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Research achievements

In his research Max Tilzer has been engaged mainly in work on production biology with emphasis on the phytoplankton, both in freshwater lakes and in the ocean. His lake research has been conducted in Vorderer Finstertaler See, Austria, a small high-mountain lake, large and extremely clear Lake Tahoe, USA, and in mesotrophic Lake Constance, Germany-Switzerland-Austria. A major research topic has been the utilization of underwater light for the primary production process, and the role of primary production in controlling the dynamics of the phytoplankton community. His oceanographic research mainly was conducted in the Southern Ocean where he was focusing on the effects of the prevailing low water temperatures on the primary production process. Moreover, he participated in research in the Gulf of Aqaba / Red Sea.

Max Tilzer could show that, as a general rule, aquatic ecosystems are less productive than terrestrial ones. Main reasons for this is that water as a medium is considerably more opaque than air. As a consequence, aquatic phototrophic organisms have to compete for photons with the medium surrounding them. By contrast, closed terrestrial plant stands are able to absorb and subsequently utilize virtually all light impinging on the Earth surface. In dense phytoplankton, water transparency is diminished by phytoplankton self-shading, thus reducing the vertical extent of the productive layer. Due to self-shading, areal production increases with biomass according to a saturation hyperbola. This saturation curve can also be explained by the fractional light absorption due to phytoplankton with increasing pigment concentration relative to background absorption by water. The theoretical upper limit of aquatic primary productivity would be reached if 100% of the light penetrating the water would be absorbed by the photosynthetic pigments. As a rule, however, only a relatively small proportion of the light entering the water is actually absorbed by plant pigments.

Because, moreover, even clear water strongly absorbs red light, only the blue-light absorption maximum of aquatic phototrophs can be utilized for photosynthesis. By deep vertical water column mixing, the light available to phytoplankton is further diminished because algae travel through a light gradient, together with the circulating water masses. Surface inhibition, especially in clear waters, reduces photosynthesis further. By acclimation to the prevailing light climate, phytoplankton can to some extent increase the utilization efficiency of underwater light for pghotosynthesis. The most common mechanism consists of alterations in the cellular pigment contents. When the productive layer is thermally stratified, surface algae are acclimated to higher radiances than phytoplankton in deeper water. Another strategy to optimize the light environment, consists of diel vertical migrations of flagellated phytoplankton.

The quantum yield of photosynthesis reaches its highest value only in deeper water where light is limiting. The highest values reached are 0.03 – 0.04, which is considerably below the theoretical upper limit of the quantum yield of 0.125. For all the above-mentioned reasons, the overall light utilization efficiency by phytoplankton photosynthesis is generally low. Only in exceptional cases with high phytoplankton biomass, more than 1% of the incident short-wave radiant energy is converted into chemically stored energy in photosynthates.

Investigations in Vorderer Finstertaler See and Lake Constance revealed that the relationship between areal daily gross primary production rates and rates of biomass increase is poor. This can be explained by the high proportions of metabolic (mainly respiratory) losses relative to gross photosynthesis during the primary production process. Moreover, metabolic losses are highly correlated with potential biomass growth rates as derived from photosynthesis estimate. The high proportions of metabolic losses during the primary production process restricts the transfer efficiency of energy and organic carbon from the primary producers to the subsequent food web.

The dramatic decrease of external phosphorus loading of Lake Constance during the 1980's, as a consequence of sewage treatment and wastewater diversion, did not immediately result in decreasing annual primary productivity. It was hypothesized that during the "eutrophic" phase of Lake Constance, intense grazing by zooplankton as well as sedimentation led to an effective removal of phytoplankton from the euphotic zone, thus preventing the nutrient-dependant carrying capacity to be reached. As phosphorus loading decreased, the annual biomass initially remained unchanged thus increasing the nutrient-dependent carrying capacity.

Photosynthetic measurements during the first Antarctic expedition of Max Tilzer showed that chlorophyll-specific photosynthetic rates, both at saturating and at limiting light levels, where significantly smaller than in warmer environments. Subsequent laboratory experiments on board of "Polarstern" on the temperature-dependence of photosynthesis suggested that chlorophyll-specific photosynthetic rates were temperature-sensitive both at saturating and at limiting light levels. In another study, the temperature dependence of light-saturated photosynthesis and respiration were compared. It could be shown that respiration tends to be more strongly diminished at low temperatures than is photosynthesis. This would mean that at extremely low water temperatures, the mass balance between photosynthesis and respiration is shifted in favor of photosynthesis. Model calculations based on these experimental results have suggested that algal population growth rates are not as much decreased by low temperatures than one would expect from experience at high temperatures. This could be of particular importance during seasons with short daylengths when nightly respiratory carbon losses are comparatively small.

Extensive studies on the spectral composition of the underwater light of the Southern Ocean have revealed the extreme water clarity of this predominantly unproductive sea. The main reason for the exceptionally low non-algal vertical light attenuation in Antarctic waters is the minimal terrestrial influence. Because in most cases blue light is best transmitted, light absorption cross-sections of the phytoplankton cell suspensions are comparatively high as compared to green and/or turbid waters. As a consequence, phytoplankton has a comparatively strong influence on both overall light attenuation and the spectral composition of underwater light.