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A Quick Review of the Family Chironomidae (Order Diptera) with Effect on the Environment

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Abstract

Context: The Chironomidae family is more sensitive to changes in water environment quality. This taxon is tolerant in stream ecosystems. Thus, it could be used as a bio-indicator of freshwater to recognize the presence of contaminants with deleterious effects on human health.
Evidence Acquisition: We searched keywords Chironomidae, bioindicator, environment, water stream, water quality, anthropogenic disturbance, pollutant, fossil, industrial waste, and aquatic habitats. Chironomidae was used once in single and again in combination with others. Google Scholar, Scopus, Springer, ScienceDirect, PubMed, ProQuest, JSTOR, EBSCO, BioOne, ResearchGate, Sage, Wiley Online Library, and SID were used as databases or search engines. Then, the results were sorted into four sections: Distribution and ecology, biotic indicators, food, and paleoecological studies.
Results: The identification key of chironomids should be improved based on morphological and molecular data to determine this family more clearly. Identifying sub-fossil chironomid insects found in the sediments of lakes unravels the range of environments during the history of its aquatic habitat through paleoecological investigations.
Conclusions: Chironomidae at genera or species has variations in traits in the ecosystems. Each species as a bio-indicator has different tolerable condition in its own habitat .Overall, the role of this family in all types of pollutants is ambiguous. More studies are needed to particularize the importance of Chironomidae based on genera and species.

Keywords: Chironomidae, Diptera, Indicator, Pollutants, Environment

1. Context

Organics, pathogens, nutrients, agriculture runoff, suspended solids, sediments, inorganic pollutants (salts and metals), and thermal pollution are significant water contaminants (1, 2). Toxic metals in waste streams affect fish life. They harm growth, change liver glycogens and triglycerides, and disrupt metabolic enzyme activities in the catfish (3). Some chemical elements negatively affect embryonic development, hatching, and viability of the mallard (4). Also, they are harmful to human health in either short or long-term exposure. The kidney, pancreas, heart, bones, veins, arteries, liver, and brain would be dysfunctioned by the intake of certain pollutants ingested through drinking water (5).

Bioindicators are sensitivities to the ecological and natural changes caused by anthropogenic disturbance. It affects biodiversity and community of insect (6-8). Aquatic macroinvertebrates such as *Baetis* sp., *Fallceon* sp., *Leptohyphes* sp., *Tricorythodes* sp., *Farrodes* sp., *Phyllogomphoides* sp., *Hydroptila* sp., *Mayatrichia* sp., *Neotrichia* sp., *Oxyethira* sp., *Nectopsyche* sp.1, *Nectopsyche* sp.2, and *Oecetis* sp. are bioindicators sensitive to water contamination (9).

Chironomidae has been used as a significant insect for the bioassessment of water quality for a long time (10). This study aims to explore Chironomidae as an important bioindicator in all types of water bodies and environments. Furthermore, this macroinvertebrate has a role in the food chain, energy transfer, and paleoecological investigations. This family adapts to environmental conditions and predicts unexpected contamination from human activities or other agents. Studying the Chironomidae traits helps us clarify the dynamic of the species-environment relationship. Moreover, due to its predictability, it demonstrates the effects of stressors on ecosystems.

2. Evidence Acquisition

We used keywords such as Chironomidae, bioindicator, environment, water stream, water quality, anthropogenic disturbance, pollutant, fossil, industrial waste, and aquatic habitats. Chironomidae was used once in single and again in combination with others. Google Scholar, Scopus, Springer, ScienceDirect, PubMed, ProQuest, JSTOR, EBSCO, BioOne, ResearchGate, Sage, Wiley Online Library, and SID were used as databases or search engines. Then, the results were sorted into four sections: Distribution and ecology, biotic indicators, food, and paleoecological studies. The obtained articles and scientific documents were often helpful. Few were dropped from our work because of low quality or overlap.

3. Results

3.1. Distribution and Ecology

The family Chironomidae (order: Diptera) comprises predominant insects in freshwater environments. Little studies have been carried out about the lifecycle and ecology of this family. The family has more than 5,000 species worldwide, but the exact number is unclear. A few chironomids have terrestrial habitats (11). This family is categorized into 11 subfamilies and 22 tribes. The subfamilies include Telmatogetoninae, Usambaromyiinae, Aphroteniinae, Chilenomyiinae, Podonominae, Tanypodinae, Buchonomyiinae, Diamesinae, Prodiamesinae, Orthocladiinae, and Chironominae (12). *Belgica antarctica*, *Eretmoptera murphyi* (subfamily Orthocladiinae), and *Parochlus steinenii* (subfamily Podonominae) are the only chironomid species identified in the Antarctica areas (13). The subfamily Chilenomyiinae is restricted to Chile. Buchonomyiinae has two species identified in Europe and Asia. Aphroteniinae, including four genera, has been recognized only in South America, South Africa, and Australia. Subfamilies, including Orthocladiinae, Tanypodinae, and Chironominae, are established more in lake sediments (14). Genus *Dicrotendipes* Kieffer from China comprises eight species: *Dicrotendipes flexus*, *Dicrotendipes fusconotatus*, *Dicrotendipes nervosus*, *Dicrotendipes nudus sp. n.*, *Dicrotendipes pelochloris*, *Dicrotendipes saetanumerosus* sp. n., *Dicrotendipes septemmaculatus*, and *Dicrotendipes tamaviridis* (15). This family has four larval instars with around one year of longevity, but pupal and adult stages last about a few days or weeks, depending on species and climate. Males swarm about one hour before sunrise and scatter about one hour after sunset for mating with females (16). The larvae stages of *Paratendipes albimanus* and *Rheotanytarsus curtistylus* are remained in the second and third instar in winter (17). Chironomidae are abundant in the organic content of sediments or beds of lakes and rivers (18). For example, macrophytes (*Potamogeton pectinatus* and *Ruppia maritima*) or benthic algae (*Rhizoclonium hieroglyphicurn*) significantly affect the growth of *Cricotopus ornatus* (Meigen) (Diptera: Chironomidae) (19). Also, it has been found in gravel sediments. Overall, it is limited to the surface layers of soft sediments, but some species habitat more deeply, and the sediment depth may be confining to population density in some instances. Some species ingest wood because of having symbiotic microorganisms in their gut (20). Notably, chironomids larvae use physiological or behavioral strategies to survive in habitats with repeated changes in the situation, such as rain pools, phytotelmata, freshly filled ponds or soil layers, urban rivers, hot springs, and coastal lagoons (21-23).

3.2. Biotic Indicators

Chironomid midges adapt to sites with different water quality streams in the Scioto River basin, Ohio. (1) *Stictocbironomus* was found in the hard, alkaline unpolluted water; (2) *Pentaneura*, *Cricotopus*, and *Tanytarsus* were observed in the sewage enriched water; (3) *Procladius* and *Dicrotendipes* have existed in the high agricultural runoff; (4) *Ablabesmyia* and *Tribelos* were adapted to general organic pollution, soft acid water (24). Moreover, *Chironomus riparius* is an indicator of organic pollution and sediment toxicity monitoring (20, 25). Chironomidae larvae exist in lentic and lotic environments with different taxonomic levels (26-30). This aquatic macroinvertebrate was found at polluted spots of Barbados Stream in Brazil, where pollutants like domestic sewage, plastic materials, root, and slime were sorted (31). Remarkably, riparian vegetation affects Chironomidae assemblage and has a significant role in the composition of aquatic fauna in neotropical streams (32, 33).

Neonicotinoid insecticides affect Chironomidae life in all stages. Chironomidae represent high densities of high-affinity nicotinic acetylcholine receptors (34). Also, significant factors influencing Chironomid distribution are temperature associated with O_2, Cl^-, Al^{3+}, Mg^{2+}, and Na^+ ions in lakes of central Yakutia, Russia (35). The chironomid species (i.e., *Anatopynia plumipes*, *Procladius* sp., *Psectrotanypus rarius*, *Cricotopus sylvestris*, *Psectrocladius edwardsi*, *Chironomus tentans*, *C. polaris*, *Chironomus* sp. I and

II, *Einfeldia dissidens*, *E. pagana*, and *Glyptotendipes paripés*) have shown tolerance to low oxygen pressures and temperature in a frozen lake in northern Sweden (36). Moreover, larval and pupal of *Pseudodiamesa arctica* were observed in temperatures between 0°C and 4°C of Nettilling lake in Baffin Island, Canada, but 15°C is desirable temperature in small water bodies for larval growth (37). Besides, pH is another environmental parameter. Chironomids species are diverse in pH ranging from 6.4 to 8.3 in small prairie ponds in central Saskatchewan, Canada (38). *Chironomus salinarius* Kieffer can tolerate a range of salinity levels (39). *Baeotendipes noctivagus* (Kieffer, 1911) is possibly the most inflexible species to salinity in the world (40). A special subfamily or tribe of chironomids is inhabited in different sampling sites of Swartkops River, south of Africa, by water quality. Dissolved oxygen, electrical conductivity, orthophosphate-phosphorus, total inorganic nitrogen, and turbidity were the critical variables for chironomid communities (41). Hydrocarbon phenanthrene as a chemical substance harms benthic organisms in sediments through acute/chronic exposure. *Chironomus sancticaroli* larvae frequently have shown susceptibility to this compound (42). Additionally, biodegradation of amorphous carbon was identified in the digestive tract of Chironomidae species (43). Deformities in larvae are reported, often resulting from responding of Chironomidae to anthropogenic and environmental disturbances (44). The deformity rate may be a practicable parameter for biomonitoring (45). This event has been seen in *Ablabesmyia* sp. and *Procladius* sp. larvae in acid mine drainage (46). Mouthpart deformities of the *Chironomini* tribe in response to sediments containing metals such as Pb, Zn, Cu, As, and Cd are recorded from a river in the USA (47).

3.3. Food

Chironomus plumosus larvae are the source of natural substances more beneficial for farm fish diet. For instance, crude protein content is 7.6% and 55.7% in fresh larvae and dry weight, respectively. Amino acids such as Arginine, Histidine, Isoleucine, Leucine, Valine, Lysine, Phenylalanine, Methionine, Threonine, and Tryptophan have been isolated from larvae of this species (48, 49). Other food values of chironomid larvae are carbohydrate 23%, chitin 4%, ash 9%, and caloric content (4.6 to 6.1 kcal.g^{-1}) (50). Dragonfly larvae feed at least 30% of their body weight on midges (51). Similarly, Chironomidae larvae are solely dieted for kind of leech (*Erpobdella octoculata*) so that leech survives where Chironomidae grow and increase in running water (52). Sometimes, predators like nine-spine stickleback, *Pungitius pungitius*, and the damselfly, *Enallagma clausum*, threaten the *Cricotopus ornatus* population in the fourth instar and pupal phases (19). Chironomids are the main in the early dietary regime of young flightless dabbling ducks after hatching (36). Furthermore, this family, particularly Corynoneura, participates in the trophic cycle and decomposition of plant detritus in subtropical streams. Chemical elements of the detritus assemblage influence the structure of the chironomids community during a long time of exposure (53). Moreover, chironomids with small body sizes have been detected in an environment with high levels of disturbance. Anthropic and climatic factors may cause this morphological trait (54). There is a symbiotic relationship between Chironomidae larvae and benthic animals as follows: *Demeijerea rufipes*, Chironomidae, a parasite of sponges and bryozoan, *Eukiefferiella ancyla*, subfamily Orthocladiinae, as commensal of the snail *Ancylus fluviatilis*, and *Symbiocladius rhithrogenae*, Orthocladiinae, a true and obligate parasite of Heptageniidae/Ephemeroptera larvae, feeding on the mayfly's hemolymph (55).

3.4. Paleoecological Studies

Climate affects chironomid fauna composition and their morphological structures (56). Surficial sediments sampling upon altitudinal range can be helpful. It means we can trace chemistry among lakes according to lake depth. On the other hand, Chironomid fauna presents the past condition of the environment in different depths. *Heterotrissocladius* was predominant in deep lakes rather than shallow ponds. In contrast, *Cladopelma* was limited to shallow lakes as warmer habitats in summer (57). Analysis of deposits has approved that more chironomid taxa were discovered at low elevations in the southern Canadian Cordillera lakes (58). In a study using the larval head capsule fossils from surface sediment samples of 50 lakes, 7,771 chironomids were identified, following 13 species, 10 species groups, four subgenera, 41 genera, four genus groups, five types, and three with unknown taxonomic affiliation. Taxon richness was described with physical, chemical, and biological variables such as water temperature, lake depth, pH, conductivity, alkalinity, calcium, magnesium, sodium, potassium, total organic carbon, latitude, longitude, and altitude (59).

4. Conclusions

Chironomids are a favorable candidate to use in bioassessment approaches in toxicity tests and paleolimnology. Detailed life-history information of some species is available from laboratory studies. In contrast, they might be disqualified as biochemical and physiological indicators of environmental stress resulting from taxonomic problems with larvae and small size (60). However, the role of this family in all types of pollutants is ambiguous. More studies are needed to particularize the importance of Chironomidae based on genera and species.

Footnotes

Authors' Contribution: The first author, F.SH., designed, searched, and wrote the final version of the manuscript. MH. and AM. collected data from scientific resources. M.KH. searched for required information about variables related to the insect and environment and wrote the draft.

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