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Vitória Cristina Pompermayer de Mattos

**EFFECTS OF MICROPOLLUTANTS ON FRESHWATER ZOOPLANKTON: A
SYSTEMATIC REVIEW**

Juiz de Fora

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Trabalho de Conclusão de Curso apresentado ao Curso de Graduação em Ciências Biológicas da Universidade Federal de Juiz de Fora como requisito à obtenção do título de Bacharel em Ciências Biológicas. Área de concentração: Ecologia.

Orientadora: Prof^ª. Dr^ª. Simone Jaqueline Cardoso

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SIMONE JAQUELINE CARDOSO
Data: 22/01/2026 18:28:26-0300
Verifique em <https://validar.iti.gov.br>

Profa. Dra. Simone Jaqueline Cardoso - Orientadora
Universidade Federal de Juiz de Fora

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Verifique em <https://validar.iti.gov.br>

Dra. Iollanda Ivanov Pereira Josué
Analista ambiental da Secretaria de Meio Ambiente e
Mudanças Climáticas da prefeitura de Juiz de Fora

Documento assinado digitalmente
THAIANE CANTARINO COSTA
Data: 23/01/2026 10:35:20-0300
Verifique em <https://validar.iti.gov.br>

Msc. Thaianne Cantarino Costa
Universidade Federal de Juiz de Fora

Dedico este trabalho aos meus pais, pelo incansável esforço e apoio.

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“Depois do medo, vem o mundo”

(Clarice Lispector)

RESUMO

O uso contínuo e excessivo de micropoluentes como fármacos, pesticidas, microplásticos e metais pesados tem gerado diversos impactos nos ecossistemas de água doce e nos organismos que neles habitam, como o zooplâncton. Esses organismos apresentam alta sensibilidade a mudanças ambientais e desempenham um papel ecológico crucial, atuando como elo entre os produtores primários e os níveis tróficos superiores. Para compreender os efeitos dos micropoluentes sobre o zooplâncton, realizamos uma revisão sistemática e coletamos nos estudos primários informações sobre poluentes e traços funcionais dos organismos zooplanctônicos, como morfologia corporal, fisiologia e comportamento, que influenciam diretamente a sobrevivência dos organismos. Nos estudos que relacionam traços funcionais e funções ecossistêmicas, consideram-se quatro principais funções ecológicas desempenhadas pelos organismos, categorizadas em Sobrevivência, Reprodução, Alimentação e Crescimento. A revisão sistemática foi realizada utilizando a metodologia PRISMA (do Inglês *Preferred Reporting Items for Systematic Reviews and Meta-Analyses*). Os estudos publicados até 2019 foram obtidos do trabalho de Josué et al. (2021), e de 2019 até julho de 2025 realizamos novas buscas nas bases de dados Web of Science utilizando o mesmo código de busca, totalizando um período de 21 anos de pesquisas. Na compilação das buscas, foram identificados 1.387 trabalhos publicados entre 2004 e 2025, dos quais 113 atenderam aos critérios de inclusão e foram incorporados à revisão sistemática. Os principais efeitos observados dos micropoluentes sobre o zooplâncton foram negativos, afetando sua capacidade reprodutiva, sobrevivência no ambiente, modo de alimentação, capacidade de fugir de predadores e de natação, tamanho corporal, entre outros parâmetros. Desse modo, este estudo evidencia o crescimento gradual do número de publicações sobre a temática e ressalta os riscos representados por esses poluentes para o zooplâncton de água doce.

Palavras-chave: zooplâncton, água doce, micropoluentes, traços funcionais, funções ecológicas.

ABSTRACT

The continuous and excessive use of micropollutants such as pharmaceuticals, pesticides, microplastics, and heavy metals has generated various impacts on freshwater ecosystems and the organisms that inhabit them, such as zooplankton. These organisms are highly sensitive to environmental changes and play a crucial ecological role, acting as a link between primary producers and higher trophic levels. To understand the effects of micropollutants on zooplankton, we conducted a systematic review and collected information from primary studies on pollutants and functional traits of zooplankton organisms, such as body morphology, physiology, and behavior, which directly influence organism survival. In studies linking functional traits and ecosystem functions, four main ecological functions performed by organisms are considered, categorized as Survival, Reproduction, Feeding, and Growth. The systematic review was conducted using the PRISMA methodology (*Preferred Reporting Items for Systematic Reviews and Meta-Analyses*). Studies published up to 2019 were obtained from the work of Josué et al. (2021), and from 2019 to July 2025 we conducted new searches in the Web of Science database using the same search code, covering a total period of 21 years of research. In the search compilation, 1,387 studies published between 2004 and 2025 were identified, of which 113 met the inclusion criteria and were incorporated into the systematic review. The main observed effects of micropollutants on zooplankton were negative, affecting their reproductive capacity, environmental survival, feeding mode, ability to escape predators and swim, body size, among other parameters. Thus, this study highlights the gradual increase in the number of publications on the subject and emphasizes the risks posed by these pollutants to freshwater zooplankton.

Keywords: zooplankton, freshwater, micropollutants, functional traits, ecological functions.

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1. INTRODUCTION

Among the various anthropogenic pressures affecting freshwater ecosystems, the introduction of micropollutants stands out. These are organic and inorganic contaminants that are released in the environment at low concentrations, typically in the range of micrograms, nanograms, or picograms per liter or kilogram (KOMOLAFE et al., 2021). These pollutants encompass a vast array of compounds, such as pharmaceuticals, personal care products (PPCPs), pesticides, microplastics, and heavy metals (BERTRAM, 2022). The main sources of emission of these substances include rapid urbanization, population growth, agricultural practices, and industrial development (PATEL et al., 2019). The relevance of these compounds lies in their potential for environmental persistence, bioaccumulation in the trophic chain and potentially deleterious effects on organisms (KANAUJIYA et al., 2019). Such effects can manifest on organisms through growth anomalies, reduced fertility and reproductive health, delays in neurological development and degradation of aquatic ecosystems (DULIO et al., 2018; RODRIGUEZ-NARVAEZ et al., 2017).

The increasing production and use of micropollutants have resulted in their release into aquatic ecosystems worldwide, especially freshwater ecosystems (LI et al., 2016). Conventional wastewater treatment processes often have limited efficiency in removing such compounds, resulting in their discharge in treated effluents, which are released into the river basin (WESTERHOFF et al., 2005; SNYDER et al., 2003; DI NICA et al., 2015; LI et al., 2016; JIANG et al., 2014). Once in the environment, the transport, persistence, and distribution of micropollutants are influenced by a complex interaction of factors, including the physicochemical properties of the contaminants and the aquatic environment, as well as geographical and climatic conditions (STEFANAKIS et al., 2015). In this context, one of the greatest contemporary challenges lies in the insufficient understanding of the long-term effects these substances may have on aquatic biota (ARMAN et al., 2021).

Among the organisms that compose freshwater ecosystems, zooplankton, commonly represented by the groups Cladocera, Copepoda, and Rotifera, are among the most sensitive to environmental changes and the action of micropollutants (DANTAS-SILVA et al., 2013). These organisms play a crucial ecological role, acting as a central link between primary producers and higher trophic level consumers, such as fish, birds, and mammals, in addition to influencing biogeochemical cycles through direct and indirect feedback mechanisms (PITOIS

et al., 2012; RUZICKA et al., 2012; LAURIA et al., 2013; HENEGHAN et al., 2016). Due to their biological characteristics, such as short life cycles, which confer a rapid response to disturbances, they are widely used as bioindicators of water quality (CARVALHO et al., 2013; KHALIFA et al., 2015). For this reason, they provide both a specific assessment of contaminant levels and early detection of broader changes in the ecosystem (HANAZATO et al., 2001). Considering their central position in the trophic web, variations in zooplankton diversity can lead to significant impacts on the functioning and stability of continental aquatic ecosystems (PAQUETTE et al., 2022).

Understanding and predicting the structure and function of plankton communities under varying environmental conditions, such as micropollutants pollution, is a critical scientific challenge, particularly given the significant diversity in ecological strategies, dominance patterns, and ecosystem impacts exhibited by freshwater zooplankton (LITCHMAN et al., 2013). To address this challenge, ecologists have adopted, in recent years, an approach centered on functional trait diversity. This perspective broadens ecological understanding by focusing on the attributes that define how organisms interact with the physical, chemical, and biological environment around them (HOOPER et al., 2005; NOCK et al., 2016), as exemplified by Bruijning et al. (2018) in their investigation of water temperature effects on zooplankton body size, and by Gu et al. (2017) in their examination of how predation influences organism life history.

Functional traits can be defined as a well-delimited and measurable characteristics of an organism, typically assessed at the individual level and used for comparisons between species. Functional traits fulfill two main purposes: they can characterize the responses of organisms to environmental changes or quantify the influence these organisms exert on ecosystem processes (VIOLLE et al., 2007; DÍAZ et al., 2001). These characteristics are used to describe key aspects of organisms, which are broadly categorized into physiological, morphological, life history and behavioral dimensions (POFF et al., 2006).

Traits such as body size, feeding mode, motility, reproductive capacity and others, in addition to influencing individual fitness, play an important role in various ecological processes in aquatic habitats (RIZO et al., 2017). In the context of studies on functional traits and ecological functions, Litchman et al. (2013) proposed a classification of the main characteristics of zooplankton, highlighting four fundamental ecosystem functions: feeding, growth, reproduction, and survival, associating them with the functional traits and the different key

aspects of organisms. These properties are directly related to the organism's fitness, thus exerting a determining influence on the ecological niches they can occupy. (LITCHMAN et al., 2013).

Global anthropogenic transformations, especially the intense and careless use of micropollutants have caused significant impacts on freshwater environments, affecting the multiplicity of species that inhabit them and potentially compromising their capacity to continue providing services such as nutrient cycling, water purification, climate regulation and cultural benefits (ALBERT et al., 2021; NOCK et al., 2016). Considering the continuous use of micropollutants, their alarming concentrations found in continental waters, and their already observed effects on zooplankton communities, the objective of this work is to present a systematic review of the scientific literature on the impact of micropollutants on freshwater zooplankton functional traits and ecosystem functions, updating data from a previous search. Therefore this study contributes to the consolidation of existing knowledge and the delineation of priorities for future research to address questions relevant to the functioning of freshwater ecosystems.

2. METHODOLOGY

2.1. SYSTEMATIC REVIEW AND SCIENTOMETRIC ANALYSIS

Evidence on the effects of micropollutants on the ecosystem functions of zooplankton was obtained through a systematic literature review, using the PRISMA methodology (Preferred Reporting Items for Systematic Reviews and Meta-Analyses; Moher et al., 2015), which considers the quality and transparency of the analyzed studies. The search was conducted in the Web of Science database, limited to peer-reviewed articles, written in English. The search code included the following keywords: “(Freshwater) AND (Zooplankton* OR Cladocera* OR Rotifer* OR Copepod) AND (Antrop* OR Human OR Pollut* OR Micro Pollut* Metal* OR Contamina*)”. Part of the data used (until 2019) was sourced from the database compiled by Josué et al. (2021), whose study included 50 articles and did not apply a publication year limit. To update this dataset, this study included reviewed articles published between January of 2020 and July 2025, resulting in a cumulative search period of 21 years.

The article screening process was conducted in two stages: (i) an initial assessment of titles, abstracts, and keywords, followed by (ii) a full-text review. Articles were deemed eligible

if they met the predefined inclusion and exclusion criteria. Inclusion criteria required that articles: (1) were written in English and peer-reviewed; (2) were laboratorial ecotoxicology study on zooplankton; (3) focused on micropollutant analysis; and (4) detail the ecosystem functions and functional traits analyzed. Exclusion criteria consisted of: (1) review articles; (3) modeling studies; (4) mesocosms experiments, as they cannot directly analyze the effects of micropollutants due to the various variables within the system; or (5) studies that considered only indirect effects of the pollutant. The following data were extracted from each eligible article: (1) type of micropollutant, (2) taxonomic group of the studied zooplankton, and (3) affected functional traits or characteristics.

Scientometric analysis was conducted to evaluate research and publication trends. Essential data, including the year of publication, the scientific journal and the country in which the research took place, was compiled. This information was then analyzed to identify worldwide patterns over time in the volume of scientific studies investigating how micropollutants affect zooplankton ecosystem functions.

The functional traits were categorized in this study according to their most closely related ecosystem functions (feeding, survival, reproduction and growth). However, it is important to note that traits from each function can also be interrelated. For instance, an organism's swimming speed is important for its survival, but also for feeding, as some representatives are active predators. Similarly, body size is related to growth, but also to reproduction and survival, since predation rates can be influenced by increases in an organism's body size.

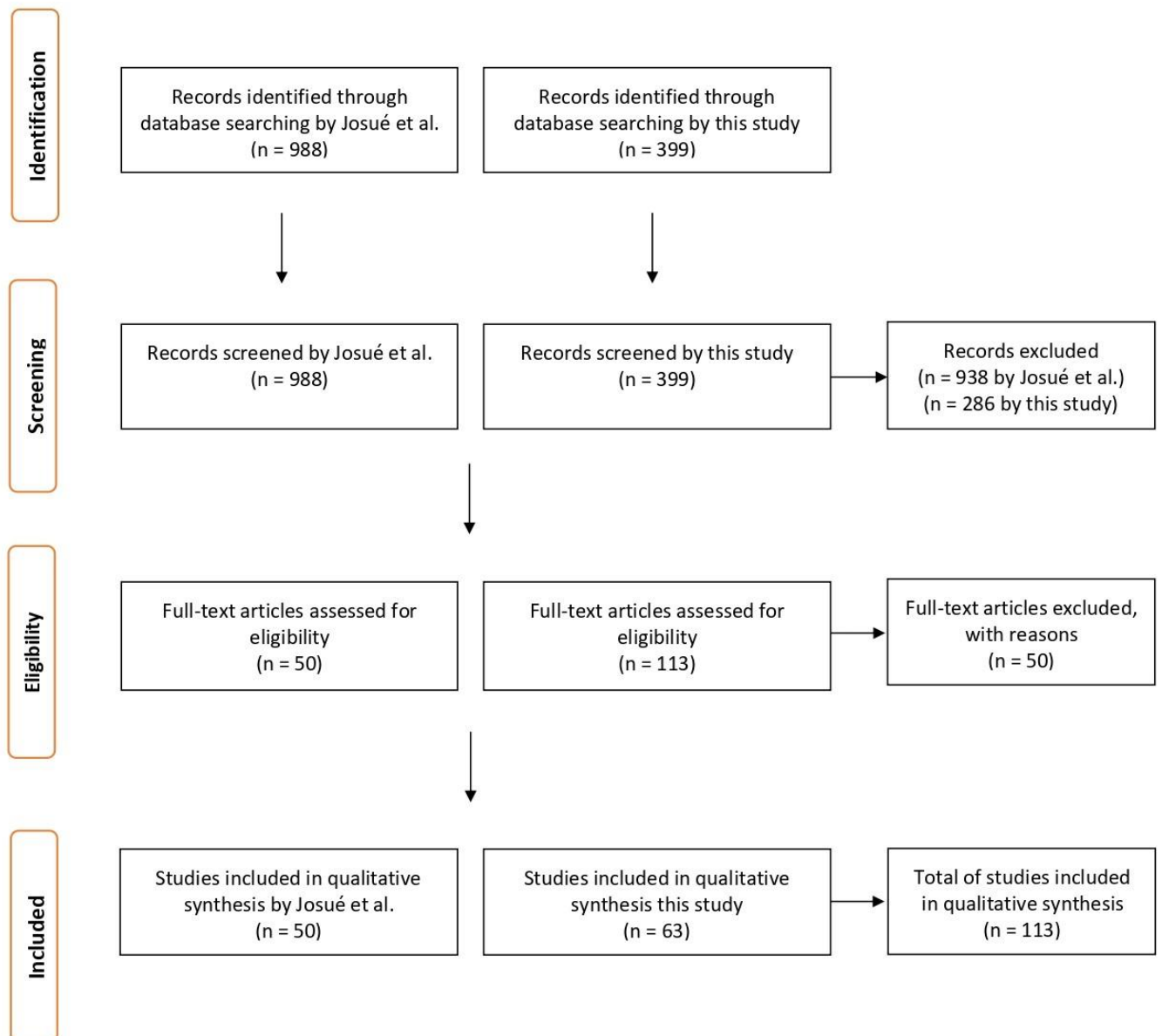
Micropollutants were classified into the following categories: Pharmaceuticals, Microplastics, Pesticides, Personal Care Products, Illicit Drugs and Metallic Trace Elements, with the last category including heavy metals, metal oxides, and metallic particles. The ecosystem functions considered in this review were Survival, Growth, Reproduction, and Feeding (Litchman et al., 2013), as each of these functions has traits related to the organism's life history, behavior, physiology, and morphology. Graphs and tables for the qualitative analysis were generated using Google Sheets and Canva (CANVA, 2023).

3. RESULTS

3.1. SYSTEMATIC REVIEW AND SCIENTOMETRICS ANALYSIS

The database search yielded a total of 1,387 published articles, of which 988 were compiled by Josué et al. (2021) and 399 were compiled in the present study. After the first phase and the second screening phase, a final number of 113 articles were included in our database (Figure 1).

Figure 1. PRISMA flowchart describing the process for selecting articles for this systematic review including articles searched on Web of Science from 2004 to 2025 (adapted from Moher et al., 2015).



The articles included in our database comprise studies originated from 29 countries, and the largest contributions were from China (21), Brazil (12), Portugal (9), and Mexico (9) (Fig. 2). The included articles were published between 2004 and 2025 (no publications found for the year 2005), and the year 2022 had the highest number of publications (14) (Fig. 3).

Figure 2. Number of articles published sorted by the country where the studies were published between 2005 and 2025. China was the country with the highest number of publications, with 21 articles published, followed by Brazil with 12.

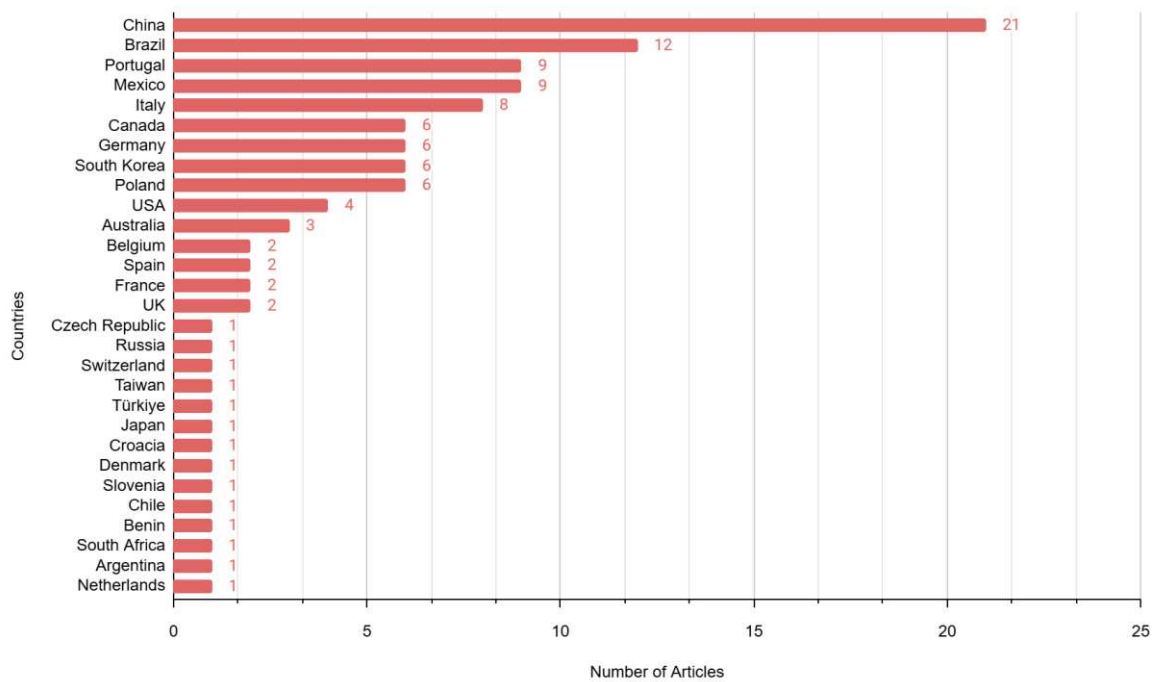
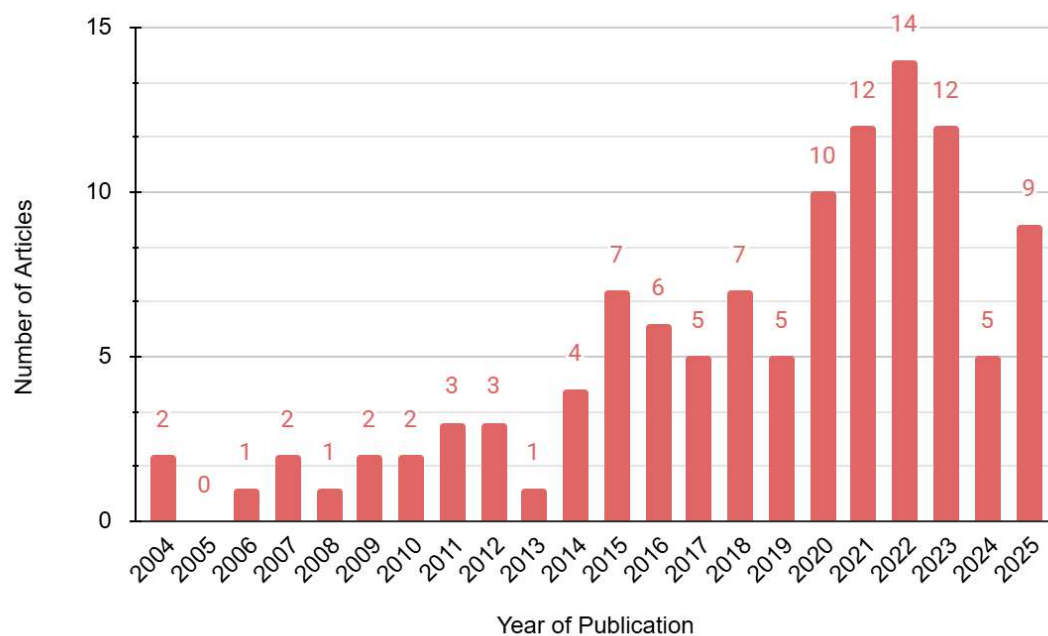
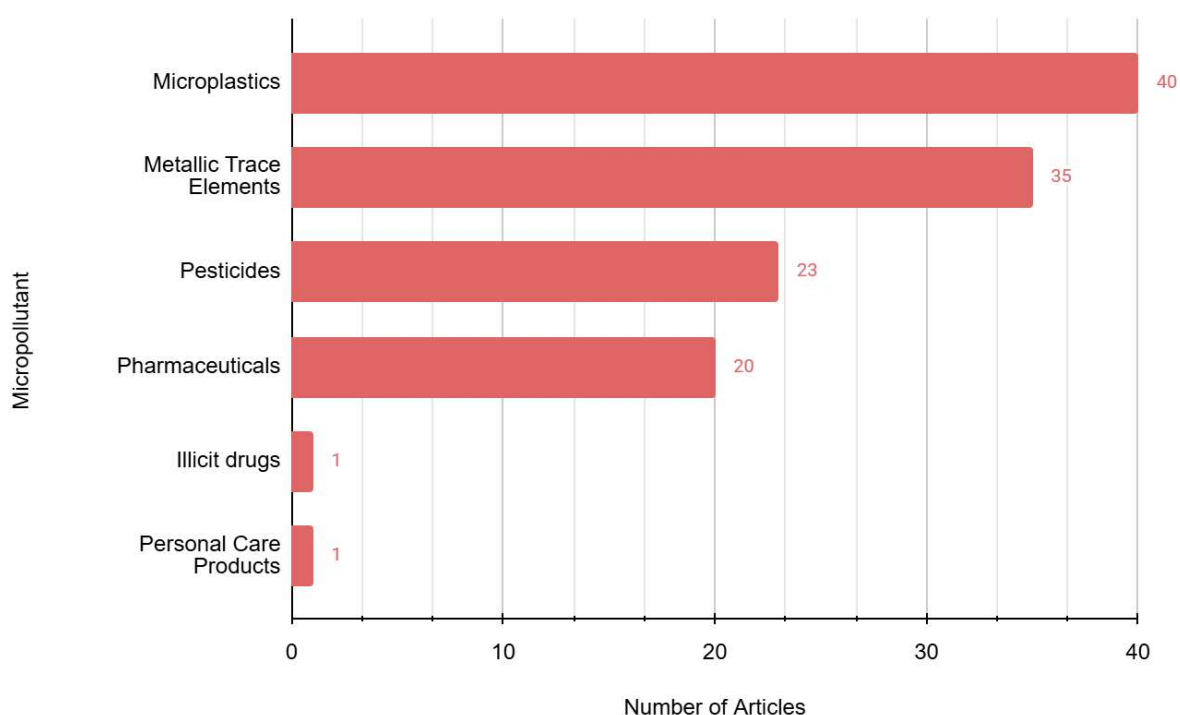


Figure 3. Number of articles published per year between 2004 and 2025. The year 2005 had no publication recorded by our search.



The primary studies reported 75 different micropollutants grouped into Illicit drugs, Personal Care Products, Pharmaceuticals, Microplastics, Pesticides and Metallic Trace Elements. Studies tested various micropollutant exposure conditions, including exposing different species to micropollutants, exposing organisms to multiple types of micropollutants and over different periods. The most frequently assessed micropollutant was Microplastics, with 40 studies, followed by Metallic Trace Elements (35), Pesticides (23), and Pharmaceuticals (20). These numbers do not represent the total number of individual studies, but rather how many times each category was sampled, as a single study could analyze more than one type of micropollutant. Illicit Drugs and Personal Care Products were each analyzed in only one study, represented by cocaine and sunscreen, respectively (Fig. 4).

Figure 4. Number of articles per micropollutants analyzed. Each article can contribute to more than one micropollutant group analysed.

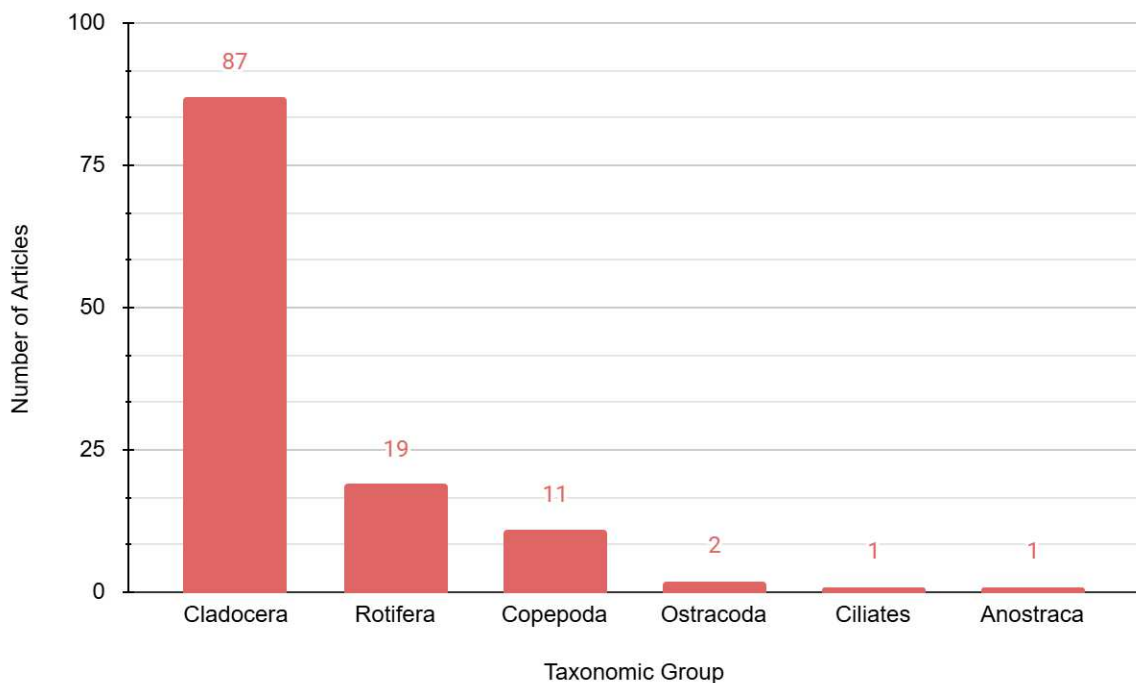


Within the Metallic Trace Elements category, the heavy metals cadmium (Cd) and copper (Cu) were the most frequently analyzed. Among the most sampled Pharmaceuticals were fluoxetine, commonly used to treat depression (AMERICAN PSYCHIATRIC ASSOCIATION, 2023), and diclofenac, a non-steroidal anti-inflammatory drug (MINISTÉRIO DA SAÚDE, 2023). Microplastics, the most sampled micropollutant across the analyzed articles, were most represented by polyethylene (PE), commonly used to produce plastic bags

(HARPER et al., 2021), and polystyrene (PS), used in the production of Styrofoam® (PLASTICS EUROPE, 2023). Finally, the most analyzed Pesticides were Imidacloprid (insecticide), Fipronil (insecticide), Atrazine (herbicide), and Fenoxycarb (insecticide).

Among the studies, the majority used the Cladocera (Latreille, 1829) group as the study subject, followed by Rotifera (Cuvier, 1798) and Copepoda (H. Milne-Edwards, 1840), which are among the main representatives of freshwater zooplankton. Four studies were conducted with other groups: two with planktonic species of Ostracoda (Latreille, 1802), one with a planktonic larvae of Anostraca, and the last one with a Ciliate (Doflein, 1902) species, representing the protozooplankton (Fig. 5). Again, these numbers do not represent the total number of individual studies, but rather how many times each category was sampled, as a single study could analyze more than one taxonomic group.

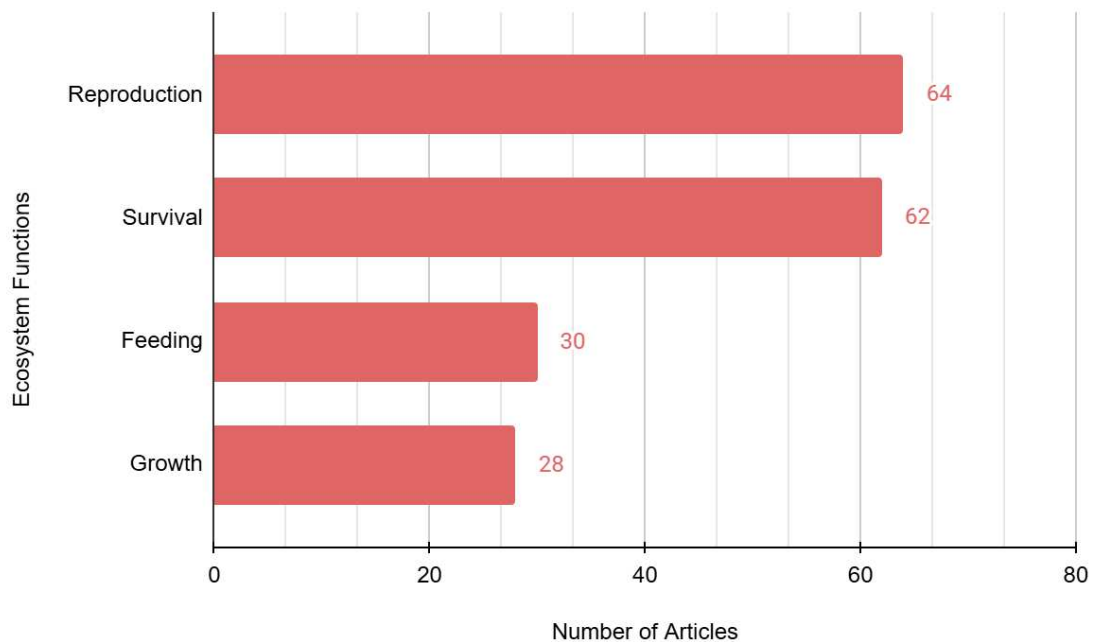
Figure 5. Number of articles per taxonomic group studied. Each article can contribute to more than one group.



The ecosystem functions analyzed were Survival, Feeding, Growth, and Reproduction. Among these functions, effects on reproduction were the most frequently analyzed, followed by impacts on survival, feeding, and growth (Fig. 6). Regarding the functional traits related to the reproduction function, studies primarily focused on the age at primipara, that is, the age at

which the first reproduction occurs, the reproductive rate of organisms, and the number of neonates produced by each female upon exposure to the pollutants. Concerning survival traits, mortality was the most studied, particularly in acute studies, which are short-term analyses lasting usually 48 hours with the main objective of determining the potential toxicity and establishing a safe or lethal dose (ABNT, 2022). For feeding, ingestion was the most analyzed trait, especially in microplastic studies, where the main objectives were the particle ingestion rate and their retention sites within the organism. Finally, body size was the most sampled growth trait among the articles reviewed in this work.

Figure 6. The ecosystem functions analyzed in this review. Each article can contribute to more than one group of ecosystem functions analyzed.



The relationship between micropollutants and the year of publication is detailed in Fig. 7, demonstrating the increasing trend in the number of studies that analyzed each of the considered micropollutants. Articles on metallic trace elements were published almost every year, whereas studies on microplastics became more frequent from 2016 onwards, highlighting the moment researchers began to consider this pollutant a threat to aquatic life. A total of 56 scientific journals published research on the effects of micropollutants on zooplankton between 2004 and 2025. Among the identified journals, *Science of the Total Environment* published the highest number of articles, followed by *Ecotoxicology and Environmental Safety* and

Environmental Pollution. The six most prolific journals accounted for over 50% of the total publications, highlighting their significant contributions to the field. A list of the top 10 journals by publication count is provided in Fig. 8.

Figure 7. The relationship between micropollutants and the publication years.

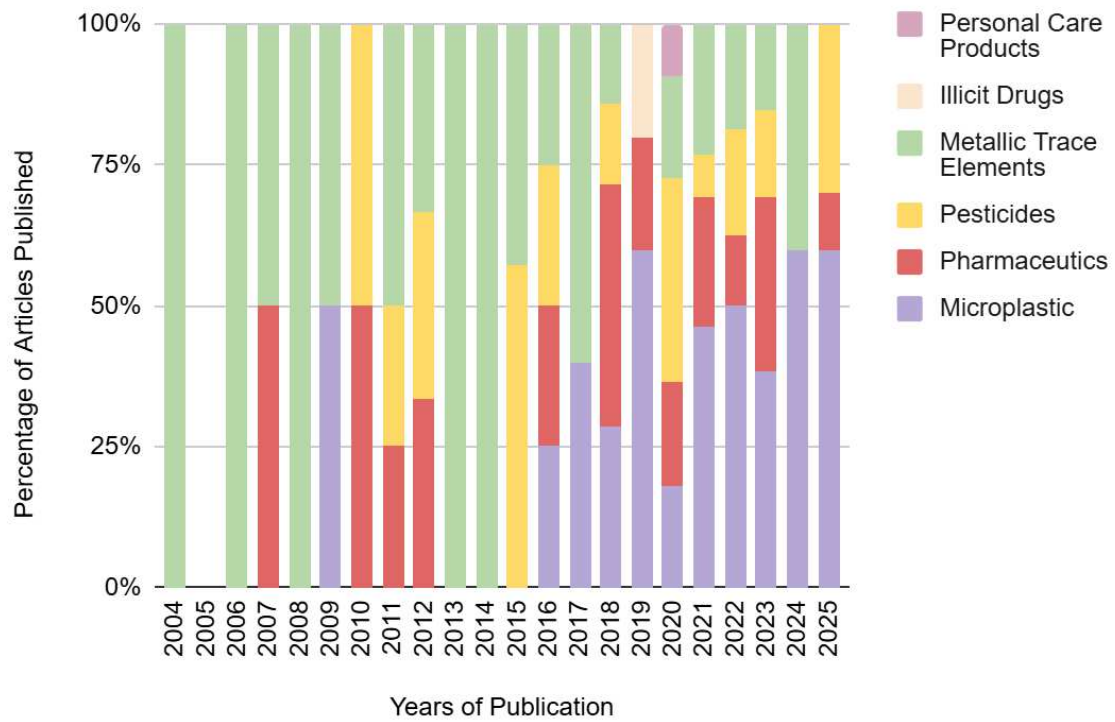
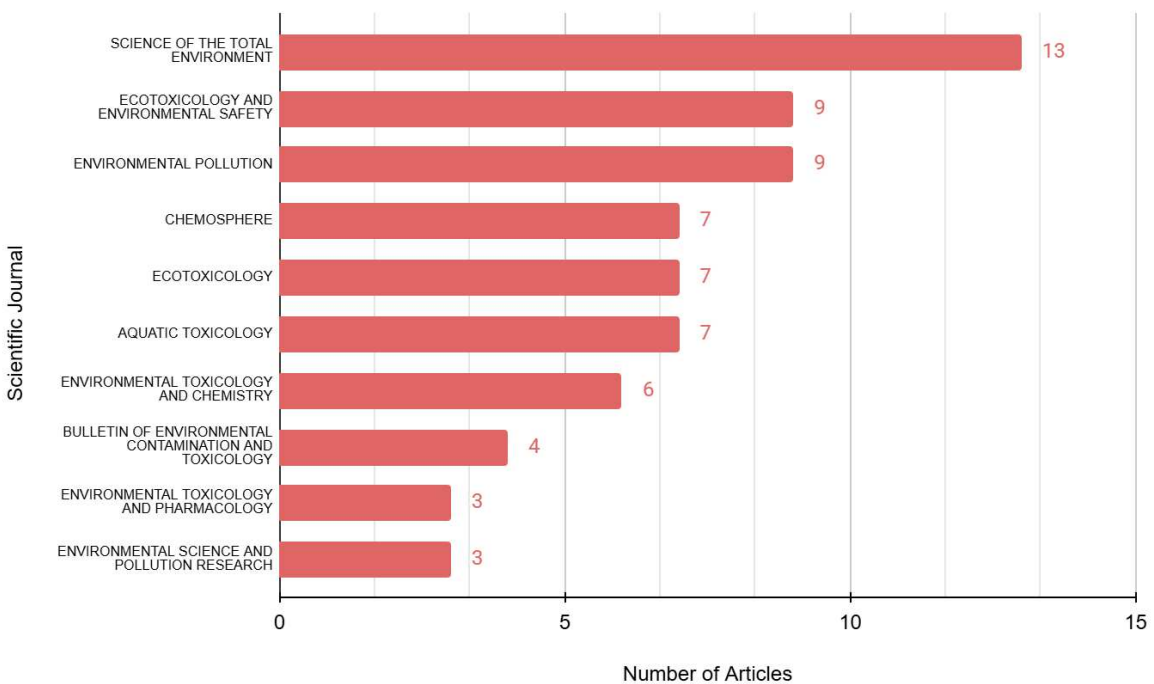


Figure 8. The scientific journals with the most published articles between 2004 and 2025.



The summary of studies included in the systematic review plus the study organisms, zooplankton traits, pollutant type and related ecological functions are detailed in Apendice 1.

4. DISCUSSION

This systematic review compiles existing research to concisely understand and describe how micropollutants impact freshwater zooplankton. It demonstrates that these substances adversely affect crucial ecosystem functions, such as survival, feeding, growth, and reproduction, and their functional traits and diversity, thereby addressing key questions pertaining to freshwater ecosystem functioning.

To enhance clarity, the discussion of results will focus on the ecosystem functions and functional traits analyzed per micropollutant, categorized as microplastics, metallic trace elements, pesticides, and pharmaceuticals. The categories of personal care products and illicit drugs, as each is represented by only one article, will be consolidated into a single topic. This will be followed by an examination of the scientometric analysis findings, highlighting the most active countries, publication years and journals in the field. Thus, the discussion is structured into two main sections: micropollutants and scientometric analysis.

4.1. SCIENTOMETRICS ANALYSES

The scientometric analysis demonstrated an increase in studies examining the consequences of micropollutants on zooplankton survival from 2004 to 2025. This trend reflects the growing concern among researchers regarding this topic, particularly following the surge in studies on water pollutants and the heightened focus on plastic pollution, heavy metals from mining and other activities, and increased pharmaceutical consumption in recent years. Furthermore, the rise in studies demonstrating the ineffectiveness of water and sewage treatment plants in removing such pollutants has also contributed to the growing interest in the consequences of these substances for aquatic organisms, such as zooplankton.

Regarding the taxonomic groups studied, Cladocera was the most sampled among the analyzed studies. This is probably due to the ease of cultivation and maintenance of these organisms compared to other groups. However, this fact demonstrates the oversampling of Cladocera, with a lack of studies of groups with the same ecological importance, deviating from a true reflection of the aquatic ecosystem. Therefore, studies with Rotifera, Copepoda, Ciliates,

and others should be conducted in a way that prioritizes better cultivation and management methods for these organisms, so that studies on their ecosystem functions can be carried out.

Furthermore, there is an overuse of acute studies, that is, short-term studies used to indicate a lethal dose of the contaminant being tested. Thus, chronic, long-term analyses are not performed in the same way. This prevents an analysis of pollutants throughout the organisms' lifespan, which is crucial for analyzing not only mortality but also the effects on other ecosystem functions. Therefore, it is crucial that laboratories possess the necessary infrastructure to conduct chronic studies, so that there is a better understanding of how zooplankton is affected throughout its life.

Twenty-nine countries contributed research on the effects of micropollutants on zooplankton. China and Brazil stood out with the highest number of published articles, underscoring their sustained contributions to this field of study. This prominence also invites reflection on the use of micropollutants in these nations, as both rank among the world's most industrialized countries (IEDI, 2020). *Science of the Total Environment*, *Ecotoxicology and Environmental Safety* and *Environmental Pollution* were the three journals with the highest publication output. This prominence is likely attributable to their high impact factors, a metric that quantifies the average citation frequency of a journal's articles in subsequent scientific literature.

This study examined functional traits, measurable individual-level characteristics categorized as morphological, physiological, or behavioral, and their link to key ecosystem functions such as reproduction, survival, feeding, and growth, which collectively enhance an organism's fitness. In terms of growth function, aside from a few studies that analyzed body biomass, the functional trait of body size was the only one analyzed. This trait, along with reproductive capacity, feeding habits, and others, are called key traits (RIZO et al., 2017). By using key traits, it is possible to perform objective analyses based on functional characteristics and categorize organisms into distinct functional groups, defined as a set of species in a given community that share similar functional characteristics related to a specific ecological function (RIZO et al., 2017). Consequently, an alteration in any of these traits can affect the organism's overall development and behavior. Through a systematic review, we analyzed how these functions in zooplankton are affected by micropollutants and the evidence predominantly demonstrates that these substances have adverse consequences, negatively impacting zooplankton functional traits and ecosystem functions.

4.2 MICROPOLLUTANTS

4.2.1. MICROPLASTICS

The studies reviewed in this work highlights that microplastic induce deleterious effects in freshwater zooplankton, affecting vital parameters such as survival, growth, feeding and reproduction (GALIR et al., 2025; MALINOWSKI et al., 2023; BULANNGA et al., 2022; DANIEL et al., 2024; IMHOF et al., 2017 and others). Among the reviewed studies that evaluated the reproduction of organisms exposed to microplastics, a significant negative effect on fecundity was found, expressed by a reduction in the number of neonates per brood, as well as a decrease in the age at first reproduction. For instance, it was found that the reduction in reproductive success may be associated with increased intracellular levels of Reactive Oxygen Species (ROS) resulting from exposure to plastic particles (NUGNES et al., 2022). Several investigations demonstrate that the exposure of organisms to environmental contaminants contributes to the establishment of oxidative stress, a state of imbalance between the rate of generation of free radicals, such as ROS, and the capacity of the antioxidant system to neutralize them, favoring the former (SHARIFI-RAD et al., 2020; BELLO-MEDINA et al., 2022). Oxidative stress, if not mitigated, can dysregulate various biochemical, cellular, and physiological mechanisms, directly or indirectly impacting the survival of aquatic and terrestrial organisms (XU et al., 2018; CAO et al., 2020; ZHENG et al., 2021; SANDYS; TE-VELDE, 2022; ANETOR et al., 2022).

However, contradictory results have been reported in the literature, including increases in reproductive rate, generation time, and lifespan of zooplankton under exposure to microplastics (ZHAO et al., 2009). Such discrepancies suggest that the observed effects are dependent on the dose and size of the particles in the experimental treatments, since microplastics can exhibit a wide granulometric distribution, influenced by the degree of fragmentation. Polyethylene terephthalate (PET), for example, exhibits a density ranging from 1.37–1.45 g cm⁻³ (WEBER et al., 2018; ISSAC et al., 2021), which influences its behavior and bioavailability in the environment.

Regarding feeding, the most frequently investigated functional trait was the ingestion of plastic particles. Most ingested particles are retained in the organisms' digestive tract, which can cause morphological changes, such as internal or external abrasions and ulcerations, in addition to the mechanical blockage of the digestive tract and obstruction of feeding appendages

(WRIGHT et al., 2013). Such effects can result in false satiety, starvation, and physical deterioration of the organism (WRIGHT et al., 2013). The consequences of microplastic ingestion also include reduced reproductive capacity, impaired swimming, inability to evade predators, compromised feeding efficiency, and the potential for absorption and transfer of toxic chemicals adsorbed onto the plastic surface (DERRAIK, 2002; WRIGHT et al., 2013; HE et al., 2022). Furthermore, the accumulation of microplastics on appendages has been reported, hindering the movement and feeding of exposed individuals (RAJTAR et al., 2025). The one study with ciliates demonstrate that micro and nanoplastic particles can be ingested at rates similar to natural prey, such as bacteria, suppressing organism growth by reducing the effective nutritional intake. The consumption rate of these particles is size-dependent, with smaller particles being ingested more efficiently, and efficiency decreasing with increasing particle diameter (BULANNGA et al., 2022).

In the aquatic environment, plastic waste undergoes decomposition processes via weathering, mechanical abrasion, photodegradation, and oxidation, resulting in the generation of smaller particles (<5 mm), classified as secondary microplastics (PRATA et al., 2019). In contrast, plastic particles intentionally incorporated into personal hygiene products and cosmetics, or released from textile fibers, are defined as primary microplastics (YONKOS et al., 2014). Microplastic particles constitute an emerging contaminant of global concern for aquatic ecosystems (NUGNES et al., 2022).

4.2.2. METALLIC TRACE ELEMENTS

It was observed that, in most of the analyzed articles, there was significant mortality in the tested individuals, whose survival range is directly influenced by the pollutant concentration (REJOMON et al., 2010). This can be due to the fact that the bioaccumulation of metals in zooplankton is modulated by multiple factors, such as assimilation potential, life cycle, as well as elimination and absorption rates, which vary among different planktonic groups (JU et al., 2019; EL-METWALLY et al., 2022).

The primary studies also found differences in sensitivity to heavy metals among different zooplankton groups (SCHANZ et al., 2021). The data indicated that the metals did not affect community components uniformly: cladocerans demonstrated greater sensitivity, while copepods and rotifers exhibited greater resistance (GAGNETEN et al., 2009). It is recognized that cladocerans are particularly sensitive to toxic substances and are, therefore, frequently used

in standardized toxicity tests. In natural ecosystems, such differential responses can facilitate the proliferation of r-strategist species, resulting in decreased biomass, species richness and diversity, as well as favoring the dominance of tolerant species to the detriment of more sensitive ones (GAGNETEN et al., 2009).

In studies focusing on reproduction, adverse effects were reported, including decreased reproductive rate, reduction in the number of offspring per reproductive event, production of non-viable eggs and delayed first reproduction. The negative impact on fertility directly affects the intrinsic population growth rate (SNELL; SERRA, 2000; NEVES et al., 2015; TOMILINA et al., 2011; ARÂNGUIZ-ACUÑA et al., 2016). In these contexts, the energy investment in survival maintenance occurs at the cost of reduced reproductive potential, prioritizing longevity in scenarios of high mortality (LITCHMAN et al., 2013; HÉBERT et al., 2017). Additionally, exposure to heavy metals can induce immobility in organisms, which reflects behavioral alterations such as predator avoidance, impairment of feeding strategies, and reduced efficiency in finding mates for sexual reproduction (VISSER, 2007; LITCHMAN et al., 2013; HÉBERT et al., 2017).

The contamination of water resources by heavy metal ions, which are recognized as toxic and persistent elements, constitutes an environmental problem on a global scale. This phenomenon is primarily attributed to the rapid expansion of the industrial and urban sectors, coupled with the intensive use of chemical compounds in various segments of economic activity (QU et al., 2018). Although they can be introduced naturally into the environment through processes such as wind erosion, wildfires, volcanic activity and marine aerosols (ZAYNAB et al., 2022), the contribution from human sources is often predominant. Anthropogenic contamination by heavy metals occurs through activities such as mining, the use of agricultural inputs (fertilizers and pesticides), and the irrigation of crops with untreated domestic and industrial wastewater (LUO et al., 2022; ZAYNAB et al., 2022). Due to their deleterious effects on ecosystems and the health of organisms, these elements represent one of the main contemporary challenges for environmental preservation (FAN et al., 2021; ROY et al., 2021).

4.2.3. PESTICIDES

The studies reviewed showed that negative effects of high pesticide concentrations on zooplankton were observed, affecting their most important ecosystem functions and, consequently, their interactions with the environment and other organisms. The results showed

that contamination by pesticides, such as chlorpyrifos, led to a decrease in zooplankton abundance, particularly affecting some Cladocera populations. This effect was expected based on the mode of action of this insecticide, which acts by inhibiting the enzyme acetylcholinesterase (AChE) in insects and crustaceans, causing overstimulation of the nervous system, damaging synapses, and impairing muscle function, feeding, and mobility (MATSUMURA, 2012). Furthermore, the reduction in the abundance of filter-feeding zooplankton can lead to an increase in chlorophyll-a concentration due to reduced grazing pressure on algae (GARCÍA-ASTILLERO et al., 2024).

The studies in this review reported that the insecticide imidacloprid, at higher concentrations, decreased the reproduction and population growth of *Daphnia magna* by inhibiting feeding and increasing metabolic energy expenditure through chronic experiments, which are those that evaluate organisms throughout their entire life cycle (PESTANA et al., 2010; AGATZ et al., 2013). Beyond the inhibition of survival, reproduction, and population growth caused by higher concentrations of pesticides, the stimulation of these same parameters at lower concentrations has also been documented (WEN et al., 2022). This phenomenon, i.e., the stimulation of performance at low concentrations of toxic chemicals, is termed hormesis (CALABRESE, 2008) and has been observed in ecotoxicological studies of the insecticides aldrin and chlordane with *Brachionus calyciflorus*, and thiamethoxam with *Ceriodaphnia dubia* (HUANG et al., 2007; ZHA et al., 2007; RABY et al., 2018).

Additionally, studies also observe the trade-off effect between reproduction and survival: under pesticide stress, the rotifer *Philodina roseola* allocates more energy to reproduction, which would negatively affect the future reproductive performance of the offspring and its own survival (MOREIRA et al., 2015). It was also reported the trade-off relationship between lifespan and reproduction under different food conditions in the rotifer *Brachionus plicatilis* (SUN et al., 2017).

Pesticides can be defined as chemical products applied to a wide range of crops to protect them against insects, weeds, and other organisms considered pests, thereby improving productivity (GARCÍA et al., 2022; RANI et al., 2021). Pesticide contamination is recognized as one of the main factors contributing to biodiversity loss and the decline in aquatic biota abundance (BARMENTLO et al., 2021). These products can be classified in various ways, including according to the pests they control. Freshwater ecosystems are often exposed to

different types of these pollutants through surface runoff from agricultural areas (MALAJ et al., 2014; STEHLE; SCHULZ, 2015).

4.2.4. PHARMACEUTICS

This study found that the action of pharmaceuticals significantly affected the reproduction, survival, growth, and feeding of organisms. It was observed that pharmacological substances, such as sertraline, are capable of reducing the swimming speed of the tested organisms (HEYLAND et al., 2020). This reduction, in response to acute treatment with selective serotonin reuptake inhibitors (SSRIs), could be an indirect consequence of a decreased heart rate, since muscular activity for swimming depends on oxygen availability, or a direct effect of the SSRI treatment. Swimming speed is a crucial trait for aquatic animals, as their fitness, expressed by the probability of survival, reproductive success, feeding, predator escape, and habitat exploration, is strictly dependent on this ability (DE CICCIO et al., 2021).

Fluoxetine has been shown to increase the body size of *Daphnia magna* at certain concentrations (GRYGLEWICZ et al., 2023). This effect can be explained by the drug's mode of action, as the administration of fluoxetine can elevate glucose and hyperglycemic hormone levels in the hemolymph (FANJUL-MOLES, 2006). The hyperglycemic hormone, along with others produced and released by the X-organ/sinus gland complex, is known to regulate reproduction, nutrient metabolism, chromatic adaptation, and growth (WEBSTER et al., 2012). Furthermore, fluoxetine can also alter the perception of food conditions in *Daphnia* sp., inducing a shift in the life cycle to the pattern typical of food-rich environments, that is, producing offspring earlier and in greater numbers, even in scenarios of food scarcity (CAMPOS et al., 2012). In the aquatic ecosystem, such changes compromise the organisms' survival capacity, making them more vulnerable to predation and affecting their feeding behavior (GRYGLEWICZ et al., 2023).

A negative effect on the production of neonates per reproductive event and on the reproductive rate was observed as a result of exposure to pharmaceuticals (HERNANDEZ-ZAMORA et al., 2025). This review reported that the number of broods in *Daphnia magna* and *Moina macrocopa* decreased significantly with increasing concentrations of diclofenac (LEE et al., 2011) and that cladocerans exhibit a plastic response, allowing them to adjust their reproductive rates according to the environmental conditions in which they develop (SMIRNOV et al., 2017).

Pharmaceutical compounds are a significant source of environmental concern due to their design, which aims for prolonged bioactivity even at low concentrations. Their stable chemical structures and the presence of specific functional groups contribute to their environmental persistence and the maintenance of bioactivity, which can result in biological toxicity for both target and non-target species (MADADIAN; SIMAKOV, 2022). After consumption, medications can reach aquatic ecosystems, primarily due to the inefficiency of sewage treatment plants (STPs) in completely removing them (NUGNES et al., 2025).

4.2.5. PERSONAL CARE PRODUCTS AND ILLICIT DRUGS

The study in this review have investigated the toxicity of sunscreen in different species of zooplankton and the results depends on the type of sunscreen, the time of exposure and the organisms (HERNÁNDEZ-PEDRAZA et al., 2020). The study reported that, when testing the toxicity of four sunscreens on *Diaphanosoma celebensis*, the short-term exposure to two of the products did not cause significant mortality, while the other two drastically reduced the survival rate (YOO et al., 2025). Furthermore, in chronic tests evaluating growth and reproduction, the same study showed that a one-day delay in the total fertility rate, a significant reduction in the total number of offspring, and a decrease in the body length of exposed organisms were observed.

Personal care products (PCPs) constitute a diverse group of compounds used in soaps, lotions, toothpastes, fragrances, and sunscreens, among other items (BRAUSCH et al., 2011). In contrast to pharmaceuticals, which are developed for internal use, PCPs are intended for external application on the human body and, therefore, do not undergo significant metabolism. Among PCPs, sunscreens deserve special attention. Tourist activity in coastal zones constitutes a significant source of contamination for aquatic environments by these products, which contain organic and inorganic compounds associated with adverse effects for biota (HERNÁNDEZ-PEDRAZA et al. 2020). Consequently, large quantities of these compounds are disposed into the environment in their original form (TERNES et al., 2004). Many PCPs are used on a large scale, and recent studies indicate that several of them exhibit environmental persistence, bioactive potential, and bioaccumulation capacity (MACKAY; BARNTHOUSE, 2010).

The one study about illicit substances showed that the exposure of *Daphnia magna* to environmental concentrations of cocaine caused an imbalance in the oxidative status, in addition to negatively affecting swimming activity and reproductive effort (DE FELICE et al.,

2019). Such evidence suggests that the oxidative imbalance observed in the treated specimens may have induced the establishment of oxidative stress, a condition often associated with behavioral impairments at the individual level (HEDGESPETH et al., 2014; RIVETTI et al., 2016). Furthermore, exposure to cocaine can lead to significant alterations in the swimming behavior of cladocerans, both in terms of distance traveled and locomotion speed. The mechanism of action of cocaine in *D. magna* and other zooplankton representatives appears to be concentration-dependent: at low concentrations, it acts as a stimulating agent, increasing swimming activity, while at higher concentrations it manifests toxic effects and compromises locomotor performance. Cocaine is also capable of altering reproductive parameters, resulting in a significant reduction in the total number of offspring and decreased reproductive success (DE FELICE et al., 2019).

Illicit substances are traditionally recognized as a relevant socioeconomic and public health problem. However, they have only recently been identified as agents of environmental concern, arousing the interest of fields such as analytical and environmental chemistry (ZUCCATO; CASTIGLIONI, 2009) and ecotoxicology (CAPALDO et al., 2018; PAROLINI et al., 2013; 2017).

5. CONCLUSION

This systematic review allowed for an understanding of the effects of micropollutants in the ecosystem functions and functional traits of zooplankton. We found that the alterations caused by pollutants depend on the tested concentrations and organisms, as well as the experiment duration, since acute experiments report instantaneous effects, while chronic experiments demonstrate effects over the organisms' lifespan. Pollution from pesticides, heavy metals, pharmaceuticals, microplastics, personal care products, and illicit drugs systematically affects zooplankton, causing concerning effects on their ability to feed, survive, reproduce, and grow in a polluted environment. Consequently, by affecting zooplankton, micropollutants can alter the entire dynamics of the aquatic ecosystem, interfering with the food web and environmental balance. Furthermore, it is important to highlight the relevance of mixing effects for future work, since in aquatic ecosystems, organisms will not encounter just one pollutant, but rather a mixture of various contaminants and variables. Therefore, continuous studies with these organisms is crucial for understanding the state of the environment and for proposing solutions to mitigate the changes caused by micropollutants.

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Apendice I

Table 1. Summary of studies analyzed in the systematic review. The table includes columns for the lead author and year of publication, the type of micropollutant tested, the taxonomic group used as a test organism, the functional trait analyzed and its corresponding ecosystem function, as well as the study used as a reference (the data from 2004 to 2019 belongs to the database compiled by Josué et al (2021)).

Study	Pollutant type	Taxonomic group	Trait Type	Ecological Function	Reference Source
Galir et al. 2025	Microplastic	Copepoda, Cladocera and Rotifera	Mortality and Ingestion	Survival and Feeding	This study
Rajtar et al. 2025	Microplastic	Cladocera and Anostraca	Ingestion	Feeding	This study
Xu et al. 2025	Microplastic	Rotifera	Body length and Body biomass	Growth	This study
Gayosso- Morales et al. 2025	Pesticides	Cladocera	Mortality, Reproduction rate and Time for primipara	Survival and Reproduction	This study

Bandeira et al. 2025	Microplastic and Pesticides	Cladocera	Mortality, Reproduction rate, Offspring per female, Time for primipara and Swimming speed	Survival, Reproduction and Feeding	This study
Hernandez- Zamora et al. 2025	Pharmaceuticals	Cladocera	Mortality, Time for primipara, Reproduction rate and Offspring per female	Survival and Reproduction	This study
De Felice et al. 2025	Microplastic	Cladocera	Mortality and Swimming speed	Survival and Feeding	This study
Karimova et al. 2025	Pesticides	Cladocera	Mortality, Reproduction rate, Offspring per female and Body length	Survival, Reproduction and Growth	This study
Prochazkova et al. 2025	Microplastic	Cladocera	Ingestion	Feeding	This study
Rocha et al. 2024	Metallic Trace Elements	Copepoda	Mortality and Number of broods per female	Survival and Reproduction	This study
Daniel et al. 2024	Microplástico	Cladocera	Offspring per female	Reproduction	This study

Gong et al. 2024	Microplastic	Cladocera	Ingestion	Feeding	This study
Nenova et al. 2024	Metallic Trace Elements	Cladocera	Mortality	Survival	This study
De Felice et al. 2024	Microplastic	Cladocera	Mortality, Ingestion and Swimming speed	Survival and Feeding	This study
Rocha et al. 2023	Metallic Trace Elements and Pesticides	Copepoda	Mortality and Number of broods per female	Survival and Reproduction	This study
Malinowski et al. 2023	Microplastic	Cladocera and Copepoda	Ingestion	Feeding	This study
Martins et al. 2023	Metallic Trace Elements	Cladocera	Mortality, Reproduction rate and Number of broods per female	Survival and Reproduction	This study
Russo et al. 2023	Pharmaceuticals	Rotifera and Cladocera	Reproduction rate	Reproduction	This study
Grzesiuk et al. 2023	Pharmaceuticals	Cladocera	Body length	Growth	This study

Isinibilir et al. 2023	Microplastic	Cladocera	Mortality, Ingestion and Number of broods per female	Survival, Reproduction and Feeding	This study
Qin et al. 2023	Pesticides	Cladocera	Escape responses, Time for primipara, Offspring per female and Body length	Survival, Reproduction and Growth	This study
Gao et al. 2023	Microplastic	Cladocera	Mortality, Offspring per female, Reproduction rate and Time for primipara	Survival and Reproduction	This study
Mielecki et al. 2023	Pharmaceuticals	Cladocera	Mortality, Time for primipara, Offspring per female and Body length	Survival, Growth and Reproduction	This study
Wang et al. 2023	Microplastic	Cladocera	Ingestion	Feeding	This study
Na et al. 2023	Microplastic	Cladocera	Mortality	Survival	This study
Monteiro et al. 2023	Pharmaceuticals	Rotifera	Mortality	Survival	This study
Bulannga et al. 2022	Microplastic	Ciliate	Ingestion	Feeding	This study

Nugnes t al. 2022	Microplastic, Pesticides and Pharmaceuticals	Cladocera	Offspring per female	Reproduction	This study
Martins et al. 2022	Metallic Trace Elements	Cladocera	Mortality, Time for primipara and Offspring per female	Survival and Reproduction	This study
Mondellini et al. 2022	Microplastic	Cladocera	Reproduction rate, Offspring per female and Body length	Reproduction and Growth	This study
Pawlak et al. 2022	Microplastic	Rotifera	Reproduction rate	Reproduction	This study
Liu et al. 2022	Microplastic	Cladocera	Body length, Time for primipara, Offspring per female	Growth and Reproduction	This study
Huang et al. 2022	Microplastic	Cladocera	Ingestion, Time for primipara and Offspring per female	Feeding and Reproduction	This study
Sikorski et al. 2022	Pesticides	Cladocera and Ostracoda	Mortality and Swimming speed	Survival	This study
Zhu et al. 2022	Microplastic	Cladocera	Ingestion, Body length and Reproduction rate	Feeding, Growth and Reproduction	This study

Wen et al. 2022	Pesticides	Rotifera	Reproduction rate	Reproduction	This study
Verdu et al. 2022	Microplastic	Cladocera	Mortality	Survival	This study
Nguyen et al. 2022	Pharmaceuticals	Cladocera	Mortality	Survival	This study
Bai et al. 2022	Metallic Trace Elements	Copepoda, Cladocera and Rotifera	Mortality	Survival	This study
Trenfield et al. 2022	Metallic Trace Elements	Cladocera	Mortality	Survival	This study
Di Cicco et al. 2021	Pharmaceuticals	Copepoda	Swimming speed	Survival and Feeding	This study
Geppert et al. 2021	Metallic Trace Elements	Rotifera	Mortality, Number of broods per female and Ingestion	Survival, Reproduction and Feeding	This study
Di Lorenzo et al. 2021	Pharmaceuticals	Copepoda	Mortality	Survival	This study
Martins et al. 2021	Pharmaceuticals	Rotifera	Mortality and Reproduction rate	Survival and Reproduction	This study
Portugal et al. 2021	Microplastic	Cladocera	Ingestion	Feeding	This study

Xue et al. 2021	Microplastic	Rotifera	Ingestion, Reproduction rate and Swimming speed	Feeding, Survival and Reproduction	This study
Dung et al. 2021	Metallic Trace Elements and Microplastic	Cladocera	Mortality	Survival	This study
Lyu et al. 2021	Microplastic	Cladocera	Ingestion, Offspring per female and Reproduction rate	Feeding and Reproduction	This study
Rodriguez- Miguel et al. 2021	Pesticides	Cladocera	Mortality, Reproduction rate, Time for primipara and Body length	Survival, Reproduction and Growth	This study
Hoffschroeer et al. 2021	Microplastic	Cladocera	Ingestion	Feeding	This study
Schanz et al. 2021	Metallic Trace Elements	Rotifera	Mortality and Offspring per female	Survival and Reproduction	This study
Brans et al. 2021	Microplastic	Cladocera	Mortality	Survival	This study
Sobrino- Figueroa et al. 2020	Metallic Trace Elements	Copepoda	Mortality	Survival	This study

Dong et al. 2020	Metallic Trace Elements	Rotifera	Mortality, Reproduction rate, Number of broods per female and Swimming speed	Survival, Reproduction, Growth and Feeding	This study
Hernandez- Pedraza et al. 2020	Personal Care Products	Ostracoda	Mortality	Survival	This study
Moreira et al. 2020	Pesticides	Cladocera	Offspring per female	Reproduction	This study
Heyland et al. 2020	Pharmaceuticals	Cladocera	Swimming Speed, Reproduction rate and Body length	Survival, Growth and Reproduction	This study
Lu et al. 2020	Pesticides	Cladocera	Mortality	Survival	This study
Elizalde- Velazquez et al. 2020	Microplastic	Cladocera	Ingestion	Feeding	This study
Xu et al. 2020	Pesticides	Rotifera	Mortality, Reproduction rate and Time for primipara	Survival and Reproduction	This study

Felten et al. 2020	Microplastic and Pesticides	Cladocera	Mortality, Time for primipara, Reproduction rate, Offspring per female and Body length	Survival, Reproduction and Growth	This study
Dionisio et al. 2020	Pharmaceuticals	Cladocera	Swimming speed and Body length	Survival and Growth	This study
De Felice et al. 2019	Illicit drugs	Cladocera	Mortality and Swimming speed	Survival and Feeding	Josué et al. 2021
Bownik et al. 2019	Pharmaceuticals	Cladocera	Swimming speed	Survival and Feeding	Josué et al. 2021
Jaikumar et al. 2019	Microplastic	Cladocera	Time of primipara, Number of broods per female and Body length	Reproduction and Growth	Josué et al. 2021
Tang et al. 2019	Microplastic	Cladocera	Body length	Growth	Josué et al. 2021
Liu et al. 2019	Microplastic	Cladocera	Mortality, Body length, Time of primipara and Offspring per female	Survival, Reproduction and Growth	Josué et al. 2021
Nielsen et al. 2018	Pharmaceuticals	Cladocera	Swimming speed	Survival and Feeding	Josué et al. 2021

de Lucca et al. 2018	Metallic Trace Elements	Cladocera	Mortality, Offspring per female and Body length	Survival, Reproduction and Growth	Josué et al. 2021
Canniff et al. 2018	Microplastic	Cladocera	Mortality and Reproduction rate	Survival and Reproduction	Josué et al. 2021
Damasceno de Oliveira et al. 2018	Pharmaceuticals	Cladocera	Offspring per female	Reproduction	Josué et al. 2021
Martins et al. 2018	Microplastic	Cladocera	Number of broods per female and Body length	Growth and Reproduction	Josué et al. 2021
Grzesiuk et al. 2018	Pharmaceuticals	Cladocera	Mortality and Body length	Survival and Growth	Josué et al. 2021
Houssou et al. 2018	Pesticides	Copepoda	Hatchability and Mortality	Survival and Reproduction	Josué et al. 2021
Schiffer et al. 2017	Metallic Trace Elements	Cladocera	Offspring per female	Reproduction	Josué et al. 2021
Ziajahromi et al. 2017	Microplastic	Cladocera	Body length and Offspring per female	Growth and Reproduction	Josué et al. 2021
Imhof et al. 2017	Microplastic	Cladocera	Body length and Offspring per female	Growth and Reproduction	Josué et al. 2021

Liu et al. 2017	Metallic Trace Elements	Cladocera	Mortality	Survival	Josué et al. 2021
Lari et al. 2017	Metallic Trace Elements	Cladocera	Frequence of limb movements	Survival	Josué et al. 2021
Jemec et al. 2016	Microplastic	Cladocera	Mortality	Survival	Josué et al. 2021
da Silva et al. 2016	Pesticides	Cladocera	Offspring per female and Growth rate	Growth and Reproduction	Josué et al. 2021
Rocha, GS et al. 2016	Metallic Trace Elements	Cladocera	Body length and Time of primipara	Growth and Reproduction	Josué et al. 2021
Di Lorenzo et al. 2016	Pesticides	Copepoda	Respiration rate and Body length	Survival and Growth	Josué et al. 2021
Rehse et al. 2016	Microplastic	Cladocera	Immobilization	Survival	Josué et al. 2021
Aranguiz-Acuna et al. 2016	Metallic Trace Elements	Rotifera	Hatchability and Diapausing egg production	Reproduction	Josué et al. 2021
Kristi Tatsi et al. 2015	Metallic Trace Elements	Cladocera	Immobilization	Survival	Josué et al. 2021

Xu et al. 2015	Metallic Trace Elements	Rotifera	Reproduction rate and Diapausing egg production	Reproduction	Josué et al. 2021
Marus et al. 2015	Metallic Trace Elements	Copepoda	Mortality and Body length	Survival and Growth	Josué et al. 2021
Perez et al. 2015	Pesticides	Cladocera	Mortality	Survival	Josué et al. 2021
Neves et al. 2015	Pesticides	Cladocera	Offspring per clutch and Number of broods per female	Reproduction	Josué et al. 2021
Moreira et al. 2015	Pesticides	Rotifera	Offspring per female	Reproduction	Josué et al. 2021
Navis et al. 2015	Pesticides	Cladocera	Time of maximum hatching	Reproduction	Josué et al. 2021
Souza et al. 2014	Metallic Trace Elements	Cladocera	Mortality, Feeding rate, Time of primipara, Body length and Offspring per female	Survival, Reproduction, Growth and Feeding	Josué et al. 2021
Xu et al. 2014	Metallic Trace Elements	Rotifera	Reproduction rate	Reproduction	Josué et al. 2021

Freitas et al. 2014	Metallic Trace Elements	Cladocera	Offspring per female	Reproduction	Josué et al. 2021
Leonard et al. 2013	Metallic Trace Elements	Cladocera	Mortality	Survival	Josué et al. 2021
Nam et al. 2014	Metallic Trace Elements	Cladocera	Immobilization	Survival	Josué et al. 2021
Kim et al. 2012	Pharmaceuticals	Cladocera	Offspring per female and Time of primipara	Reproduction	Josué et al. 2021
Freitas et al. 2012	Pesticides	Cladocera	Offspring per female	Reproduction	Josué et al. 2021
Arzate- Cardenas et al. 2012	Metallic Trace Elements	Cladocera	Body length	Growth	Josué et al. 2021
Tomilina et al. 2011	Metallic Trace Elements	Cladocera	Mortality and Number of broods per female	Survival and Reproduction	Josué et al. 2021
Lee et al. 2011	Pharmaceuticals	Cladocera	Time of primipara and Offspring per female	Reproduction	Josué et al. 2021

Gutierrez et al. 2011	Metallic Trace Elements and Pesticides	Cladocera	Time of primipara and Offspring per female	Reproduction	Josué et al. 2021
Manar et al. 2010	Pesticides	Cladocera	Offspring per female and Time of primipara	Reproduction	Josué et al. 2021
Han et al. 2010	Pharmaceuticals	Cladocera	Time of primipara and Offspring per female	Reproduction	Josué et al. 2021
Zhao et al. 2009	Microplastic	Rotifera	Reproduction rate	Reproduction	Josué et al. 2021
Kolts et al. 2009	Metallic Trace Elements	Cladocera	Number of broods per female and Offspring per female	Reproduction	Josué et al. 2021
Martinez- Jeronimo et al. 2008	Metallic Trace Elements	Cladocera	Body length	Growth	Josué et al. 2021
Heckmann et al. 2007	Pharmaceuticals	Cladocera	Time of primipara and Offspring per female	Reproduction	Josué et al. 2021
Garria-Flores et al. 2007	Metallic Trace Elements	Cladocera	Reproduction rate	Reproduction	Josué et al. 2021

Guan et al. 2006	Metallic Trace Elements	Cladocera	Mortality, Ingestion and Body biomass	Survival, Feeding and Growth	Josué et al. 2021
Ramirez-Perez et al. 2004	Metallic Trace Elements	Rotifera	Offspring per female	Reproduction	Josué et al. 2021
Pane et al. 2004	Metallic Trace Elements	Cladocera	Body biomass	Growth	Josué et al. 2021