Primary production by stream autotrophs is the source of autochthonous organic matter in stream food webs. Aquatic autotrophs include periphyton (found on substrata), phytoplankton (suspended in water column), and macrophytes (vascular plants and bryophytes).

**Primary production and community respiration in streams.**
The term, algae, is used to describe a taxonomically diverse group of photosynthetic organisms. Most, but not all, algae are microscopic. In streams, algal cells, bacteria, fungi, and their waste products form a mucus-like biofilm over all submerged surfaces. The attached algae, or periphyton, within this biofilm can be important as both food and habitat to other stream organisms.

Primary production is represented in the equation:

\[ NPP = GPP - R \]

where net primary production (NPP) is the amount of stored energy in the autotrophic organisms and gross primary production (GPP) is the total primary productivity (net productivity plus autotrophic respiration, R).

Respiration and primary production are related by the expression for net daily metabolism (NDM). Community metabolism is calculated in the net daily metabolism expression:

\[ NDM = GPP - CR_{24} \]

where \( CR_{24} \) is community respiration (both autotrophic and heterotrophic) over a 24-hour period.

Respiration can be calculated using 24-hour dissolved oxygen measurements. Dissolved oxygen exhibits a diurnal pattern, known as a diel curve (Figure 1). Respiration is estimated by measuring oxygen consumption during the dark hours, when primary production isn’t also yielding oxygen production, and extrapolating to the daytime hours. More details on this methodology are covered in the metabolism methods section.

The relationship between production and respiration provides an indication of stream energetics. If GPP < \( CR_{24} \), then allochthonous organic matter should support a large portion of the food web (net carbon consumers). If GPP < \( CR_{24} \), then the system is producing more carbon than is consumed.

![Figure 1. Dissolved oxygen diel curve.](image-url)
**Why primary production and metabolism are important metrics.** Both primary production and metabolism are integrative functional measurements. Because many variables influence primary production and metabolism rates, the metrics provide an estimate of stream health (Bunn et al. 1999).

Algae are frequently the major primary producers in aquatic ecosystems. By fixing carbon through photosynthesis, primary producers convert low-energy inputs (N, P, C, light) into high-energy organic molecules. These compounds then become important energy sources. These compounds then become important energy sources for consumers.

**Controls on primary production.** Many variables affecting primary production influence each other, or can change on a seasonal basis.

1. **Light.** Light a major limiting factor and highly influences stream periphyton, but typically doesn’t affect diatoms. In general, greater light intensity will lead to increased primary production. Thus, light accounts for the seasonal change in the periphyton community of streams with a deciduous riparian zone. Shaded streams will typically have less green algae than unshaded streams.

2. **Temperature.** Seasonal changes in temperature, like seasonal changes in light, can change the composition of the periphyton community. However, the total autotrophic biomass does not widely fluctuate on a seasonal basis.

3. **Flow characteristics.** Water velocity affects the composition and distribution of the autotrophic community. Some species are better than others at attaching to the substrate in high currents. Thus, the community composition can differ between riffles and pools or slower water. Scour due to storm events may slough off or bury some periphyton, but accumulation resumes when flow conditions are tolerable.

4. **Nutrient Availability.** Nitrate and phosphate are limiting nutrients for primary production. The delivery of nutrients by the hydrologic regime can affect periphyton distribution. Because downstream transport continually supplies the periphyton community with nutrients, in many streams neither nitrate nor phosphate is a limiting factor. Some stream systems, however, do have limiting levels of inorganic phosphate.

5. **Type of substrate.** Grain size, substrate characteristics, and substrate heterogeneity can influence periphyton colonization and biomass accrual.

6. **Grazers.** Macroinvertebrate grazers and herbivorous fish can reduce the standing crop of periphyton biomass. Species composition and distribution may also change as a result of selective herbivory.

**Controls on metabolism.** Many variables affect metabolism, including:

- size and composition of the heterotrophic community
- availability of organic matter for respiration
- temperature
- nutrients
- system energetics
**Importance of primary production and metabolism in stream restoration.** Primary production and metabolism measurements can be used to evaluate changes in ecosystem function before and after a stream has been restored. Given that many restoration practices may involve initial vegetation removal or in-channel work, the functional aspects of the ecosystem may shift over a long-term study. Some stream restoration objectives, such as bank stabilization or channel reconfiguration, may not address ecosystem function. However, some objectives, such as habitat improvement, riparian work, flow modification, may lead to long-term changes in production or metabolism.

Sometimes algae are so productive that they form nuisance blooms. These blooms can deplete dissolved oxygen concentrations as they are decomposing, which can cause anoxic conditions resulting in fish kills. Preventing nuisance blooms requires an understanding of processes that can keep algal populations in check.

Many blue-green algae (Cyanobacteria) can fix nitrogen (convert N$_2$ gas from the atmosphere into forms of nitrogen that are accessible to other organisms). Thus, these algae have the ability to drastically change the nutrient status of their environment.

Algae can be useful indicators of stream condition. Algae are species-rich and are useful in biomonitoring because many algal taxa can only persist in a narrow range of conditions. Algae are good indicators of environmental pollution because they obtain nutrients directly from the water column, respond quickly to change (have short generations) and are sessile.

**References**


