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ZOOPLANKTON: AN INVISIBLE FOOD WEB

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ABSTRACT

Zooplankton are essential for the proper functioning and well-being of aquatic ecosystems on a global scale. Zooplankton, which are tiny, independent organisms, play a crucial role in food chains by feeding on phytoplankton and serving as a source of nourishment for larger creatures. This article provides an assessment of the ecological importance, variety, and ongoing scientific investigations concerning zooplankton. Zooplankton consist of several taxonomic groups, such as copepods, cladocerans, rotifers, and meroplanktonic larval stages of bigger animals. Their variety is shaped by a range of environmental conditions, including temperature, salinity, nutrient availability, and predation. Zooplankton have a considerable influence on the biogeochemical cycles, energy transfer, and the biological pump in oceans. Additionally, they serve as highly responsive indicators of alterations in the environment and have been utilised in studies pertaining to the effects of toxins on ecosystems. Current research endeavours persist in elucidating the intricate interplays and adjustments of zooplankton in an evolving environment. Recent advancements in genetic techniques and in situ imaging devices are offering fresh perspectives on the field of zooplankton ecology. Preserving and controlling zooplankton communities is crucial for sustaining the well-being and efficiency of aquatic ecosystems in response to human-induced pressures such as climate change, pollution, and overfishing.

Keywords: Zooplankton, Phytoplankton, Copepod, Microalgae, Food web

INTRODUCTION:

Zooplankton are found everywhere in aquatic habitats, living in freshwater, estuarine, and marine ecosystems worldwide. Zooplankton, despite being small in size, usually measuring from micrometres to a few millimetres, have a significant impact on the organisation and operation of aquatic food chains. They function as primary consumers, feeding on phytoplankton and bacteria, and are subsequently hunted by larger creatures like fish, jellyfish, and baleen whales **[1]**. Zooplankton play a crucial role in transferring energy and nutrients from primary producers to higher trophic levels. The zooplankton population is highly diverse, consisting of a vast range of taxonomic groups and life styles. Copepods, cladocerans, and rotifers are very prevalent and extensively researched types of zooplankton found in both marine and freshwater habitats **[2]**. Several species of zooplankton display intricate life cycles, characterised by discrete developmental stages and vertical movement patterns. Zooplankton include the meroplanktonic larval stages of benthic invertebrates and fish, which have significant impacts on the dispersion and recruitment of these animals **[3]**.

Zooplankton communities exhibit a high degree of dynamism and adaptability in response to environmental conditions. Temperature, salinity, nutrition availability, and predation pressure are influential factors that can greatly affect the number, distribution, and species composition of zooplankton. Zooplankton grazing and nutrient recycling can significantly impact primary production and the structure of phytoplankton communities **[4]**. Zooplankton have been more prominent in recent years as they are being recognised as reliable indicators of environmental change and the overall health of ecosystems. Extended surveillance initiatives and controlled investigations have uncovered alterations in zooplankton populations as a result of climate change, ocean acidification, and human-induced pressures such as pollution and overfishing **[5]**. Therefore, it is essential to comprehend the ecology and dynamics of zooplankton in order to forecast and alleviate the effects of worldwide change on aquatic ecosystems. This article seeks to offer a thorough examination of the ecological importance and variety of zooplankton in aquatic ecosystems. We provide a comprehensive analysis of the existing knowledge regarding zooplankton taxonomy, distribution, life strategies, and their interactions with other animals and the environment. In addition, we explore the function of zooplankton in biogeochemical cycles, the transmission of energy, and the biological pump. Ultimately, we emphasise the current areas of study and technological advancements that are enhancing our comprehension of zooplankton ecology and efforts to protect them in a dynamic environment **[6]**.

RESULTS AND DISCUSSION:

Zooplankton display a remarkable variety of shapes and abilities, which are a result of their evolutionary adjustments to various aquatic environments. The primary categories of zooplankton comprise:

Copepods: Copepods are the most abundant and diverse category of zooplankton in the ocean, with over 10,000 identified species **[7]**. They are small crustaceans, typically 1-2 mm in length, with a teardrop-shaped body and long antennae. Copepods are present in all marine environments, from the surface to the deep sea, and are also widespread in freshwater ecosystems. The organisms are categorised into three primary orders: Calanoida, Cyclopoida, and Harpacticoida. Each order possesses unique morphological and ecological traits.

Cladocerans: It sometimes referred to as water fleas, are diminutive crustaceans that are highly prevalent in freshwater habitats. Their body is small and contained within a hard outer shell, with a big compound eye and a set of huge antennae that they utilise for swimming. Cladocerans are organisms that feed by filtering water, utilising their thoracic limbs to separate particles from the water. *Daphnia* is the most renowned genus that is extensively utilised as a model organism in ecological and ecotoxicological research **[8]**.

Rotifers: It is minuscule creatures, usually measuring less than 1 mm in size, that possess a ring of cilia encircling their mouth, which they employ for movement and nourishment. They are found in both freshwater and marine settings, with over 2,000 identified species. Rotifers have a diverse range of feeding techniques, such as suspended feeding, raptorial feeding, and scraping. Certain species are recognised for their capacity to endure severe climatic circumstances and exhibit fast rates of population growth **[9]**.

Meroplanktonic larvae: It refer to the planktonic larval stages of several benthic invertebrates and fish. These larvae play a significant role in zooplankton populations. These encompass the veliger larvae of mollusks, the pluteus and bipinnaria larvae of echinoderms, the zoea and megalopa larvae of crustaceans, and the trochophore larvae of polychaetes. The meroplanktonic larvae have essential functions in the dispersion and recruitment of benthic populations.

Gelatinous zooplankton: It comprises cnidarians (jellyfish and siphonophores), ctenophores (comb jellies), and pelagic tunicates (salps and doliolids). These organisms possess a significant amount of water and frequently have a transparent appearance, which poses challenges in terms of sampling and quantification. Nevertheless, they have the ability to create extensive clusters and exert substantial influence on marine food chains and biogeochemical processes.

Additional groups: Zooplankton encompass a diverse range of additional classifications, including chaetognaths (arrow worms), appendicularians (larvaceans), ostracods (seed shrimp) and foraminifera (amoeboid protists). These groups exhibit a wide range of physical structures and perform many ecological functions, which collectively enhance the complexity and functioning of zooplankton communities.

The spatial arrangement and quantity of zooplankton in aquatic habitats are impacted by a multifaceted interaction of physical, chemical, and biological factors. Temperature is a crucial environmental factor that impacts the physiology, growth, and reproduction of zooplankton. Zooplankton species have distinct temperature preferences that dictate their geographic range and seasonal abundance. In general, higher temperatures are related with faster growth and development rates, but can also raise metabolic costs and diminish body size **[10]**. Salinity is a significant factor that influences the distribution of zooplankton in estuarine and coastal areas. These areas see significant variations in salinity levels due to the presence of both freshwater and marine ecosystems. Several zooplankton species exhibit limited tolerance to salinity and are confined to specific locations along the salinity gradient. The copepod *Eurytemora affinis* has developed osmoregulatory systems that let it to survive in various salinity levels **[11]**. The abundance and composition of zooplankton are strongly influenced by the availability of nutrients, which in turn affect primary production and the organisation of phytoplankton communities. Typically, increased nutrient levels promote greater amounts of zooplankton biomass and production **[12]**. Nevertheless, an overabundance of nutrients can result in eutrophication and hypoxia, causing detrimental effects on zooplankton populations **[13]**. Predation is a significant cause of death for zooplankton and can greatly impact their distribution and population size. Larger zooplankton, fish, and other organisms are the main predators responsible for this mortality. Zooplankton species have developed various physical and behavioural mechanisms to protect themselves from being eaten, including spines, transparency, and diel vertical migration **[14]**. Predation can also cause a chain reaction on lower levels of the food chain, as the consumption of zooplankton can control the population of phytoplankton **[15]**. Hydrography refers to the study of physical processes, including as currents, upwelling, and mixing, which can move zooplankton across vast distances and result in uneven distributions. Many species of zooplankton are found in specific water masses or oceanic fronts, where they can take advantage of favourable conditions for their growth and reproduction **[16]**. Vertical stratification of the water column can also lead to diverse zooplankton communities at various depths **[17]**. Anthropogenic variables, which refer to human activities, including climate change, pollution, and overfishing, can exert substantial influences on zooplankton communities. Climate change is causing changes in ocean temperature, acidity, and circulation patterns. These changes can lead to shifts in the distribution and timing of zooplankton species **[18]**. The presence of nutrients, pollutants, and microplastics in the environment can have a negative impact on the health and reproductive abilities of zooplankton **[19]**. Overfishing has the potential to disturb marine food chains and have an indirect impact on zooplankton by triggering trophic cascades **[20]**.

Zooplankton have developed a wide range of life strategies and adaptations to deal with the difficulties of surviving in a constantly changing and sometimes unpredictable environment. Zooplankton exhibit a vast range of feeding strategies, suited to diverse food sources and sizes. Suspension feeders, such as copepods and cladocerans, employ their appendages to create feeding currents to strain minute particles from the water **[21]**. Raptorial feeders, such as chaetognaths and certain copepods, employ gripping appendages to actively grab and consume larger prey **[22]**. Certain species, such as salps and appendicularians, employ mucous nets to ensnare particles and consume aggregated material **[23]**. Zooplankton exhibit a wide range of reproductive techniques, including both asexual and sexual reproduction, as well as various life cycles that can involve direct development or complex phases with many larvae. Many species have high fecundity and short generation times, allowing them to respond swiftly to favorable environmental conditions **[24]**. Certain species, like copepods, have the ability to generate dormant eggs that can endure unfavourable periods and hatch when conditions become more favourable **[25]**.

Vertical migration is a behaviour observed in many zooplankton species where they move up to the surface at night to feed and then move back down to deeper waters during the day to avoid predators that rely on vision. The behaviour described can have substantial effects on biogeochemical cycles, as migrating zooplankton facilitate the transfer of organic matter and nutrients between the surface and deep ocean **[26]**. Certain species also experience seasonal or ontogenetic vertical migrations, when they move to varying depths or water masses at different periods of their life cycle **[27]**. Zooplankton have developed a range of morphological changes to improve their chances of survival and reproductive success. Several species possess translucent or camouflaged bodies in order to evade identification by predators **[28]**. Some organisms possess spines, shells, or gelatinous structures that serve as a defence mechanism against predators and physical harm **[29]**. Some species have specialized sensory organs, such as the naupliar eye in copepods, that allow them to perceive light, gravity, and chemical stimuli **[30]**. Zooplankton have developed physiological adaptations to deal with environmental stressors, including temperature variations, changes in salinity, and fluctuations in oxygen levels. Certain species possess elevated metabolic rates and enzyme activity, enabling them to sustain rapid growth and reproduction rates in warm aquatic environments **[31]**.

Some organisms possess osmoregulatory mechanisms that allow them to endure a broad range of salt levels **[32]**. Certain species, like the copepod *Calanus hyperboreus,* possess lipid reserves that enable them to endure extended periods of limited food availability in polar locations **[33]**. Symbiotic connections: Many zooplankton species create symbiotic associations with other creatures, such as microalgae, bacteria, and protists. These relationships can confer advantages such as nutrient acquisition, protection, and modulation of buoyancy. For instance, several types of radiolarians and foraminifera host photosynthetic algae, which supply them with both fixed carbon and oxygen (Anderson, 1983). Some copepods have chemosensory skills that allow them to sense and track chemical cues generated by their prey or partners. Zooplankton are crucial for the proper functioning and well-being of aquatic ecosystems, as they offer a wide range of biological and ecosystem services.

Zooplankton serve as the principal consumers of phytoplankton and bacteria in aquatic food webs. They play a crucial role in transferring energy and nutrients to higher trophic levels **[34]**. Zooplankton play a crucial role in controlling the population of phytoplankton and have a significant impact on the composition and behaviour of aquatic ecosystems. Zooplankton have a crucial role as prey for larger animals, including fish, jellyfish, and marine mammals. This supports fisheries and helps maintain biodiversity **[35]**. Zooplankton are essential for the biogeochemical cycles, specifically in the cycling of carbon, nitrogen, and phosphorus. Zooplankton play a crucial role in the transformation and recycling of nutrients in the water column through their eating, metabolism, and excretion. The process of the biological pump, involves the contribution of zooplankton faecal pellets and moults to the transfer of organic matter from the surface to the deep ocean. Zooplankton play a crucial role in regulating the Earth's climate and supporting benthic organisms by sequestering carbon in the deep sea **[36]**. Ecosystem resilience and stability: Zooplankton communities can influence the resilience and stability of aquatic ecosystems in the face of environmental shocks. Diverse and plentiful zooplankton assemblages can provide a buffer against the effects of climate change, pollution, and other stressors **[37, 38]**. Zooplankton can also promote the recovery of ecosystems after disturbances, by regulating primary production and promoting the recruitment of higher trophic levels. Zooplankton serve as reliable markers of ecosystem health, as they are highly responsive to environmental changes and can reflect the combined impacts of several stressors. Zooplankton abundance, species composition, size structure, and physiological alterations can serve as early indicators of ecosystem shifts and deterioration. Continuous monitoring of zooplankton communities over an extended period can provide valuable information for making informed management decisions and implementing conservation measures. This helps to preserve the overall health and functionality of aquatic ecosystems. Zooplankton possess various biotechnological applications, including their use as bioindicators and biomarkers, as well as sources of bioactive chemicals and biomaterials. As an illustration, the bioluminescent protein GFP (green fluorescent protein) was initially extracted from the jellyfish *Aequorea victoria* and has significantly transformed the field of biomedical research and imaging.

CONCLUSION:

Zooplankton are a captivating and varied collection of species that have essential functions in the composition and operation of aquatic ecosystems on a global scale. Zooplankton, ranging from small copepods to large jellyfish, display a remarkable variety of physical structures, actions, and survival tactics that enable them to flourish in many habitats. Zooplankton, as initial consumers, play a crucial role in aquatic food webs. They not only contribute to the productivity and diversity of higher trophic levels but also facilitate the cycling of nutrients and energy in the ocean. Zooplankton communities, which play a crucial role in the environment, are facing growing threats from several human-induced stresses including as climate change, pollution, and overfishing. Modifications in the number, distribution, and species composition of zooplankton can trigger a series of repercussions throughout ecosystems, which can have significant and widespread implications for human cultures that rely on thriving and fruitful oceans.

To enhance our comprehension of zooplankton ecology and conservation, it is necessary to adopt a comprehensive and interdisciplinary strategy that incorporates state-of-the-art technologies, sustained monitoring efforts, and inventive modelling frameworks. Through comprehending the intricate interplay among zooplankton, their surroundings, and other organisms, we can enhance our ability to forecast and alleviate the consequences of global change on marine and freshwater ecosystems. In a rapidly changing world, it is crucial to conserve and manage zooplankton communities to ensure the health, resilience, and productivity of aquatic ecosystems. By safeguarding these diminutive yet powerful organisms, we can guarantee the ongoing delivery of the crucial ecosystem services that sustain human welfare and the variety of life on our planet.

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