Limnetica, 43(1): 75-88 (2024). DOI: 10.23818/limn.43.06
© Asociación Ibérica de Limnología, Madrid. Spain. ISSN: 0213-8409

Freshwater microcrustaceans of Hispaniola: new records and potential as biological control agents

Carla Olmo[1], Juan Rueda[2], María Altagracia Rodríguez-Sosa[2], Mikel A. González[2] and Pedro María Alarcón-Elbal[2,*]

[1] GRECO, Institute of Aquatic Ecology, University of Girona, Girona, Spain.
[2] Instituto de Medicina Tropical & Salud Global, Universidad Iberoamericana (UNIBE), Santo Domingo, Dominican Republic.

[*] Corresponding author: pedro.alarcon@uv.es

Received: 10/11/22 Accepted: 08/03/23

ABSTRACT

Freshwater microcrustaceans of Hispaniola: new records and potential as biological control agents

Some species of freshwater microcrustaceans have been widely used for biological control of mosquito larval populations. These zooplankton communities play an important role against some species of mosquitoes by exerting competitive pressure or predation. However, zooplankters are scarcely studied in many Caribbean islands such as Hispaniola. The goal of this study was to improve the knowledge of these microcrustaceans in order to better understand the biodiversity and ecology of this Antillean Island. Samples of zooplankton were taken from 28 ponds in the northern Dominican Republic during 2020. The total richness of microcrustaceans was 25 species, comprising 17 copepods and 8 cladocerans. Most of the collected species were previously described for the island, and some of them are registered as potential biological controllers of mosquito larvae populations. Five genera (including 6 species) of microcrustaceans that inhabit the ponds are recorded for the first time for Hispaniola: *Simocephalus* Schoedler, 1858; *Pleuroxus* Baird, 1853; *Ilyocryptus* G.O. Sars, 1861; *Apocyclops* Lindberg, 1942; and *Diacyclops* Kiefer, 1927. Here, we discuss these new findings in relation to the competitive and/or predatory potential of these species against mosquito larvae. The present study improves the knowledge of biodiversity in ponds in the Dominican Republic.

Key words: ponds, zooplankton, mosquitoes, Dominican Republic, Antilles

RESUMEN

Microcrustáceos dulceacuícolas de La Hispaniola: nuevos registros y potencial como agentes de control biológico

Algunas especies de microcrustáceos dulceacuícolas se han utilizado ampliamente para el control biológico de poblaciones de larvas de mosquitos. Estas comunidades de zooplancton desempeñan un importante papel contra algunas especies de mosquitos ejerciendo presión competitiva o depredación. Sin embargo, el zooplancton está escasamente estudiado en muchas islas del Caribe, como La Hispaniola. El objetivo de este estudio fue mejorar el conocimiento de estos microcrustáceos para comprender mejor la biodiversidad y la ecología de esta isla antillana. Se tomaron muestras de zooplancton en 28 charcas del norte de la República Dominicana, durante el año 2020. La riqueza total de microcrustáceos fue de 25 especies, que incluyeron 17 copépodos y 8 cladóceros. La mayoría de las especies capturadas fueron descritas previamente para la isla, y algunas de ellas están registradas como potenciales controladores biológicos de las poblaciones de larvas de mosquitos. Se aportan por primera vez 5 géneros (incluyendo 6 especies) de microcrustáceos que habitan en las lagunas de La Hispaniola: Simocephalus *Schoedler, 1858;* Pleuroxus *Baird, 1853;* Ilyocryptus *G.O. Sars, 1861;* Apocyclops *Lindberg, 1942; y* Diacyclops *Kiefer, 1927. Se discuten estos nuevos hallazgos en relación con el potencial competitivo y/o depredador de estas especies contra las larvas de mosquitos. El presente estudio contribuye a mejorar el conocimiento de la biodiversidad en las charcas de República Dominicana.*

Palabras clave: *charcas, zooplancton, mosquitos, República Dominicana, Antillas*

INTRODUCTION

For decades, the number of different types of water bodies has been dramatically reduced worldwide in order to diminish the organisms which are vectors of pathogens that cause diseases such as malaria (Le Prince, 1915), by far the most lethal vector-borne disease in humans (Franklinos et al., 2019). Ponds, lagoons, and wetlands were frequently desiccated due to their role as sources of mosquitoes that can transmit diverse pathogens of medical and veterinary interest (Carlson et al., 2004; Malan et al., 2009). Trying to couple aquatic biodiversity protection with the control of vector populations, some non-harmful techniques such as biological control methods have been applied to different water bodies.

One of these methods is the use of microcrustaceans of the order Cyclopoida, which share habitats with pestiferous species within the Nematocera suborder (Blaustein & Chase, 2007). Negative effects from interactions such as predation between these crustaceans and mosquitoes represent natural methods of population control (Blaustein & Margalit, 1994; Marten & Reid, 2007; Kroeger et al., 2013). Cyclopoida have been widely tested in laboratory and field experiments and are among the most voracious predators of first and second instars of mosquito (Diptera: Culicidae) larvae (Kumar & Ramakrishna Rao, 2003; Marten & Bordes, 2004; Marten & Reid, 2007; Kumar et al., 2008; Soumare & Cilek, 2011; Cuthbert et al., 2018a, 2018b). Only large-body cyclopoids (> 1.4 mm) from the genera *Acanthocyclops* Kiefer, 1927, *Diacyclops* Kiefer, 1927, *Megacyclops* Kiefer, 1927, and *Macrocyclops* Claus, 1893, seem to be efficient at preying on mosquito larvae (Marten et al., 2004; Marten & Reid, 2007). Other microcrustaceans that inhabit water bodies are the Calanoida copepods, which share feeding resources with mosquito larvae, but overall, they are not able to prey on them (Marten & Reid, 2007). Nevertheless, Cuthbert et al. (2018) observed the predatory behaviour of the freshwater calanoid species *Lovenula raynerae* Suárez-Morales, Wasserman, & Dalu, 2015, on larvae of *Culex pipiens* Linnaeus, 1758. Other zooplankters, such as cladocerans, also share feeding habits with mosquito larvae. The macrofilter cladoceran *Daphnia magna* Straus, 1820, has been experimentally tested against mosquito establishment, and it has been proven as a proficient inhibitor of *Cx. pipiens* oviposition (Duquesne et al., 2011). With all this ecological evidence, zooplankton communities become an important actor against immature stages of mosquitoes.

There is limited information about freshwater zooplankton in the continental and insular Caribbean. The main efforts have been focused in south-eastern Mexico (e.g. Cervantes-Martínez & Gutiérrez-Aguirre, 2015; Gutiérrez-Aguirre & Cervantes-Martínez, 2016; Cervantes-Martínez et al., 2018) or, more recently, in Costa Rica (Gálvez et al., 2020, 2022). However, the freshwater zooplankton of the Caribbean islands is still poorly studied or the information is outdated (e.g. Collado et al., 1984), except in Cuba (Menéndez Díaz et al., 2004; Fimia-Duarte et al., 2016a, 2016b). In Hispaniola, Perez-Gelabert (2020) provides the latest checklist for zooplankton, including 24 species of the suborder Cladocera (only 3 species of the family Daphniidae), 4 species of the order Calanoida, and 31 species of the order Cyclopoida. Nevertheless, it is expected that biodiversity is greater, as the previous studies were carried out only in coastal brackish lakes in Haiti (Collado et al., 1984), and in bryophytes (Acosta-Mercado et al., 2012).

Highlighting the predatory and competitive potential of this group of organisms, it is key to explore the regional richness, densities, and distribution of zooplankters throughout unexplored territories, where water systems are frequently threatened and disregarded. Therefore, different ponds in the Dominican Republic were sampled for microcrustaceans in order to identify potential species for biological control of mosquitoes (via predation or competition).

METHODS

Study area

The study was carried out in the Cibao Valley in the northern Dominican Republic (Fig. 1). It extends about 235 km, from Manzanillo Bay (Monte Cristi Province, bordering Haiti) in the west to Samana Bay (Samana Province) in the east. The mountain ranges of the Cordillera Septentrional

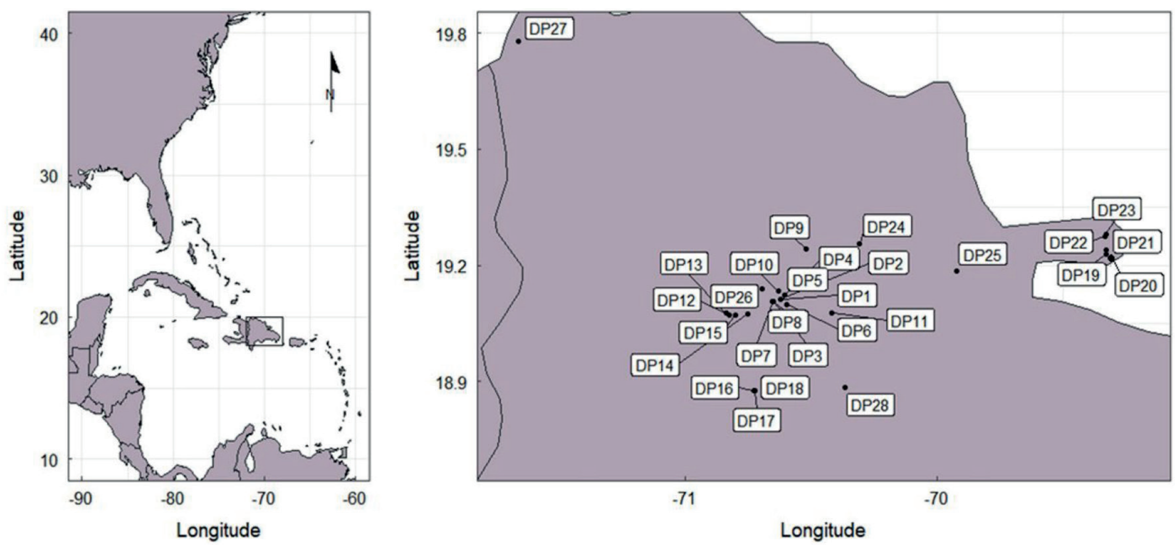

Figure 1. Location of ponds in the study area of Hispaniola. *Localización de las charcas en la zona de estudio en La Hispaniola.*

and the rugged Cordillera Central bound the Cibao Valley on the north and south, respectively. It has two climatic zones: the drier western section, traversed by the Yaque del Norte River, which includes savanna vegetation with patches of low, thorny bushes, and the east, watered by the Yuna River, which is the humid and fertile La Vega region. Cibao Valley is the main agricultural area of the Dominican Republic: the main crops are wheat, rice, bananas, coffee, tobacco, cacao, and corn. Additionally, there are multiple ecosystems that host important biodiversity in this Caribbean region that comprises a wide altitudinal range (0-3098 m a.s.l.) (The World Bank, 2022).

Zooplankton sampling and identification

The water environment of the Cibao is complex and includes many types of lentic water bodies, such as ditches, seeps, ponds, lagoons, seasonal pools, basin marshes, and lakes, among others. The study was focused on ponds, which are a type of small, shallow water body (< 10 ha and < 8 m depth) (Grillas et al., 2004), overall formed by intermittent hydroperiods (ephemeral, seasonal, or yearly). Sampling sites were selected by searching on Google Earth followed by a field survey. The final selection of sites was determined by the verification of the state of the water body (in some cases, it could be dry or non-existent) and its accessibility (Fig. 1).

The study included copepods (Crustacea: Maxillopoda) and cladocerans (Crustacea: Branchiopoda) because they have been rarely investigated in this country, as shown by the scarcity of references in the most recent checklists of Hispaniola (Perez-Gelabert, 2020). Zooplankton qualitative samples were taken with a hand-net of 105 µm mesh size covering most of the possible microhabitats in 28 accessible ponds (DP1-DP28) of the Cibao Valley between the end of October and the second half of November 2020. Samples were immediately fixed and preserved with 70 % ethyl alcohol. At each sampling point, we recorded the geographical coordinates (WGS84). In addition, we measured the temperature (°C), conductivity (µS/cm), and pH of the water using a portable multiparameter HM DIGITAL® EC-3 equipment at each location. We also measured the depth (cm) of each water body.

Organisms were first identified with a Leica M205C stereomicroscope and then under a Leica DMIL LED inverted microscope. When needed, individuals were dissected. The identification of cladocerans (Calanoida) and copepods (Cyclopoida) were carried out by appropriate keys

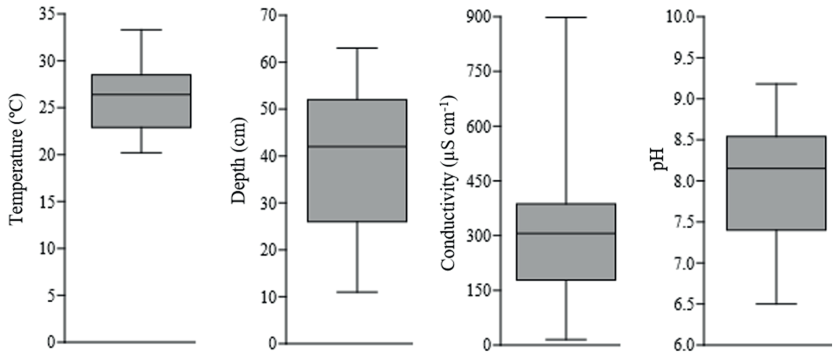

Figure 2. Boxplots with the environmental variables for the whole set of sampled ponds. The boundaries of the boxes indicate the 25th and the 75th percentiles; lines within the boxes mark the median. Whiskers (error bars) indicate the 90th and 10th percentiles. *Diagramas de cajas con las variables ambientales para el conjunto de charcas de estudio. Los límites de las cajas indican los percentiles 25 y 75; la línea dentro de cada caja indica la mediana. Los bigotes (barras de error) indican los percentiles 90 y 10.*

(Elías-Gutiérrez et al. 2008). Immature stages of mosquitoes were identified with the key of González Broche (2006).

The collected material is deposited in the Aquatic Entomology Collection, Department of Microbiology and Ecology, University of Valencia, Spain.

RESULTS AND DISCUSSION

The 28 studied ponds (Fig. 1) were shallow (< 75 cm), freshwater (maximum conductivity of 898 µS/cm), and slightly basic (pH of 8.0 ± 0.7). The range of water temperature during the samplings was between 20.2 and 33.3 ºC (Fig. 2). More information on limnological variables of each studied pond is displayed in Supplementary material (Available at http://www.limnetica.net/en/limnetica).

Zooplankton richness per pond was generally low (average of 2.1 ± 1.2 species). The richest ponds were DP8 and DP17, containing five species (Table 1). No species appeared in all ponds, but some organisms (i.e. the copepodites of cyclopoids) were frequently detected in 13 of the 28 ponds. Also, the calanoid copepod *Arctodiaptomus dorsalis* (Marsh, 1907) and its juveniles were common. The remaining species appeared at low frequencies (≤ 5 ponds). This low richness was also observed by Collado et al. (1984) on the island. The previous authors described 23 cyclopoid species and 18 cladoceran species collected in one sampling campaign from around 20 water bodies distributed throughout the Dominican Republic and Haiti. Six species of organisms that appeared in our sampling campaign (four cyclopoids: *Macrocyclops albidus* (Jurine, 1820), *Ectocyclops phaleratus* (Koch, 1838), *Mesocyclops longisetus* (Thiébaud, 1912), *Thermocyclops oithonoides* (Sars G.O., 1863); two cladocerans: *Ceriodaphnia cornuta* (Sars, 1885) and *Moinodaphnia macleayi* (King, 1853) were cited 36 years ago. Nevertheless, common cladoceran species from the genera *Chydorus* Leach, 1816, or *Diaphanosoma* Fisher, 1850, which were described for Haitian water bodies, were not present in the studied ponds. On the other hand, well-distributed species such as the calanoid copepod *A. dorsalis*, which was very frequent in Cuba (Smith & Fernando, 1978), were also absent in Collado et al. (1984). A scarcity of Branchiopoda was also recently recorded in other Caribbean islands such as St. Maarten (Soesbergen & Sinkeldam, 2019). It is interesting to note that our study only shares one Cyclopoida species (*Ectocyclops phaleratus*) with Acosta-Mercado et al. (2012), but the latter focused on zooplankton communities inhabiting bryophytes.

The total number of microcrustacean taxa recorded in the ponds was 25, including 16 cyclopoid species, one calanoid species, and 8 cladoceran species (Table 1). Six species were never

Table 1. Zooplankton species, their frequencies in the study area and total richness per pond. In bold and underlined, the new genus and new species, respectively. Abbreviation "Freq" corresponds to frequency of each species at the total set of studied ponds. *Especies de zooplancton, sus frecuencias en el área de estudio y la riqueza total por charca. En negrita y subrayado, los nuevos géneros y nuevas especies, respectivamente. La abreviación "Freq" corresponde a la frecuencia de cada especie para el total de las charcas estudiadas.*

	DP1	DP2	DP3	DP4	DP5	DP6	DP7	DP8	DP9	DP10	DP11	DP12	DP13	DP14	DP15	DP16	DP17	DP18	DP19	DP20	DP21	DP22	DP23	DP24	DP25	DP26	DP27	DP28	Freq
Cyclopoid																													
Cyclopoid nauplii			X					X									X										X		**4**
Cyclopoid copepodite		X		X	X		X	X			X						X		X		X		X		X		X	X	**13**
***Apocyclops* sp.**											X			X	X											X	X		**5**
Apocyclops* cf. *dimorphus																					X						X		**2**
Cyclopoid sp. 2							X																						**1**
Cyclopoid sp. 3																												X	**1**
Cyclopoid sp. 4																					X								**1**
Cyclopoid sp. 5								X																					**1**
Ectocyclops cf. *phaleratus*				X	X								X																**3**
Diacyclops ecabensis								X																					**1**
Macrocyclops sp.												X	X																**2**
Macrocyclops albidus		X		X																									**2**
Mesocyclops cf. *longisetus*								X			X																		**2**
Mesocyclops sp. 1										X									X	X					X				**4**
Mesocyclops sp. 2																						X	X						**2**
Metacyclops sp.																	X												**1**
Microcyclops sp.			X																										**1**
Thermocyclops cf. *oithonoides*																		X	X										**2**
Calanoid																													
Calanoid nauplii									X																				**1**
Calanoid copepodites		X				X			X		X						X	X	X										**7**
Arctodiaptomus dorsalis	X	X			X	X	X				X					X	X	X											**9**
Harpacticoid																	X												**1**
Cladocerans																													
Ceriodaphnia cornuta																X	X												**2**
Ilyocrytus* cf. *spinifer			X			X					X								X	X									**5**
Kurzia cf. *media*				X															X										**2**
Moina sp.																		X							X				**2**
Moina micrura																											X		**1**
Moinodaphnia macleayi								X	X								X							X				X	**5**
Pleuroxus quasidenticulatus								X																					**1**
Simocephalus* cf. *mixtus																X													**1**
RICHNESS	**1**	**2**	**2**	**3**	**2**	**2**	**2**	**5**	**1**	**1**	**4**	**1**	**2**	**1**	**1**	**3**	**5**	**3**	**4**	**2**	**2**	**1**	**1**	**1**	**2**	**1**	**3**	**2**	
Culicidae																													
Aedes scapularis									X																			X	**2**
Anopheles albimanus			X		X					X												X			X	X		X	**6**
Anopheles grabhamii										X		X																	**2**
Anopheles crucians													X																**1**
Culex atratus		X						X							X	X	X					X		X		X			**7**
Culex corniger															X														**1**
Culex garciai																X													**1**
Culex nigripalpus		X						X	X	X									X				X			X		X	**8**
Culex secutor		X						X				X		X												X			**5**
Psorophora confinnis									X											X								X	**3**
Uranotaenia sapphirina								X							X														**2**
RICHNESS	**0**	**3**	**1**	**0**	**1**	**0**	**0**	**4**	**3**	**3**	**0**	**2**	**1**	**1**	**3**	**2**	**1**	**0**	**1**	**1**	**0**	**2**	**1**	**1**	**1**	**4**	**0**	**4**	

described before for Hispaniola, and five of them were also new genera not previously cited. It is reasonable to think that the number of new taxa could be even higher, as some organisms were recorded in low numbers, and it was not possible to identify some of them at the species level (e.g. 4 unidentified cyclopids). The rest of the identified taxa were included in the recent checklist of Perez-Gelabert (2020). Therefore, more samplings at other hydroperiod moments could help to collect more specimens to confirm the contributions recorded in this study.

Regarding cladocerans, 3 new genera were new records for the island: *Simocephalus* Schoedler, 1858 (*S. mixtus* Sars, 1903), *Ilyocryptus* G.O. Sars, 1861 (*I. spinifer* Herrick, 1882), and *Pleuroxus* Baird, 1853 (*Picripleuroxus* Frey, 1993) (*P. quasidenticulatus* Smirnov, 1996).

Simocephalus (*S. mixtus*): According to Kotov et al. (2019), the genus *Simocephalus* (Daphniidae family) contains 24 species. It has a relatively large body size and a cosmopolitan distribution, like cladocerans from the genus *Daphnia* O.F. Müller, 1785. *Simocephalus mixtus* shares similar size and feeding habits with its congener *S. vetulus* (O.F. Müller, 1776) (2.7 mm size). Both species have been frequently mistaken, as they only differ in two morphological traits: *S. mixtus* has a larger prominence in the posterior end of its valve and a deeper depression on the ventral margin of its head (Elías-Gutiérrez et al., 2008). In addition, the presence of hybrids is common in this genus (Hann, 1987), which complicates their correct identification at the species level. Collado et al. (1984) collected *S. vetulus* in Cuba and Jamaica, but it has never been reported in Hispaniola (Perez-Gelabert, 2020). On the other hand, the presence of *S. mixtus* was recently recorded

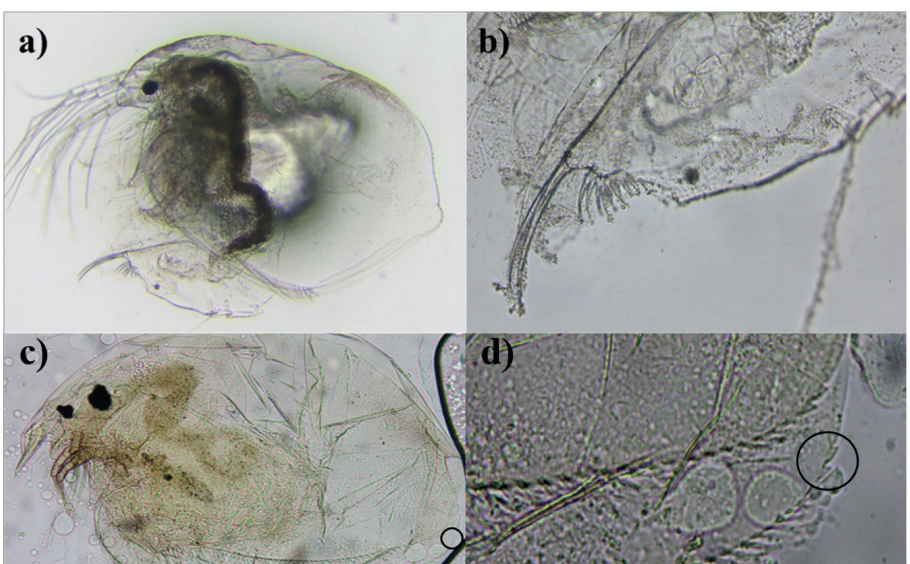

Figure 3. Pictures of some of the new species found on Hispaniola island. (a) Female of *Simocephalus mixtus* at 4× magnification, (b) detail of postabdomen in *S. mixtus* at 20× magnification, (c) female of *Picripleuroxus quasidenticulatus* at 4× magnification, and (d) detail of denticles in *P. quasidenticulatus* at 20× magnification. Circles in (c) and (d) denote the denticles in the posterior-ventral angle of the carapace valve. *Fotografías de algunas de las nuevas especies encontradas para la isla La Hispaniola. (a) Hembra de* Simocephalus mixtus *a 4× aumentos (b) detalle del postabdomen de* S. mixtus *a 20× aumentos, (c) hembra de* Picripleuroxus quasidenticulatus *a 4× aumentos, y (d) detalle de los dentículos de* P. quasidenticulatus *a 20× aumentos. Los círculos en (c) y (d) enmarcan los dentículos de la zona ventral posterior de las valvas.*

in south-eastern Mexico (Elías-Gutiérrez et al., 2001) and was commonly found in ponds in Costa Rica and Nicaragua (Gálvez, personal communication). In our samples, five parthenogenetic females (Fig. 3a, 3b) were collected coexisting with another planktonic species from the same family (i.e. *C. cornuta*).

Ilyocryptus (*I. spinifer*): The genus *Ilyocryptus* has a worldwide distribution (Kotov et al., 2019). It is the only representative of the Ilyocryptidae family and includes 38 species. This genus is characterized by antennules with two segments and a group of long plumose setae located at the bottom margin of the carapace valve. Most of the species within this genus do not discard the old, moulted valves, which can be perceived as concentric lines. *I. spinifer* was found in five ponds in our study area (containing between one and 26 individual parthenogenetic females). Our specimens did not exhibit concentric lines, which is the main diagnostic characteristic used to separate *I. agilis* from *I. spinifier* Kurz, 1878 (Elías-Gutiérrez et al., 2008). However, unlike in the common *I. sordidus* (Liévin, 1848), the antennule in our collected individuals was 8-10 times longer than it was wide, which is characteristic of *I. spinifer*. A worldwide study of morphology confirmed that this species is Neotropical (Kotov & Dumont, 2000). Consequently, this species has been recorded in several countries of Central and South America and the Caribbean (Collado et al., 1984; Kotov & Dumont, 2000; Elías-Gutiérrez et al., 2008; Elmoor Loureiro, 1997). Moreover, *I. spinifer* was collected from seven of the 18 Caribbean islands analysed, except in Hispaniola (Acosta-Mercado et al., 2012). Generally, members of this genus inhabit the benthonic part of water bodies as they collect small particles at the bottom sediments or from submerged plants (Fryer, 1974).

Pleuroxus subgenus *Picripleuroxus* [*P. (Picripleuroxus) quasidenticulatus*]: This is considered one of the most difficult genera to determine at the species level (Smirnov et al., 2006), as it comprises a group of sibling species that can be only separated based on ephippial morphologies of females or males (Sinev & Sanoamuang, 2013). In fact, there are numerous discrepancies between taxonomists about how to split *Pleuroxus* into the subgenus *Picripleuroxus* (Smirnov et al., 2006), which would include eight species (Kotov et al., 2019). Some taxonomic studies have shown that differences among both subgenera are due to thoracic limbs (Chiambeng & Dumont, 2004) and/or the body shape, which is more elongated in *Picripleuroxus*. Most of the species of both subgenera present one or several denticles in the posterior-ventral angle of the carapace valve (also the third subgenus *Tylopleuroxus* Frey, 1993). Our single collected specimen had two denticles (Fig. 3c) and was a parthenogenetic female. It seems clear that the two denticles in the carapace were pointing towards the rear of the animal (Fig. 3d), which is a morphological trait that contrasts with *P. denticulatus* Birge, 1879 (Elías-Gutiérrez et al., 2008). Moreover, our described specimen presented a straight dorsal margin of the postabdomen with numerous anal teeth, many of which were double, differing from *P. denticulatus*, which has larger clustered anal teeth in the dorsal distal margin of the postabdomen (Bledzki & Rybak, 2016). Neither Collado et al. (1984) nor Acosta-Mercado et al. (2012) found either of the two subgenera in the Caribbean islands, while Elías-Gutiérrez et al. (2008) recorded them in some locations of Mexico and Gálvez et al. (2020) recorded another species, *P. varidentatus* Frey, 1993, in ponds from Nicaragua and Costa Rica. In order to reach a more accurate identification of this species, more individuals should be sampled. Smirnov et al. (2006) suggested that new genetic studies for this genus are needed for the construction of a reliable phylogenetic tree. Finally, the species *P. quasidenticulatus* is generally associated with macrophytes in the littoral zones in ponds (Sinev & Sanoamuang, 2013).

Regarding cyclopoids, 3 species belonged to 2 newly recorded genera for the island: *Apocyclops* Lindberg, 1942 [*Apocyclops* sp. and *A.* cf. *dimorphus* (Kiefer, 1934)] and *Diacyclops* Kiefer, 1927 (*D. ecabensis* Fiers, Ghenne, & Suárez-Morales, 2000).

Apocyclops (*Apocyclops* sp. and *Apocyclops* cf. *dimorphus*): Two species of this genus were collected; however, only one was identified at the species level. *Apocyclops* sp. was found in five ponds located within 50 km of the centre of the country, while *A.* cf. *dimorphus* was spotted in one pond in the northeast. The genus *Apocy-*

clops has a tropical distribution, but its presence was reported in the Iberian Peninsula as a recent colonization (Miracle et al., 2010). In fact, this genus was not cited in the identification key for European freshwater crustacean zooplankton (Bledzki & Rybak, 2016). On the other hand, the northern species *A. dengizicus* (Lepeshkin, 1900) was located in Lake Siletiteniz (53 °N) in northern Kazakhstan, the known northern limit for this genus (Gusakov, 2011), and was recorded by Reid et al. (2002) in North America and the Caribbean. In the Neotropical region, *A. panamensis* (Marsh, 1913) is the most widespread species of this genus (Reid, 1990; Reid et al., 2002). It has been recorded in the Yucatan Peninsula, along the northern coast of South America, and on Caribbean islands such as Cuba and the Lesser Antilles (Suárez-Morales et al., 2004). The morphological trait used to determine the genus was the fifth leg, which is characterized by a broad terminal segment with a short apical spine and an external seta twice as long as the spine (Elías-Gutiérrez et al., 2008). The nauplii of *Apocyclops* are especially indicated for the diet of juvenile fish in aquaculture; this is why several studies have been carried out to obtain cultures of different species of this genus (Miracle et al., 2010). These juveniles are normally fed with microalgal diets (Farhadian et al., 2008; Nielsen et al., 2021); however, the feeding ecology of the adults is still poorly known.

Diacyclops (*D.* cf. *ecabensis*): This genus is the richest among the family Cyclopidae and is considered to be very ubiquitous (Stoch, 2001). Some cosmopolitan species of this genus, such as *D. bicuspidatus* (Klaus, 1857) and *D. bisetosus* (Rehberg, 1880), are especially abundant in temporary ponds (Champeau, 1966). According to Stoch (2001), there are more than 100 species of *Diacyclops*; however, wide regions of the planet, such as Central and South America, are underexplored, so the number of species of the genus could be greatly underestimated. In fact, the species *D. ecabensis* was described for the first time only 22 years ago from man-made wells in the Yucatan Peninsula (Fiers et al., 2000). Six or more species of the genus can coexist in the same sampling area (Stoch, 2001). A single female species was found in a pond in our study, so the identification must be corroborated with more individuals of both sexes. *D. ecabiensis* is a small species within the genus; the length of females ranges from 833 to 848 µm (Fiers et al., 2000), which fits with the collected individual and contrasts with other species, such as *D. bisetosus*, that exhibit larger size (0.84-1.50 mm) (Dussart, 1969). The fifth leg was typical for *Diacyclops*; however, more individuals are needed to confirm the species and distinguish it from other species from the genus, such as *D. pilosus* Fiers, Ghenne, & Suárez-Morales, 2000, which are broadly similar in several morphological traits to our collected individual. As it represents a recent finding, further studies are needed in order to better define the ecological requirements and the feeding habits of this species.

It is well known that all the new taxa and most of the already described species for Hispaniola are also present in the Yucatan Peninsula, whose water bodies have been extensively studied (Farhadian et al., 2008; Elías-Gutiérrez et al., 2008). This south-eastern region of Mexico, together with the Peninsula of Florida, is the closest continental region to the Caribbean island. It implies that the Yucatan Peninsula would probably have been one of the historical sources of zooplankton propagules, which could be dispersed by anemochory and zoochory and colonize the sinks as water bodies in these islands.

Some of the zooplankton species collected share habitats and feeding resources with mosquito larvae from the genera *Aedes* Meigen, 1818, *Anopheles* Meigen, 1818, *Culex* Linnaeus, 1758, *Psorophora* Robineau-Desoidy, 1827, and *Uranotaenia* Lynch Arribálzaga, 1891. The total richness of mosquitoes was 11 species. Mosquito richness per pond was low (average of 1.4 ± 1.3 species). The richest ponds were DP8 (coincident with zooplankton richness), DP26 and DP28, containing four mosquito species. No species appeared in all ponds, but some species were very frequent, such as *Anopheles albimanus* Wiedemann, 1820, and *Culex nigripalpus* Theobald, 1901, which were found in 6 and 8 sampling points, respectively (Table 1).

In recent years, several studies have been carried out on the mosquito fauna of the Cibao region. Many of these have focused on synanthropic mosquito species, which inhabit in domestic environments and develop in small and medium-sized artificial reservoirs, such as barrels, buckets, drinking troughs, and tanks, among others (Alarcón-Elbal et al., 2021). The species that breed in such containers are *Aedes aegypti* (Linnaeus, 1762) and *Aedes albopictus* (Skuse, 1894), which are the main vectors of arboviruses such as dengue, chikungunya, and Zika in the Americas (Alarcón-Elbal et al., 2017). Other studies have focused on the distribution and bioecology of mosquitoes, some of them vector species, that inhabit natural water bodies such as ponds. *Anopheles albimanus* is the main vector of malaria in the insular Caribbean, a disease that has not yet been eradicated in Hispaniola, despite the efforts made in recent years (Frederick et al., 2016). This species appeared with a frequency of 21.4 % in the ponds sampled in our study. *Culex quinquefasciatus* Say, 1823, which can also occur in the domestic environment (Diéguez-Fernández et al., 2020), breed in ponds and is a vector of parasitosis such as lymphatic filariasis or viruses such as West Nile virus, both of which are present on the island (Alarcón-Elbal et al., 2017). Other mosquito vector species such as *Aedes scapularis* (Rondani, 1848), *Cx. nigripalpus*, and *Psorophora confinnis* (Lynch Arribálzaga, 1891), among others, typically occur in ponds in the Dominican Republic (Rodríguez Sosa et al., 2019; 2020). In fact, these 3 vectors were well represented in some of the ponds sampled cohabiting with predatory microcrustaceans, and therefore can be consumed by them.

All mosquito species found in the present study had been previously reported on the island. *Culex garciai* Broche, 2000 was reported for the first time recently (Rueda et al., 2018), and it appears punctually in DP16. Other species recently found in Hispaniola such as *Culex interrogator* Dyar & Knab, 1906, and *Aedes vittatus* (Bigot, 1861) (Rodríguez-Sosa et al., 2020; Alarcón-Elbal et al., 2020) were not found in the study. Regarding the latter, this invasive alien species prefers to breed in small-sized habitats such as puddles, rock pools, tree holes, bamboo cups, and even artificial containers (Díaz Martínez et al., 2021), which would explain its absence in ponds.

Already in the 1990s, Marten et al. (2004) easily incubated two species of larger cyclopoids (*M. longisetus* and *M. albidus*) in the laboratory and translocated them to discarded tires, temporary ponds, and other sites (rice fields, marshes, and domestic containers, among others) where mosquitoes from the genera *Aedes*, *Culex*, and *Anopheles* breed, and a reduction of these mosquito populations was observed. *Macrocyclops*, *Apocyclops*, and the newly cited genus, *Diacyclops*, have been described as potential organisms to control mosquito larvae populations (Marten et al., 2004; Marten & Reid, 2007). It would be interesting to assess the predation potential of the species collected, i.e. *M. albidus* and *D.* cf. *ecabensis*, on mosquito larvae in laboratory trials and under semi-natural conditions. The potential of *A. dorsalis* should not be underestimated, since successful predatory assays have been performed with another calanoid species, *L. raynerae* (Cuthbert et al., 2018).

Among the collected cladocerans, only *C. cornuta*, *M. macleayi*, and *S. mixtus* are planktonic, living and feeding in the water column, as occurs with the mosquito larvae. It could be interesting to test the effect of these microcrustaceans on the oviposition of mosquitoes and assess if they can be competitors for food resources. The newly cited species *S. mixtus*, with a similar size to *D. magna*, might be a potential candidate, as the latter exert demonstrated effects on mosquito populations (Duquesne et al., 2011). The other identified cladocerans occupy the benthonic niche in water bodies, usually living in the bottom sediments or in the submerged macrophytes and feeding on organic particles and the periphytic fractions attached to pond surfaces. Therefore, it could be ruled out that they might have some interaction with the populations of mosquito larvae.

Although biocontrol is a remarkable tool against the nuisance to human populations triggered by mosquitoes, the use of copepods is a risky strategy, as it could alter the natural ecological communities. In fact, introductions of non-native zooplankton may generate not only negative environmental damages but also economic impacts (Walsh et al., 2016). Therefore, to ensure behavioural efficiency of these agents, and to avoid the introduction of non-native species, predatory copepods should be selected from the local fauna (Baldacchino et al., 2017). This biological technique could be implemented in man-made structures such as gardening ponds, untreated swimming pools, and residential roadside ditches, or in artificial water holding containers in peri-domestic or domestic settings. Along these lines, some studies have recommended using the artificial translocation of mosquito predators combined with *Bacillus thuringiensis* var. *israelensis* (*Bti*) treatments (Rivière et al., 1987; Marten et al., 2004; Marten & Reid, 2007; Dhanker et al., 2014).

Unfortunately, the Dominican Republic holds a scarce scientific production in medical and veterinary entomology (Alarcón-Elbal et al., 2022). Our research shows important findings in relation to freshwater microcrustaceans of Hispaniola, as we provide 6 new records of species with potential as biological predators and competitors. To better understand the predator–prey interactions, quantitative studies on their behaviour and feeding preferences of native copepods are needed. Consequently, and as suggested above, more local and experimental studies are required to provide a better understanding of the optimal native species that can serve as promising tools for mosquito larvae suppression. It is also proposed to enlarge the zooplanktonic studies in Hispaniola, including genetic tools such as metabarcoding studies studies, to depict the whole biodiversity in each water body, together with taxonomic descriptions.

ACKNOWLEDGMENTS

Sampling was carried out under special permit from the Ministry of Environment and Natural Resources of the Dominican Republic. Thanks to Camila López Allendes for the support with the map code. The authors are also grateful to Dr. Alexey Kotov and Dr. Xavier Armengol for their valuable contribution to the identification of *Ilyocryptus spinifer* and *Apocyclops* cf. *dimorphus*, respectively.

FUNDING

This work is part of the project “Búsqueda, caracterización y evaluación de agentes ecológicamente amigables para el control de mosquitos (Diptera: Culicidae) de importancia médica en República Dominicana”, supported by the Fondo Nacional de Innovación y Desarrollo Científico y Tecnológico (FONDOCyT), Ministerio de Educación Superior, Ciencia y Tecnología (MESCyT), Project No. 2018–19–2B2–043. C. Olmo has a “Recualificación del sistema universitario español + Next Generation”: (C21.I4.P1/AEI/10.13039/501100011033).

REFERENCES

Acosta-Mercado, D., Cancel-Morales, N., Chinea, J. D., Santos-Flores, C. J., & Sastre De Jesús, I. (2012). Could the canopy structure of bryophytes serve as an indicator of microbial biodiversity? A test for testate amoebae and microcrustaceans from a subtropical cloud forest in Dominican Republic. *Microbial Ecology*, 64(1), 200-213. DOI: 10.1007/s00248-011-0004-8

Alarcón-Elbal, P. M., Paulino-Ramírez, R., Diéguez-Fernández, L., Fimia-Duarte, R., Guerrero, K. A., & González, M. (2017). Arbovirosis transmitidas por mosquitos (Diptera: Culicidae) en la República Dominicana: una revisión. *The Biologist*, 15(1), 193-219. DOI: 10.24039/rtb2017151155

Alarcón-Elbal, P. M., Rodríguez-Sosa, M. A., Newman, B. C., & Sutton, W. B. (2020) The First Record of *Aedes vittatus* (Diptera: Culicidae) in the Dominican Republic: Public Health Implications of a Potential Invasive Mosquito Species in the Americas. *Journal of Medical Entomology*, 57(6), 2016-2021. DOI: 10.1093/jme/tjaa128.

Alarcón-Elbal, P. M., Rodríguez-Sosa, M. A., Ruiz-Matuk, C., Tapia, L., Arredondo Abreu, C. A., Fernández González, A. A., Rodríguez Lauzurique, R. M., & Paulino-Ramírez, R. (2021). Breeding Sites of Synanthropic Mosquitoes in Zika-Affected Areas of the Dominican Republic. *Journal of American Mosquito Control Associaton*, 37(1), 10-19. DOI: 10.2987/20-6953.1

Alarcón-Elbal, P. M., Suárez-Balseiro, C., Holguino-Borda, J., & Riggio-Olivares, G. (2023). Research on medical and veterinary entomology in the insular Caribbean: a bibliometric analysis. *International Journal of Tropical Insect Science*, 43: 149-162. DOI: 10.1007/s42690-022-00929-w

Baldacchino, F., Bruno, M. C., Visentin, P., Blondel, K., Arnoldi, D., Hauffe, H. C., & Rizzoli, A. (2017). Predation efficiency of copepods against the new invasive mosquito species *Aedes koreicus* (Diptera: Culicidae) in Italy. *The European Zoological Journal*, 84, 43-48, DOI: 10.1080/11250003.2016.1271028

Blaustein, L., & Chase, J. M. (2007). Interactions Between Mosquito Larvae and Species that Share the Same Trophic Level. *Annual Review of Entomology*, 52, 489-507. DOI: 10.1146/annurev.ento.52.110405.091431

Blaustein, L., & Margalit, J. (1994). Differential vulnerability among mosquito species to predation by the cyclopoid copepod, *Acanthocyclops viridis*. *Israel Journal of Zoology*, 40(1), 55-60. DOI:10.1080/00212210.1994.10688734

Bledzki, L. A., & Rybak, J. I. (2016). *Freshwater Crustacean Zooplankton of Europe: Cladocera & Copepoda (Calanoida, Cyclopoida). Key to species identification, with notes on ecology, distribution, methods and introduction to data analysis*. Springer. Switzerland.

Carlson, J., Keating, J., Mbogo, C. M., Kahindi, S., & Beier, J. C. (2004). Ecological limitations on aquatic mosquito predator colonization in the urban environment. *Journal of Vector Ecology*, 29(2), 331-339.

Cervantes-Martínez, A., Elías-Gutiérrez, M., Arce-Ibarra, A. M., & Gutiérrez-Aguirre, M. A. (2018). Aquatic biodiversity in cenotes from the Yucatan Peninsula (Quintana Roo, Mexico). *Teoría y Praxis*, 25, 49-68.

Cervantes-Martínez, A., & Gutiérrez-Aguirre, M. A. (2015). Physicochemistry and zooplankton of two karstic sinkholes in the Yucatan Peninsula, Mexico. *Journal of Limnology*, 74(2), 382-393.

Champeau, A. (1966). Contribution à l'étude écologique de la faune des eaux temporaires de la haute Camargue. *Archivio di Oceanografia e Limnologia*, 14, 309-357.

Chiambeng, G. Y., & Dumont, H. J. (2004). The genus *Pleuroxus* Baird, 1843 (Crustacea: Anomopoda: Chydoridae) in Cameroon, Central-West Africa. *Annales de Limnologie*, 40(3), 211-229. DOI: 10.1051/limn/2004019

Collado, C., Fernando, C. H., & Sephton, D. (1984). The freshwater zooplankton of Central America and the Caribbean. *Hydrobiologia*, 113, 105-119. DOI: 10.1007/BF00026597.

Cuthbert, R. N., Dalu, T., Wasserman, R. J., Callaghan, A., Weyl, O. L., & Dick, J. T. (2018). Calanoid copepods: an overlooked tool in the control of disease vector mosquitoes. *Journal of Medical Entomology*, 55(6), 1656-1658. DOI: 10.1093/jme/tjy132

Cuthbert, R. N., Dick, J. T. A., & Callaghan, A. (2018a). Dye another day: the predatory impact of cyclopoid copepods on larval mosquito *Culex pipiens* is unaffected by dyed environments. *Journal of Vector Ecology*, 43(2), 334-336. DOI: 10.1111/jvec.12318

Cuthbert, R. N., Dick, J. T. A., & Callaghan, A. (2018b). Interspecific variation, habitat complexity and ovipositional responses modulate the efficacy of cyclopoid copepods in disease vector control. *Biological Control*, 121, 80-87. DOI: 10.1016/j.biocontrol.2018.02.012

Dhanker, R., Kumar, R., & Raghvendra, K. (2014). Efficiency of copepods to control *Aedes aegypti* larvae in medium applied with insecticides *Bacillus thuringiensis* and temephos. Ram Kumar, Ed. In: *Climate change, Aquatic community structure and Disease*, pp. 41–57.

Díaz Martínez, I., Diéguez Fernández, L., Santana Águila, B., Atiénzar de la Paz, E. M., Ruiz Domínguez, D., & Alarcón-Elbal, P. M. (2021). New introduction of *Aedes vittatus* (Diptera: Culicidae) into the East-Central region of Cuba: ecological characterization and medical relevance. *InterAmerican Journal of Medicine and Health*, 4. DOI: 10.31005/iajmh.v4i.175

Diéguez-Fernández, L., Rodríguez-Sosa, M. A., Vásquez-Bautista, Y. E., Borge-de Prada, M., & Alarcón-Elbal, P. M. (2020). Aportes a la bioecología de *Culex quinquefasciatus* (Diptera: Culicidae), vector de encefalitis, en Jarabacoa, República Dominicana. *Folia Entomológica Mexicana (nueva serie)*, 6, 26-32.

Duquesne, S., Kroeger, I., Kutyniok, M., & Liess, M. (2011). The potential of cladocerans as controphic competitors of the mosquito *Culex pipiens*. *Journal of Medical Entomology*, 48, 554-560. DOI: 10.1603/ME09282

Dussart, B. (1969). *Les copépodes des eaux continentales d'Europe occidentale*. Tome II: Cyclopoïdes et Biologie. Boubee and Cie. Paris. France.

Elías-Gutiérrez, M., Suárez-Morales, E., Gutiérrez-Aguirre, M., Silva-Briano, M., Granados-Ramírez, J., & Garfias-Espejo, T. (2008). Cladocera y Copepoda de las Aguas Continentales de México: Guía Ilustrada. Universidad Nacional Autónoma de México. México D. F. Mexico.

Elías-Gutiérrez, M., Suárez-Morales, E., & Sarma, S. S. S. (2001). Diversity of freshwater zooplankton in the neotropics: the case of Mexico. *Verhandlungen der Internationalen Vereinigung für Theoretische und Angewandte Limnologie*, 27, 4027-4031. DOI: 10.1080/03680770.1998.11901752

El-moor Loureiro, L. M. A. (1997). *Manual de identificação de cladóceros límnicos do Brasil (Vol. 1)*. Universa. Brasília. Brazil.

Farhadian, O., Yusoff, F. M., & Arshad, A. (2008). Population growth and production of *Apocyclops dengizicus* (Copepoda: Cyclopoida) fed on different diets. *Journal of the World Aquaculture Society*, 39, 384-396. DOI: 10.1111/j.1749-7345.2008.00172.x

Fiers, F., Ghenne, V., & Suárez-Morales, E. (2000). New species of continental cyclopoid copepods (Crustacea, Cyclopoida) from the Yucatan Peninsula, Mexico. *Studies on Neotropical Fauna and Environment*, 35(3), 209-251. DOI: 10.1076/snfe.35.3.209.8862

Fimia-Duarte, R., Aldaz-Cárdenas, J. W., Aldaz-Cárdenas, N. G., Segura-Ochoa, J. J., Segura-Ochoa, J. J., & Cepero-Rodríguez, O. (2016a). Mosquitoes (Diptera: Culicidae) and their control by means of biological agents in Villa Clara province, Cuba. *International Journal of Current Research*, 8(12), 43114-43120.

Fimia-Duarte, R., Iannacone Oliver, J., Alarcón-Elbal., P. M., Hernández Contreras, N., Armiñana García, R., Cepero Rodríguez, O., Cabrera García, A. M., & Zaita Ferrer, Y. (2016b). Potencialidades del control biológico de peces y copépodos sobre mosquitos (Diptera: Culicidae) de importancia higiénica-sanitaria en la provincia de Villa Clara, Cuba. *The Biologist*, 14(2), 371-386. DOI: 10.24039/rtb2016142114

Franklinos, L. H. V., Jones, K. E., Redding, D. W., & Abubakar, I. (2019). The effect of global change on mosquito-borne disease. *Lancet Infectious Diseases*, 19(9), e302–e312. DOI: 10.1016/S1473-3099(19)30161-6

Frederick, J., Saint Jean, Y., Lemoine, J. F., Dotson, E. M., Mace, K. E., Chang, M., Slutsker, L., Le Menach, A., Beier, J. C., Eisele, T. P., Okech, B. A., Beau de Rochars, V. M., Carter, K. H., Keating, J., & Impoinvil, D. E. (2016). Malaria vector research and control in Haiti: a systematic review. *Malaria Journal*, 15(1), 376. DOI: 10.1186/s12936-016-1436-x

Fryer, G. (1974). Evolution and adaptive radiation in the Macrothricidae (Crustacea: Cladocera): a study in comparative functional morphology and ecology. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 269(898), 137-274. DOI: 10.1098/rstb.1974.0044

Gálvez, Á., Aguilar-Alberola, J. A., Armengol, X., Bonilla, F., Iepure, S., Monrós, J. S., Olmo, C., Rojo, C., Rueda, J., Rueda, R., Sasa, M., & Mesquita-Joanes, F. (2020). Environment and space rule, but time also matters for the organization of tropical pond metacommunities. *Frontiers in Ecology and Evolution*, 8, 353. DOI: 10.3389/fevo.2020.55883

Gálvez, Á., Peres-Neto, P. R., Castillo-Escrivà, A., Bonilla, F., Camacho, A., García-Roger, E. M., Iepure, S., Miralles-Lorenzo, J., Monrós, J. S., Olmo, C., Picazo, A., Rojo, C., Rueda, J., Sahuquillo, M., Sasa, M., Segura, M., Armengol, X., & Mesquita-Joanes, F. (2022). Inconsistent response of taxonomic groups to space and environment in mediterranean and tropical pond metacommunities. *Ecology*, e3835. DOI: e3835.10.1002/ecy.3835.

González Broche, R. (2006). *Culícidos de Cuba*. Editorial Científico Técnica. La Habana. Cuba.

Grillas, P., Gauthier, P., Yavercovski, N., & Perennou, C. (2004). *Mediterranean Temporary Pools, vol 1. Issues Relating to Conservation, Functioning and Management*. Station biologique de la Tour du Valat. Arles. France.

Gusakov, V. A. (2011). Contribution to the study of the northern limits of the range of *Apocyclops dengizicus* (Lepeschkin, 1900) (Copepoda, Cyclopoida). *Inland Water Biology*, 4, 397-399. DOI: 10.1134/S1995082911030096

Gutiérrez-Aguirre, M. A., & Cervantes-Martínez, A. (2016). Taxonomic evaluation of eleven species of *Microcyclops* Claus, 1893 (Copepoda, Cyclopoida) and description of *Microcyclops inarmatus* sp. n. from America. ZooKeys, 603, 33-69. DOI: 10.3897/zookeys.603.7480

Hann, B. J. (1987). Naturally occurring interspecific hybridization in *Simocephalus* (Cladocera, Daphniidae): its potential significance. *Hydrobiologia*, 145, 219-224. DOI: 10.1007/BF02530283

Kotov, A. A., & Dumont, H. J. (2000). Analysis of the *Ilyocryptus spinifer*-species group (Anomopoda, Branchiopoda), with description of a new species. *Hydrobiologia*, 428, 85-113. DOI: 10.1023/A:1003977208875

Kotov, A., Forró, L., Korovchinsky, N. M., & Petrusek A. (2019). FADA Cladocera: World checklist of freshwater Cladocera species (version Jan 2013). In: Roskov, Y., Ower, G., Orrell T., Nicolson, D., Bailly N., Kirk, P. M., Bourgoin, T., DeWalt, R. E., Decock, W., Nieukerken, E. van, Zarucchi, J., Penev, L. (Eds.). *Species 2000 & ITIS Catalogue of Lif*e, 25th March 2019. Naturalis. Leiden. The Netherlands.

Kroeger, I., Duquesne, S., & Liess, M. (2013). Crustacean biodiversity as an important factor for mosquito larval control. *Journal of Vector Ecology*, 38(2), 390-400. DOI:10.1111/j.1948-7134.2013.12055.x

Kumar, R., Muhid, P., Dahms; H. U., Tseng, L. C., & Hwang, J. S. (2008). Potential of three aquatic predators to control mosquitoes in the presence of alternative prey: a comparative experimental assessment. *Marine and Freshwater Research*, 59(9), 817-835. DOI: 10.1071/MF07143

Kumar, R., & Ramakrishna Rao, T. (2003). Predation on mosquito larvae by *Mesocyclops thermocyclopoides* (Copepoda: Cyclopoida) in the presence of alternate prey. *International Review of Hydrobiology*, 88(6), 570-581. DOI: 10.1002/iroh.200310631

Le Prince, J. A. A. (1915). Malaria Control: Drainage as an Antimalarial Measure. *Public Health Reports*, 30(8), 536-545. DOI: 10.2307/4571955

Malan, H. L., Apleton, C. C., Day, J. A., & Dini, J. (2009). Wetlands and invertebrate disease hosts: are we asking for trouble? *Water*, 35(5), 753-767. DOI: 10.4314/wsa.v35i5.49202

Marten, G. G., Bordes, E. S., & Nguyen, M. (2004). Use of cyclopoid copepods for mosquito control. In: *Ecology and Morphology of Copepods*. pp. 491-496. Springer. Dordrecht. The Netherlands.

Marten, G. G., & Reid, J. W. (2007). Cyclopoid copepods. *Journal of American Mosquito Control Association*, 23(2), 65-92. DOI:10.2987/8756-971X

Menéndez Díaz, Z., Suárez Delgado, S., Rodríguez Rodríguez, J., García Ávila, I., Díaz Pérez, M., & García García, I. (2004). Evaluación de *Macrocyclops albidus* (J.) para el control larval de *Aedes aegypti* (L.) bajo condiciones de laboratorio en Cuba. *Revista Cubana de Medicina Tropical*, 56(3), 227-229.

Miracle, M. R., Oertli, B., Cereghino, R., & Hull, A. (2010). Preface: conservation of European ponds-current knowledge and future needs. *Limnetica*, 29(1), 1-8. DOI: 10.23818/limn.29.01

Nielsen, B. L. H., Gréve, H. V. S., & Hansen, B. W. (2021). Cultivation success and fatty acid composition of the tropical copepods *Apocyclops royi* and *Pseudodiaptomus annandalei* fed on monospecific diets with varying PUFA profiles. *Aquaculture Research*, 52(3), 1127-1138. DOI: 10.1111/are.14970

Perez-Gelabert, D. E. (2020). Checklist, bibliography and quantitative data of the arthropods of Hispaniola. *Zootaxa*, 4749(1), 1-668. DOI:10.11646/zootaxa.4749.1.1.

Reid, J. W. (1990). *Continental and coastal free-living Copepoda (Crustacea) of Mexico, Central America and the Caribbean region. Diversidad Biologica en la Reserva de la Biosfera de Sian Ka'an, Quintana Roo, Mexico*. Navarro, D.; Robinson, J.G. Eds. CIQRO/University of Florida, Mexico, pp. 175–213.

Reid, J. W., Hamilton, R., & Duffield, R. M.

(2002). First confirmed New World record of *Apocyclops dengizicus* (Lepeshkin), with a key to the species of Apocyclops in North America and the Caribbean region (Crustacea: Copepoda: Cyclopidae). *Jeffersoniana*, 10, 1-25.

Rivière, F., Kay, B. H., Klein, J. M., & Séchan, Y. (1987). *Mesocyclops aspericornis* (Copepoda) and *Bacillus thuringiensis* var. *israelensis* for the Biological Control of Aedes and Culex Vectors (Diptera: Culicidae) Breeding in Crab Holes, Tree Holes, and Artificial Containers. *Journal of Medical Entomology*, 24(4), 425-430. DOI: 10.1093/jmedent/24.4.425

Rodríguez Sosa, M. A., Rueda, J., Pichardo Rodríguez, R. J., Vásquez Bautista, Y. E., Durán Tiburcio, J. C., Fimia-Duarte, R., & Alarcón-Elbal, P.M. (2020). Primera cita de *Culex interrogator* (Diptera: Culicidae) para la Hispaniola y actualización del listado de mosquitos de Jarabacoa, República Dominicana. *Novitates Caribaea*, 16, 110-121. DOI: 10.33800/nc.vi16.230

Rodríguez Sosa, M. A., Rueda, J., Vásquez Bautista, Y. E., Fimia-Duarte, R., Borge de Prada, M., Guerrero, K. A., & Alarcón-Elbal, P. M. (2019). Diversidad de mosquitos (Diptera: Culicidae) de Jarabacoa, República Dominicana. *Graellsia*, 75(1), 84. DOI: 10.3989/graellsia.2019.v75.217.

Rueda, J., Rodríguez-Sosa, M. A., Vásquez-Bautista, Y. E., Guerrero, K. A., & Alarcón-Elbal, P. M. (2018). Primera cita de *Culex (Culex) garciai* González Broche, 2000 (Diptera: Culicidae) para La Española. *Anales de Biología*, 40, 95-101. DOI: 10.6018/analesbio.40.11

Sinev, A. Y., & Sanoamuang, L. O. (2013). Notes on *Pleuroxus (Picripleuroxus) quasidenticulatus* (Smirnov, 1996) (Cladocera: Anomopoda: Chydoridae) from South-East Asia and the East of Russia. *Invertebrate Zoology*, 10(2), 269-280.

Smirnov, N. N., Kotov, A. A., & Coronel, J. S. (2006). Partial revision of the *aduncus*-like species of *Pleuroxus* Baird, 1843 (Chydoridae, Cladocera) from the southern hemisphere with comments on subgeneric differentiation within the genus. *Journal of Natural History*, 40(27-28), 1617-1639. DOI: 10.1080/00222930600958870

Smith, K., & Fernando, C. H. (1978). The freshwater calanoid and cyclopoid copepod Crustacea of Cuba. *Canadian Journal of Zoology*, 56(9), 2015-2023. DOI: 10.1139/z78-271

Soesbergen, M., & Sinkeldam, J. (2019). An annotated checklist of the Branchiopoda (Crustacea) of the Dutch Caribbean islands. *Zootaxa*, 4701(1), 25-34. DOI: 10.11646/zootaxa.4701.1.2

Soumare, M. K. F., & Cilek, J. E. (2011). The Effectiveness of *Mesocyclops longisetus* (Copepoda) for the Control of Container-Inhabiting Mosquitoes in Residential Environments. *Journal of the American Mosquito Control Association*, 27(4), 376-383. DOI: 10.2987/11-6129.1

Stoch, F. (2001). How many species of *Diacyclops*? New taxonomic characters and species richness in a freshwater cyclopid genus (Copepoda, Cyclopoida). *Hydrobiologia*, 453, 525-531. DOI: 10.1023/A:1013191429008

Suárez-Morales, E., Reid, J. W., Fiers, F., & Iliffe, T. M. (2004). Historical biogeography and distribution of the freshwater cyclopine copepods (Copepoda, Cyclopoida, Cyclopinae) of the Yucatan Peninsula, Mexico. *Journal of Biogeography*, 31(7), 1051-1063. DOI: 10.1111/j.1365-2699.2004.01053.x

The World Bank. (2022). Integrated Landscape Management in Dominican Republic Watersheds Project (P170848). Available online: https://www.gtai.de/resource/blob/737442/7133593b23da2b7e3708be4f692c09e2/PRO201904175010.pdf (accessed on 10 Sep 2022).

Walsh, J. R., Carpenter, S. R., & Zanden, M. J. V. (2016). Invasive species triggers a massive loss of ecosystem services through a trophic cascade. *Proceedings of the National Academy of Sciences*, 113, 4081-4085. DOI:10.1073/pnas.160036611.