R. Guerrero: ECOPHYSIOLOGY OF PHOTOTROPHIC SULFUR BACTERIA IN LAKES: VERTICAL DISTRIBUTION OF PLANKTONIC POPULATIONS

Purple and green sulfur bacteria typically stratify in sulfide-containing anaerobic waters, often accumulating massively and placing themselves at the depth where physico-chemical conditions most favor their growth. The three main prerequisites for photosynthesis of purple sulfur (Chromatiaceae) and green sulfur (Chlorobiaceae) bacteria are light, absence of oxygen, and the availability of a suitable electron donor, usually sulfide (van Gemerden and Beeftink, 1983). In the present ecosphere. this is a combinatio: only achieved in aquatic, shallow, and oligotrophic or mesotrophic environments such as ponds, lakes, and estuaries. Under such conditions, planktonic purple and green sulfur bacteria may periodically form thick, spectacularly colored layers, the most frequent being brown, green. pink, and variations of pink (Biehl and Pfennig, 1979).

During stratification in summer Chromatiaceae frequently dominate in these bacterial layers, constituting up to 90 percent of the total biomass (Guerrero et al., 1980). Although the physiology of purple sulfur bacteria has been extensively studied in the laboratory (Pfennig, 1978: van Gemerden, 1983), little attention has been devoted to their metabolism in nature. In natural habitats, very sharp physico-chemical gradients are often established. As a consequence, heterogeneous conditions within the bacterial layer result in differences of the physiological state of the cells along the gradients (Fig I-13).

The study of purple and green sulfur bacterial populations in nature is of interest for the following reasons: (a) high quantities of biomass, with low species diversity can be collected (b) study of planktonic life permits us to understand the mechanisms. structural as well as physiological. used to maintain their vertical position without sinking. and (c) because they are capable of sulfur oxidations and reductions that act as important intermediates in the global sulfur cycle. Purple and green photosynthetic bacteria, moreover, may be responsible for certain geological deposits.

The purpose of our research was the analysis of planktonic phototrophic sulfur bacteria in relation to their vertical distribution in the water column, to assess the factors. including competition for light, that determine their sedimentation rates and the numerical changes in species and populations.

C-2

HOLOMICTIC LAKE

Parameter ⟶

Depth

Epilimnion
Thermocline
Hypolimnion

Winter   Summer

MEROMICTIC LAKE

Thermocline

Mixolimnion

Chemocline
(Pycnocline)

Chemocline
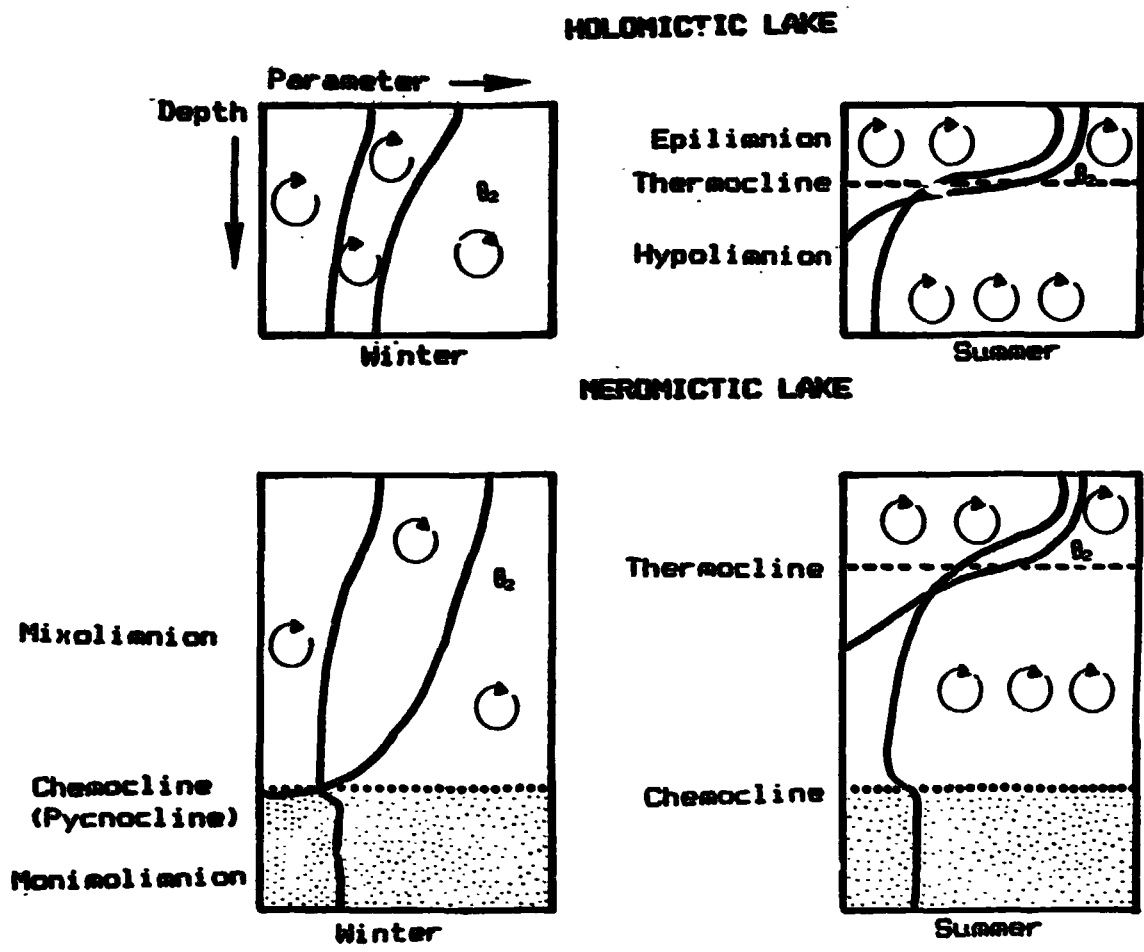
Monimolimnion

Winter   Summer

Figure I-13. Vertical structure of the water column in lakes of temperate regions. When sulfide and light are present massive populations of phototrophic sulfur bacteria can develop at the hypolimnion during the summer and in the monimolimnion of meromictic lakes during the remainder of the year.
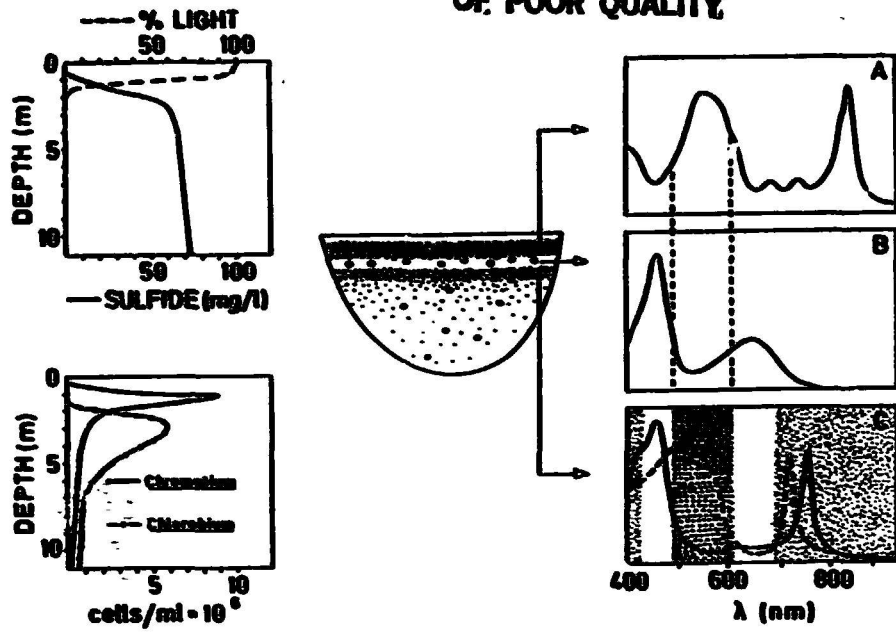
Figure I-14. Shading and light filtering effect of
Chromatium and Chlorobium and resulting competition in
Lake Ciso, Spain. (Left) Vertical distribution of light,
sulfide, Chromatium and Chlorobium during
stratification. (Right) (A) Chromatium layer, in
vivo absorption spectrum. (B) Spectral distribution of
the light below the Chromatium layer, which was at 0.5
meters. (C) Absorption spectra of Chlorobium
phaeobacteroides (------) and Chlorobium limicola (————)
cultures isolated from the layers of Chlorobium.
Stippled areas represent the bands of light absorbed by water
and by the Chromatium layer.

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In correlated field and laboratory experiments the buoyant densities of populations of selected Chromatiaceae and Chlorobiaean were measured and investigated for the association between cell density and cytoplasmic inclusions (Guerrero, 1984). The influence of buoyant density on sedimentation was also studied.

Annual changes in *Chromatium* and *Chlorobium* populations were documented (Pedros-Alio, 1983) as was competition, both intra- and interspecific, for light. The competition observed was between two species of *Chlorobium*, *C. limicola* and *C. phaeobacteroides* (Montesinos, 1983) and between *Chromatium* sp. and different chlorobia. The species of *Chlorobium* that develops depends on the presence of *Chromatium* sp. When conditions of light and sulfide are adequate *Chromatium* easily forms as the overlying layer; because it is motile, it resists low concentrations of oxygen, and it tolerates a high light intensity. *Chlorobium limicola* develops under this *Chromatium* layer because it can use the light either filtered by water or by the overlying purple photosynthetic bacteria whereas *Chlorobium phaeobacteroides*, which requires greater light intensity, does not develop underneath (Fig. I-14).

These bacteria, found vertically stratified in lakes, are not equally capable of reproduction: only the *Chromatium* cells receiving sufficient light at the surface of the bacterial layer grow and divide. Cells incapable of maintaining themselves at the top of the layer progressively accumulate at a lower level in the water column, one which is more densely populated but in which the cells are less active. Cells of this layer are replete (from their previous photosynthetic metabolism) with sulfur globules and glycogen and have a correspondingly higher buoyant density (Guerrero, 1984).

As the *Chromatium* cells slowly sink further and further away from the light, they may remain viable for variable periods of time (van Gemerden, submitted for publication). This is apparently done by the conversion of glycogen into poly-beta-hydroxybutyrate, the accumulation of which also leads to high buoyant densities of the cells (Guerrero, submitted for publication). Thus, as the populations develop throughout the year, the bottom of the bacterial layer increases in width and in cell concentration. The sinking cells eventually reach the anaerobic sediment at the bottom where rich populations of sulfate-reducing bacteria are present (Fenchel and Reidl, 1970; Nedwell, 1982). The remains of the photosynthetic bacteria contribute a significant portion of the organic matter necessary to complete the anaerobic carbon and sulfur cycles of lakes. This anaerobic, photosynthetically-driven cycling of carbon and sulfur probably provides an example of the kinds of processes typical of the early ecosystems on Earth.

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