Chlorophyll-f: Earth’s Unseen Production and Habitation Under Red Light

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Introduction: Chlorophyll-f

Chlorophyll-f (chl f) was first discovered in 2010 being utilized by the cyanobacteria, Halomicronema hongdechloris, living within the stromatolites of Hamelin pool, Shark Bay, Western Australia [1]. Laboratory-based studies have been able to characterize the absorbance of chl f in vivo and in vitro (naturally occurring as a combination of chl a + f) [2, 3]. In vitro absorption has a Soret band at 406 nm and a red absorption band of 707 nm, redefining what was thought to be the long wavelength limit for oxygenic photosynthesis held by chlorophyll of at 696 nm [4]. Notably, the absorbance efficiency in vivo can be extended to 740 nm [2].

Earth’s Primary Productivity

Although many more primary producers have since been found to use chl f [5, 6], these studies have been limited to laboratory-based analyses. Remote sensing techniques offer the ability to monitor global primary production with great temporal and spatial resolution for considerably less than field measurements would cost. With no simple in situ technique for measuring chl f, remote sensing may provide an opportunity to better understand these red-shifted chlorophylls in our environment in both space and time. Based on the absorption characteristics of chl f, MERIS data has been chosen (having a band nearest the red absorption maxima of chl f at 709 nm) to assess the potential of remotely detecting chl f.

Astrobiological Significance

Much of oxygenic photosynthesis on Earth occurs via utilization of chl a, which absorbs wavelengths of light optimally suited for our sun’s wavelength emission. But what about the wavelengths emitted by red dwarfs? Through utilizing red-shifted chlorophylls, such as chl f, planets and moons orbiting red dwarfs may be able to receive the necessary solar energy to drive photosynthesis. Because red dwarfs make up such a large percentage of the universe’s observable stars understanding the surface reflectance of a planet utilizing red-shifted chlorophylls as a primary pigmentation is likely to be a critical step in observing biosignatures of extrasolar life. The first step is to document an Earth-based reflectance signature.

Study Site: Hamelin Pool, Western Australia

Initial Questions: (cont’d)

1. Is there a lower relative reflectance at 709 nm in Hamelin Pool?

Hamelin Pool (a) has a lower relative reflectance (higher absorption) at 709–710 nm compared to nearby regions. Areas of highest reflectance coincide with seagrass-dominated bottom type and/or extremely shallow banks.

2. Can this be explained by bathymetry?

Hamelin Pool has a significantly lower Rrc(709) for a shallow average bottom depth. For example, region (b) is on average shallow, yet still deeper than Hamelin Pool and has higher overall Rrc(709) than Hamelin Pool.

Future Work

In situ

In order to validate any algorithm, collecting in situ samples is necessary. Although this study is focused on the region of Shark Bay, it is clear that chl f is utilized in other similar niche environments. Once the accuracy of a chl f algorithm can be assessed in Shark Bay, this study may be extended to multiple regions.

Remote Sensing

Although MERIS data was chosen for the preliminary study based on having daily repeat cycles and a band nearest that of chl f’s red absorption maxima, it is not presently collecting data. Optimal hyperspectral data should be collected to fine-tune a chl f remote sensing quantification method including same-day in situ [chl f] measurements.

In vivo

In comparison to local areas (e.g., regions (b) & (c)), Hamelin Pool has anomalously low Rrc(709) for a shallow average bottom depth. For example, region (b) is on average shallow, yet still deeper than Hamelin Pool and has higher overall Rrc(709) than Hamelin Pool.