The Effect of Increased Nutrient Availability on Freshwater Phytoplankton Growth

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Abstract

This study examines the impact of nutrient enrichment on phytoplankton biomass and water chemistry in pond water samples. Three concentrations of organic fish fertilizer (0 μL, 10 μL, and 20 μL per 10 mL of pond water) were tested over 18 days under constant illumination. Phytoplankton biomass was spectrophotometrically measured at 750 nm, with pH and turbidity also assessed to evaluate changes in water quality. The results indicated that increasing nutrient concentrations resulted in enhanced phytoplankton growth, as evidenced by reduced light transmittance and increased turbidity. Higher fertilizer levels also raised pH values, suggesting greater photosynthetic activity and more alkaline conditions. These findings support the hypothesis that nutrient enrichment stimulates primary production, although it may also contribute to eutrophication processes. Overall, the experiment provides valuable insights into how localized nutrient inputs influence aquatic ecosystems and highlights the relationship between nutrient availability, algal biomass, and water chemistry.

Keywords: phytoplankton, nutrients, eutrophication, aquatic ecosystems

Introduction

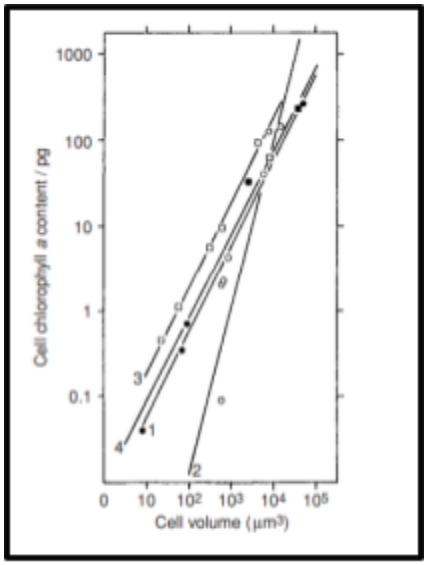


Figure 1
Log/log plot of cell chlorophyll-a content against cell volume of various freshwater phytoplankters
Adapted from *The Ecology of Plankton*, by Collin Reynolds, from page 34.

Phytoplankton are microscopic, photosynthetic organisms that play a crucial role in aquatic ecosystems by supporting higher trophic levels and driving global biogeochemical cycles (Northeast Fisheries Science Center). Collectively, phytoplankton contribute nearly half of Earth's primary production, making them vital in carbon cycling and climate regulation (Falkowski & Raven, 2007, 18; Mattei & Scardi). Phytoplankton in the contemporary ocean fix approximately 45 Gt of carbon per year, with around 16 Gt being exported to the deep ocean (Falkowski et al.). Additionally, of the total global net primary production, which is about 100 Gt of carbon per year, roughly 45% is attributed to marine phytoplankton (Falkowski et al.). Phytoplankton are autotrophs and photosynthetic, utilizing chlorophyll to absorb photons for photosynthesis. The most common pigment is chlorophyll a, which varies in content based on cell volume (Reynolds, 2006). Due to their rapid production, phytoplankton populations respond quickly to changes in environmental conditions, including light, temperature, and nutrient availability (Reynolds, 2006). The average carbon turnover time for phytoplankton is approximately one week or less, indicating that their biomass and productivity are highly responsive to external factors (Falkowski et al.). These characteristics make phytoplankton an essential bioindicator of aquatic ecosystem health.

Nutrients, specifically nitrogen and phosphorus, are often limiting factors in aquatic systems, constraining the amount of phytoplankton biomass that can be sustained (D.W. Schindler, 1977).

When additional nutrients are introduced, phytoplankton populations typically increase in biomass, sometimes leading to blooms (Marino & Howarth, 2006). While moderate enrichment may increase productivity, excessive nutrient inputs are associated with eutrophication, which can decrease water clarity, lead to oxygen depletion during decomposition, and alter species composition (Nekola et al., 1999). Agricultural fertilizer runoff is a major contributor to this process, supplying readily bioavailable forms of nitrogen and phosphorus to rivers, lakes, and coastal waters. Therefore, understanding how phytoplankton respond to different levels of nutrient addition is critical for predicting and managing eutrophication in freshwater and estuarine systems.

Phytoplankton biomass can be estimated using various methods, including direct cell counts, pigment extraction, and molecular approaches. However, spectrophotometry offers a quick and non-destructive alternative by measuring the amount of light that can pass through a sample. Because phytoplankton absorb and scatter light, an increase in plankton abundance reduces transmittance and increases light absorption at particular wavelengths (Jeffrey & Humphrey, 1975). Optical density at 750 nm (OD750) is usually used as a proxy for biomass as it minimizes interference from pigments while capturing turbidity caused by suspended algal cells. Monitoring changes in absorbance over time allows researchers to quantify phytoplankton growth under different nutrient conditions.

The present study examines the impact of fertilizer addition on phytoplankton biomass in pond water samples collected from the coastal sites of a single pond. Samples were exposed to three treatments (0, 10, and 20 μL of fertilizer per 10 mL of pond water). Phytoplankton biomass was

estimated using spectrophotometric absorbance measurements at 750 nm, a wavelength commonly used as a proxy for algal turbidity (Jeffrey & Humphrey, 1975). Based on the nutrient limitation theory, it is expected that increasing fertilizer concentration will result in greater phytoplankton biomass, as reflected in higher absorbance values over time. This experiment contributes to understanding the effects of small-scale nutrient enrichment and provides a model for how localized inputs may drive algal community responses in aquatic ecosystems.

Methods and Materials

A spectrometer was used to measure the optical density at 750 nm (OD_{750}). Spectrophotometric absorbance at 750 nm is often utilized as a proxy for biomass since this wavelength minimizes direct pigment absorption and primarily indicates light scattering from suspended cells (Havlik et al.). A strong correlation was observed between the optical density at 750 nm (OD750) and the measured biomass of cultured microalgae (Hotos and Bekiari). Organic fish fertilizer served as the nutrient source, providing nitrate and phosphorus enrichment. Additional materials included acetone, glass test tubes, a test tube rack, a glass stir rod, plastic sample containers, a micropipette with disposable tips, pH strips, tweezers, and white paper for visual turbidity assessments. A continuous 24-hour greenhouse growth light was used to maintain consistent illumination. All pond samples were collected from a single pond in its coastal areas to ensure environmental uniformity.

Pond water samples were collected from a single pond along its edges using plastic containers and transferred to the laboratory. Each 10 mL subsample was poured into a clean glass test tube. Three fertilizer treatments were prepared: a control (0 µL), 10 µL, and 20 µL of organic fish fertilizer per 10 mL of pond water. Each treatment was replicated three times to improve

accuracy and account for natural variability in phytoplankton abundance. Fertilizer additions were made using a calibrated micropipette to ensure precise dosing. Samples were gently mixed with a sterile glass stir rod to distribute nutrients evenly without damaging algal cells. Each test tube was labeled with the corresponding concentration and replicate number using a wax pencil.

All samples were placed under a greenhouse growth light that remained illuminated 24 hours per day to provide a consistent light source for photosynthesis. The samples were maintained at room temperature (~22℃) and remained undisturbed except during measurements.

Optical Density (OD_{750}) was measured on Days 1, 4, 5, 7, 8, 11, 13, 14, 15, and 18 using a spectrometer set to 750 nm. The wavelength was chosen to minimize pigment interference and isolate changes in turbidity associated with phytoplankton biomass. Each sample's absorbance value was recorded, and the mean was calculated for each treatment group.

pH measurements were taken periodically using pH indicator strips, and changes in acidity or alkalinity were recorded for each treatment. Turbidity was assessed visually by placing each test tube against a sheet of white paper and rating opacity on a scale from 1 (clear) to 10 (highly opaque). Observations were made under consistent lighting conditions to minimize visual bias.

Data were compiled into tables, and average values along with rates of change in OD_{750} and turbidity were calculated to assess the effects of increasing nutrient availability, while pH was graphed to show the average pH after multiple days of growth; this was done to determine the impact of growing nutrient availability on phytoplankton growth and water chemistry.

Results

Phytoplankton growth, pH, and turbidity were monitored across three fertilizer concentrations (0 µL, 10 µL, and 20 µL) over 18 days. Absorbance readings at 750 nm (OD_{750}) were used as a proxy for phytoplankton biomass.

Samples with higher fertilizer concentrations exhibited decreased percent transmittance, indicating increased phytoplankton biomass. The control sample (0 µL) showed an average increase in light transmittance of 7.67%, while samples treated with 10 µL and 20 µL of fertilizer displayed decreases of 38.77% and 46.80% respectively (Table 1).

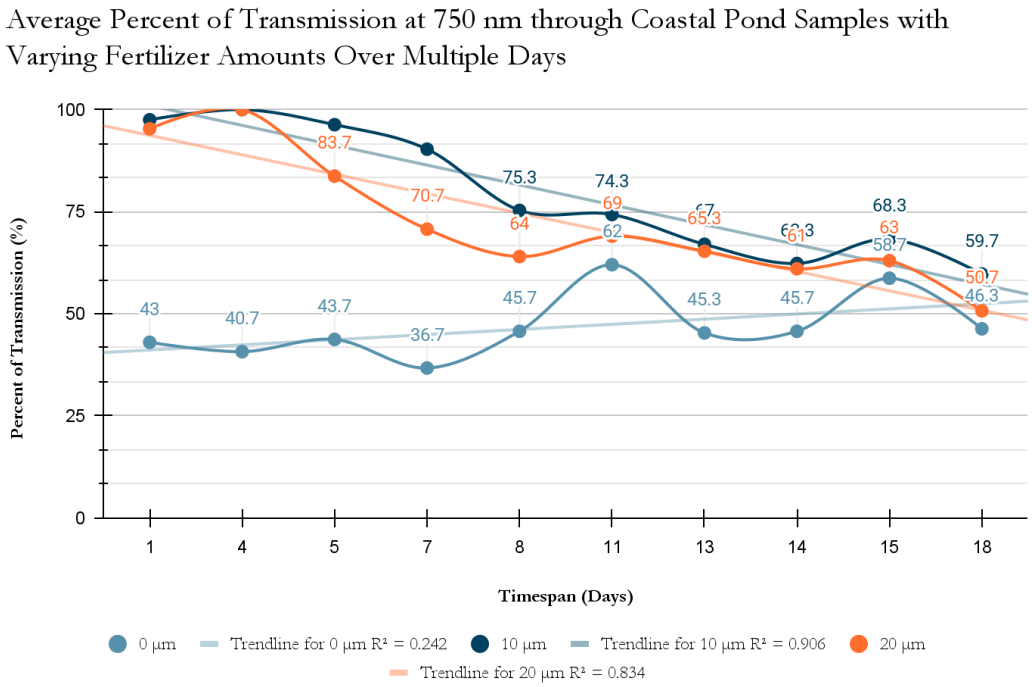
Table 1: Percent Transmittance (OD_{750}) over time

Percent of transmission at 750 nm through coastal pond samples with varying fertilizer amounts over multiple days

Treatment	Day 1	Day 4	Day 5	Day 7	Day 8	Day 11	Day 13	Day 14	Day 15	Day 18
0 µm (1)	53	54	62	52	54	68	58	53	61	51
0 µm (2)	55	52	54	44	57	67	54	57	66	54
0 µm (3)	21	16	15	14	26	51	24	27	49	34
10 µm (2)	87	100	99	81	68	72	51	49	59	39
10 µm (3)	100	100	95	95	79	76	75	69	73	70
20 µm (1)	100	100	93	77	62	75	71	63	68	56
20 µm (2)	90	100	87	68	52	64	57	58	55	40
20 µm (3)	96	100	87	82	65	72	68	62	66	56

Note. Lower transmission values indicate higher phytoplankton biomass due to increased light absorption and scattering.

Figure 1: Graph showing percent transmittance vs. day



Note. The trendlines represent the average change in light transmission, with lower averages indicating increased growth in phytoplankton biomass.

pH values increased proportionally with fertilizer concentration, reflecting more basic conditions as nutrient levels rose. The control group maintained an average pH of 5.00 ± 0.00, while the 10 µL and 20 µL treatments reached averages of 6.50 ± 0.50 and 7.65 ± 0.33, respectively (Table 2).

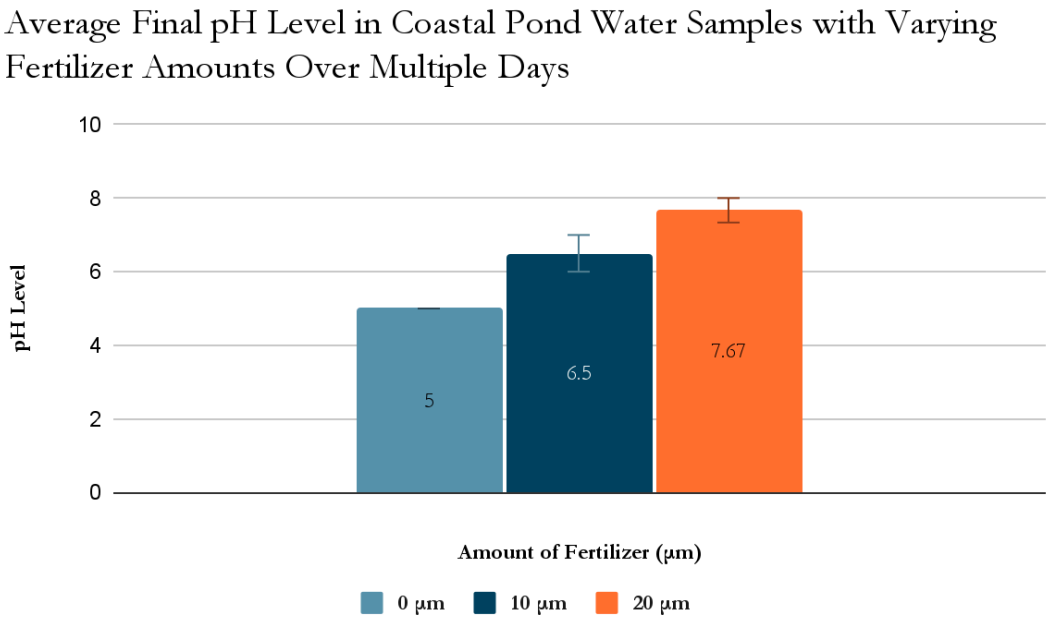
Table 2: pH changes across treatments over time

Changes in pH level in coastal pond water samples with varying fertilizer amounts over multiple days

Treatment	Day 1	Day 2	Day 3	Day 4	Day 7	Day 9	Day 10	Day 11	Day 15
0 μm (1)	5	5	5	5	5	5	5	5	5
0 μm (2)	5	5	5	5	5	5	5	5	5
0 μm (3)	5	5	5	5	5	5	5	5	5
10 μm (2)	5	6	6	6	7	7	7	7	7
10 μm (3)	5	5	6	6	6	6	6	6	6
20 μm (1)	5	6	6	6	6	7	7	7	8
20 μm (2)	5	6	6	6	7	7	7	7	7
20 μm (3)	5	6	6	7	7	7	7	7	8

Note. As pH increases, the water chemistry becomes more basic.

Table 2: Bar graph of pH averages



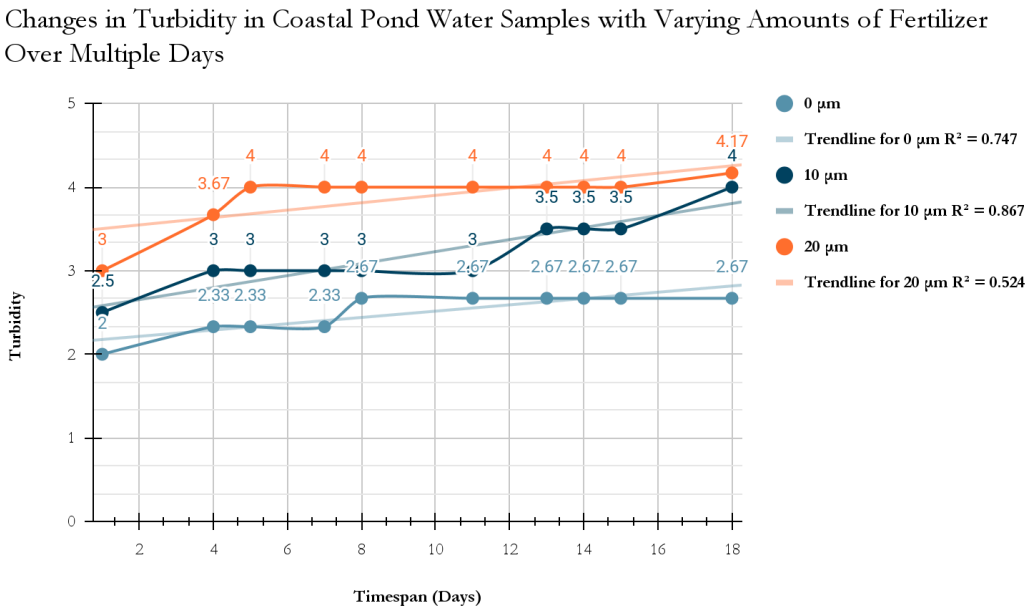
Turbidity also increased throughout the experiment in all treatments, though patterns varied across fertilizer levels. The 0 µL samples increased by 33.5%, the 10 µL samples by 60%, and the 20 µL samples by 39%. Indicating that higher nutrient availability enhanced algal density but may have led to overlapping effects such as light limitation (Table 3).

Table 3: Turbidity ratings over time

Changes in Turbidity in Coastal Pond Water Samples with Varying Amounts of Fertilizer Over Multiple Days (1 being least & 10 being most)

Treatment	Day 1	Day 4	Day 5	Day 7	Day 8	Day 11	Day 13	Day 14	Day 15	Day 18
0 µm (1)	2	2	2	2	2	2	2	2	2	2
0 µm (2)	2	2	2	2	3	3	3	3	3	3
0 µm (3)	2	3	3	3	3	3	3	3	3	3
10 µm (2)	3	3	3	3	3	3	4	4	4	5
10 µm (3)	3	3	3	3	3.5	3.5	3.5	3.5	4	5
20 µm (1)	3	3	3	3	3	3	3	3	3	3.5
20 µm (2)	3	4	4	4	4	4	4	4	4	4
20 µm (3)	3	4	5	5	5	5	5	5	5	5

Figure 3: Line graph showing turbidity change over time



Overall, nutrient enrichment resulted in higher phytoplankton biomass and more basic water conditions, with varying effects on turbidity depending on fertilizer concentration and duration of exposure.

Discussion

The results of this study indicate that increasing nutrient availability through the addition of fertilizers stimulates phytoplankton growth, as evidenced by a decline in light transmittance and an increase in turbidity over time. Samples treated with 10 μL and 20 μL of fertilizer displayed significant reductions in transmittance compared to the control, supporting the hypothesis that nutrient enrichment enhances phytoplankton biomass. Simultaneously, pH levels rose with increasing fertilizer concentrations, suggesting that heightened photosynthetic activity consumed carbon dioxide, thereby shifting the equilibrium toward more basic conditions.

These findings align with previous research identifying nitrogen and phosphorus as critical limiting nutrients in aquatic ecosystems (Schindler, 1977; Marino & Howarth, 2006). Increased nutrient input promotes algal growth, which can subsequently alter water chemistry and diminish light penetration. The observed variations in turbidity among treatments imply that light limitation and cell shading may have moderated growth at elevated nutrient levels, reflecting typical patterns of self-shading in dense algal populations (Reynolds, 2006).

Despite strong trends, several experimental limitations could have influenced the results. Although light intensity was maintained constant, fluctuations in temperature or uneven nutrient mixing might have introduced variability among replicates. Furthermore, pH measurements using strips provided approximate rather than precise values, and assessments of turbidity were subjective. Future studies could address these limitations by utilizing electronic pH probes,

nephelometers for turbidity quantification, and automated sampling methods to enhance reproducibility.

In summary, this experiment supports the hypothesis that nutrient enrichment increases phytoplankton biomass and alters water chemistry. These results reinforce the ecological understanding that excessive nutrient input can trigger eutrophication, affecting water clarity and ecosystem balance. Continued research into nutrient thresholds and community composition will be vital for managing nutrient pollution and preserving aquatic ecosystem health. These findings emphasize the critical relationship between nutrient availability and water quality, highlighting the necessity of sustainable nutrient management in freshwater ecosystems.

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