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THE CHIRONOMIDAE (INSECTA: DIPTERA) OF SAN SALVADOR ISLAND: A PRELIMINARY SURVEY AND A LOOK TO THE FUTURE

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ABSTRACT

Chironomidae (Diptera) are among the most diverse and widespread aquatic insects, with over 5,000 species described worldwide. Nearly 900 species are recognized from the Neotropical region, while over 1,200 species are known from the Nearctic region. This pattern of fewer species at lower latitudes, particularly in tropical ecoregions, does not conform to trends for other insects, which show highest species diversity in tropical areas. However, comparatively few field investigations have examined the species richness of Chironomidae in the Neotropical region. To date, only four species of Chironomidae have been recorded in the Bahamas. The goal of this study was to document Chironomidae species diversity on San Salvador Island in the Bahamas. In March of 2012, a variety of aquatic habitats representing fresh to saline waters were sampled for chironomid larvae and pupal exuviae. Two sites yielded abundant numbers of immature and recently emerged Chironomidae, as indicated by presence of pupal exuviae. Twelve species new to the Bahamas were found: *Chironomus* Meigen (3 morphospecies), *Dicrotendipes* sp. A Epler, *Polypedilum* (*Tripodura*) *scalaenum* group (1 morphospecies), *Goeldichironomus fluctuans* Reiss, *Tanytarsus mendax* Kieffer, *Tanytarsus* cf. *confusus* Malloch, *Ablabesmyia* (*Sartaia*) *metica* Roback, *Labrundinia maculata* Roback, *Paramerina anomala* Beck and Beck, and *Djalmabatista pulchra* (Johannsen). All of these are new records for the Bahamas, with *Tanytarsus mendax* and *Paramerina anomala* new for the Neotropical region.

INTRODUCTION

The Chironomidae, commonly known as non-biting midges, are a family of flies that typically live out their immature stages (egg, larvae, pupae) in or closely associated with water (Fig. 1). This family of flies is among the most diverse and widespread of aquatic insects, with a worldwide total of over 5,000 described species (Ferrington 2008). Many species have not yet been discovered, with current species estimates ranging up to 20,000 (Ferrington et al. 2008). Chironomids are recognized as important and effective biological indicators of aquatic ecosystems (Wiederholm 1984); thus, accurate assessments of their diversity and richness can be critical for biological monitoring studies (King and Richardson 2002; Hayford and Ferrington 2005; Calle-Martinez and Casas 2006). However, considering the extraordinary richness of the family, there is often considerable variation among species in response to environmental change, even within a single genus. Therefore, it is critical to identify taxa to genus or, preferably, species to obtain the most biologically informative data (Bailey et al.

2001; Lenat and Resh 2001; King and Richardson 2002).

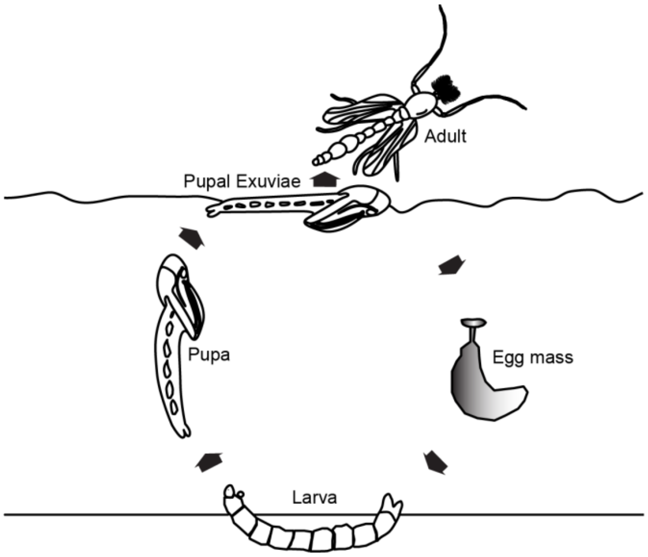

Figure 1. Chironomidae life cycle.

Of the Chironomidae currently described, nearly 900 species from 191 valid genera are known from the Neotropical zoogeographical region (M. Spies, Zoologische Staatssammlung München, personal communication), while over 1,200 species are known from the Nearctic region (Ferrington et al. 2008). This pattern of fewer species at lower latitudes does not conform to generalized trends for other insects (e.g., Godfray et al. 1999; Hoang and Bae 2006). A key factor that may account for this trend is that there have been comparatively fewer field investigations examining the species richness of Chironomidae in the Neotropical region. Yet, the work that has been done has indicated high species diversity and many undescribed species. For example, in a study of 13 Costa Rican streams, Coffman et al. (1992) found 266 chironomid species, 50 of which could not even be identified to the genus level, indicating many Chironomidae genera have yet to be described. Spies and Reiss (1996) echo this finding, asserting that hundreds of undescribed species are likely to exist in the Neotropics. Finally, work by Coffman and de la Rosa (1998) showed that when comparing Chironomidae species richness in Neotropical and Nearctic streams over a one-year period, species richness from tropical samples were, on average, 1.8 times greater than temperate samples.

Of the Chironomidae research that has been conducted in Neotropical region, most tends to focus primarily on species inhabiting freshwater streams (e.g., Coffman et al. 1992; Coffman and de la Rosa 1998). Much less is known about marine species, although there is considerably lower worldwide marine chironomid diversity, with only about 50 known species from 12 genera in three subfamilies: Telmatogetoninae, Orthocladiinae, and Chironominae (Hashimoto 1976; Pinder 1995).

Furthermore, most Neotropical Chironomidae research has taken place in Central and South America. Knowledge of Caribbean Chironomidae is relatively poor, with only little information from countries such as Cuba and the Bahamas. In Cuba, 21 genera and at least 29 species belonging to the subfamilies Chironominae, Tanypodinae and Orthocladiinae have been documented. More than half of the species were found in the benthos, periphyton or digestive tracts of fish, mostly in reservoirs, while there are isolated records from other habitats (Bello González et al. 2013).

Prior to our work, only four species of Chironomidae had been recorded from the Bahamas: *Goeldochironomus amazonicus* (Fittkau), *Clunio marshalli* Stone and Wirth, *Ablabesmyia cinctipes* (Johannsen), and *Tanypus neopunctipennis* (Sublette) (Johnson 1908; Spies and Reiss 1996). Graves and Cole (2007) examined invertebrate communities in tide pools on Man Head Cay, located in Rice Bay on San Salvador Island, and documented larval chironomids, identified only to family, in one coastal freshwater pool. Finally, no chironomid species were included in the recent checklist of insects of San Salvador Island, compiled by Elliot et al. (2009). This highlights the need for work on this insect family. The goal of our study was to begin to document Chironomidae diversity of San Salvador Island, Bahamas. We intend for our results to serve as a baseline for future Chironomidae research on San Salvador Island and the Bahamas as a whole.

MATERIALS AND METHODS

Study Area

San Salvador Island covers an area of approximately 150 km^2 in the east-central part of the Bahamas (N 24°, W 74°) (Fig. 2). Climate on the island is fairly stable year-round, ranging from 20 to 28°C, with relatively high humidity (Sealy 2006). The island is composed primarily of limestone rock and calcareous sand, and has several large saline or hypersaline inland lakes, which are interconnected by subterranean channels (White 1985, Diehl et al. 1986). As on most Bahamian islands, there is no surface flowing freshwater on San Salvador Island, and all freshwater is supplied by precipitation (Crump and Gamble 2006). Mean annual precipitation is 1,007 mm (Crump and Gamble 2006), with the majority of rainfall occurring between August and November or between May and June (Elliott et al. 2009). During the dry season, evaporation is greater than precipitation, resulting in diminished water levels or arid conditions (Sealey 2006; Elliott et al. 2009).

Sample Collection

In March of 2012, various fresh, brackish, and saline water tide pools, wetlands, ponds and lakes were sampled for both chironomid larvae and pupal exuviae (the cast skins left behind by adult flies leaving the water column; these skins can be found floating at the water's surface). Dip-nets (20 cm diameter, 500 µm mesh) were used to collect larvae. Collections of Chironomidae surface-floating pupal exuviae (SFPE) followed methods of Ferrington et al. (1991). Briefly, pupal exuviae were collected from multiple areas of known accumulation (e.g. areas with accumulated foam or debris, or along margins of emergent vegetation) by scooping SFPE, debris, and water into a white enamel pan and pouring all contents through a 125µm sieve. All scoops from a site and date were pooled into a single composite sample. An important benefit of collecting pupal exuviae, compared with collecting larvae or adults, is that this technique provides estimates of individuals that survived all immature stages and emerged as functional adults. By collecting Chironomidae from a wide variety of accumulation areas at a sample site, such as behind a fallen log or near areas of aquatic vegetation, one can rapidly evaluate emergence of Chironomidae from a broad spectrum of aquatic microhabitats (Ferrington et al. 1991). All SFPE samples were preserved in the field using 70% ethanol and later sorted in the lab under 12X magnification. Representatives of every taxon in each sample were slide mounted in Euparal® for species identification. Voucher specimens will be deposited in the University of Minnesota's Insect Collection (UMSP) and the Gerace Research Centre Specimen Repository.

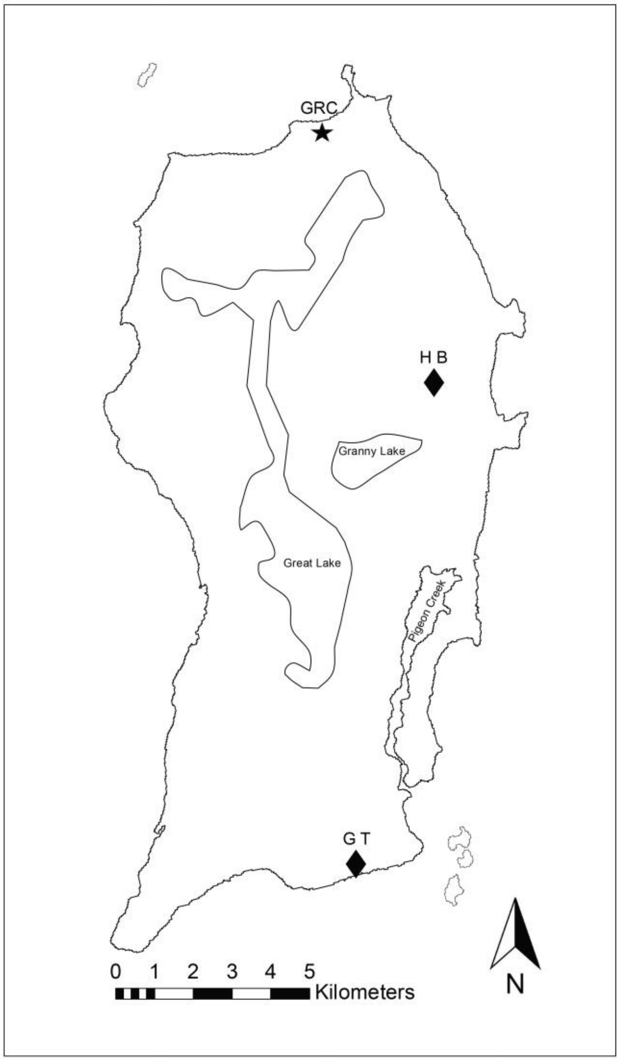

Figure 2. Location of sample sites on San Salvador Island, Bahamas. Diamonds indicate sample sites: HB = Hard Bargain Pond; GT = Gulf Tide Pools. GRC = Gerace Research Centre (starred).

RESULTS

Of the five sites sampled, Chironomidae larvae and SFPE were only found at two locations: rock pools located on The Gulf (hereafter, referred to as "Gulf Rock Pools") on the southern coast (N 23° 56.84'; W 74° 30.82') and a small quarry pond (hereafter, referred to as "Hard Bargain Pond") (N 24°03.65'; W 74° 27.23') located at the trail head to Six Pack Pond (locally known as Hard Bargain Trail). As indicated by Elliott et al. (2009), Hard Bargain Pond has been permanent since at least the year 2000 and is composed of fresh water. Chironomidae larvae were collected from tidal pools at Gulf Rock Pools and Hard Bargain Pond, while SFPE were found exclusively at Hard Bargain Pond (Table 1). Numerous adults were collected from fluorescent light and pan traps placed around Gerace Research Centre (N 24° 07.13' W 74° 27.90'), however these specimens will be treated in subsequent work.

Table 1. Chironomidae taxa collected on San Salvador Island, Bahamas, March 2012. Pex = pupal exuviae; L = larvae; HB = Hard Bargain Pond; GT = Gulf Tide Pools.

Chironomidae Taxa	**Life Stage Collected**	**Locality**
Chironominae		
Chironomini		
Chironomus sp. 1	Pex, L	HB, GT
Chironomus sp. 2	Pex, L	HB, GT
Chironomus sp. 3	Pex	HB
Dicrotendipes sp. A Epler	L	HB
Polypedilum (*Tripodura*) *scalaenum* group	Pex, L	HB
Goeldichironomus fluctuans Reiss	Pex	HB
Tanytarsini		
Tanytarsus mendax Kieffer	Pex	HB
Tanytarsus cf. *confusus* Malloch	Pex	HB
Tanypodinae		
Pentaneurini		
Ablabesmyia (Sartaia) metica Roback	Pex	HB
Labrundinia maculata Roback	Pex	HB
Paramerina anomala Beck and Beck	Pex	HB
Procladiini		
Djalmabatista pulchra (Johannsen)	Pex	HB

Analyses of larvae and pupal exuviae revealed the following twelve species: *Chironomus* Meigen (3+ morphospecies), *Dicrotendipes* sp. A Epler, *Polypedilum* (*Tripodura*) *scalaenum* group (1 morphospecies), *Goeldichironomus fluctuans* Reiss, *Tanytarsus mendax* Kieffer, *Tanytarsus* cf. *confusus* Malloch, *Ablabesmyia* (*Sartaia*) *metica* Roback, *Labrundinia maculata* Roback, *Paramerina anomala* Beck and Beck, and *Djalmabatista pulchra* (Johannsen) (Table 1). These species are all new records for the Bahamas, with *Tanytarsus mendax* and *Paramerina anomala* new for the Neotropical region.

In the genus *Chironomus*, two morphospecies were determined from larvae and three from exuviae; none of these could be determined to either subgenus or species level and it is possible that more than three species are present in our collection. *Dicrotendipes* sp. A is noted in Epler (2001) from Lake Okeechobee and Suwannee River basin in Florida, but is not yet described so this identification should be considered tentative (John Epler, personal communication, 28 August, 2013). *Polypedilum* specimens key to the subgenus *Tripodura* and *scalaenum* group in both Epler (2001) and Maschwitz and Cook (2000), but larvae cannot currently be identified to species. Reiss (1974) noted *G. fluctans* among dead plant material on central Amazonian lakes and rivers, and artificial ponds on Caribbean islands. *Tanytarsus confusus* is known from creeks, reservoirs, and lakes throughout the eastern US, including Florida, while *T. mendax* is broadly distributed in the Holarctic and is found in ponds, lakes, and creeks (Ekrem et al. 2003). Specimens that key to *T. confusus* do not fit all measurements for this species in Ekrem et al. (2003), leading us to include a "cf." modifier for caution. *Ablabesmyia* (*Sartaia*) *metica* have been associated with macrophytes in southern Brazilian ponds (Oliveira et al. 2008) and a lagoon in central Columbia (Roback 1983). *Ablabesmyia metica* has only been recorded in South America, and *Sartaia* is a monotypic subgenus (Roback 1983; Oliveira et al. 2008). *Labrundinia maculata* is known from ditches, reservoirs, rivers, creeks, and ponds in states including California, Florida, Georgia, Kansas, North Carolina, and Texas, as well as from

Mexico and Trinidad (Roback 1987; Epler 2001). *Paramerina anomala* is known from a northern Florida creek (Beck and Beck 1966), and has been separated from similar exuviae by Roback (1972). Finally, larvae of *Djalmabatista pulchra* are predators of arthropods in rivers, creeks, lakes, and ponds in the eastern and southern USA (Roback and Tennessen 1978).

DISCUSSION

The most comprehensive published database of insects in the Bahamas has been compiled by Kjar et al. (2011) (see also: http://bio2.elmira.edu/bahamas/). However, this resource includes only two entries of Chironomidae. Moreover, one of these entries (*Ceratapogon bahamensis* Johnson) no longer belongs to the family Chironomidae, but instead to the Ceratopogonidae (valid name: *Dasyhelea bahamensis* (Johnson)) (Ronderos et al. 2003). Spies and Reiss (1996) gave a comprehensive overview of Neotropical Chironomidae, including a more accurate assessment of Bahamian chironomid fauna, yet only four valid chironomid species are listed: *Goeldochironomus amazonicus* (Fittkau), *Clunio marshalli* Stone and Wirth, *Ablabesmyia cinctipes* (Johannsen), and *Tanypus neopunctipennis* (Sublette).

Chironominae and Tanypodinae, the two subfamilies collected in our study, each include representative taxa from two tribes (Chironomini and Tanytarsini, and Pentaneurini and Procladiini, respectively). Nine genera and twelve species were collected. Superficially, it appears that the species richness of Chironomidae in surface-water habitats on San Salvador Island is low. Alternatively, and perhaps more realistically, this result of low species richness may merely be a reflection of the narrow snapshot of time in which this study was conducted. We recognize the limited timeframe and geographic range associated with our study and how these may relate to species diversity. However, these limitations indicate a diverse and clearly understudied freshwater aquatic community occurring across the Bahamas. A fourfold increase in chironomids, all new to the archipelago, suggests a rich aquatic macroinvertebrate community. Furthermore, based on general ecological patterns from other archipelago studies (e.g. Egan and Ferrington in review), we would not be surprised if the Bahamian macroinvertebrate community was dominated by Chironomidae.

The discussion to follow will give a general outline of some major drivers that may influence and define the Bahamas chironomid community. Island size and elevation appear to drive diversity differences on Caribbean islands (Bass 2003), as expected from island biogeography and metapopulation theory (MacArthur and Wilson 1967; Hanski 1998), and may partially explain the low species richness found in our study. Other key mechanisms influencing the diversity of Chironomidae populations on islands include climate and weather patterns, island geomorphology, and dispersal capabilities of populations.

Prehistoric patterns of plant and animal community changes across the Caribbean region have occurred based on shifts between cool-arid and warm-moist climatic conditions (Curtis et al. 2001). In recent decades, the Bahamian climate has become drier and warmer, with geology of many islands limiting the ability for water storage (Morrison 2010). This influences habitat available for aquatic insects, particularly those reliant on permanent water sources. When examined at the genus or species level, chironomids are critical indicator organisms that can help determine environmental health in light of recent climate change predictions. Climate change models predict that the Bahamas will experience increased average atmospheric temperature, reduced annual rainfall, increased sea surface temperatures, and potentially heightened tropical storm intensity (Simpson et al. 2012). In addition, rainfall may be greater on islands with higher elevation, while extreme rainfall events during tropical storms may cause strong disturbance, influencing establishment and persistence of some species (Bass 2003). There is no flowing surface freshwater on San Salvador Island, due to its karst geology, which is typical of low, uplift-formed islands (Bass 2003). Therefore, any changes to precipitation and temperature due to climate change could impact habitats and alter aquatic insect communities now and into the future.

Insects are able to disperse between Caribbean islands by flight and wind transport (Bass 2003), which are probably the primary methods of chironomid colonization. Recently emerged adults may also travel between islands on boats, followed by mating and egg deposition in new localities. Additionally, larvae of the marine chironomids, *Clunio* and *Pontomyia*, have been reported as epibionts on the carapace of sea turtles. This suggests that turtle transportation could be an important factor in the dispersal of marine chironomids from one Caribbean island to another (Schärer and Epler 2007).

These climate and weather patterns, island geomorphology, and dispersal capabilities probably interact to influence both geographically broad (Caribbean-wide) and narrow (on small island clusters) metapopulation relationships. Across the Caribbean, Bass (2003) found a limited range of freshwater aquatic invertebrates, with only 19 aquatic dipteran species. These aquatic communities had higher nestedness for islands in close proximity and low degrees of shared communities between more distant islands. More recent studies have shown that individual islands or island groups appear to have highly variable aquatic invertebrate communities, with chironomids generally having low generic diversity on an island scale, yet much broader diversity across the Caribbean region (e.g., Bass 2009). Based on these studies, we would also expect nested chironomid assemblages to occur in a broader survey across Bahamian islands, with low community similarity across island groups and higher overall diversity as the number of islands or island clusters included increases.

CONCLUSION

While species diversity appears low for Bahamian Chironomidae, it is important to consider that very few studies have investigated Chironomidae diversity in the Caribbean region. In contrast, the aquatic insect order Trichoptera has received much more attention in this region. Flint (1992) reported 90 species of Trichoptera from Cuba, 39 species from Jamaica, 42 species from Puerto Rico, and 30 species from Haiti and the Dominican Republic, and 130 species from the Lesser Antilles. While our results document only twelve Chironomidae species, consideration of the small island area and limited aquatic habitat suggests that targeted sampling for Chironomidae across the Bahamas will reveal much greater diversity than previously detected. In this study, we have quadrupled the species richness in the Bahamas by targeted collecting from a single island. In the future, it will be particularly important to sample from various habitats, including terrestrial, phytotelmata and brackish water.

Aquatic insect studies with a restricted geographic range in the Caribbean, or broad taxonomic targets, have generally found low diversity. This limits the present ability to utilize aquatic insects in biological monitoring studies. The current study contributes to the expansion of chironomid research in the Caribbean and Neotropical regions and will hopefully stimulate further studies in this area, which can enhance our understanding of Chironomidae biosystematics and biogeography and the use of these insects for biological monitoring.

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