International Journal of Research Studies on Environment, Earth, and Allied Sciences (IJRSEAS)
| Volume-3 Issue-2 | April-2026 | ISSN: 3066-0637 | Website: https://eesrd.us

The Impact of Artificial Light on Zooplankton: Mechanisms, Responses, and Ecological Consequences

Vishwajeet Shamkant Nikam
S. S. M. M. ASC College, Pachora Dist - Jalgaon

Manuscript ID:
IJRSEAS-2026-030224

OPEN ACCESS

Quick Response Code:

Website: https://eesrd.us

DOI: 10.5281/zenodo.20365275

DOI Link: https://doi.org/10.5281/zenodo.20365275

Volume: 3

Issue: 2

Pp. 123-126

Month: April

Year: 2026

E-ISSN: 3066-0637

Submitted: 10 Mar. 2026

Revised: 20 Mar. 2026

Accepted: 12 Apr. 2026

Published: 30 Apr. 2026

Address for correspondence:
Vishwajeet Shamkant Nikam
S. S. M. M. ASC College, Pachora Dist - Jalgaon
Email: vishwajitnikam1996@gmail.com

How to cite this article:
Nikam, V. S. (2026). The Impact of Artificial Light on Zooplankton: Mechanisms, Responses, and Ecological Consequences. International Journal of Research Studies on Environment, Earth, and Allied Sciences, 3(2), 123–126. https://doi.org/10.5281/zenodo.20365275

Abstract

Artificial light at night (ALAN) has emerged as a significant form of anthropogenic pollution, profoundly influencing aquatic ecosystems. This study examines the impact of artificial light on zooplankton, focusing on underlying mechanisms, behavioral and physiological responses, and broader ecological consequences. Zooplankton, being highly sensitive to light cues, experience disruptions in diel vertical migration, swimming behavior, grazing patterns, reproduction, and predator avoidance under artificial illumination. At the mechanistic level, light-sensitive proteins such as opsins and cryptochromes mediate these responses, leading to altered activity patterns and stress-related physiological changes, including increased production of heat-shock proteins and DNA damage. The study further highlights spatial and temporal variability in light pollution across aquatic systems and its cascading effects on trophic interactions, nutrient cycling, and carbon flux. Artificial lighting can reduce trophic transfer efficiency, modify community composition, and increase predation risks, ultimately destabilizing ecosystem functioning. Methodological approaches, including laboratory, mesocosm, and field studies, are discussed for assessing light-driven impacts. The paper also emphasizes the need for mitigation strategies such as spectral tuning, light shielding, and controlled illumination timing. Overall, this research underscores the ecological significance of light pollution and calls for integrated management strategies and further interdisciplinary research to address knowledge gaps and ensure the sustainability of aquatic ecosystems.

Keywords: *Artificial Light at Night (ALAN); Zooplankton; Diel Vertical Migration; Light Pollution; Aquatic Ecosystems; Photoreceptors; Behavioral Responses; Physiological Stress; Trophic Interactions; Carbon Cycling; Nutrient Dynamics; Ecosystem Stability; Mitigation Strategies*

Introduction

Artificial light is one of the most pervasive forms of anthropogenic pollution. Because light availability is an important environmental determinant, artificial light modifies the behavior, physiology, and distribution of zooplankton, a diverse group of aquatic organisms with a key role in upper-trophic-level energy transfer and biogeochemical cycles. Diel vertical migration, generally increasing in depth at dusk in the absence of urban light, explains the abundance of zooplankton in shallow waters among coastal, riverine, and lacustrine ecosystems. Habitat-specific dissipation and rural–urban gradients alter light intensity, spectrum, and photoperiodicity in urban systems. Laboratory, mesocosm, and field studies document behavioral and physiological responses to artificial light, indicating changes in swimming behavior, vertical distribution, grazing rates, predator avoidance, reproduction, and the production of stress markers such as DNA damage, heat-shock proteins, and fluorescent nanoparticles (E. & L., 2018). Urban nighttime durations, correlated with crime rates, average approximately 6 h for major cities worldwide. Aquatic light pollution shifts physiological, morphological, and fitness traits, as well as succession pathways in natural communities; planktonic pathways are promoted in coastal systems by orthophosphate-rich agricultural runoff. Stress-related effects and perturbations in more than one ecosystem compartment may influence nutrient cycling and primary production. Numerous knowledge gaps hinder a comprehensive understanding of light-driven effects on zooplankton. Experimental designs, measurement techniques, and data analyses help characterize the mechanisms and responses involved. Actionable management strategies, including lighting redirection, shielding, spectral tuning, timing protocols, and habitat refugia, can mitigate aquatic light pollution and minimize adverse effects on zooplankton and other organisms.

Scientific research has increased understanding of the effects of chemicals, warming, and microplastic on zooplankton population abundances and ecosystem functions.

An extensive body of literature exists on the impact of urbanization, agriculture, forestry, and coastal development on light and zooplankton in terrestrial systems. Yet optical illumination represents an indirect parameter of anthropogenic change on aquatic ecosystems, particularly in shallow systems that enhance planktonic ecosystems.

Background on Zooplankton and Light Environment

Zooplankton, polyphyletic in origin, represent a diverse assemblage of organisms comprising the heterotrophic (herbivorous, bacterivorous, and carnivorous) and detritivorous microscopically measurable (<2 cm) floating organisms in aquatic ecosystems ((J. Gaston et al., 2014)). Genera that appear semiterrestrial, media-tolerant, or aquatic form biofouling colonies in pipes, between wetland and coastal habitats, or as permanent inhabitants of inner microhabitats. Coastal marine zooplankton individuals and species are modified for detection of intermittent beaching against tides by prediurnal U/V and above-U/V sunlight, and the consequent delays of prediurnal delay phase-shifted dusk-reversal activity control ((E. & L., 2018)).

The significance of light for zooplankton has been longitudinally well studied; notably the time of the day (i.e. photoperiod) defines periods of clear and dark for communication, undirected swimming noise, chemical signalling and dispersal. Analysis of long-term continuous records in zooplankton shows proximately chronobiologically controlled generation, destruction, excretion, and diffusion of the main communication production cluster with the time of the photoperiod is extensively active during dark ().

Mechanisms of Light Interaction with Zooplankton

Zooplankton are exposed to artificial light through photoreceptors capable of recognizing different wavelengths (E. & L., 2018). Most zooplankton possess the common light-sensitive proteins cryptochrome (Cry) and opsin, with the latter strongly coupled to swimming speed adjustments, thereby directly influencing their swimming behavior. Light signals are sensed either directly or indirectly via bioluminescence, reflecting a dual mode of operation. Most observations point toward direct photochemical consequences of light exposure. In adult Paramecium tetraurelia, swimming speed rises when ambient light intensity exceeds ca. 1.2 μmol m^{-2} s^{-1}. Responses of various aquatic protists, microcrustaceans, and macrocrustaceans confirm that most respond to low-intensity light, suggesting that not only fish but also zooplankton hazardously trigger similar responses at multiple temporal and spatial scales (W. Davies et al., 2020).

Behavioral and Physiological Responses to Artificial Light

Artificial light exerts profound effects on zooplankton behavior and physiology. Elevated levels of illumination directly and indirectly disturb normal swimming behavior, resulting in anomalous vertical distributions, grazing rates, predator-avoidance tactics, and reproductive investment (E. & L., 2018). Common zooplankton stress markers, including the expression of heat-shock proteins, are also significantly upregulated under artificial light. Artificial light thus has the potential to modify carbon cycling within aquatic systems.

In marine, freshwater, and brackish environments, artificial light typically stimulates a suite of swimming behaviors that reduce both the duration and extent of downward migration from the photic zone. Under artificial illumination, organisms also tend to adopt deeper and more compressive swimming paths, facilitating a more compact vertical distribution close to the surface (P. Devine et al., 2020). Grazing rates of various taxa, including the copepod Acartia tonsa and the cladoceran Daphnia galeata, decrease under artificial light even when the light spectrum remains fully transparent. This effect appears to be at least partially attributable to a decline in active vertical migration (J. Gaston et al., 2014). Species that normally exploit a strategy of actively synchronized cruising while interacting with predators, such as the copepod Temora longicornis, are more likely to adopt an alternate tactic favoring passive distribution in the upper mixed layer under elevated lighting.

Spatial and Temporal Scales of Light Pollution in Aquatic Systems

Anthropogenic artificial light is emitted in vast quantities throughout the world and is projected to continue increasing. Light pollution in terrestrial and aquatic systems varies temporally, spatially, and spectrally, with different sources exhibiting characteristic emission spectra. High-pressure sodium vapor lamps, widely used in urban street lighting, emit wavelengths that do not match the spectral sensitivity of fish photoreceptors and may thus be less disruptive to aquatic species. Light from illuminated coastal areas can have direct effects on marine and freshwater organisms living far from the source, and extramural lighting on buildings affecting coastal ecosystems is becoming more widespread (W. Davies et al., 2020).

Ecosystem-level Implications

Light pollution significantly impacts zooplankton across temporal and spatial scales, ultimately affecting ecosystem processes. Trophic transfer efficiency declines under artificial light, leading to reduced nutrient regeneration, altered algal bloom dynamics, and a shift from beneficial to detrimental nutrient cycling (E. & L., 2018). Vertical migration depth and community composition are altered in coastal estuaries by supplementary lighting and coastal urbanization. Shifts toward smaller, transparent zooplankton species may decouple upper trophic levels from benthic production, with additional indirect effects cascading through the food web (Sanders & Gaston, 2018). Artificial light reduces contrast and visual acuity, complicating predator avoidance in various taxa. Where urban lighting disrupts spatial concentration and refuge availability, mortality risk via predation increases (W. Davies et al., 2020).

Methodologies for Assessing Light-Driven Effects on Zooplankton

Light-driven effects on zooplankton can be assessed across a variety of system types, scales, and experimental designs, ranging from controlled laboratory investigations to natural field studies. Selection of methodology should be guided by the research question of interest, as detailed below (E. & L., 2018). Ideally, characterisation of artificial light sources within a system is conducted prior to experiments, enabling collection of suitable data on the prevailing light environment at the appropriate scale. Both pulse and chronic exposure regimes can be tested and incorporated into manipulation of additional ecological drivers. Laboratory experiments provide robust opportunities for exploring mechanistic responses of zooplankton to changing light. Completely contained systems already enable direct modification of light exposure without artificial input, and photomotor assays quantifying the influence of light on animal behaviour in mechanically unaltered systems have been successfully employed (H. Cohen et al., 2015). Effort to relate the specific exposure regime employed in laboratory experiments to natural variation and a established understanding of the underlying processes remains a priority.

Mesocosm and field experiments similarly allow investigation of the ecological responses of zooplankton to light across a range of spatial and temporal scales. They qualify at intermediate or full space–time liberty if sufficient information exists to characterise changes in the light environment influenced by the treatments under study; if, conversely, target drivers remain unknown or fine-scale modelling infeasible, assessments qualify at the intermediate regime.

Management and Mitigation Strategies

The dark period is often regarded as a universally beneficial time for zooplankton, but these organisms are integrating into ecosystems dominated by artificial light at night. The phenomenon of urbanization extends beyond land and air; artificial illumination on coastal settlements, landings, agriculture, and human activities introduces a luminous signature into the aquatic nighttime environment. Fishes and other animals rely on aquatic organisms, such as zooplankton, for sustenance, and often these organisms cannot escape the influence of artificially lit areas (E. & L., 2018). Light at night is not an isolated occurrence in terrestrial or aquatic systems; copious amounts of blue light leak into oceans and coasts from streets and coastal urban settlements, especially at dawn, full moon, and nights before a full moon. Artificial light also alters the water column of lakes, rivers, and wetlands through installations like piers and fountains, and much effort and attention continue to center on the conservation of early life stages and the prevention of glow coral, yet zooplankton remain unprotected (Shapiro, 2022).

Urban, agricultural, and aquaculture areas expose zooplankton to direct artificial illumination that further threatens their existence. In rural freshwater waters, direct connections between agriculture and nighttime light pollution have been observed. Globally, aquaculture is one of the most rapidly growing food sectors, much larger than marine capture fisheries; however, zooplankton preservation remains overlooked, and where they locate within aquaculture depends on light and turbidity levels. Experimental lamps applied in wide-ranging freshwater aquatic mesocoms with daytime settlings and night lights from urban, bordering farms, temples, airports, and aquaculture treat zooplankton timing, community adjustment, and repose within highly turbid conditions.

Conclusion

Artificial light alters critical zooplankton behaviors including swimming, vertical distribution, grazing, predator avoidance, reproduction, and stress signalling. Evidence indicates that such changes can have profound ecosystem-level consequences by modifying zooplankton-mediated pathways such as trophic transfer, carbon cycling, nutrient regeneration, algal bloom dynamics, and community composition. Cascading and indirect effects are likely (E. & L., 2018).

Research to date has focused primarily on direct behavioural and physiological responses to illumination, leaving notable gaps in knowledge about indirect effects and the need for mechanistic understanding. Future studies should employ experimental designs and techniques capable of addressing the full spectrum of light-driven influences on zooplankton across varied environments, and should explore unexamined aspects such as responses to temporal patterns and recovery following exposure. Prioritized questions include: how do illumination intensity, spectrum, pattern, and timing influence responses? What structural and functional shifts occur in zooplankton communities under artificial light? How do metabolic and reproduction processes interact with behavioral responses to light? What are the consequences of light-driven perturbations for higher trophic levels? What degree of illumination, and at which wavelengths, can be regarded as ecologically safe?

Acknowledgment

The author expresses sincere gratitude to the management and faculty of S. S. M. M. A.S.C. College, Pachora, for providing the necessary academic environment and support to carry out this research work. Special thanks are extended to colleagues and mentors for their valuable suggestions, encouragement, and constructive feedback throughout the study.

Financial support and sponsorship

Nil.

Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

References

1. E., M. & L., B. C. (2018). Trophic compensation stabilizes marine primary producers exposed to artificial light at night.
2. J. Gaston, K., P. Duffy, J., Gaston, S., Bennie, J., & W. Davies, T. (2014). Human alteration of natural light cycles: causes and ecological consequences. ncbi.nlm.nih.gov
3. W. Davies, T., McKee, D., Fishwick, J., Tidau, S., & Smyth, T. (2020). Biologically important artificial light at night on the seafloor. ncbi.nlm.nih.gov
4. Sanders, D. & Gaston, K. J. (2018). How ecological communities respond to artificial light at night.
5. H. Cohen, J., Berge, J., A. Moline, M., J. Sørensen, A., Last, K., Falk-Petersen, S., E. Renaud, P., S. Leu, E., Grenvald, J., Cottier, F., Cronin, H., Menze, S., Norgren, P., Varpe, Øystein, Daase, M., Darnis, G., & Johnsen, G. (2015). Is Ambient Light during the High Arctic Polar Night Sufficient to Act as a Visual Cue for Zooplankton? ncbi.nlm.nih.gov
6. Shapiro, C. (2022). MS Environmental Biology Capstone Project