Chapter

Chironomidae: Biology, Ecology and Systematics

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Abstract

The family of Chironomidae is a group of Diptera insects belonging to the suborder of Nematocera, commonly called “non-biting midges” in the adult stage and “bloodworms” in the larval stage. The Chironomidae are often the most abundant group of macroinvertebrates, in number of species and individuals, encountered in all aquatic environments of freshwater, brackish, terrestrial and even the sea. Likewise, Chironomidae occur in all the continents. The Chironomidae family is divided into 11 sub-families that have diffrent ecological statues. Despite the wealth of data on Chironomidae in the Holarctic region, other parts of the world are poorly studied and few guides to identifying Chironomidae have been produced. This chapter includes a theoretical synthesis on the Chironomidae, it deals with the Biology (life cycle and description of different stages), description of all subfamilies and the ecology of this important family of Diptera.

Keywords: Biology, Chironomidae, Diptera, ecology, subfamilies

1. Introduction

The Chironomidae family is a group of Diptera insects belonging to the suborder of Nematocera. Members of this family are commonly called “non-biting midges” in the adult stage and “bloodworms” in the larval stage.

The Chironomidae are often the most abundant group of macroinvertebrates, in number of species and individuals, found in all freshwater aquatic environments. They are widely distributed and live in both lentic and lotic ecosystems [1, 2]. Indeed, the Chironomidae are among the few insects living in the sea and the ocean [3, 4]. Likewise, they occur in all continents where they have been found alive at heights of 5600 m on the glaciers of the Himalayas [5] and in the depths of the lakes [6]. Several qualitative observations showed that larvae of terrestrial Chironomidae are able to colonize the vegetation above the soil surface on heathlands [7].

Chironomidae are holometabolous insects, their larvae, pupae and adults form an integral part of the trophic chain serving as food for other invertebrates, fish, birds and amphibians [8, 9]. The larval and pupal stages are generally subservient to aquatic habitats while the adults are aerial and often collected at more or less distances from their emergence habitats.

The Chironomidae family is divided into 11 sub-families: Telmatogetoniinae, Usambaromyiinae, Podonominae, Tanypodinae, Buchonomyiinae, Diamesinae, Prodiamesinae, Orthocladiinae, Chironominae, Chilomyiinae and Aphroteniinae. In fact, the subfamilies of Telmatogetoniinae, Podonominae, Buchonomyiinae, Chilomyiinae, Usambaromyiinae and Aphroteniinae are restricted in their distributions and even in number of species. The occurrence of Diamesinae and Prodiamesinae depends on climatic conditions. However, the subfamilies of Orthocladiinae, Tanypodinae and Chironominae are those which encompasses the maximum number of species and are very widely distributed throughout the world [2, 10].

Among the Chironomidae family, description of species is traditionally based on adults, and knowledge of immature stages is variable within tribes or even across species of the same genus. Indeed, some genera have immature terrestrial stages, other genera have exclusively aquatic larvae. However, many species have unknown immature stages [11].

Regional catalogs provide valid data on the distribution of Chironomidae: [12] for the Eastern region, [13] for the Afrotropical region, [14] for the Australian and Antarctic regions, [15] for Nearctic Chironomidae, [16] for the Neotropical region, [17] for Europe and [18].

The common problem in the literature dealing with the morphology of Chironomidae is that several alternative names are frequently used for the same structure. In fact, [19] glossary is a constructive attempt to rationalize this situation. For this reason, his recommendations have been followed throughout this chapter.

The objective of this work is to present an overview on the Chironomidae family. This chapter will mainly deal with the morphology of all the subfamilies as well as the biology and ecology of the different stages.

2. Morphology

Chironomidae are Diptera belonging to the morphological group of the Culiciforma, so their general appearance is that of a mosquito. They are Nematoceran and as such, they are characterized by long antennae (more or less as long as the head). Their mouthparts are much regressed and the atrophy of the mandibles in the adult stage does not allow them to bite.

Chironomidae undergo during their life cycle four morphologically very different stages which, while having a general appearance identical from one subfamily to another, present anatomical variations which constitute essential bases of their systematics.

2.1 Eggs

2.1.1 Structure

The egg of Chironomidae, like all insects, is of the centrolecithic type, rich in yolk which constitutes a central mass of nutrient reserves. The cytoplasm containing several nuclei is peripheral [20].

The eggshell has, from the inside to the outside, the yolk envelope and the chorion separated by a protective waxy layer. In general, the chorion of eggs of Chironomidae is not very thick and contains protrusions and has a micropyle [21]. However, it may be smooth in other species such as *Tanytarsus barbitarsis* [22] or thick providing some protection against desiccation in eggs of Telmatogetoninae [23].

In general, all Chironomidae laid their eggs in the form of gelatinous masses in contact with water. However, members of the Telmatogetoninae subfamily are an exception since their eggs are laid individually without a gelatinous matrix [23].

2.1.2 Number of eggs

Often, the egg masses of Chironomidae contain approximately 20 to 30 eggs. This number can increase to over 3000 in large species [24]. In fact, the largest number of eggs laid was recorded in *Chironomus tentans* with 3300 eggs in a single mass. However, there may also be intraspecific variations [23].

2.1.3 The shape and size of the eggs

The shape of the eggs in Chironomidae is usually elliptical or kidney-shaped. Likewise, the eggs can also be deltoids in some Telmatogetoninae (*TelmatogeIton japonicus*) and some Orthocladiinae such as *Orthocladius* sp. and *Eukiefferiella claripennis* [23].

Egg sizes vary greatly between species. Indeed, the smallest eggs are those of *Corynoneura* and *Thienemanniella* whose size is around 170 μm long and 70 μm wide, while *Tanypus punctipennis*, a large Tanypodinae, lays eggs 612 μm long and 135 μm wide. Generally, in Chironomidae the ratio: length/width is 2.5 to 3 [23].

Egg masses may be globular or rod-shaped in Tanypodinae, laid as chains in Diamesinae, or linear in Orthocladiinae. In Chironominae, Chironomini egg masses are cylindrical in shape with a gelatinous peduncle (**Figure 1**) [24, 25].

2.1.4 Embryonic development

The duration of embryonic development is largely influenced by environmental factors especially temperature [26]. In fact, *Thiennemanniella vittata* eggs hatch in a minimum of 4 days at 20°C, 6 days at 15°C, 13 days at 10°C and 31 days at 5°C [21].

2.2 The larvae

The Chironomidae undergo four larval stages but all morphological and taxonomic observations have been made on the last stage. The majority of structures appear in the early larval stages [27] but many characters of the final stage, especially the shapes and ratios, do not apply to the early stages and do not allow good differentiation [28, 29].

The larvae of Chironomidae have a well-individualized, developed, exposed, complete, and non-retractile head capsule and a narrow, elongated segmented body that lacks thoracic legs (**Figure 2**) [28].

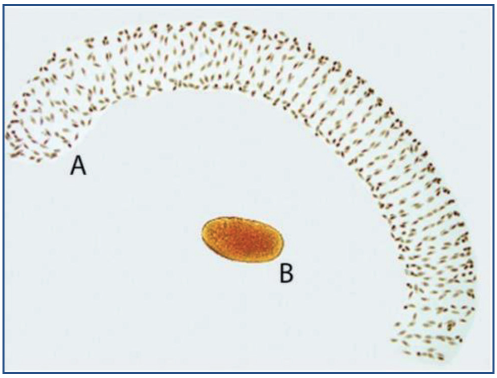

Figure 1.
Chironomus striatipennis*. (A): Egg mass; (B): Egg [25].*

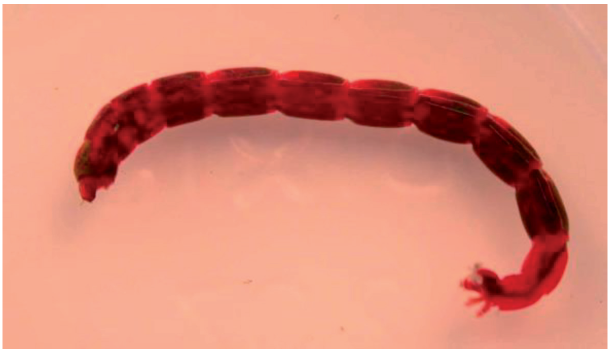

Figure 2.
Chironomidae larva [30].

The larvae of Chironomidae are almost 3 to 25–30 mm long. Their coloration is variable ranging from whitish yellow to red, green or blue. They can also be brownish, purple or orange. Sometimes there is ornamentation on the body segments.

The main parts of the larva's body are:

2.2.1 The cephalic capsule

For the identification of Chironomidae larvae it is necessary to know the morphological details, especially on the head and the perianal region.

2.2.1.1 The cephalic skeleton

The head capsule of Chironomidae consists of a sclerotinized cranium, which consists of the dorsal apotome and a pair of lateral genae. These three sclerites are separated by sutures. There are morphological differences between the different subfamilies but in the most divided state, the clypeus is inconspicuous and more than five labral sclerites are found anterioriorly to the frontal apotome. Variations can occur and include the fusion of the clypeus and the frontal apotome to form the frontoclypeal apotome (**Figure 3**).

The position of the dorsal cephalic seta is related to these sclerites, in fact, S1 and S2 are found on the labrum (labral seta), S3 on the clypeus (clypeal seta) and S4 and S5 on the frontal apotome (frontal seta).

The genae form the lateral and ventral parts of the sclerotinized head and on which are the remaining seta: S6 (suborbital seta), S7 (supraorbital seta), S8 (parietal seta), S9 and S10 (genal seta) and S11, S12 (coronal seta). All of these seta are localized as their name implies and they are of great taxonomic value [1].

2.2.1.2 Antenna

Most Chironomidae have well-developed, segmented antennae placed anterodorsally on the upper genae. The antenna are divided into five segments but there can be 4 or 3 or 7 segments.

Usually the antenna of Chironomidae larvae are formed by a basal segment of varying length and diameter and a flagellum with a varying number of segments. On the the basal segment we can note a circular sensillum: the annular organ. On the apex of the second segment, and sometimes on others, is a special sensory-function formation: the Lauterborn organs, which may be sessile or pedunculated.

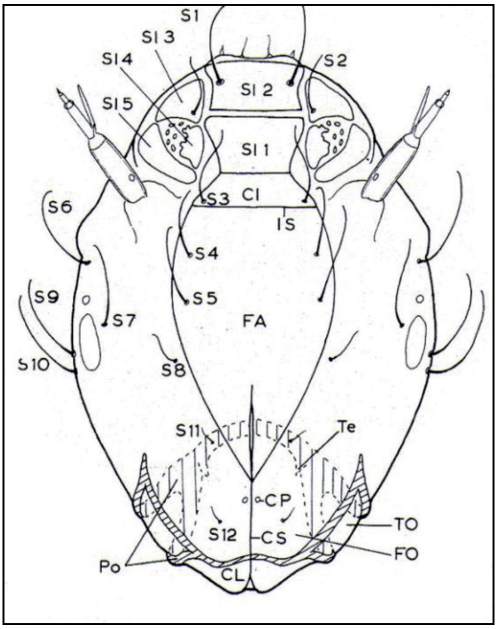

Figure 3.
Cephalic capsule of a Chironominae (dorsal view). Cl: clypeus, CL: coronal lobe, CP: coronal pores, CS: coronal suture, FA: frontal apotome, FO: occipital foramen, IS: clypeolabral suture, Po: postmentum, S 1–12: cephalic seta, Sl (Sl 1–5): sclerites. Te: tentorium, TO: occipital triangulum [19].

2.2.1.3 Labrum

The labrum represents the anterior portion of the frontal apotome. The ventral surface of the labrum is the epipharynx or palatum, which bears seta, lamellae or spinula, it has a sensory and nutritional role (**Figure 4**).

On the labrum are inserted the posterior labral seta named: SIVA and SIVB. SIVA are large sensilla and the SIVB are smaller and may be missing. More anteriorly, there are three pairs of seta: the SIII which are fine simple and in a mid-posterior position compared to the SII seta. The latter are also often simple but can be large and pectinate. The most posterior labral setae are the SI which are very variable and have an important taxonomic role (especially in Orthocladiinae). Indeed, they can be simple or bifid, fluffy or pectinate.

In the ventral surface of the labrum are inserted the premandibles which are mobile appendages bearing one or more apical teeth. They are with or without a tuft of seta called: the premandibular brush.

2.2.1.4 Mandibles

The mandibles are mouthparts. They are toothed with a dorsal external tooth which is missing in the majority of taxa, an apical tooth and a variable number of internal teeth (often 2–3) (**Figure 5**).

Three seta or groups of seta can be identified:

- the pecten mandibularis: which has the shape of a comb, it is located on the subapical surface.

- the seta subdentalis on the internal mola.

- the seta interna, basal, branch-like, often located on the internal mandibular surface.

The mandibles can be sickle-shaped in Tanypodinae or larger in other subfamilies.

2.2.1.5 Mentum or Labium or inferior labrum

The mentum is a mid-central sclerotized part of the cephalic capsule almost always provided with teeth. This piece has two walls: the dorsomentum and the ventromentum, the latter may extend laterally in ventromental or paralabial plates (**Figure 6**).

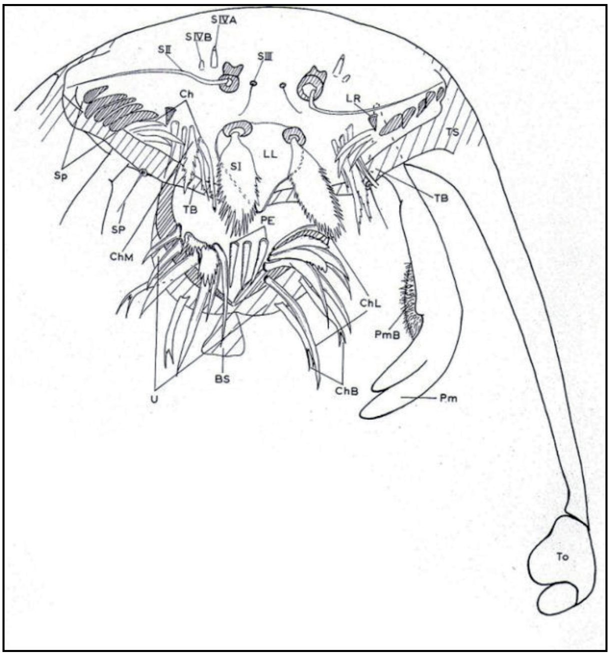

Figure 4.
Structure of the labrum. BS: basal sclerite, Ch: chaeta, ChB: basal chaetulae, ChL: Chaetulae laterales, ChM: media chaetules, LL: lamella labrales, LR: labral rod, PE: pecten epipharyngis, Pm: premandibles; PmB: premandibular brush; SI, SII, SIII, SIVA, SIVB: labral setae, SP: seta premandibularis, TB: tormal bar, To: occipital triangulum, TS: triangular sclerite, U: ungula [19].

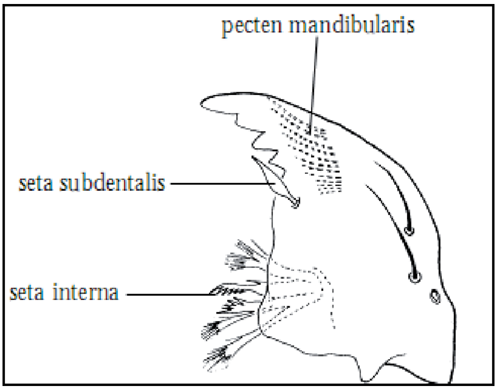

Figure 5.
Structure of the mandible of Chironomidae [29].

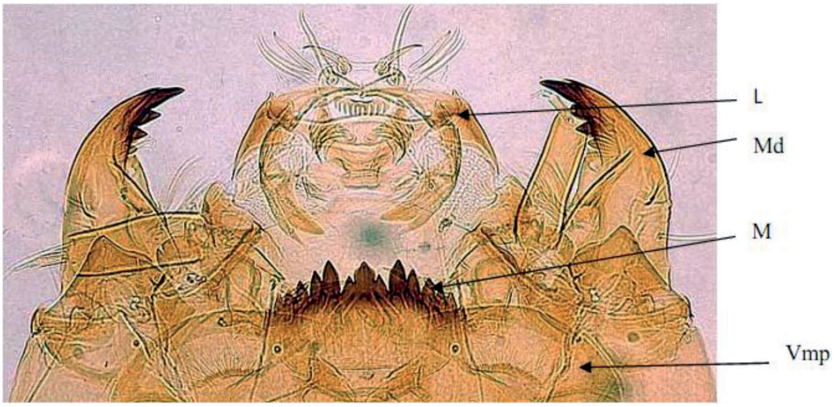

Figure 6.
Structure of the mentum of Chironominae. L: labrum, M: mentum, Md: mandible, Vmp: paralabial plates [31].

The presence or absence of these paralabial plates, in addition to their shape, is of great systematic importance. Indeed, in Tanypodinae the ventromentum is hyalin and the dorsomentum appears as a toothed surface. In the Orthocladiinae subfamily, the ventromental plates are reduced. In Chironominae, they are highly developed and their dorsal surface is variably striated.

2.2.1.6 Premento-hypopharyngial complex

The Premento-hypopharyngial complex lies dorsally to the mentum, and is completely covered by it in the ventral position. It consists of two lobes:

- The prementum: ventral, it is well developed in Tanypodinae. In the other subfamilies, these structures are very small and differently constructed.
- The hypopharynx: dorsal and never well developed. It has several rows of scales or, in Tanypodinae, has rows of teeth on each side forming the hypopharyngial pecten.

2.2.1.7 Eyes spots

The eyes of the larvae of Chironomidae are simple subcuticular areas of pigment. There are taxonomic differences regarding the shape and position of eyes spots. In fact, in the larvae of the Chironominae there are two vertical eyes spots, while those of the Orthocladiinae are also double and superimposed on each other (**Figure 7**). In Tanypodinae there is a single eye spot on each side and are kidney shaped. In all the other subfamilies the eyes spots are simple.

2.2.2 The body

The body is divided into a thorax and an abdomen (**Figure 8**).

- Thorax: always with three segments. The only appendages found in the thorax are two non-segmented pseudopods with a crown of simple or hook-shaped claws.
- Abdomen: narrower, made up of nine segments. It bears on the terminal segment the posterior pseudopods. On the dorsal side of the penultimate segment there are a pair of tubercles, each supporting a tuft of setae, called: the procercus. In the terminal region of the abdomen there are also often 02 pairs of anal tubules.

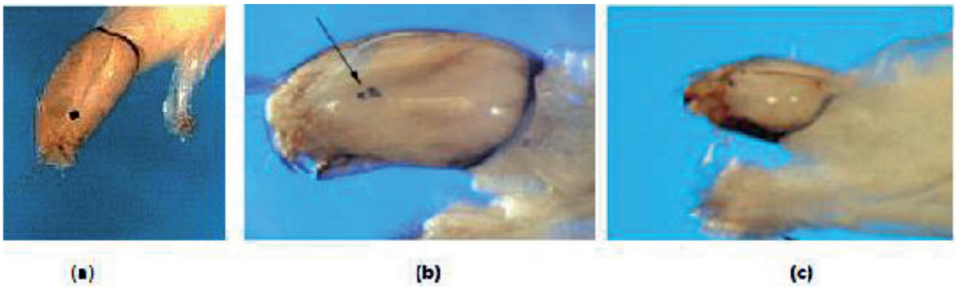

Figure 7.
Position of eye spots in Chironomidae. (a): Tanypodinae, (b): Orthocladiinae and (c): Chironominae [32].

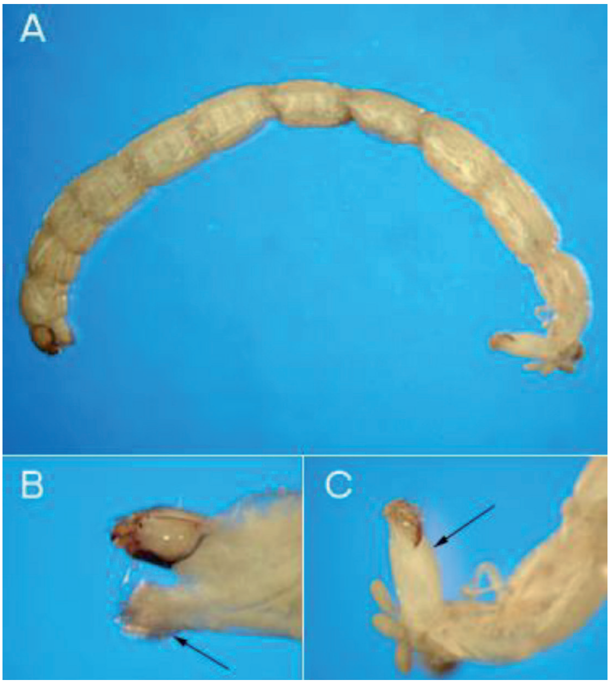

Figure 8.
The body of the larva of Chironomidae. (A): complete larva; (B): anterior pseudopods; (C): anal region of a Chironominae. Arrows show the anterior and posterior pseudopods [32].

2.3 The pupa

The pupal stage of Chironomidae is very short compared to the larval stage, its duration is from a few hours to several days.

The characters of the pupae of Chironomidae are best seen on their exuviae, which are very useful tools for species determination [33, 34].

The pupae of Chironomidae are comma shaped with a swollen cephalothorax and a dorsoventrally flattened abdomen (**Figure 9**). Their length varies from just under 3 to 18 mm. Their coloration usually follows that of the larva.

There are three regions in the pupa: the head (the cephalic region), thorax and abdomen. However, the head and thorax are fused together forming the cephalothorax.

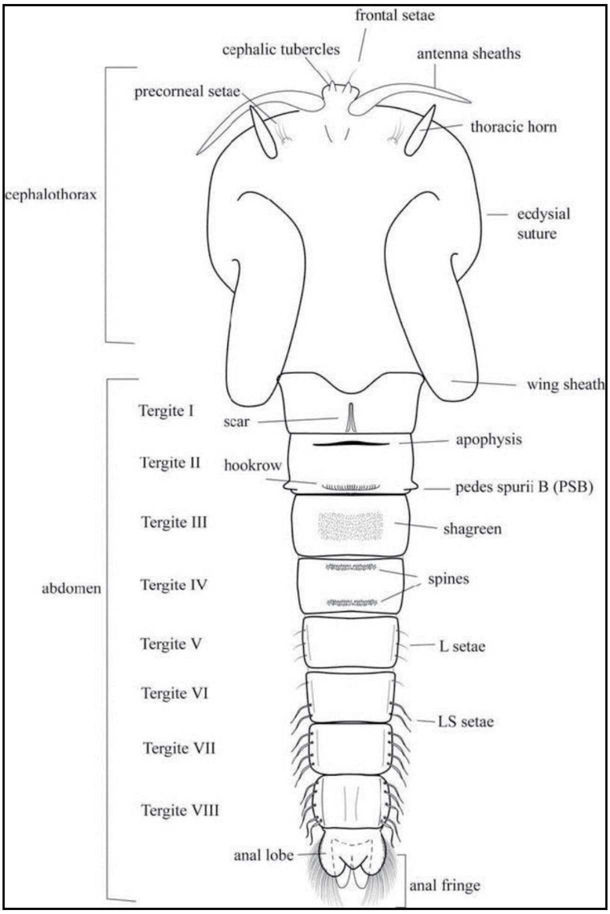

Figure 9.
Morphology of Chironomidae pupa (Illustration by M.R. Rufer).

2.3.1 Cephalothorax

The head bears the antennal sheaths, a pair of cephalic tubercles and a pair of frontal setae. Of great taxonomic importance are features of the cephalic region: location, number and length of frontal setae, the vertex, the postorbit and the ocular region.

The thorax has a pair of respiratory organs, also called: prothoracic horns or thoracic horns, which vary greatly in shape depending on the species or genera, these organs serve for respiration. The thorax also carries the wing sheaths, or pterotheca and the legs sheaths or podotheca.

2.3.2 Abdomen

The abdomen of Chironomidae pupa is made up of nine articulated segments. In addition to a number of setae, the pupal exuvia exhibits highly variable ornamentation (spines, spinules and tubercles) useful for the characterization of the various taxonomic levels.

The last segment widens forming the two anal lobes. The external margin of these anal lobes always bears swimming setae forming the swimming fringe. In addition to the swimming setae, near the apex of the last segment there are often thick and curved setae, in number of 3 or 4, which are called the apical and subapical setae. These can also be missing. In their distal part, the anal lobes bear filamentous setae called: anal macrosetae.

2.4 The adult (the imago)

The body of the adult of Chironomidae consists of three parts [35]:

2.4.1 The head

The head: globular, it carries:

- The antennae: long and exhibit sexual dimorphism since they are fluffy in males and moniliform in females. The antenna of the adult Chironomidae consists of a narrow scape, a globose pedicel and a number (often 11–14) of flagellomeres. The number of antenna segments and their shape depend on the species [36].
- The eyes are very large and kidney-shaped.
- The mouthparts are very reduced.

2.4.2 Thorax

Thorax generally well developed, it has three parts of equal importance: pronotum, mesonotum and metanotum. The thorax bears the wings and the legs.

2.4.3 Abdomen

Abdomen composed of 10 segments, the seven anterior segments are flattened dorsoventrally. The female's abdomen is shorter and more swollen than that of the male. The dorsal part has coloring or ornamentation often useful for identification. The last abdominal segments form the genitalias. The tergite IX has a posteromedial extension forming the anal point (**Figure 10**). Among the most distinctive characters of male genitalias are: basal gonocoxites and apical or subapical gonostyles. The gonocoxites of

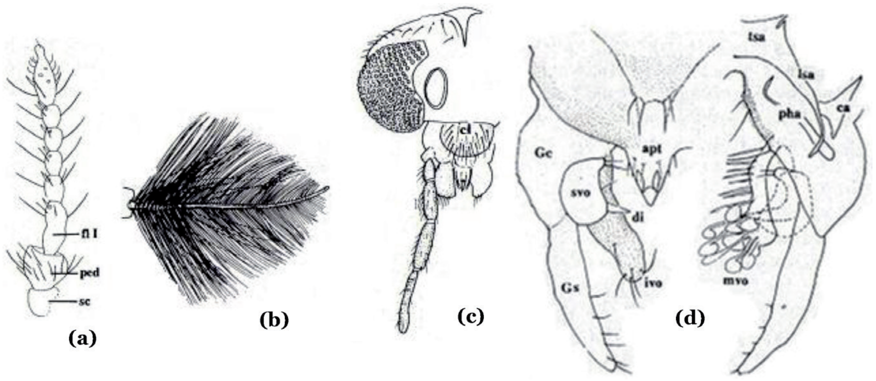

Figure 10.
Morphology of the adult: (a): antenna of the female; (b) the male antenna; (c): the head; (d): male genitalia. Apt: anal point; ca: coxapodema; cl: clypeus; di: digitus; fl: flagellomere; Gc: gonocoxitis; Gs: gonostyle; ivo: inferior volsella; lsa: lateral sternapodema; mvo: median volsella; ped: pedicel; pha: phallapodema; sc: scape; svo: superior volsella; tsa: transverse sternapodema [1, 35].

Chironomidae support a varying number of appendages called: volsellae and they are named according to their relative positions (middle, inferior and superior). Likewise, there may be other lobes associated with the aedeagus and the penis.

3. Subfamilies of the Chironomidae family

The Chironomidae family is divided into 11 subfamilies and 22 tribes revised and provided by [37]. The subfamilies of the Chironomidae are: Telmatogetoninae, Podonominae, Tanypodinae, Buchonomyiinae, Diamesinae, Prodiamesinae, Orthocladiinae, Chironominae, Chilenomyiinae, Aphroteniinae and Usambaromyiinae (**Table 1**).

3.1 Subfamily of Orthocladiinae

The Orthocladiinae subfamily includes species characterized at the adult stage by the fact that the distal article of the hypopygium (gonostyle) is folded over the proximal article (gonocoxite). Likewise, the first section of the tarsus of the first pair of legs is shorter than the tibia, therefore the tibio-tarsal ratio (or leg ratio) is less than 1 (**Figure 11**).

Sub families	Tribes
Tanypodinae	•Coelotanypodini •Macropelopiini •Pentaneurini •Tanypodini •Anatopyiini •Coelopyiini •Natarsiini •Procladiini
Podonominae	•Boreochlini •Podonomini
Telmatogetoninae	
Diamesinae	•Diamesini •Protanypodini •Boreoheptagyiini •Harrisonini •Heptagyiini •Lobodiamesini
Prodiamesinae	
Orthocladiinae	•Metriocnemini •Orthocladiini •Corynoneurini
Chironominae	•Chironomini •Tanytarsini •Pseudochironomini
Buchonomyiinae	
Aphroteniinae	
Chilenomyiinae	
Usambaromyiinae	

Table 1.
Major divisions of the Chironomidae family [37].

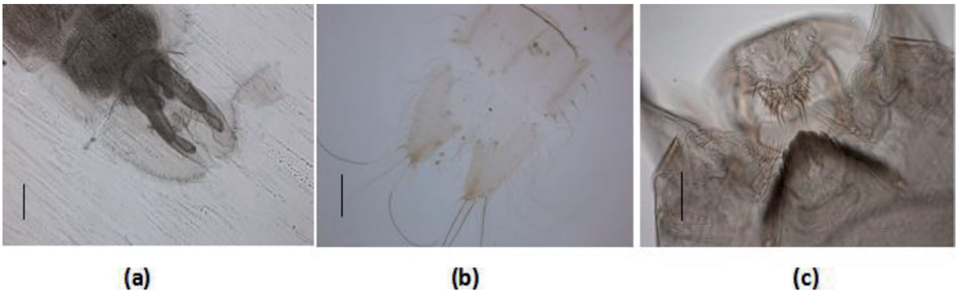

Figure 11.
Orthocladiinae subfamily (a): anal lobe and hypopygium of Psectrocladius *(*Allopsectrocladius*)* platypus*; (b): anal lobe of* P. *(*P.*)* limbatellus*; (c): cephalic capsule of the larva of* Cricotopus flavocinctus *[38].*

Thoracic horn can be absent in the pupae. When it is present it never be branched. On the posterolateral angle of the tergites there are never any hooks. In some genera the anal lobe have a swimming fringe.

The larvae (3 to 15 mm) are always devoided of ventral tubules and hemoglobin, therefore their coloring is never reddish. Usually they are white or yellowish, sometimes greenish, brown or purple. The ventromental plates are in general narrow and never developed.

3.2 Subfamily of Tanypodinae

Tanypodinae are Chironomidae characterized by antennae with 15 segments in adult males and 11–15 segments in females. Males are distinguished from those of Diamesinae and Prodiamesinae by the morphology of their hypopygium having a simple structure and lacking basal lobes at the coxites (**Figure 12**).

The pupae have generally extended anal lobes always provided with 02 large lateral setae which have a swimming function. In the majority of species the respiratory organs end distally in a sieve plate.

The larvae are usually slender with long procerci and pseudopods and anal tubules. What characterizes the larvae of Tanypodinae is the presence of relatively long retractile antennae, the eyes spots are kidney-shaped and characteristic mouthparts (the premento-hypopharyngial complex).

3.3 Subfamily of Chironominae

The Chironominae subfamily includes species characterized in the adult stage by a reduced anterior tibial spur, genitalia most often having a complex structure. The gonostylus cannot be folded up and are always in the prolongation of the coxites.

The respiratory horn may be lacking in pupae, if they exist they can be fluffy or simple. The tergites are often ornamented with hooks. Numerous sub-equal setae are also present in swimming fringe (**Figure 13**).

The larvae of Chironominae are generally provided with hemoglobin and colored red. They are easily recognized by the arrangement of their eyes spots, the paralabial plates which are always well developed and striated and the presence, in many species, of ventral tubules in the anal region.

3.4 Subfamily of Diamesinae

The Diamesinae are characterized in the adult stage by the morphology of the male hypopygium and the antennae. They are distinguished from the Prodiamesinae by the bifurcation of the cubital vein. Likewise, tarsomere 4 is cordate.

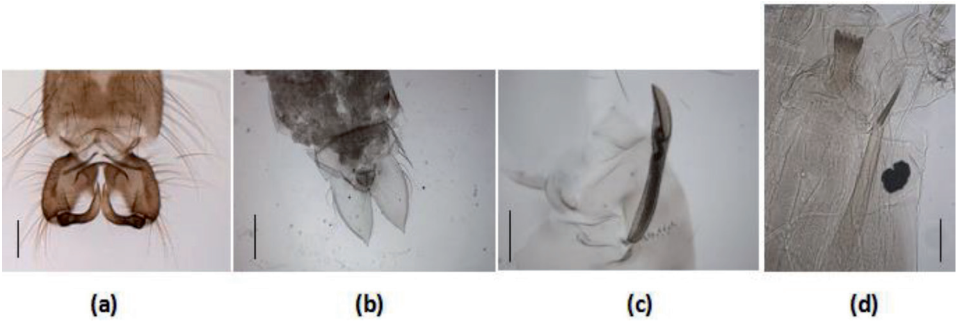

Figure 12.
Tanypodinae subfamily (a): male hypopygium of Arctopelopia melanosoma*; (b): anal lobe of the pupa of* Psectrotanypus varius*; (c):* thoracic *horn of* Xenopelopia falcigera*; (d): cephalic capsule of the larva of* X. falcigera *(scale bar: 200 µm) [38, 39].*

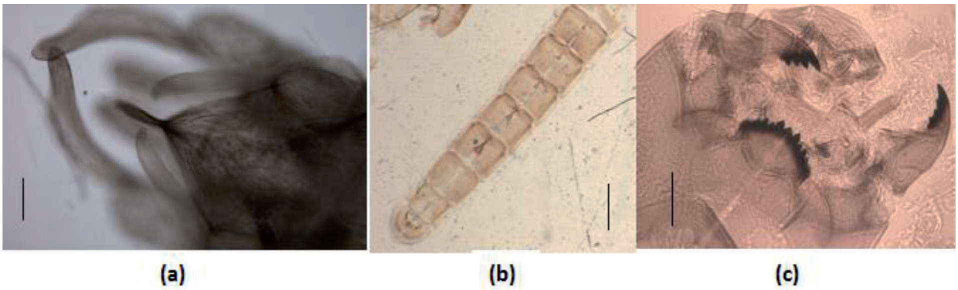

Figure 13.
Subfamily of Chironominae (a): hypopygium of Chironomus plumosus *(scale bar 200 µm); (b): pupal exuvia of* Glyptotendipes barbipes *(scale bar 200 µm); (c): mentum and mandible of* Endochironomus tendens *(scale bar 100 µm) [38].*

Diamesinae pupa often have a thoracic horn which is very variable in shape but it may be lacking in some genera such as *Pseudodiamesa* and *Pottasia* (**Figure 14**).

The larvae are characterized by the presence of a large dark occipital border and the third antenna segment which is annular.

Among the species belonging to the Diamesinae subfamily: *Pseudodiamesa nivoka, Potthastia longimanus, Diamesa steinboecki, Diamesa aberrata, Boreoheptagyia* sp.

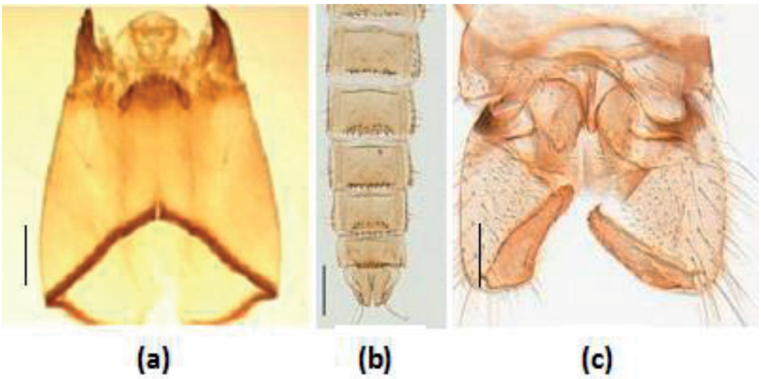

Figure 14.
Diamesinae subfamily: (a): the cephalic capsule; (b): pupal exuvia; (c): male hypopygium [39, 40].

3.5 Subfamily of Prodiamesinae

The Prodiamesinae are characterized by the fact that in the adult stage the wings have, like the Diamesinae and the Tanypodinae, the mediocubital cross-vein, but the difference is that the bifurcation of the cubitus is in a distal position with respect to the radio-median and the medio-cubital cross-veins.

The pupae of Prodiamesinae are very similar to those of Orthocladiinae, but they are distinguished mainly by the thoracic horn which is always present.

Prodiamesinae larvae are characterized by antennae constituted by four segments. The basal segment is much larger than the three successive ones. At the apex of the second segment there are two Lauterborn organs (**Figure 15**).

Among the species belonging to the Prodiamesinae subfamily: *Monodiamesa tuberculata, Prodiamesa olivacea, Odontomesa fulga.*

3.6 Subfamily of Podonominae

Podonominae adults are characterized by wings with the mediocubital cross-vein more distal than in Prodiamesinae. Male genitalia are very variable, in fact, gonostyles are either simple (*Lasiodiamesa sphagnicola*) or bilobed (*Parochlus kiefferi*). Larvae are characterized by their antennae in which the segment 3 is often with annulations (**Figure 16**).

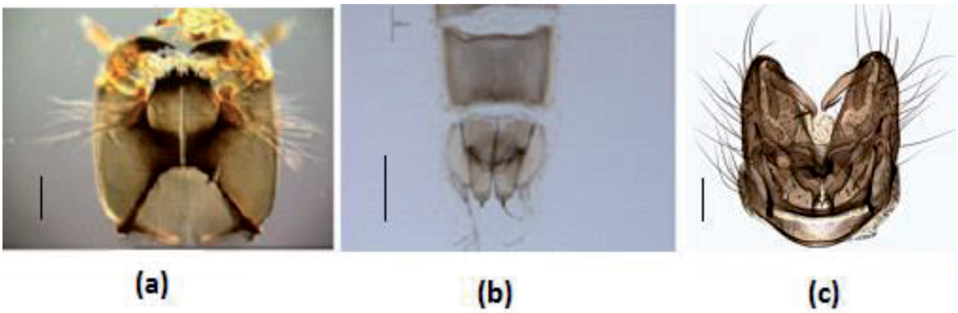

Figure 15.
The Prodiamesinae subfamily. (a): cephalic capsule; (b): pupal exuvia; (c): male hypopygium (scale bar: 200 µm) [41, 42].

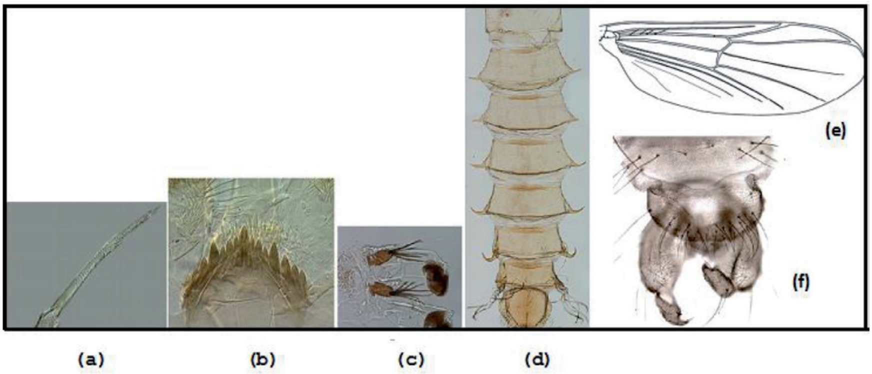

Figure 16.
The Podonominae subfamily. (a): antenna of Boreochlus *sp.; (b): mentum of* Boreochlus *sp.; (c): procerci of* Podonomus amarali*; (d): pupal exuvia of* Podonomus amarali*; (e): wing; (f): male hypopygium of* Podonomus tehuelche *[43–45].*

3.7 Subfamily of Telmatogetoninae

Species belonging to the Telmatogetoninae subfamily are characterized by having wings with R2 + 3 absent. In addition the veins R1 and R4 + 5 are widely separated. Likewise, the fourth tarsal segment is cordate and the male genitalia are large and variously constructed (**Figure 17**).

Among the species belonging to the Telmatogetoninae subfamily: *Telmatogeton remanei*, *Telmatogeton japonicus, Thalassomyia frauenfeldi*, *Psammathiomyia pectinata*.

3.8 Subfamily of Buchonomyiinae

Adults of the Buchonomyiinae subfamily are characterized by wings with the M-Cu vein very close to the base. Male sternite IX with small lateral lobes never exceeding the genitalia. The subfamily of Buchonomyiinae consists of a single genus: *Buchonomyia* (**Figure 18a,b**).

3.9 Subfamily of Aphroteniinae

Adults of the Aphroteniinae subfamily are characterized by wings with R2 + 3 absent, in addition R1 and R4 + 5 are widely separated. Likewise, the fourth tarsal segment is cylindrical (**Figure 18c,d**). Among the species of the Aphroteniinae subfamily: *Aphroteniella filicornis.*

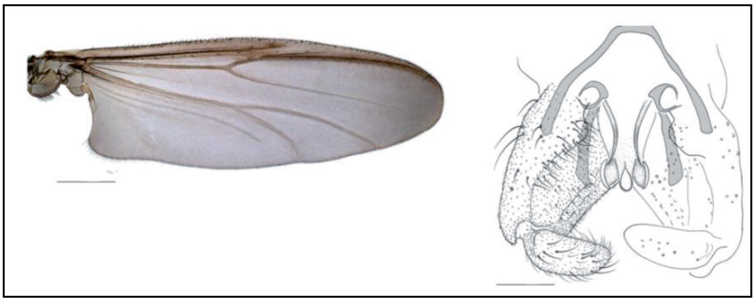

Figure 17.
The Telmintogetoninae subfamily. Wing and male hypopygium of Telmatogeton yamaguchiae *(scale bar: 100 μm) [46].*

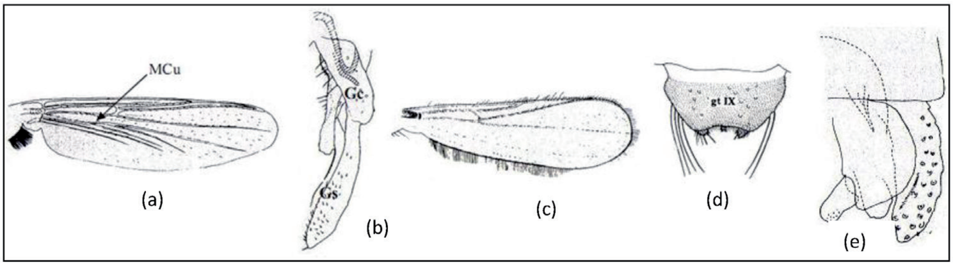

Figure 18.
Subfamilies of Buchonomyiinae, Aphroteniinae and Chilenomyiinae. (a) and (b): wing and hypopygium of Buchonomyiia*; (c) and (d): wing and hypopygium of* Aphroteniella filicornis*; (e): hypopygium of* Chilenomyia *sp. (Gc: gonococcite; Gs: gonostyle; gt: gonotergite) [1].*

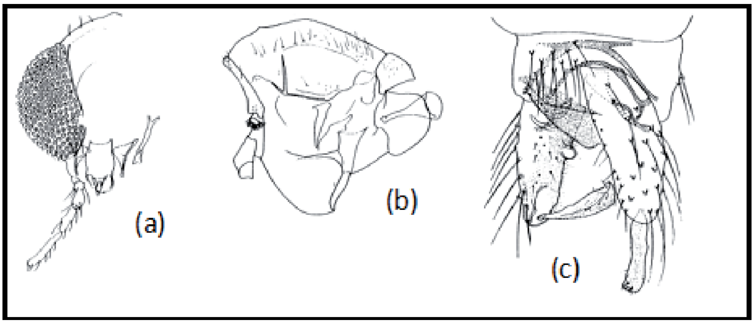

Figure 19.
The subfamily of Usambaromyiinae: (a) the head; (b): thorax; (c): male hypopygium [48].

3.10 Subfamily of Chilenomyiinae

The Chilenomyiinae subfamily is characterized by adults having wings with the mid-cubital vein present, the R1 and R4 + 5 veins are widely separated, in addition, the R2 + 3 is absent. The IX sternites of males are not attached to the IX gonocoxites, but lateral lobes extend further forward than the gonocoxites and gonostyles (**Figure 18e**).

Chilenomyiinae species have been described only from adult males and females. The larvae and pupae of this subfamily are not known.

Among the species belonging to this subfamily: *Chilenomyia paradoxa* [47].

3.11 Subfamily of Usambaromyiinae

This subfamily described by [48] represented by a single species: *Usambaromyia nigrala,* conceived as forming the plesiomorphic sister group of the Tanypodinae, the Podonomiinae and the Aphroteniinae combined.

The species differs from other chironomids by having nearly completely black wings in both sexes, tibial spurs with lateral denticles making them Tanypodinae—like, male gonostylus without megaseta. Pupae and larvae are unknown [48] (**Figure 19**).

4. Biology of Chironomidae

4.1 Life cycle

Chironomidae are Holometabolous insects, their development cycle comprises four morphologically very different states which, while having a general appearance identical from one subfamily to another, present anatomical variations which constitute one of the essential bases of systematics (**Figure 20**).

The life cycle of Chironomidae begins with the deposition of eggs in water. These are gathered in gelatinous masses or deposited individually. The eggs may be free or attached to an object. They hatch after a more or less long period releasing the larvae. The latter undergo a reduced number of moults and go through four larval stages. The larvae can be free, sedentary or live inside a tube that they build with the substrate and salivary secretions.

The larval stage is followed by that of the pupa. This can swim freely or, in tubicolous species, can remain partially included in the larval tube. At maturity, the pupa reach the surface of the water with the air produced in the intercuticular space of

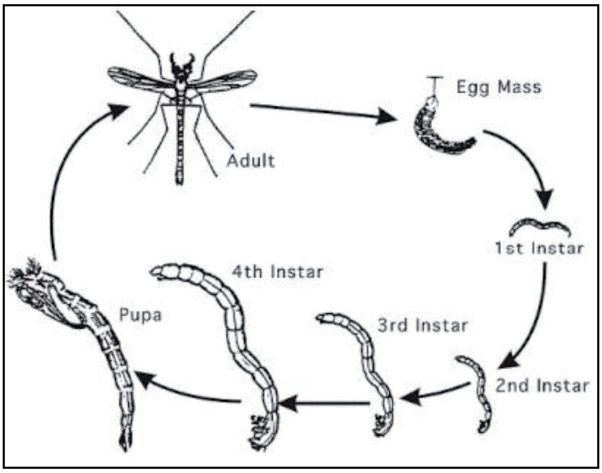

Figure 20.
Chironomid life cycle [49].

the adult. The adult emerges from the surface of the water in a very short period of time. Imaginal life is short. It does not take long for the adults to mate and lay the eggs.

4.2 Biology of the larvae

4.2.1 Feeding

During the first hours of their post-embryonic life, the young larvae feed on the mucilaginous substance of the egg mass, then they pierce the envelope to become planktonic and become microdetritivores ingesting small organic particles.

From the second instar, when the larvae are looking for a support, they feed on the detrital film of the bottom, ingesting both dead and living algae as well as inorganic particles [50].

Based upon the feeding mode, larvae can be grouped in six categories: collectors (gatherers and filterers), shredders, scrapers, and predators (engulfers and piercers) [51]. They feed on a great variety of resources including coarse particulated organic matter fragmentation, periphyton, algae, microorganisms; and dissolved organic matter [52].

4.2.2 Locomotion

Larvae display three modes of motility: swimming, crawling and whole-body respiratory undulation. Swimming and respiratory undulation involve the use of metachronal waves of body bending which travel in a head-to-tail direction. Whereas swimming is produced by side-to-side flexures of the whole body, respiratory undulation employs a sinusoidal wave [53].

4.3 Biology of the pupae

The pupal stage links two active stages in the life of insects: the larval and imaginal stages. While the pupal stage of most insects is immobile, the pupae of most Chironomidae are active for a very large part of their existence. In the majority of Chironomidae the pupae move to accomplish three main functions: moulting from the larval cuticle, providing oxygen for respiration, and moving to the surface for emergence of the adult.

4.3.1 Moulting from the larval cuticle

The pupal cephalothorax is formed in the thoracic segments of the larva, and its large volume exercise a pressure on the dorsal suture. Undulations of the abdomen engage the points on the pupal tegument with the larval tegument, leading the pupa forward into the larval thorax. This extra pressure causes the rupture of the suture to push the back of the larval head to the first abdominal tergum, continuous undulations easily release the pupa outward [1].

4.3.2 Locomotion

The pupa displays two swimming modes, somersaulting and eel-like whole-body undulation, the former being principally a brief, escape manoeuvre, the latter being a faster form of locomotion employed to deliver the pupa to the surface prior to adult emergence [53].

The pupae of the majority of chironomidae swim freely, and they are susceptible to flotation and are provided with structures allowing them to adapt to this way of life. Indeed, these pupae have horns with a large plastron to allow them to float. Likewise, in some chironomidae (Pentaneurini) the anal macrosetae are covered with a sticky gelatinous material forming a natatory fringe that allows them to adhere to the substrate and with sudden flexion of the abdomen the pupae move to the surface. Tubicole species only leave their tubes to hatch on the surface of the water, and their anal fringes are therefore not used for swimming.

Figure 21.
A swarm of Chironomus plumosus *over a tree top [55].*

4.4 Biology of the adults

The adults of Chironomidae are aerial. Swarm flight has long been discussed in several studies [54]. Indeed, dense columnar swarms of Chironomidae are often observed, they extend from the tops of trees, the roofs of houses or around lakes (**Figure 21**) [1, 55].

There is a close relationship between the size of the swarm and the number of matings. Indeed, the formation of flight in swarms allows a high rate of mating especially if the population density is low [56]. Thus, the denser swarms attract more females [57].

Most Chironomidae lay their eggs on or near water. The egg laying sites are very varied depending on the species. Indeed, egg masses of Chironomidae have been observed in lakes, rivers, streams [21], rice fields, sea and vegetation in the case of terrestrial species [58].

In general, the eggs are laid on the surface of the water, it can be carried by the wind and the current and travel long distances before the eggs hatch, which contributes significantly to ensure the dissemination of the species despite increased risk of destruction [24].

5. Ecology of Chironomidae

The Chironomidae is the most ubiquitous group of macroinvertebrates and the most abundant in number of species and individuals, moreover they exist in the majority of habitats [2, 29]. Chironomidae invade the sea, nesting at the seashore and living 30 m at the bottom of the ocean [3, 4]. In addition, the larvae of Chironomidae are found in all freshwater and even terrestrial environments [7, 23, 59].

Under certain conditions, such as an extremely low content of dissolved oxygen, the larvae of Chironomidae are the only insects present in the bottom sediments. Extreme variations in temperature, pH, salinity, depth, current and productivity are exploited by the larvae and imagos of some species of Chironomidae [60]. Thus, they are found in the glacial regions of the highest mountains, included at altitudes above 5600 m in the Himalayan massif [61] and remain active at temperatures of - 16°C [62–64]. Some Chironomidae tolerate the high osmotic pressure of coastal waters such as *Clunio marinus* [65–68].

Ecological studies have shown that the distribution of Chironomidae larvae is conditioned by certain environmental factors such as: temperature, depth, type of substrate, trophic level of the environment and chemical factors such as oxygen concentration and pH [69, 70]. Likewise, certain physiological factors intervene in the spatial variations of Chironomidae such as: the physiological adaptations of the species with the physical and chemical conditions of the environment [71].

Chironomidae are primordial candidates for their use in bioindication for several reasons. In fact, they have intimate contact with solid sediment as well as water pores and the surface layer of water for long periods of their life cycle. In addition, they are widely distributed and often the most abundant of all insect species in aquatic ecosystems [72].

The Chironomidae have been used in the classification of aquatic systems according to their eutrophication and the degree of toxicity by heavy metals [70, 73, 74]. In plus, Paleolimnologists have also used Chironomidae as environmental and climatic indicators in retrospective studies of the great lakes to know their life history [75].

6. Conclusion

The Chironomidae is the most ubiquitous group of macroinvertebrates and the most abundant in number of species and individuals. In fact, there are an estimated 6 359 species of Chironomidae worldwide [18]. However, this number is open to discussion since species are still discovered and newly described.

The larvae of Chironomidae are found in all freshwater and even terrestrial environments. It is certain that the clear preference for aquatic habitats no longer needs to be demonstrated: these vary from conventional running waters (torrents, streams, rivers) and stagnant waters (ponds, lakes, rice fields) [70, 76, 77].

Ecological studies have shown that the distribution of Chironomidae larvae is conditioned by certain environmental factors such as: depth, type of substrate, trophic level of the environment and chemical factors such as oxygen concentration [76].

Throughout the Chironomidae family, description of species is traditionally based on adults, and knowledge of immature stages varies across tribes or even across species of the same genus. Indeed, some genera have immature terrestrial stages, other genera have exclusively aquatic larvae. However, many species have unknown immature stages [47].

A specific and generic richness is recorded in the Palearctic and Nearctic regions, this is probably due to the fact that the majority of researchers on Chironomidae are located in these regions. It would be very interesting to broaden the research spectrum of studies on Chironomidae in other regions of the world such as the Mediterranean region in order to better understand the occurrence and distribution of chironomid species and even to discover other species new for the regions and for science.

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