



Assessment of Primary Productivity of Milak River, Mokokchung, Nagaland, India

Pukhrambam Rajesh Singh^{*1}, Bendang Ao¹, Kahoshe Sumi¹, and Maibam Romeo Singh²

¹Department of Zoology, Nagaland University, Lumami, Nagaland, India

²Department of Botany, Nagaland University, Lumami, Nagaland, India

ABSTRACT

The present study was carried out to determine the primary productivity of the Milak River. Estimation of primary productivity is essential to determine the ecosystem's health. Water samples from the selected sites were collected in triplicate in the first week of each month between 6.30 am and 8.30 am for 1 year, between February 2022 and January 2023. The light and dark bottles (Winkler's titration) method was used to determine the gross primary productivity, Net primary productivity, and community respiration. The GPP ranged from 19.3 mg C/m³/h– 57 mg C/m³/h, with an annual mean of 36.39±13.2. The highest reading (57 mg C/m³/h) was recorded in the month of March, while the lowest reading (19.3 mg C/m³/h) was recorded in August. The NPP ranged from 7.33 mg C/m³/h to 25.3 mg C/m³/h, with an annual mean of 15.46±5.96 mg C/m³/h. The CR ranged from 12.0 mg C/m³/h to 32.3 mg C/m³/h with an annual mean of 21.21±7.48. The ratio of NPP: GPP (0.49 mg C/m³/h) was highest in October and lowest (0.38 mg C/m³/h) in August. The ratio of GPP: CR (1.81 mg C/m³/h) was highest in October and lowest (1.61 mg C/m³/h) in August. Whereas the % respiration was highest in December and lowest in May.

Keywords: Milak River, Primary productivity, ecosystem health, Light and dark bottles.

Citation: Pukhrambam Rajesh Singh, Bendang Ao, Kahoshe Sumi, and Maibam Romeo Singh [2026]. Assessment of Primary Productivity of Milak River, Mokokchung, Nagaland, India. *Journal of Diversity Studies*. DOI: <https://doi.org/10.51470/JOD.2026.5.2.01>

Corresponding Author: Pukhrambam Rajesh Singh

E-mail Address: prajesh@nagalanduniversity.ac.in

Article History: Received 04 March 2026 | Revised 28 March 2026 | Accepted 04 April 2026 | Available Online July 01, 2026

Copyright: © 2026 by the author. The license of Journal of Diversity Studies. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

Introduction

Productivity is the rate of production of organic matter per unit time. Primary productivity (PP) is “the rate at which radiant energy is stored by the photosynthetic and chemosynthetic activity of producers” [1]. Estimation of PP is essential to determine the ecosystem's health. In an aquatic ecosystem like the Milak River (MR), the ecosystem health depends on the energy flow in the food chain, less environmental stress, water quality, carbon dynamics, nutrient cycle, and physicochemical properties of water. The PP is generally used to assess the energy available in an aquatic ecosystem [2]. Weather conditions influenced the photosynthesis of plants and the productivity of the aquatic ecosystem [3]. Primary producers such as Phytoplankton and aquatic plants play a primary role in trapping and converting the radiant energy into organic molecules through the process of photosynthesis, which is the most important biological phenomenon in nature. All the organisms on the globe depend on the primary producers, either directly or indirectly [4]. Therefore, the primary productivity of an ecosystem can be said to be a manifestation of its biological production and forms the basis of ecosystem functioning.

Production at each level can be further distinguished into *gross production* and *net production*. In an aquatic ecosystem, most of the organic matter is produced by phytoplankton and utilized by the consumer.

The estimation of primary productivity is based on the relationship between oxygen evolution and carbon fixation. For instance, primary productivity varies from stream to stream, which is due to increased oxygen-demanding pollutants, or photosynthetic-inhibiting pollutants, particularly more in the downstream region [5]. It is also known that four main processes influence O₂-CO₂ concentrations between sites in flowing waters – (a) release of O₂ into the water by aquatic plants and phytoplankton as a result of photosynthetic activity (b) uptake of O₂ as a result of respiration other organisms along with chemical oxidation (c) exchange of O₂ with the atmosphere in a direction based on the saturation gradient and (d) influx of O₂ via surface drainage [6].

Gross Primary productivity (GPP) is the total organic carbon obtained via photosynthesis in unit time [7]. Net Primary Productivity (NPP) is obtained by subtracting the amount utilized for autotrophic respiration [8], which reflects the efficiency or intensity of carbon fixation and is thus an indicator of productivity (9). NPP would have a positive value under optimal conditions, because production of organic matter via photosynthesis would be sufficiently greater than other respiratory needs, while it would be nil or even negative under adverse/unfavorable conditions because photosynthetic gains cannot offset respiratory losses (10). Several workers have made immense contributions to the assessment of the PP of water bodies.

Some of the notable workers are Sharma & Giri, 2018 (11). Kemp and Boynton, 2004 (12). Dutta, 2003 (13), Kumar, 2001 (14). Bharti and Malik, 2005 (15). Harikrishnan and Azis, 2000 (16), and Lawton and McNeill, 1972 (17).

Study Area

Mokokchung district is located in the northwest of Nagaland and between 26.32° 19' 21.3293 N Latitude and 94.50° 30' 24.4663 E Longitude. Milak, Dikhu, Tsurang, or Desai, Tsumok, and Menung are some of the notable rivers of Mokokchung. This river originates at the center of Mokokchung town and is joined by many small drainage systems after it starts its journey. The total length of this river is 67 km, and the catchment area is approximately 845 Km² [18]. This river confluences with the Brahmaputra River in Assam. Based on the topography, altitude, and accessibility, 3 sampling sites were selected for the present study: Site I (94° 30' 56" E, 26° 22' 04" N, 646 msl), S II (94° 29' 09" E, 26° 26' 45" N, 362 msl), and S III (94° 33' 17" E, 26° 32' 233 msl) (Fig. 1). Site I, Site II, and Site III are located upstream, midstream, and downstream, respectively. Sampling sites were chosen based on accessibility, altitude, physical habitat, and a similar gap of 10-15 km between the sites.

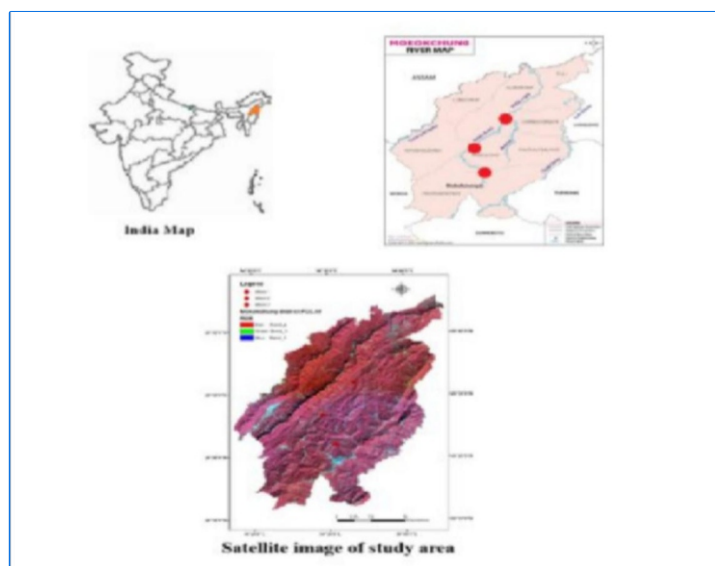


Fig 1: Study area map

Methodology

Water samples from the selected sites were collected in triplicate in the first week of each month between 6.30 am and 8:30 am for 1 year, between February 2022 and January 2023. The light and dark bottles (Winkler's titration) method was used to determine the PP. The sample in the first bottle was used immediately to determine the initial level of DO content following Winkler's Volumetric method [19]. The second bottle (dark) was warped by black polythene to prevent light. The third bottle (light) was used to estimate the net primary productivity. The light and dark bottles were incubated under water in a well-lit area to mimic the euphotic zone for a period of 24 hours, after which the DO content of each bottle was determined.

GPP, NPP, and CR were calculated using the following formulas

Gross Primary Productivity (GPP)

$$GPP = \frac{(LB - DB) \times 0.375 \times 1000}{T \times PQ} \text{ mg/L/h}$$

Net Primary Productivity (NPP)

$$NPP = \frac{(LB - IB) \times 0.375 \times 1000}{T \times PQ} \text{ mg/L/h}$$

Community Respiration (CR)

$$CR = \frac{(IB - DB) \times 0.375 \times 1000}{T \times PQ} \text{ mg/L/h}$$

Where, LB = Light bottle DB = Dark bottle IB = Initial bottle

T = Time of incubation

PQ = Photosynthesis quotient = 1.25

Results and Discussion

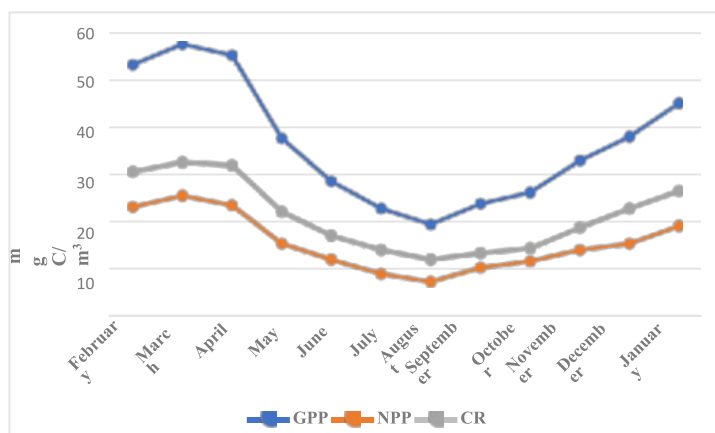
The primary productivity of an aquatic body is the outcome of photosynthetic activity and thus a manifestation of its biological production. This makes energy available to the entire biological component of the system. Solar energy is converted to chemical energy by chlorophyll-bearing organisms [20]. The rate of this conversion is dependent on quite a few factors, like the hydrological cycle, water level, light intensity, photo period, wind velocity, etc. [21, 22]. Assessment of primary productivity is an essential part of ecological studies, showing the fixation of carbon over a period. This assessment requires an understanding of other aspects like the GPP, NPP, and CR, which basically depict how much energy is captured or harnessed and the available energy after necessary expenditure. Understanding these aspects is necessary for assessment of ecological health, and this can, in turn, provide the cue for designing comprehensive models on sustainable resource management.

The GPP of the Milak river ranged from 19.3 mg C/m³/h– 57 mg C/m³/h, with an annual mean of 36.39±13.2. The highest reading (57 mg C/m³/h) was recorded in the month of March, while the lowest reading (19.3 mg C/m³/h) was recorded in August. The NPP of the Milak River ranged from 7.33 mg C/m³/h – 25.3 mg C/m³/h, with an annual mean of 15.46±5.96 mg C/m³/h. The CR ranged from 12.0 mg C/m³/h to 32.3 mg C/m³/h with an annual mean of 21.21±7.48. The ratio of NPP: GPP (0.49 mg C/m³/h) was highest in October and lowest (0.38 mg C/m³/h) in August. The ratio of NPP: GPP (0.49 mg C/m³/h) was highest in October and lowest (0.49 mg C/m³/h) in August. The ratio of GPP: CR (1.81 mg C/m³/h) was highest in October and lowest (1.61 mg C/m³/h) in August. Whereas the % respiration was highest in December and lowest in May (Table 1).

The highest monthly average of GPP, NPP, and CR (57, 25, 30.3 mg C/m³/h) were recorded in March, while the lowest (19.3, 7.33, and 12 mg C/m³/h) were recorded in August. Similar results were reported by Patralekh and Patar 2016 [23] in Shivaganga pond in Jharkhand and Sharma and Giri 2018 in lotic and lentic water bodies of Himachal Pradesh, India [11]. Low nutrient due to high turbidity leads to low PP (24). Alkaline water is the primary factor for high productivity [25].

Table 1: Monthly average of GPP, NPP, CR, NPP/GPP, GPP/CR, and R% of the Milak River (mg C/m³/h)

Par	Feb	Mar	Apri	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan
GPP	52.7	57.0	54.7	37.3	28.3	22.7	19.3	23.6	26.0	32.7	37.7	44.7
NPP	23.0	25.3	23.3	15.3	12.0	9.00	7.33	10.3	11.7	14.0	15.3	19.0
CR	30.3	32.3	31.7	22.0	17.0	14.0	12.0	13.3	14.3	18.7	22.7	26.3
NPP/GPP	0.43	0.44	0.42	0.41	0.42	0.39	0.38	0.43	0.49	0.42	0.41	0.42
GPP/CR	1.74	1.76	1.73	1.7	1.67	1.62	1.61	1.77	1.81	1.75	1.66	1.70
R %	57.6	56.7	58.0	53.6	60.0	61.8	62.1	56.3	55.1	57.1	69.4	58.9

**Fig 2: Graphical representation of monthly average GPP, NPP, and CR****Table 2: GPP, NPP, and CR of Sites**

Parameter	S I	S II	S III	MEAN
GPP	42.83±17.0	34.50±11.6	31.83±11.6	36.38±5.74
NPP	15.58±6.44	13.75±6.08	14.00±6.05	15.00±6.00
CR	25.83±10.9	20.00±6.05	17.83±5.73	21.22±4.14

S=Site

Among the sites, the highest GPP was recorded at site I (42.83 mg C/m³/h), and the lowest was at Site III (31.83 mg C/m³/h). The highest NPP and CR were recorded in site I (15.58 and 25.83 mg C/m³/h), and the lowest NPP was at Site II (13.75 mg C/m³/h), and the lowest CR was recorded at site III (17.83 mg C/m³/h) as seen in Table 2. It indicates that photosynthetic activity is higher at site I and comparatively lower at sites II and III. The reasons could be less disturbance, more plants in the upper region of the river. NPP values across the site are relatively similar. Site I still shows slightly higher, which means that more energy is available at site I. Comparatively less energy is available at Site II. Site I shows higher biological activities and more organic matter decomposition.

Table 3: Seasonal variation of GPP, NPP, and CR (mg C/m³/h) of Milak River

Seasons	GPP	NPP	CR
Premonsoon	50.66 ± 7.37	22.00 ± 1.73	28.66 ± 6.81
Monsoon	23.66 ± 2.31	9.66 ± 1.53	14.66 ± 4.04
Postmonsoon	35.33 ± 7.57	15.66 ± 3.06	22.66 ± 7.51

Among the seasons, the highest average GPP of Milak River (50.66 mg C/m³/h) was recorded during the pre-monsoon and the lowest (23.66 mg C/m³/h) was during the monsoon season (Table 3). The highest average GPP during the premonsoon season indicates good autotrophic activity. The values were quite reduced in the monsoon season, and this could be attributed to increased cloud cover (which corresponds to increased temperature and humidity, but reduced sunlight), higher turbidity, and potential nutrient dilution from rainfall. Monthly comparisons further confirm a similar trend with peak productivity in March and the lowest in August, respectively. This consistency suggests that the primary drivers of productivity are likely regional climatic patterns rather than localized disturbances.

NPP and CR. The highest averages NPP and CR (22.00 and 28.66 mg C/m³/h) were recorded during pre-monsoon, and the lowest averages (9.66 and 14.66 mg C/m³/h) were recorded during the monsoon season (Table 3). NPP can be said to be the portion left after autotrophic respiration

[8] and reflects the efficiency of carbon fixation in an ecosystem [26]. This efficiency depends on a host of factors like climatic regimes and anthropogenic activities [27]. It is sensitive to climatic factors and human activities, and therefore, knowing spatio-temporal dynamics over periods of time is required to forecast future trends in ecosystem changes [28]. CR is highest in premonsoon and lowest in monsoon. This suggests that Site I may possess more favorable environmental characteristics, such as better light conditions or higher nutrient availability. Warmer temperatures and clear water during pre-monsoon months stimulate microbial and heterotrophic activity, enhancing respiration [29]. Besides this, Greater photosynthesis due to warmer temperatures leads to more organic matter production, which microbes decompose and thereby raise CR. Decrease River current during the premonsoon season may concentrate nutrients and organic matter and provide a conducive environment for microbial activity [30]. In contrast, the lowest CR was recorded during the monsoon season, possibly due to dilution effects and reduced light penetration from increased turbidity. Spatially, Site I showed the highest CR in both rivers in March, suggesting that higher organic activity is taking place.

Conclusion

The present study on the Milak River shows clear spatial and seasonal variations in productivity, represented by GPP, NPP, and CR. The results indicate that the river exhibits the highest productivity during the pre-monsoon season, while the lowest productivity occurs during the monsoon season. More turbidity, cloud cover, and nutrient dilution during the monsoon period reduce light penetration and photosynthetic activity, resulting in lower productivity. Site I consistently recorded the highest values of GPP, NPP, and CR, indicating more favorable environmental conditions such as increased light availability, higher nutrient concentration, and lower disturbance. In contrast, Site II and Site III showed comparatively lower productivity levels. The higher productivity and respiration at Site I also suggest greater biological activity and organic matter decomposition in this region of the river. Seasonal trends further reveal that warmer temperatures and clearer water during the pre-monsoon season enhance photosynthesis and microbial respiration, thereby increasing ecosystem productivity. Overall, the study highlights that climatic factors, hydrological conditions, and local environmental characteristics strongly influence the productivity dynamics of the Milak River ecosystem. Understanding these patterns is important for assessing ecosystem health and managing riverine resources effectively.

Completing interests

The authors have no conflict of interest.

Acknowledgement

We are grateful to the Dept of Zoology, NU, Lumami, for allowing us to utilize the lab facilities.

References

1. Odum, E.P. (1971). Fundamentals of Ecology, 3rd Ed. W.B. Saunders Company, Philadelphia. 574.
2. Ohle, W. (1956). Bioactivity, production, and energy utilization of lakes. *Limnol Oceanogr.* 1: 139-149.
3. Kaul, V. (1985). Primary productivity of Inland Aquatic ecosystem under varying Climate – a review. *Trop. Ecol.*, 26(2): 164-178.
4. Ahmed, S. U. (2003). An overview of aquaculture resources and fish biodiversity of Nagaland. Participatory approach for fish biodiversity conservation in Northeast India. NBFGR Publication Lucknow, Eds. P.C. Mahanta and L.K. Tyagi. 106-113.
5. Sahu, B.K., Rao, R. J., and Behera, (1995). Studies of some physico-chemical characteristics of the Ganga River water (Rishikesh Kanpur) within twenty-four hours during winter, 1994. *Ecol. Env. And Cons.* 1 (1-4): 35-38.
6. Odum, H.T. (1956). Primary production in flowing waters. *Limol. Oceanogr.* 1, 102-117.
7. Joiner, J; Yoshida, Y; Zhang, Y; Duveiller, G; Jung, M; Lyapustin, A; Wang, Y; Tucker, C. J. (2018). Estimation of terrestrial global gross primary production (GPP) with satellite data-driven models and eddy covariance flux data. *Remote sens.*, 10:1346.
8. Cramer, W; Kicklighter, D. W; Bondeau, A; Iii, B.M; Churkina, G; Nemry, B; Ruimy, A; Schloss, A. L. (1999). NPP model intercomparison. Comparing global models of terrestrial net primary productivity (NPP): Overview and key results. *Glob. Chang. Biol.* 1999, 5: 1-15.
9. Zhou, G, and Zhang, X. (1995). A natural vegetation NPP model. *Chin. J. Plant Ecol.*, 19: 193.
10. Yeragi, S.G. and Shaikh, N. (2003). Studies on the primary productivity of the Tansa River. *J. Natcon* 15, 125-130.
11. Sharma, P., and Giri, A. (2018). Productivity evaluation of lotic and lentic water bodies in Himachal Pradesh, India. *MOJ Eco & Environ Sci.* 2018; 3 (5): 311-317. DOI: 10.15406/mojes.2018.03.00105
12. Kemp, W.M., and Boynton, W.R. (2004). Productivity, trophic structure, and energy flow in the steady – state ecosystems of Silver Springs, Florida. *Science Direct Ecological Modelling* 178 (2004) 43-49.
13. Dutta, S. (2003). Net primary production of phytoplankton in some tropical wetlands. *Environ & Ecol.* 21 (spl.pub): 6-9.
14. Kumar, A. (2000). Impact of coal mining on the productivity of wetlands with special reference to aquaculture technology. In *Industry, Environment and Pollution* (ed. A.Kumar and P.K. Goel), A.D.B. Publ. Jaipur.
15. Bharti, P.K., and Malik, D.S. (2005). Primary production efficiency in different environmental settings of the Sahstradhara hill-stream, Dehradun. *Envi. Conser. Journal.* 6(1-3): 117-121. DOI: 10.36953/ECJ.2005.0612317.
16. Harikrishnan, K. and Abdul Azis, P.K. (2000). Primary productivity studies in a freshwater Temple Tank in Kerala. *Indian J. Environ and Ecoplan.* 3: 127-130.
17. Lawton, J.H., and McNeill, S. (1972). Pollution and world primary production. *Biological Conservation*, Vol-4, Issue 5, 329-334.
18. Temjen, W., Singh, M.R. (2018). EM International, "Analysis of some selected physicochemical properties of water from Milak river, Mokokchung, Nagaland", Vol. 37, Issue 1, P- 197-204. ISSN 0257-8050. *Poll Res.* 37 (1): 197-204.
19. APHA (American Public Health Association). (2017). *Standard Methods for the Examination of Water and Wastewater* (23rd ed.). Washington, D.C.
20. Mishra, S.R. and Saxena, D.N. (1992). The primary productivity of phytoplankton in a sewage collecting morar (kalpi) river at Jaderrua Bundha, Gwalior, Madhya Pradesh. *Journal of Inland Fisheries Society India*, 24(1): 61-68.
21. Gupta, B.P. (1982). Studies on primary production in Bhabanisagar reservoir (Tamil Nadu). *Journal of Inland Fisheries Society India*, 34: 49-54.
22. Verma, P. K. and Datta Munshi, J. (1989). Influence of certain abiotic factors on primary production in a thermal stream. *Proceedings of the National Academy of Science India*, 59 (3): 87-91.
23. Patralekh, M. and Patar, P. (2016). Estimation of Primary Productivity of Shivaganga Pond of Baidyanathdham-Deoghar, Jharkhand (India). *The Biobrio, an international quarterly journal of Life science*, ISSN: 2393-9508; 166-170.
24. Ogbuagua, D.H., and A.A. Ayoade. (2011). Estimation of primary production along gradients of the middle course of Imo River in Etche, Nigeria. *International Journal of Biosciences* Vol. 1 Issue 4: 68-73.
25. Khaiwal, R., Ameena, Meenakshi, Monika, Rani, and A. Kaushik. (2003). Seasonal variations in physico-chemical characteristics of the river Yamuna in Haryana and its ecological best designated use. *Journal of Environmental Monitoring*. Vol. 5: 419-426.
26. Allan, J.D., & Castillo, M.M. (2007). *Stream Ecology: Structure and Function of Running Waters* (2nd ed.). Springer.
27. Chen, T; Tang, G; Yuan, Y; Guo, H; Xu, Z; Jiang, G; Chen, X. (2020). Unraveling the relative impacts of climate change and human activities on grassland productivity in Central Asia over last three decades. *Sci. total Environ.*, 743: 140649.
28. Ahmed, K.K.U., Ahmed, S.U., Haldar, G.C., Hossain, M.R.A., and Ahmed, T. (2005). Primary productivity and fish yield estimation in the Meghna river system, Bangladesh. *Asian Fisheries Science*, 18: 95-105.
29. Noel R. Urban, Defne S. Apul, and Martin T. Auer (2004). Community respiration rates in Lake Superior. *Journal of Great Lakes Research*, Vol. 30 Supplement 1, Pp 230-244.
30. Wetzel, R.G. (2001). *Limnology: Lake and River Ecosystems* (3rd ed.). Academic Press.