GROWTH TEMPERATURES AND THE GLOBAL DISTRIBUTION OF PRIMARY PRODUCERS.

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Introduction: Habitability is a qualitative concept, generally defined as the suitability of an environment to support life, which depends on many environmental physical, chemical and biological factors. Planetary habitability is an essential astrobiology concept that needs a practical and universal definition if we want to measure, assess and compare the distribution of life on Earth and beyond [1]. Primary production is the production of organic compounds from atmospheric or aquatic carbon dioxide using the photosynthesis process [2]. All life forms on planet earth have a strictly dependency on primary production. The organisms responsible for primary production are known as primary producers. This type of organisms can be divided in several groups based in their growing environments. Land producers can be defined as vascular plants and ocean producers as phytoplankton [3]. The plankton can also be divided on algae and cyanobacteria [4].

Net primary production is the rate at which all the plants in an ecosystem produce net useful chemical energy; it is equal to the difference between the rate at which the plants in an ecosystem produce useful chemical energy (GPP) and the rate at which they use some of that energy through cellular respiration. The NPP is difficult to measure because it requires in situ observations and it is difficult to do at global scales. However, many computer models can estimate terrestrial NPP from climatology data from surface or satellites measurements [5].

The Standard Primary Habitability (SPH) of an environment can be defined as the ratio of the net primary production (NPP) and the maximum net primary production (NPP_{max}). SPH can be modeled from the temperature and relative humidity (or water activity) of an environment [1]. A fit of the SPH from land NPP and from global surface temperature and relative humidity shows that plants requires temperatures between 0°C to 43°C for physiological activity, with an optimum at 22°C.

The objective of this study is to collect and analyze data from the scientific literature for the growth temperature and humidity requirements of algae, vascular plants and cyanobacteria. Our goal is to determine if the different types of primary producers such as phytoplankton and cyanobacteria could be compared to land primary producers such as vascular plants in terms of growth/activity temperatures and relative humidity. This information is important in order to comprehend and create quantitative habitability models that map the global distribution of primary producers.

Methodology: In previous work, we constructed a database of more than 300 cyanobacteria, vascular plants and algae species. We searched the web for scientific articles with the following keywords: optimum, minimum and maximum growth temperature and relative humidity of cyanobacteria, algae, and plants. We extracted the data from many research articles to compile the database. We made a graphical analysis of the optimum growth temperature for each group. R, a statistical analysis and plotting program, was used to analyze and create distribution plots of the collected data.

Results and Discussions: The database of 100 species of cyanobacteria shows that their mean T_{opt} was 28°C (Fig. 1). This is similar to the optimum growth temperature for terrestrial vascular plants obtained from SPH models. The database of 104 species of algae shows that their mean T_{opt} was 19°C (Fig. 2). Once again, similar to the values for vascular plants and cyanobacteria. The database of 74 species of vascular plants shows that their mean T_{opt} was 22°C (Fig. 3). The data obtained from this analysis supports the SPH models. The mean optimum growth temperatures for many other simple and complex species are usually much higher (~37°C). The results from this study suggest that phototrophic metabolisms, among very diverse primary producers, have similar temperature requirements. We suggest that this is an intrinsic property of the physiology of photoautotrophic organisms, which strongly controls their global distribution.

Preliminary results show a mean relative humidity of 73% for 54 species of vascular plants. The data will be compared and analyzed in search of other patterns. We will use this data to improve habitability models about the potential distribution of primary producers at planetary scales.

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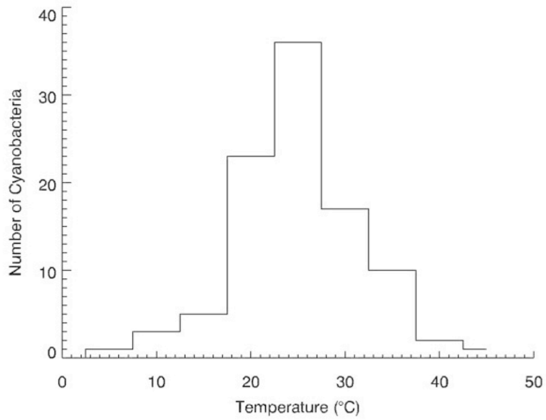

Figure 1: Distribution of optimum growth temperatures (T_{opt}) for 100 species of cyanobacteria. Most species require temperatures between 20° and 30°C for best growth.

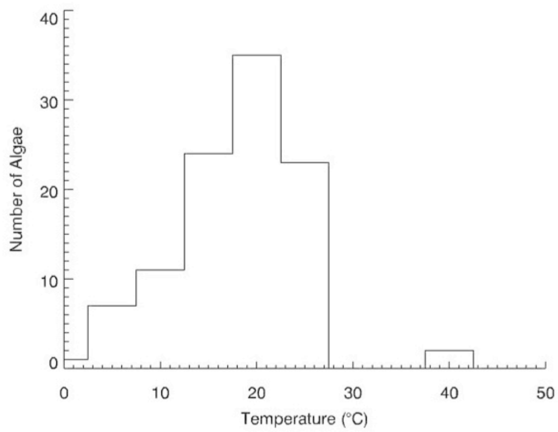

Figure 2. Distribution of optimum growth temperatures (T_{opt}) for 104 species of algae. Most species require temperatures between 15°C and 30°C for best growth.

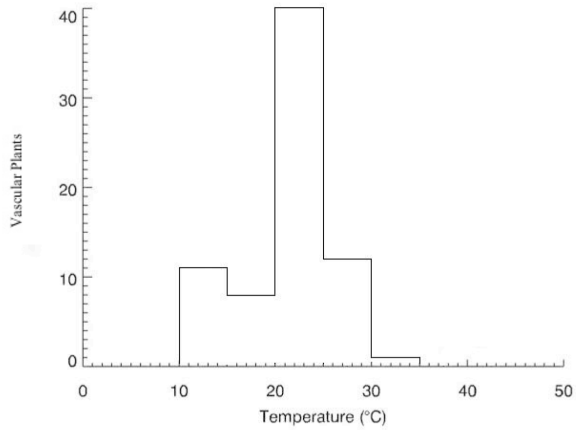

Figure 3: Distribution of optimum growth temperatures (T_{opt}) for 74 species of vascular plants. Most species require temperatures between 20° and 25°C for best growth.