Aquatic insect diversity of Costa Rica: state of knowledge

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Abstract: Costa Rica hosts an extraordinarily high biodiversity and is among the best studied neotropical countries. Insects represent the most diverse group of organisms, not only in terrestrial but also in aquatic, especially freshwater, habitats. Among the most diverse aquatic insect orders are the Trichoptera, Diptera and Coleoptera; although Ephemeroptera can locally also be very abundant and diverse. In Costa Rica, the taxonomically best known orders of aquatic insects are the caddisflies (Trichoptera), dragonflies (Odonata) and stoneflies (Plecoptera) and within the Dipterans, groups of medical importance have received special attention. The interest in aquatic insects has been constantly growing in Costa Rica over the past 10 years, but scientific publications are widely dispersed and often difficult to locate. Due to the importance of aquatic organisms in environmental impact studies and biomonitoring of freshwater habitats, there is an urgent need for comprehensive studies and publications that are locally available. In this sense, the present paper tries to give an overview on the state of knowledge and the literature published to date on the aquatic insects of Costa Rica, taking in account taxonomic, biological and ecological studies. Rev. Biol. Trop. 56 (Suppl. 4): 273-295. Epub 2009 June 30.

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Costa Rica is surely one of the best studied neotropical countries, due to many reasons, including its small size, political stability, conservation areas, and its great variety of climates and ecosystems, leading to an extraordinarily high biodiversity. It is estimated that Costa Rica hosts between 4-5% of the world's biodiversity, although for some groups this percentage is even higher, reaching up to 10% of the world's known species (Obando 2002). This high biodiversity can be found not only in terrestrial, but also in marine and freshwater habitats, and among the latter, aquatic insects represent the most diverse group of organisms. They are abundant in a great variety of aquatic ecosystems and reach their highest diversity in clean, fast flowing mountain rivers and streams. Among the most diverse orders found in these habitats, are the Trichoptera, Diptera and Coleoptera. Another diverse and locally very abundant group is Ephemeroptera, especially in lotic habitats. In Costa Rica, the taxonomically best known orders of aquatic insects are the caddisflies (Trichoptera), dragonflies (Odonata) and stoneflies (Plecoptera). Several aquatic insect species, from different orders, had been described from Costa Rica by the end of the 19th and the beginning of the 20th century (*e.g.* Sharp 1882, Eaton 1892, Calvert 1892-1908, 1911a,b, 1915, 1917, 1920a,b, 1923, Pittier & Biolley 1895, Champion 1897-1901, Cresson 1918, Banks 1914a,b, Navás 1924). A first classical ecological study was carried out by the Costa Rican scientist Clodomiro Picado (Picado 1913), who investigated the aquatic insect fauna living in bromeliad tanks.

Although interest in this particular group of organisms has been constantly growing in Costa Rica over the past ten years, scientific publications are widely dispersed and often

difficult to locate. As analized by Jackson & Sweeney (1995a,b), there exists a significant increase in studies related to tropical freshwater habitats, but the literature is widely scattered, and can be found not only in journals specialized on freshwater biology and ecology (*e.g.* Aquatic Insects, J.N. Am. Benthol. Soc., Freshwater Biology, Hydrobiologia), but also in those dealing with tropical research in general (*e.g.* Revista Biología Tropical, Biotropica, Ecotropica, Studies in Neotrop. Fauna and Environment). The taxonomic literature dealing with aquatic insects is equally dispersed, and species descriptions can be found in general entomological (*e.g*. Systematic Entomology, Ann. Entomol. Soc. Am., Entomol. News, Pan-Pacific Entomologist, Folia Entomológica Mexicana) or taxonomic journals (*e.g.* Proc. Biol. Soc. Wash., Smithsonian Contributions to Zoology, Spixiana), as well as in more specialized ones (*e.g.* The Coleopterists Bulletin, Odonatalogica, Bull. Am. Odonatol.), including proceedings of Symposiums. Finally, many studies remain unpublished in the so-called "grey literature", with very restricted distribution. One important comprehensive study on the aquatic biota of Central America that should be mentioned here, was edited by Hurlbert & Villalobos-Figueroa (1982), consisting in summaries (in spanish and english) on the taxonomic, biological and ecological knowledge of the different aquatic insect orders and families. Unfortunately very little specific information is given for each country of the region and no taxonomic keys are presented.

The lack of local taxonomic keys makes identification of family and genera difficult for the non-specialist, and next to impossible for species. A first identification guide (in Spanish) to the genera of Costa Rican freshwater macroinvertebrates is going to be published soon by our group with the collaboration of over 40 international specialists. An electronic field-guide with pictures of the most commonly collected Costa Rican stream insect families is available on the Internet (http://bdei.cs.umb.edu/keys/html/index.html), and an illustrated field guide of Costa Rican aquatic insect families is being prepared by Springer and Co-workers. An illustrated field guide to the dragon- and damselflies of Costa Rica was published recently by Esquivel (2006). Also, the Webpage from the National Institute of Biodiversity, INBio, hosts information on some aquatic insect species, especially mosquitoes (http://darnis.inbio.ac.cr/ubis). Very important for the development of identification keys for a given region is the establishment of reference collections, which also helps to avoid miss-identifications. Many of the scientific collections at the different Costa Rican institutions (especially Universidad de Costa Rica, Museo Nacional, INBio and Universidad Nacional) hold specimens that belong to aquatic insect orders or families. Also, some biological stations (*e.g*. Maritza, Area de Conservación Guanacaste) and local ONG's (*e.g.* ANAI in the Talamanca-Atlantic Area) host collections of aquatic macroinvertebrates from specific areas. The most complete aquatic insect collection, with emphasis on aquatic stages (mainly immatures), had been established since 1992 at the Museo de Zoología, University of Costa Rica (Springer 1998). This collection includes at the moment over 300 genera in 95 families and 11 orders; a complete and updated list of the genera deposited can be accessed through the Internet page of the Museum (http://museo.biologia.ucr.ac.cr), and a connection via this Webpage to the collection's database with over 12 000 registers is planned for the near future.

Due to the importance of aquatic organisms in environmental impact studies and biomonitoring of freshwater habitats, there is an urgent need for comprehensive studies and publications that are locally available. The present paper intends to help fill this gap by providing an overview of the literature published to date on the aquatic insects of Costa Rica.

Taxonomy

Plecoptera: The stoneflies are represented by just one genus, *Anacroneuria* (Perlidae), with some Costa Rican species described during the early 20th century by Banks (1914a),

Klapálek (1923) and Navás (1924). At the moment, 27 species have been registered for the country, with 18 of them described as new species by Stark (1998). Even though this is one of the smallest groups in terms of species richness, the nymphal stages of almost all species but three remain undescribed. Currently, rearing experiments are being carried out at the laboratory of CIMAR, UCR, resulting in the association of seven additional species of *Anacroneuria* (Gutiérrez & Springer, in prep.).

Odonata: The country's dragon- and damselfly fauna is very well known, especially the adults, but also, to some extent, the immatures. For the 268 species of Odonata existing in Costa Rica, a great amount of taxonomic works have been published (Calvert 1892-1908, 1911a,b, 1915, 1917, 1920a, 1920b, 1923; Calvert & Calvert 1917, Belle 1975, Donnelly 1979, Cannings 1982, Paulson 1982, Garrison 1982, 1985, Donnelly 1984, 1989, Belle 1989, Brooks 1989, Bick & Bick 1990, May 1990, 1992, Esquivel 1991, 1994, Ramírez 1992, 1994a, 1994b, 1995, 1996, 1997a, 1996-1997, Garrison 1992, 1996, Zloty *et al*. 1993, Ramírez & Novelo-Gutiérrez 1994, Bick & Bick 1995, Dunkle 1995, Novelo-Gutiérrez & Ramírez 1995, Förster 1999, Ramírez *et al.* 2000, Hedström and Sahlen 2001, Montero Moreno 2003), and the Costa Rican dragonfly fauna is considered to be the best known of all Latin-American countries (Ramírez *et al*. 2000). Despite this, only half of the species have their nymphal stages described and next to nothing is known about their behavior, natural history, ecology and distribution (Ramírez 1996-1997, Ramírez *et al*. 2000).

Ephemeroptera: A first comprehensive study on the mayfly fauna of Central America was published by Edmunds *et al.* (1976), which includes descriptions of adult as well as nymphal stages and identification keys to the genus level. In 1982, Edmunds published a comprehensive bibliographic revision of the Central American Ephemeroptera. The biogeography of Central American mayflies was also reviewed by McCafferty *et al*. (1992). Descriptions and records for Costa Rican mayfly species (nymps as well as adults) can be found in the following publications: Eaton (1892), Traver (1946, 1947, 1958a,b, 1960), Allen (1966, 1967, 1973, 1978), Traver & Edmunds (1967), McCafferty (1970, 1985), Cohen & Allen (1972, 1978), Flowers & Peters (1981), Waltz & McCafferty (1985, 1999), Flowers (1987), Flowers & Domínguez (1992), Domínguez (1995), Lugo-Ortíz *et al.* (1994), Lugo-Ortiz & McCafferty (1994, 1995a,b,c, 1996a,b,c,d), Baumgardner & McCafferty (2000), Wiersema & MacCafferty (2000), Ávila-A. & Flowers (2005, 2006 a,b), Baumgardner *et al.* (2006) and Baumgardner (2007). A first checklist of species from Costa Rica and Panama was published by Flowers (1992), who also co-described the new genus *Tikuna* (Leptophlebiidae) for Costa Rica (Savage *et al.* 2005), and *Guajirolus* (Baetidae) for Panamá (Flowers 1985), which is now also known from Costa Rica. The new genus *Cabecar* was recently described by Baumgardner & Ávila-A. for Costa Rica (2006). To date, more than 80 species have been collected in Costa Rica, but with the actual ongoing sampling efforts this number is steadily increasing. A species list of Central American mayflies with records for each country can be found at the Website "Mayfly Central" from Purdue University (http://www.entm.purdue.edu/entomology/research/mayfly/mayfly.html), and a comprehensive collection of references is available at "Ephemeroptera Galactica" (http://famu.org/mayfly/).

Hemiptera: From this mainly terrestrial order, 14 families occur in Central America and Costa Rica, which are considered aquatic or semi-aquatic. The aquatic hemipterans had been studied in Central America mainly by Polhemus, who published an overview on each family, and reported the presence of 636 species from 84 genera for Mesoamerica (Polhemus 1982). The same author also described and reported several species from Costa Rica (Polhemus & Hogue 1972, Polhemus 1975, 1976, 1985, Polhemus & Cheng 1976,

Polhemus & Spangler 1989). Other authors who published on Costa Rican Hemiptera species include: Drake 1952 (Veliidae), De Abate 1960 (Notonectidae), Matsuda 1960 (Gerridae), Menke 1963 (Notonectidae), and Spangler 1990b (Mesoveliidae). Some early works were published by Pittier & Biolley (1895), Champion (1897-1901) Hungerford (1939). A checklist of families with marine species (Gelastocoridae, Gerridae, Mesoveliidae, Saldidae, and Veliidae) from the western tropical Pacific, that includes several Costa Rican species, was published by Polhemus & Manzano (1992). Up to date no comprehensive study or species check list had been presented yet on the aquatic hemipteran fauna of Costa Rica.

Megaloptera / Neuroptera: Among the less diverse orders of aquatic insects in Costa Rica are the Megaloptera and Neuroptera (in the past often treated together in Neuroptera as two suborders). While the first (dobsonflies), is entirely aquatic during their larval stage, the second includes only one aquatic family in Costa Rica, the spongillaflies (Sysiridae). Descriptions of some Megaloptera species, a group comprising only one family and three genera in Costa Rica, were published by Glorioso & Flint (1984), Contreras-Ramos (1995), and Flint (1992); a species list for the Neotropics was presented by Contreras-Ramos (1999a). Records for species from both orders from Costa Rica can also be found in Penny (1977). Contreras-Ramos & Harris (1990) published a work on the generic determination of American dobsonfly larvae. Two genera of spongillaflies have been recorded from Costa Rica (Penny 1982), but only very few specimens (larvae) exists in the aquatic entomology collection of the Zoological Museum at UCR. This can probably be attributed to their rather secretive life style, since they are parasitic on and in freshwater sponges, which are not very frequently encountered in Costa Rican freshwater habitats.

Trichoptera: The neotropical caddisfly fauna has been intensively studied especially by O.S. Flint, and his numerous publications include many species from Costa Rica (e.g. Flint 1963a,b, 1967, 1970, 1971, 1972, 1974a,b, 1983, 1985, 1991, Flint & Bueno Soria 1977, 1979, 1987, Flint *et al.* 1987, Flint & Denning 1989). Also, further descriptions of species from Costa Rica can be found in the studies of several other authors (e.g. Mosely 1933, 1949, Yamamoto 1967, Denning & Blickle 1979, Kelley 1983, Bueno Soria 1984a,b, 1985, 1986, 1990, 2004, Hamilton 1986). An extensive inventory of the Costa Rican caddisfly fauna was done by Holzenthal and co-workers, in cooperation with the Institute of Biodiversity (INBio), and resulted in a first checklist (Holzenthal 1988c), which included 174 species. The more than 10-year inventory revealed a great percentage of undescribed species, and even genera, resulting in the description of a vast array of new species (Holzenthal 1988a,b, Holzenthal & Hamilton 1988, Holzenthal & Harris 1989, 1992, 2002, Harris & Holzenthal 1990, 1993, 1994, 1999, Blahnik & Holzenthal 1992a,b, Holzenthal & Strand 1992, Muñoz-Quesada & Holzenthal 1993, 1997, Blahnik 1995, 1998, Holzenthal 1995, Holzenthal & Flint 1995, Muñoz-Quesada 1997, 1999, Bueno-Soria & Holzenthal 1998, 2003, Harris *et al.* 2002, Chamorro-Lacayo 2003, Chamorro-Lacayo & Holzenthal 2004, Holzenthal & Andersen 2004, Prather 2003, 2004, Blahnik & Holzenthal 2006, Holzenthal & Blahnik 2006, Blahnik & Holzenthal 2008, Bueno-Soria & Holzenthal 2008). By 1990 the list included over 400 species, where more than half of these are probably endemic (Harris & Holzenthal 1990). Because of the great percentage of new species encountered, Holzenthal (1988b) estimated the total fauna of Neotropical Trichoptera to be 10 000 species. The catalog of Neotropical caddisflies published by Flint *et al*. in 1999 listed 309 species for Costa Rica, and this number is constantly growing, now reaching over 480 species from 15 families and 55 genera. Information on their distribution can be obtained through the internet pages and databases of the main collections that include Costa Rican caddisflies (INBio,

Minnesota, UCR). Unfortunately, only a few publications include descriptions of immature stages (e.g. Flint 1970, 1971, 1973, 1974a, 1983, Flint & Bueno-Soria 1982, Monson *et al.* 1988, Holzenthal 1988b, Holzenthal & Harris 1989, Muñoz-Quesada & Holzenthal 1997, Holzenthal & Andersen 2004, Blahnik & Holzenthal 2006, Rueda-Martín 2006). A first key (in spanish) to the larval stages of Costa Rican caddisfly families was published by Springer (2006), although for the Costa Rican fauna less then 10% of the larvae have been associated with their adults.

Lepidoptera: Another order that is primarily terrestrial with very few aquatic species is Lepidoptera, although the aquatic groups are especially well developed in Central America (Munroe 1982). In Costa Rica, larvae of the genus *Petrophila* (Crambidae) can very frequently be encountered in streams and rivers, and can be locally very abundant. They scrape algae from the surface of stones and rocks, while other aquatic Lepidoptera larvae feed on vascular plants in standing water, some of them living in portable cases like caddisflies. Very little has been published about this group in Costa Rica, and studies have focused on taxonomic descriptions of adults (*e.g.* Schaus 1920).

For the remaining aquatic insect orders, Coleoptera and Diptera, it is quite difficult (if not impossible) to present a comprehensive revision of the literature, since these two orders are extremely diverse, with many different aquatic or semi-aquatic families. Almost every family has its own taxonomist working on it, which results in wide-spread publications that are often not easy to locate. Therefore the following revision of these two orders is not intended to be complete, but attempts to at least give an overview of the most important aquatic families within each order.

Coleoptera: Early descriptions of aquatic beetle species from several families, collected from Central America, including Costa Rica, were published by Sharp (1882) in the Biologia Centrali-Americana. A checklist of the Coleoptera of Central America, including many species from Costa Rica, was published by Blackwelder (1944), but no recent comprehensive study has been published yet on the aquatic Coleoptera of Costa Rica. A taxonomic review for 18 aquatic and semiaquatic beetle families from Central America is given by Spangler (1982), including a comprehensive revision of the bibliography up to that date.

The most frequently encountered group of beetles in lotic habitats are the riffle beetles (family Elmidae). Neotropical riffle beetles were studied mainly by Spangler, and his publications include several species descriptions and reports from Costa Rica (Spangler 1980, Spangler & Perkins 1989, Spangler & Santiago-Fragoso 1982, 1987, 1992), taking in account both larval and adult stages. Other authors include Hinton (1936), Sanderson (1953), and Brown (1970, 1971, 1973). Recently Springer & Acosta (2003) described the larval stage for the genus *Pharceonus*, previously unknown. Spangler also published on other aquatic beetle families that include Costa Rican species, like Psephenidae (1990a).

Among predaceous water beetles (Dytiscidae), several new Costa Rican species were described by Guignot (1949, 1951, 1952) and Balke (1990), Balke *et al.* (2002), and additional species reports can be found in Zimmerman (1970) and Young (1974, 1977, 1981, 1990). Further descriptions and records of Costa Rican waterbeetles can be found in Ochs (1949) for Gyrinidae, Perkins (1979) Short (2004a,b, 2005a,b), Short & Perkins (2004) for Hydrophilidae, and Perkins (1980) for Hydraenidae, Stribling (1986) for Ptilodactylidae, and Wooldridge (1987), Spangler *et al.* (2001) for Limnichidae and Lutrochidae, Perkins (1997) for Drypodiae, Arce-Pérez & Shepard (2001) for Psephenidae, and Shepard *et al.* (2005) for Lepiceridae. A webpage for the world water beetles can be accessed under: http://www.zo.utexas.edu/faculty/sjasper/beetles, and a species list and key to families for Costa Rican Hydrophiloidea can be found under: http://www.hydrophiloidea.org/home.html.

Diptera: Within the Diptera, more than twenty families have aquatic immature stages, which can be found in a wide variety of aquatic and semi-aquatic habitats. In Costa Rica, groups of medical interest early received special attention, for example the families Simuliidae (*e.g.* Vargas & Díaz-Nájera 1951, Zeledón & Vieto 1957) and Culicidae (*e.g.* Kumm *et al.* 1940, Kumm & Komp 1941, Galindo *et al.* 1951, Galindo & Trapido 1955, Trapido *et al.* 1955). Between 1968 and 1970 a survey of the simuliid populations of 100 streams throughout Costa Rica was carried out by Vargas & Travis (1973). The collections included larvae, pupae and adults, and associations between immature and adult stages were made through rearing. This important investigation led to a variety of taxonomic (Vargas *et al.* 1977, 1980, Vargas and Ramírez-P. 1988, Peterson *et al.* 1988, Ramírez-P. *et al.* 1988), ecological (Travis & Vargas 1978, Travis *et al.* 1979) and epidemiological publications (Travis *et al.* 1974). Vargas also published the first identification keys to Costa Rican mosquito larvae (1956, 1966) and the first taxonomic key to the larvae of aquatic dipteran families of Costa Rica (1974). Other identification keys for this group in Costa Rica were published by: Kumm *et al*. 1940 (Culicidae adults, except *Culex*), Stojanovich *et al.* 1966 (*Anopheles* spp.), Vargas 1975 (*Anopheles* females), and Darsie 1993 (Culicidae, larvae and adults). Further works on Culicidae include Adames & Hogue (1969), Duret (1971), O'Meara *et al.* (1971), the World Health Organization (1971), Hogue (1975), and Vargas & Vargas (2003). A comprehensive book on Culicidae, including species list, identification keys to adults and larvae, together with a list of references, was published by Vargas in 1998. Members of the family Dixidae were originally described under Culicidae (Lane 1942, Belkin *et al.* 1965, Heinemann & Belkin 1977), and an overview of this family for Central America is given by Nowell (1982). Recently, Chaverri & Borkent (2007) published description on new species of Dixidae, including a key to the adult stages of all known species from Costa Rica.

Another family of Diptera that has been intensively studied is Chironomidae, which are supposed to be especially species rich in Costa Rica (de la Rosa, pers.com.). A preliminary survey was published by Watson & Heyn (1992), and more recent taxonomic descriptions of Costa Rican species and genera were published by Spies *et al.* (1994), Andersen & Saether (1995, 1996), Epler & de la Rosa (1995), and Epler (1996 a,b), among others. A catalog and comprehensive revision of the bibliography of neotropical Chironomidae was published by Spies & Reiss (1999), including many species from Costa Rica.

Also very diverse is the family Tipulidae with over 800 species described from the Central American region, and with many more awaiting descriptions (Byers 1982). An early work from Costa Rica was presented by Alexander (1914), who published a great amount of studies on neotropical craneflies (cited in Byers 1982). The immature stages of most species are terrestrial, but many genera have aquatic or semi-aquatic larvae and pupae, although no taxonomic keys are available for their identification in the neotropical region.

Besides the studies mentioned above, there are many more publications on Costa Rican aquatic or semi-aquatic Diptera, especially taxonomic descriptions of adults, like Fairchild 1961, Hogue & Fairchild 1974 (Tabanidae), Mathis 1977 (Ephydridae), Hogue 1979 (Blephariceridae), Murillo & Zeledón 1985, Quate 1996 (Psychodidae), Wirth & Ratanaworabhan 1972, Spinelli & Borkent 2004, Borkent *et al.* 2008 and Borkent & Picado 2004 (Ceratopogonidae), as well as catalogues for different families from the region (Papavero 1976). Even though, still a great amount of species remain undescribed and very little is known on the aquatic immature stages and their biology and ecology.

Finally, it is important to mention the comprehensive work on the "Diptera of Mesoamerica" (Brown *et al.*, in prep.) which will be published in the near future by the INBio editorial, and which also includes descriptions of aquatic life stages.

Biology and life history

Studies on the biology and life history of certain taxa of aquatic insects from Costa Rica have been carried out by several authors. For the order Hemiptera, Stout (1978, 1981, 1982) studied the biology of several species of Naucoridae, Gittelman (1974, 1975) of the family Notonectidae, and the behaviour of water striders was studies by Maier (1977), and Wheelwright & Wilkinson (1985). On the biology, life history and behaviour of certain Odonata species, studies were published by May (1980), Young (1980), Young *et al.* (1980), Hamilton & Montogomerie 1989, Fraser & Herman (1993), Pritchard 1996, Förster (1998), Eberhard (2005), Hedström & Sahlen 2007, Finke & Hedström 2008. Contreras-Ramos (1999b) published notes on life history and mating behavior of dobsonflies (Megaloptera) from Mexico and Costa Rica. De la Rosa found some interesting foretic relationships between the larvae of chironomids (Diptera) and other aquatic insect orders (de la Rosa 1992, de la Rosa & Ramírez 1995, Epler & de la Rosa 1995). A comprehensive investigation on the developmental times of several species of tropical stream insects from Costa Rica was carried out by Jackson & Sweeney (1994, 1995c). Sweeney *et al*. (1995) published aspects of the life history of the mayfly species *Euthyplocia hecuba* (Ephmeroptera: Euthyplociidae); and Young (1985), as well as Flowers & Pringle (1995), investigated seasonal fluctuations in the mayfly population from lowland rainforest streams. Studies on the drift behavior of aquatic insects and macroinvertebrates from Costa Rican streams were carried out by Ramírez & Pringle (1998a, 2001) and Boyero & Bosch (2002). Finally, for marine insects from Costa Rica, a revision was published by Springer (2009).

Ecology, methodology, biomonitoring and distribution

During the past 20 years the number of ecological investigations has also increased. These include comparative studies of diversity patterns (Stout & Vandermeer 1975, Coffman *et al.* 1992), studies of interactions between macro-and meiobenthos (Duft *et al.* 2002), and between aquatic insects and other organisms, like fish and shrimps (Pringle & Hamazaki 1997, 1998), nematods (Fallas & Vargas 1981), algae (Barbee 2005) and fungi (Lichtwardt 1994, 1997, Salazar-Chang 2005). Relationships between the aquatic fauna and their environment have been studied by Benstead (1996), Rosemund *et al.* (1998, 2002), Ramírez *et al.* (1998), Ramírez & Pringle (1998b, 2006), Boyero & Bosch (2004), Ardón *et al.* (2006), Ardón & Pringle (2008), Principe (2008), Tschelaut *et al.* (2008) and Lorion & Kennedy (2009). Other publications deal with the effect of different sampling methods for aquatic stream invertebrates (Paaby *et al.* 1998, Pringle & Ramírez 1998, Stein *et al.* 2008, Springer & Maue 2008).

Studies on the diversity and distribution of aquatic insects in certain habitats or regions of Costa Rica have focused mainly on lotic ecosystems, while relatively few works deal with the invertebrate fauna of lentic freshwater habitats, despite their great diversity and abundance in Costa Rica (Umaña *et al.* 1999). Some of the latter include volcanic lakes (Jimenez & Springer 1994, 1996), and studies of planktonic communities, which include in some cases insect larvae such as the dipteran *Chaoborus* (Umaña 1993, Haberyan *et al.* 1995). Studies on insects living in fitotelmata, like tanks of bromeliads, have been published by Picado (1913), Hogue (1975), Seifert & Seifert (1976), Fish (1977), Gómez (1977), Rotheray *et al*. (2000), Melnychuk & Srivastava (2002), Srivastava *et al.* (2005, 2008), Srivastava (2006), Ngai *et al.* (2008). Biogeographical and ecological notes on the mayfly genus *Tikuna* were recently published by Flowers & Ávila-A. (2006) and accounts on the biogeography on neotropical Megaloptera were presented by Contreras-Ramos (2005).

The composition of the macroinvertebrate fauna of many rivers and streams of Costa Rica have been studied, but the vast majority of these investigations remain unpublished in

the grey literature, such as technical reports (*e.g.* final reports of research projects and reports presented for environmental impact studies), and student papers (*e.g*. field courses of the Organization for Tropical Studies and the University of Costa Rica). Studies published of lotic habitats include surveys of several water sheds (Río San Carlos: Springer 2002, Barrantes *et al.* 2003 a,b, Río Grande del Térraba: Umaña & Springer 2006) and an inventory of aquatic insects on Caño Island (Springer 2004). Notes on aquatic insects from the Monteverde Cloud Forest were published by Ramírez (Odonata) and Springer (Trichoptera) in Nadkarni & Whellwright (1997). An inventory of insects from Cocos Island, based on adult insect collections and including some aquatic taxa was published by Hogue & Miller (1981).

Despite the growing importance of aquatic insects in biomonitoring and environmental impact studies, relatively few works had been published on this important topic in Costa Rica (Charpentier & Tabash 1988, Astorga 1993, Flowers *et al.* 1995, Standley & Sweeney 1995, Fenoglio *et al.* 2002, Castillo *et al.* 2006, Stein *et al.* 2008, Fernández & Springer 2008, Springer & Maue 2008). As is true with the surveys of different Costa Rican habitats, many studies have been carried out in this particular field of interest, but most of them never get published in scientific journals. Recently, two pictured guides for biomonitoring had been published, enfazising on Atlantic lowland streams and rivers (Mafla Herrera 2005, Springer *et al.* 2007).

Finally, it is important to take to account the several Master and PhD-thesis dealing with aquatic insects that have been carried out in Costa Rica, both by local and foreign students. These can be found at the libraries of the different Universities (UCR, UNA, TEC, EARTH and CATIE) and also at the OTS library. Unfortunately the majority of them have not been published in scientific journals.

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RESUMEN

Costa Rica alberga una biodiversidad extraordinaria y se encuentra afortunadamente entre los países neotropicales mejor estudiados. Los insectos representan el grupo más diverso de organismos, no solamente en hábitats terrestres, sino también en hábitats acuáticos, especialmente de agua dulce. Entre los órdenes de insectos acuáticos más diversos se encuentran Trichoptera, Diptera y Coleoptera; aunque Ephemeroptera también puede llegar a ser localmente abundante y diverso. En Costa Rica, los grupos taxonómicamente mejor conocidos son los tricópteros, los odonatos y los plecópteros; además, en los dípteros, han recibido mayor atención aquellos de importancia médica. El interés en los insectos acuáticos ha aumentado constantemente durante los últimos diez años en Costa Rica. Sin embargo, las publicaciones científicas se encuentran muy dispersas y en muchos casos difíciles de localizar. Debido a la importancia de los organismos acuáticos en estudios de impacto ambiental y biomonitoreo de ecosistemas de agua dulce, existe una gran necesidad por estudios comprensivos y publicaciones que sean localmente accesibles. Por lo tanto, el presente trabajo trata de proveer una sinopsis sobre el estado de conocimiento y la literatura publicada hasta la fecha sobre los insectos acuáticos de Costa Rica, tomando en cuenta tanto trabajos taxonómicos, como biológicos y ecológicos.

Palabras clave: insectos acuáticos, taxonomía, ecología, historia de vida, biomonitoreo, inventario, Costa Rica, bibliografía.

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