Dugesiana 20(2): 215-219
Fecha de publicación: 28 de diciembre de 2013

Aquatic insects of Puerto Rico: a list of families

Insectos acuáticos de Puerto Rico: lista de familias

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RESUMEN

Los estudios con insectos acuáticos en Puerto Rico se iniciaron a principios del siglo pasado. La mayoría de los taxa han sido bien documentados; sin embargo, carecemos de información sobre otros taxa y no existe un documento único que contiene toda la información dispersa. Estos son los principales obstáculos que enfrenta el estudio de insectos acuáticos en la isla. En este trabajo realizamos una recopilación de datos recolectados en artículos publicados, tesis de grado, cursos universitarios, estudios de impacto ambiental y una revisión del material depositado en Museo de Zoología de la Universidad de Puerto Rico. El objetivo fue compilar la primera lista de familias de insectos acuáticos de Puerto Rico. En total se registraron 61 familias de siete órdenes de insectos. Los órdenes mejor estudiados han sido Ephemeroptera, Trichoptera y Odonata. El orden más diverso es Diptera, seguido de Coleoptera y Hemiptera. En términos generales, Puerto Rico es una isla diversa comparada con otras islas de las Antillas Mayores, no obstante su tamaño. Este estudio es un primer intento por integrar el conocimiento de los insectos acuáticos en una lista y de esta manera contribuir a mejorar el conocimiento de los insectos acuáticos. Adicionalmente, esperamos que la información ayude a los responsables en la toma de decisiones relacionadas a la conservación, y también incentive los estudios ecológicos y biogeográficos en los ecosistemas acuáticos de Puerto Rico.

Palabras clave: Insectos acuáticos, Antillas Mayores, islas, Puerto Rico, riqueza taxonómica.

ABSTRACT

Studies on aquatic insects in Puerto Rico began early last century. Most taxa have been well documented; however, we lack information on some taxa and there is no single document containing all the scattered information. These are major obstacles for the study of insects on the island. Here we reviewed data collected in published articles, graduate theses, university courses, environmental impact studies and reviewed material deposited in the Museum of Zoology at the University of Puerto Rico. The objective was to compile the first list of aquatic insect families of Puerto Rico. Overall, 61 families belonging to seven insect orders were found. The best known orders were Ephemeroptera, Trichoptera and Odonata. The most diverse orders were Diptera, followed by Coleoptera and Hemiptera. Despite its small size, Puerto Rico is a diverse island compared to the remaining Greater Antilles. This study is the first attempt to develop a list with all information available and contribute to advance our knowledge of aquatic insects. In addition, we hope to aid decision makers and encourage ecological and biogeographical studies on aquatic ecosystems in Puerto Rico.

Key words: Aquatic insects, Greater Antilles, island, Puerto Rico, taxonomic richness.

INTRODUCTION

Aquatic insects are conspicuous components of freshwater ecosystems. Insects play important functions within stream ecosystems and are also indicators of their ecological status, due to their differential responses to changes in the environment (Rosenberg & Resh 1993). Detailed taxonomic studies of local fauna are an imperative initial step toward using aquatic insects in ecological and monitoring studies. In Puerto Rico there is a lack of extensive island-wide taxonomic studies. Most published surveys have been directed at specific taxonomic groups, such as Ephemeroptera, Odonata and Trichoptera. Furthermore, while there is a reference collection at the Zoology Museum at the University of Puerto Rico, Rio Piedras Campus, most specimens were collected in the early to mid-twentieth century and are in need of revision. The collection also needs to be updated and expanded to provide adequate support to future taxonomic and distributional studies.

Puerto Rico, a United States commonwealth since 1898, has a different economic history than other locations in Latin America and in the 1940s the economy of Puerto Rico started to shift from agricultural to industrial (Grau *et al.,* 2003). Along with this shift came rural to urban migrations, which resulted in an increase in natural forest succession on most of the island. Although the 2010 census shows that Puerto Rico is now less populated than in 2000, population density is high and the island is more densely populated than Japan (Hattam 2006). Puerto Rico's urban growth is characterized by urban sprawl around urban centers, a process influencing over 40% of the island (Martinuzzi *et al.,* 2007).

Most urban areas in Puerto Rico are connected to sewage systems and eventually to waste water treatment plants. However, illegal and accidental discharges occur and sewage overflows are common occurrences (particularly after heavy rains). In the context of Latin America, the organic pollution present in most urban river systems on the island is relatively mild (Ramírez *et al.* 2009). The high amount of urbanization and forested areas, along with key waste water legislation, makes Puerto Rico a rare case within the tropics.

These characteristics also represent a unique opportunity to understand macroinvertebrate responses to urbanization. Lessons from Puerto Rico could serve as a model of potential changes in tropical stream ecosystems once organic pollution is reduced.

Given the lack of comprehensive taxonomic studies in Puerto Rico, we present a list of aquatic insect families from Puerto Rico. The goal is to provide a basis of information to encourage the study of aquatic insects, the development of identification guides, and the use of insects in biomonitoring and ecological studies. In addition, we compare and contrast family richness with what has been reported for other islands in the Caribbean.

State of knowledge. One of the pioneers in entomological research in Puerto Rico was George Norton Wolcott, who made intensive collecting expeditions in Puerto Rico and other Caribbean islands between 1910 and 1956. He collected thousands of insect specimens, including aquatic insects that are still deposited in the Museum of Zoology at UPR, and wrote "Insects of Puerto Rico" (Wolcott 1948), which is still the primary reference for most of the current insect groups of the island (Lawrence 2000).

In Puerto Rico, some orders of insects have been extensively studied, including Ephemeroptera, Odonata and Trichoptera. In contrast, other groups have received less attention, such as Hemiptera, Coleoptera and Diptera. Intensive collecting occurred in the first half of last century. Ephemeroptera are relatively well studied due to their reduced taxonomic diversity in Puerto Rico. Traver (1938) reported 20 species in six genera and three families. Peters (1971) revised the family Leptophlebiidae and Lugo-Ortíz & McCafferty (1994) described a new species, *Farrodes taino*. Odonata has also been well studied; initial studies reported 55 species (Klots 1932, García-Díaz 1938), with only minor changes to date (Paulson 2011). Most studies within Hemiptera are focused on water striders (Barber 1939, Drake & Maldonado 1954) with 23 species in five families. Maldonado-Capriles & Navarro (1967) added seven species in five families of non-water strider Hemiptera. For Trichoptera, Flint (1964) presented a comprehensive study with 35 species, 22 genera and ten families. He further expanded this list in 1992 (Flint 1992, Harris & Flint 1992). Lepidoptera and Coleoptera have been poorly studied, aside from studies that presented general lists from a specific site (e.g. Wolcott 1948) and a hydrophilid species described in bromeliads (Hansen & Richardson 1998). Wolcott (1948) published a list of Diptera which was revised and expanded by Maldonado-Capriles & Navarro (1967). Wagner & Masteller (1996) and Wagner *et al.* (2010) described new species of Psychodidae and Hernandez & Courtnet (2010) new Blephariceridae.

MATERIALS AND METHODS

Study site

Puerto Rico (18°15'N, 66°30'W) is an oceanic island in the Caribbean Sea, the smallest and most densely populated island of the Greater Antilles. It has a maritime climate with average temperatures ranging from 25 and 31°C. Average rainfall ranges from 1000mm in seasonally dry areas, where streams are often intermittent, to ~4000mm in humid areas where rainfall is frequent and streams perennial (Calvesbert 1970). Cold fronts and tropical depressions are a major source of weather changes (García-Martinó *et al.* 1996). Even though it is small in size (8900 km^2), it possess a wide range of geomorphological areas with an interior mountain range of volcanic origin with elevations reaching 1338m, alluvial plains near the coasts, and a karst region that covers most of the north of the island (López-Marrero & Villanueva-Colón 2006). Its life zones are dominated by humid subtropical forests, very humid subtropical forests, and dry forest (DRNA 2004). The island has 64 major watersheds, ten of which are intermittent. Also, it has one natural lagoon and around 22 artificial reservoirs which were constructed mainly as potable water sources (DRNA 2004). A great number of fish species have been introduced in these reservoirs for recreational purposes (Neal *et al.* 2009).

Data survey

The data were obtained from our laboratory research collections (http://www.ramirezlab.net/research/prlist), which are the result of numerous academic projects, master and doctoral theses, field courses, and research experience for undergraduates (REU). We also had access to material related to environmental impact studies and other independent research from outside our laboratory. We also consulted the entomology collection at the Museum of Zoology of the University of Puerto Rico, Río Piedras and conducted literature reviews.

To develop a regional context for our findings and understand the state of knowledge of the aquatic fauna of Puerto Rico, we made a comparative analysis of the number of families reported for the Greater Antilles. Publications on the aquatic insects of Cuba, Hispaniola and Jamaica were reviewed to obtain the most complete list of families possible.

RESULTS

A total of 61 families in seven orders of aquatic insects have been reported for Puerto Rico. The most diverse group in the list, at family level, is the order Diptera, followed by Coleoptera and Hemiptera. The list of families divided by order is presented in Table 1.

Our review of the aquatic insect fauna of the Greater Antilles shows that some groups, such as Diptera, Coleoptera and Trichoptera, are dominant in family diversity and are also widely distributed across the Greater Antilles. In contrast, groups like Ephemeroptera and Odonata seem to be more diverse only in the northern most islands, with Puerto Rico housing the lowest number. For example, Cuba and Hispaniola houses at least two more families of Ephemeroptera and three of Odonata, than the remaining island.

It is also difficult to assess how complete is our summary for the Greater Antilles. However, using this information the islands have fairly similar richness of aquatic insect families (Table 2) despite differences in area. The only exception is Jamaica with 32 families. Although this could be the result

of island characteristics, it is more likely the result of limited research or obscure publications rather than a real lack of diversity.

DISCUSSION

Information on aquatic insects of the Caribbean is distributed in many publications and while several past projects compiled information, the literature remains scattered. The list presented here represents a significant advance in the study of aquatic insects of Puerto Rico. This is the first time such a list is compiled using all available information, including collections, manuscripts and technical reports. Our findings suggest that despite its small size, Puerto Rico has a high diversity of aquatic insect families compared to the other islands of the Greater Antilles (Table 2). However, we recommend caution when using these data, as the lists completed from other islands might be still incomplete, perhaps with the exception of Cuba (Muñoz-Riveaux *et al.* 2006, Naranjo *et al.* 2010). In relation to continental areas, Puerto Rico shows the reduced diversity expected from islands and dominance by groups that are able to disperse over long distances.

As in the other Caribbean islands, taxonomic studies in Puerto Rico are the result of the work of a limited group of specialists whose expertise have biased information toward particular groups of taxa. For example, available information on Ephemeroptera, Odonata and Trichoptera is much more abundant than information on other groups. Although there is a clear lack of information on certain groups, we do not expect to find many more families in addition to those reported here for the Caribbean. However, studies at lower taxonomic levels (i.e., genus, species) will certainly result in new reports and even new species to science. The lack of a taxonomic list for the entire Caribbean is a major limitation to the study of aquatic insects in the region.

Island studies have played an important role advancing our knowledge of factors controlling biodiversity patterns on the planet. In depth studies of island faunas were key for the development of the theory of island biogeography by MacArthur and Wilson (1963, 1967). This theory was later extrapolated to forest islands within human-dominated landscapes (Haila 2002) and now plays an important role aiding policy-makers, water quality managers, and conservation practitioners. Many studies have shown clear relations between island area and biodiversity (Bass 2003). In addition, islands have played key roles in understanding biogeographic patterns and linkages between North and South America (Morrone 2006). In the case of Puerto Rico, strong anthropogenic pressures on stream ecosystems (e.g., urban expansion and construction of dams) exacerbate the need to understand patterns in stream biodiversity and the role that organisms play in their ecosystems. In addition, Puerto Rico provides a window into the future for tropical developing countries as they strive to control and manage residual waters and protect their water resources. Stream ecosystems in Puerto Rico are representative of those present in other tropical islands and in some tropical coastal areas.

In conclusion, Puerto Rico has a high diversity of aquatic insects with some well-known groups (Ephemeroptera, Odonata and Trichoptera). Nevertheless, other groups require further research to understand their status or to complete inventories (Coleoptera, Hemiptera and Diptera). While taxonomic studies on the island started a long time ago, most information is scattered and not readily accessible. To our knowledge, this is the first list of aquatic insect families for Puerto Rico. It is our hope that this list will provide a basis for further studies on the ecology, biomonitoring and conservation of aquatic insects in Puerto Rico.

ACKNOWLEDGEMENTS

Special thanks to James Kurtenbach, US Environmental Protection Agency for sharing his data with us. The manuscript was improved with comments by R. Holzenthal and an anonymous reviewer. Our stream research in Puerto Rico is part of the Luquillo Long-Term Ecological Research program (NSF DEB-0620910) and the San Juan ULTRA program (NSF 0948507).

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Recibido: 4 de febrero 2013
Aceptado: 22 de junio 2013

Table 1. List of aquatic insect families reported for Puerto Rico

Order	Family	Order	Family
Ephemeroptera	Baetidae	**Lepidoptera**	Crambidae
	Caenidae	**Coleoptera**	Dytiscidae
	Leptophlebiidae		Elmidae
Odonata	Aeshnidae		Gyrinidae
	Coenagrionidae		Haliplidae
	Lestidae		Hydraenidae
	Libellulidae		Hydrophilidae
	Protoneuridae		Lampyridae
Hemiptera	Belostomatidae		Noteridae
	Corixidae		Ptiliidae
	Gerridae		Scarabidae
	Hebridae		Scirtidae
	Hydrometridae		Staphylinidae
	Mesoveliidae	**Diptera**	Blephariceridae
	Naucoridae		Ceratopogonidae
	Nepidae		Chaoboridae
	Notonectidae		Chironomidae
	Pleidae		Corethrellidae
	Saldidae		Culicidae
	Veliidae		Dixidae
Trichoptera	Calamoceratidae		Dolichopodidae
	Glossosomatidae		Empididae
	Helicopsychidae		Muscidae
	Hydrobiosidae		Psychodidae
	Hydropsychidae		Sciomyzidae
	Hydroptilidae		Simuliidae
	Leptoceridae		Stratiomyidae
	Philopotamidae		Syrphidae
	Polycentropodidae		Tabanidae
	Xiphocentronidae		Thaumelidae
			Tipulidae

Table 2. Family richness in the Greater Antilles.

Order	Cuba*	Hispaniola**	Jamaica***	Puerto Rico
Ephemeroptera	5	3	3	3
Odonata	7	8	7	5
Hemiptera	13	10	2	12
Trichoptera	12	12	11	10
Lepidoptera	1	1	1	1
Coleoptera	10	14	3	12
Diptera	12	15	5	18
Total	**60**	**63**	**32**	**61**

Source: Muñoz-Riveaux *et al*. (2006)*, Perez-Gelabert (2008)**, Hyslop & Hunte-Brown (2012)***