

Recent advances in the study of Chironomidae: An overview

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ABSTRACT

This special issue provides an overview of recent advances in the study of chironomids (Diptera Chironomidae), as an outcome of the 20th *International Symposium on Chironomidae* held in Trento (Italy), in July 2017. It includes 27 selected papers, representative of the six topics of the symposium: genetics and cytogenetics, taxonomy and systematics, autecology and physiology, toxicology and adaptive biology, ecology and biomonitoring, palaeolimnology. Most papers emphasise the value of chironomids in the monitoring programmes, mainly on Europe and case histories from South America and Africa. However, as our title indicates, the reported contemporary studies represent a range from the genetic through the autecological to the ecosystem scale. The aim of the volume is to give new insights on ecology and biology of non-biting midges, the freshwater insect family that comprises the highest number of species in the world, in both lentic and lotic habitats.

Key words: non-biting midges; freshwaters; genetics and cytogenetics; taxonomy and systematic; autecology and physiology; toxicology and adaptive biology; ecology and biomonitoring; palaeolimnology.

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INTRODUCTION

Chironomids (Diptera: Chironomidae), known popularly as “non-biting midges”, are the freshwater insect family that comprises the highest number of species, both in lentic and in lotic habitats (Cranston, 1995). Freshwater ecologists, histologists, molecular biologists and systematists have been attracted by these flies: the online Chironomid Worker Directory (<http://www.chironomidae.net/directory.html>) collects a list of over 550 current chironomid workers, organized to discuss midge matters in the Chironomid Exchange Forum (<http://chironomidae.net/chiroforum/index.php>).

Chironomids are dominant, in inland natural or man-made aquatic ecosystems, occurring in extremely diversified habitats and being almost the exclusive insect taxon in specific habitats (such as glacier-fed streams and springs), in terms of both individual and species number (Lindegaard, 1995; Płóciennik *et al.*, 2016; Lencioni, 2018).

Most chironomids have aquatic larvae, living in freshwater, only few species have larvae occurring in marine water or in moist ground and decaying matter (these are considered semi-aquatic). The aquatic forms inhabit all along the course of streams and rivers, from fast-flowing

mountain wetlands, to deep and slow-moving waters in lagoons. Chironomids are diverse and exhibit a wide variety of ecological preferences that provide potential in establishing reference conditions for bioassessment of freshwater ecosystems (Serra *et al.*, 2018).

However, due to taxonomic difficulties and poor knowledge of traits, chironomids are often neglected in biomonitoring programmes (Lencioni *et al.*, 2018c).

Chironomids have attracted the attention of many scientists, interested in studying the giant chromosomes in the larval salivary glands, the haemoglobin, morphological aberrations, generally in relation to specific stressors (*e.g.*, thermal and chemical) (Armitage *et al.*, 1995). Their taxonomic diversity has encouraged many systematics to study Chironomidae phylogeny; they are considered an interesting biogeographic material, in the last century (*e.g.*, Brundin, 1966; Serra-Tosio, 1973) and in our time (*e.g.*, Cornette *et al.*, 2015; Siri and Donato, 2015; Krosh *et al.*, 2017; Silva and Farrell, 2017; Lin *et al.*, 2018).

Furthermore, chironomid larvae are insects of commercial interest. They are recognized as an important food for many fishes and cultured crustaceans, and are very popular in aquarium fish trade (Das *et al.*, 2012). Larvae are an excellent source of protein, lipid, vitamins

and minerals with high energy content, and highly digestible (Armitage, 1995).

Adults are not hematophagous, so the impact of these flies excludes human blood feeding and disease transmission. Nevertheless, chironomids sometimes make people talk badly about them. It has happened frequently in Florida, UK, Sudan, Japan and Italy. These flies may become a serious problem in residential areas associated with warm, polluted, and generally also eutrophic lakes and lagoons (see Failla *et al.*, 2015 for a review). “Globally, nearly 100 of the 4,000 known chironomid species are documented as pestiferous” (Ali, 1996), creating problems as nuisances, public health risks (*e.g.*, asthma and allergies), and economic pests (plaguing tourists).

Scopus database (<https://www.scopus.com>) reports 9,452 documents with “Chironomidae” in the title, abstract or keywords, from 1893 to October 2018, of which 95% are journal articles. No record refers to the First World War period, and the number of papers/year increased significantly since 1965, reaching the highest values between 2009 and 2012 (Fig.1).

If we consider all documents, also papers not indexed in Scopus, the number of contributions is much higher. The current bibliography of Chironomidae literature (<http://literature.vm.ntnu.no/Chironomidae/> edited by Aagaard *et al.*, 2011) contains 30,511 entries on 23 October 2018, including works with content found to pertain significantly to the fly family Chironomidae (articles, books, identification manuals but also academic theses, project reports and other items of grey literature), dating back to the eighteenth century. The number of papers mentioning “Chironomidae” (in all fields) becomes even higher by consulting Google Scholar, which includes more than 70,000 records, of which 2070 only in 2018.

This volume adds other 27 peer-reviewed contributions to the 301 papers published in international journals in 2018

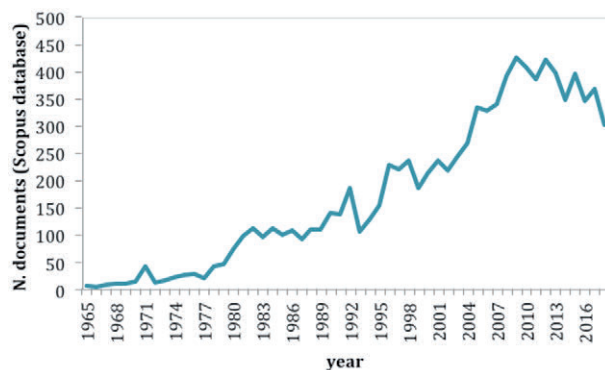


Fig. 1. Number of documents published since 1965 and indexed by Scopus with “Chironomidae” in the title, abstract or keywords [output of 23 October 2018].

(Fig. 1), giving new insights on the ecology and biology of non-biting midges. Recent advances in the study of chironomids within six main topics have been included: genetics and cytogenetics, taxonomy and systematics, autecology and physiology, toxicology and adaptive biology, ecology and biomonitoring, palaeolimnology.

SPECIAL ISSUE CONTENTS

The present volume reports recent advances on chironomid studies by participants to the twentieth edition of the International Symposium on Chironomidae, held, for the first time in the 53 years history of such symposia, in Italy (Trento), in July 2017 (the first edition was held in Plön, Germany, in 1964). The symposium, organized with a triennial cycle, is the best gathering occasion for all chironomid workers to share new data, review and discuss about new approaches, methods and future challenges. In Trento, 88 delegates attended from 28 countries of five continents. They presented 44 oral communications and 24 posters, whose abstracts were published in Lencioni (2017). The topic of the Honorary Thienemann Lecture was presented by Torbjørn Ekrem, “Molecular and integrative systematics in Chironomidae”, nowadays a cutting-edge theme, readable in a synthesised form in Lencioni (2017).

This special issue is the symposium outcome, based on a selection of 27 peer-reviewed papers dealing with six topics: genetics and cytogenetics (1), taxonomy and systematics (5), autecology and physiology (6), toxicology and adaptive biology (2), ecology and biomonitoring (9), palaeolimnology (2). Two papers “in memoriam” were devoted to lost colleagues, to Hiroshi Hashimoto (1924-2015) by Yamamoto (2018), and to Firuz Akhrorov (1937-2012) by Przhiboro *et al.* (2018).

Most papers included in this special issue emphasised the value of chironomids in the monitoring programmes, mainly on Europe and case histories from South America and Africa. However, the reported contemporary studies represent a range from genetics and biochemistry to life cycle and metacommunities at ecosystem level.

A focal issue is the assessment of environmental risk by heavy metals and organic chemicals by using biomarkers, *i.e.*, the use of biochemical, physiological, and histological changes as well as aberrations in organisms to estimate either exposure to chemicals or resultant effects (Huggett *et al.*, 1992). This challenge was faced by Michailova *et al.* (2018), who proposed genome instability as estimated by two cytogenetic indices as a good biomarker of long-term toxicity, taking as model species *Chironomus annularius* sensu Strenzke 1959. Lencioni *et al.* (2018a) studied the response of *Diamesa* spp. from alpine streams to newly emergent contaminants and pesticides at suborganismal and organismal level, by

acute toxicity and genotoxicity tests. These authors highlighted, for the first time in headwaters, a basal physiological stress condition in nature even when single pollutants are in trace. Within the topic of stress ecology, at organismal level, Villa *et al.* (2018) suggested the study of swimming behaviour in laboratory (the crustacean *Daphnia magna* Straus 1820) and wild (the chironomid *Diamesa cinerella* Meigen 1835) species to wastewaters. Two main behavioural endpoints (*e.g.*, mean distance and speed) were proposed to study the effects of chemicals at sublethal concentrations. Finally, in relation with stress tolerance, Thorat and Nath (2018) and Nath (2018) addressed interesting reviews on aquatic silk proteins and haemoglobin in *Chironomus* larvae.

Interesting updates on autecology of Tanypodinae and Podonominae were given by Syrovátka (2018) and Butler and Braegelmann (2018). Syrovátka (2018) discovered that piercing and sucking out prey by tanypods (*Monopelopia tenuicalcar* (Kieffer 1918)) may be more common than has been expected before, with a link to a video on an exceptional case of engulfing the whole prey. Butler and Braegelmann (2018) demonstrated that larvae of the arctic podonome *Trichotanypus alaskensis* Brundin 1966 in a given tundra pond appear to develop synchronously throughout the life cycle, including a period of substantial growth and rapid prepupal development between spring thaw and early-summer emergence.

A large number of papers dealt with the relationships between chironomids and environmental factors at community level. Hirabayashi *et al.* (2018) discussed the succession of benthic macroinvertebrates in relation to changes in the lake bottom environment, as evidence of lake eutrophication in Japan, while Prat and García-Roger (2018) explored the co-occurrence of chironomid larvae belonging to congeneric species within four genera (*Cricotopus*, *Eukiefferiella*, *Orthocladius* and *Rheocricotopus*) in the headwaters of a Mediterranean stream. The co-occurrence of larvae of congeneric chironomid species is common in natural stream assemblages, and raises the problem of finding mechanisms to explain the co-existence of species with similar ecological requirements.

Three papers focused on cold and hot spring-dwelling fauna, which is typically dominated by chironomids (Lencioni *et al.*, 2012), in Iceland (Kreiling *et al.*, 2018), Western Carpathians (Šorfová *et al.*, 2018) and in Northern Italy (Alps) (Lencioni *et al.*, 2018c). They focused on multiple themes, from the high individuality of springs and the utility of chironomids as bioindicators of water quality and ecological state of springs (Lencioni *et al.*, 2018c), to the importance of adopting conservation and management practices to preserve biodiversity in springs. Having springs the potential to provide stable habitats, they are currently under high anthropogenic

pressure, and should be increasingly considered in nature conservation (Kreiling *et al.*, 2018). Another key aspect addressed in this section is the importance of a multilevel approach in community ecology for proper distinction between different mechanisms of metacommunity structuring. Šorfová *et al.* (2018) highlighted that biotic interactions such as competition can result into the same community patterns as those obtained from environmental filtering, suggesting the involvement of detailed analyses of species requirements and interactions to understand the mechanisms driving community patterns.

Two papers addressed the focal issue of climate and environmental changes. The effects of global warming and glacier retreating were evaluated by Lencioni and Gobbi (2018) in a glacier foreland in the Italian Alps. They demonstrated that increasing glacial retreat differently affect epigeic and aquatic insect taxa: carabid beetles respond faster to glacier retreat than do chironomids, at least in patterns of species richness and species turnover. Deforestation for agricultural purposes is the most dangerous human action against the conservation of many forests in the world. Sonoda *et al.* (2018) gave new insights on deforestation effects by studying taxonomical and functional diversity of chironomids in Amazonian streams. They emphasised the importance in considering the feeding behaviour to understand the effects of land-use and land-cover changes in streams using benthic fauna.

Human-management practices can accelerate or decelerate natural pond siltation process, with effects on insect biodiversity (Lencioni *et al.*, 2018b in press). Ponds represent a large potential resource for biodiversity in agricultural areas of lowland Europe though many are lost through natural succession towards damp woodland depressions (terrestrialisation). Managing ponds back towards their former open-water state may result in dramatic increases of biodiversity, even on heavily farmed land. Ruse *et al.* (2018) showed evidence of the effects of terrestrialised farmland pond restoration on chironomid assemblages.

Long-term studies are essential to understand the effects on biodiversity and ecosystem functioning in a fast-changing world. Kettani and Moubayed-Breil (2018) reported two decades of data on chironomid fauna from four ecological zones delimited by the Mediterranean coastal ecosystems of Morocco (Moroccan Rif), underlying the still limited faunal knowledge of wetland coastal areas and fragility of lowland habitats in this Mediterranean area. A reduction of the taxonomical precision to genus level lowered the statistical significance and required careful examination of the species preferences of the genus, as emphasised by Orendt (2018) in a 10 year-study on chironomids from German lowland running waters differing in degradation. For some

regions (*i.e.*, Amur River, Russia), long-term studies produced checklists of hundreds of species of chironomids, with the description of many new species to science (Yavorskaya *et al.*, 2018).

The taxonomic part of the issue includes five papers. Kownacki *et al.* (2018) showed the results of studying the morphology of larval parts in some species of the genus *Chironomus* using a scanning electron microscope. Lackmann and Butler (2018) discussed the life cycle of *Trichotanypus alaskensis* Brundin 1966 (subfamily Podonominae), which turned out to have five larval instars. It is the first confirmed case of five larval instars instead of four in a chironomid. The following three papers are traditional for taxonomy, with the descriptions of new taxa for science and changes in the systematics. Yamamoto *et al.* (2018) established and described the new subgenus *Nothorthocladius* subg. n. of the genus *Orthocladius* (subfamily Orthoclaudiinae) with the new species *O. (N.) brevistylus* sp. n., and erected the new genus *Yaethauma* gen. n. with the new species *Y. longiligulata* sp. n., which bears a superficially resemblance to *Collartomyia* of the subfamily Chironominae. Makarchenko *et al.* (2018) gave morphological and molecular genetic descriptions of two new species of the genus *Diamesa* (*D. akhrorovi* sp. n. and *D. alibaevae* sp. n.) of subfamily Diamesinae and the redescription of *D. planistyla* Reiss, 1968 from Tien Shan and Pamir mountains. Caldwell and Jacobsen (2018) described the new species *Heterotrissoclaadius spiesi* sp. n. (subfamily Orthoclaudiinae) from headwaters of two small Georgia streams below the Fall Line in the Coastal Plain Physiologic Province, Atlantic Slope drainage.

In the last session devoted to paleolimnology, two papers reported data on subfossil chironomids from surface sediments of ten cenotes in SE Mexico (Hamerlík *et al.*, 2018) and from three man-made reservoirs in a mining region of Banská Štiavnica (Central Slovakia) (Chamutiová *et al.*, 2018). In total, 20 taxa of 17 genera were recorded by Hamerlík *et al.* (2018), and the total diversity was estimated to ~30 taxa. The results indicated that beside ecological features, such as low trophy, oxygen depletion, simplified habitat structure and fish predation, there are also taphonomical processes connected to the specific nature of cenotes that can hinder the accumulation of biological remains in the sediment. Chamutiová *et al.* (2018) analysed sediment cores spanning the last 170–200 years, identifying 58 taxa among which *Cladotanytarsus mancus*-type, *Polypedilum nubeculosum*-type, *Procladius* spp. and *Tanytarsus* spp. as the most common ones. Changes in the subfossil assemblages suggested that all reservoirs followed similar developmental trends.

Finally, this special issue will significantly implement the bibliography on chironomids and freshwater ecosystem functioning, including works with content found interesting for a multidisciplinary international audience.

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