michigan near Sleeping Bear Dunes National Lakeshore (hereafter, SLBE) from July–October 2010, July–November 2011, May–November 2012, and July–November 2013 at 36 sites (changing yearly) with depths of 10, 20, and 30 m (Fig. 1). At these depths, we targeted sites from three broad substrate categories determined by underwater camera surveys: bare sand, live invasive dreissenid mussel beds with *Cladophora* algae growth, and depositional areas with sloughed, decaying algae, diatoms, and other organic matter. Benthic samples were collected with a standard 523-cm^2 Ponar grab. The sample grab was rinsed of fine sediment in a 5-gallon bucket with 500-μm mesh openings. The sample was then rinsed into a collection jar and placed on ice until returning to shore (~6 h on average), when it was fixed with a 10% buffered formalin solution. Surface water temperatures were recorded from an onboard GPS/depth sounder (Garmin GPSMAP; Garmin International, Olathe, KS), and in 2013 a bathythermograph (SBE 19plusV2 Seacat Profiler; Sea-Bird Electronics, Inc., Bellevue, WA) was used to measure water temperature from approximately 1 m above the lake bottom at each site.

Chironomid identification and analysis

In the lab, samples were stained with rose bengal for at least 24 h to facilitate sorting. All invertebrates from 133 samples were removed, identified to the lowest practical taxonomic unit (usually family; Merritt et al., 2008; Smith, 2001; Thorp and Covich, 2009), enumerated, and stored in 80% ethanol. *Hydrobaenus* cocoons, the encased larvae, and the sand grains to which a cocoon was attached were photographed and measured in Image-Pro Plus 7.0 (Media Cybernetics, 2009). The number of cocoons per sample was correlated with daylight hours, surface water temperature, and lake bottom water temperature in R v3.2.2 (R Core Development Team, 2015). The number of cocoons was log-transformed to achieve normality prior to analysis.

From a subset of 19 samples, six of which contained *Hydrobaenus* cocoons or larvae, we identified Chironomidae larvae and pupae to genus or species. These samples were collected at 10 and 20 m sites at Good Harbor and South Manitou from June–November 2012 and July–November 2013. Larval specimens in each sample were first sorted by size, color, and shape, and then representative individuals (~10%) from each group were mounted in lactic acid on a glass slide with a coverslip. If the individuals mounted were identified as belonging to the same taxon, the rest of the group was counted and recorded as being that taxon as well. Individuals were identified to genus using Andersen et al. (2013). Species identifications, when possible, were determined using Epler (1988); Maschwitz and Cook (2000); Proulx et al. (2013); Roback (1985), and Sæther (2009).

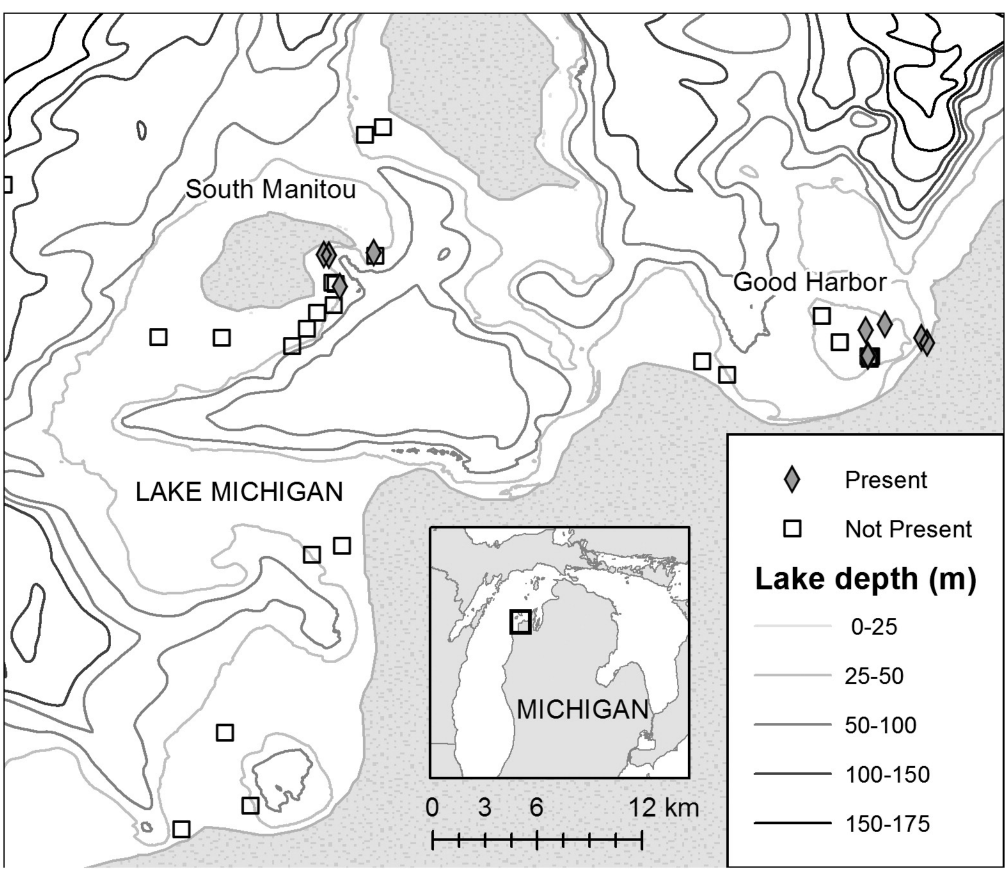

Fig. 1. Benthic sampling locations near Sleeping Bear Dunes National Lakeshore, northern Lake Michigan. "Present"/"Not present" indicate whether *Hydrobaenus* cocoons were found at a given sampling site. Bathymetry contours were derived from Michigan Technological Research Institute et al. (2015).