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# The role of coral fluorescence: Testing the major hypotheses on mesophotic corals

## Introduction

Fluorescence refers to the alteration of light by a substance that will usually absorb light in a short wavelength and will emit it in a longer wavelength. This physical phenomenon, which results in glowing colors, is prominent in the marine environment, and has ignited the imagination and drawn the attention of many researchers over the years. Corals are known for their extreme fluorescence, mainly derived from proteins belonging to the GFP-like protein family (Dove et al. 2001). Currently, fluorescent proteins (FPs) are used in the biotechnology industry as visual markers that allow us to observe and localize gene expression, follow biological processes, and identify cellular compartments in many organisms, including humans (Lippincott-Schwartz and Patterson 2003). The biological role of FPs in corals is still under debate, and hypotheses regarding this question include: (1) the enhancement of photosynthesis where light is scarce (Schlichter et al. 1994); (2) protection against harmful radiation (Salih et al. 2000); (3) antioxidant activity during oxidative stress (Palmer et al. 2009); and (4) symbiont attraction (Aihara et al. 2019). Studies have shown that FPs are upregulated when exposed to blue light (D'Angelo et al. 2008) or high-light intensities (Ben-Zvi et al. 2019), and downregulated during heat stress (Smith-Keune and Dove 2008). Mesophotic coral ecosystems are light-dependent reefs usually found between 30 m and 150 m depth (Loya et al. 2019). Interest in these unique reefs has increased in recent years due to the advances in technical diving that have facilitated the study of those depths. Furthermore, in this era of global climate change, shallow reefs are experiencing ongoing stresses and frequent mass bleaching events (Hughes et al. 2018). The mesophotic reefs have been suggested as possible refugia for their affected shallow counterparts, or as a source for larvae to replenish the shallow reefs in the future (Bongaerts et al. 2010). Despite mesophotic corals being extremely fluorescent, studies of their physiology and fluorescence are still scarce. These corals also display a variety of fluorescence morphs (i.e. expressing different FPs) within the same species, thereby offering a new and unique model system with which to test the posited hypotheses regarding the role of coral fluorescence.

## Research goals

In my PhD studies I aim to examine in mesophotic corals the previously suggested hypotheses regarding the biological role of fluorescence. The questions will be approached using long-term experiments in the sea and short-term controlled experiments in the lab. I shall examine the physiology, photosynthesis, and fluorescence of several coral species from mesophotic depths (45-80 m) using field surveys, advanced microscopy and photography, physiology analyses, and molecular biology.

## Results

Many mesophotic species present fluorescence and some species (e.g. *Euphyllia paradivisa*, *Goniopora minor*, and *Alveopora ocellata*) demonstrate fluorescence polymorphism (Fig. 1). The excitation and emission peaks differ both among species and within species, which may indicate multiple roles for FPs.

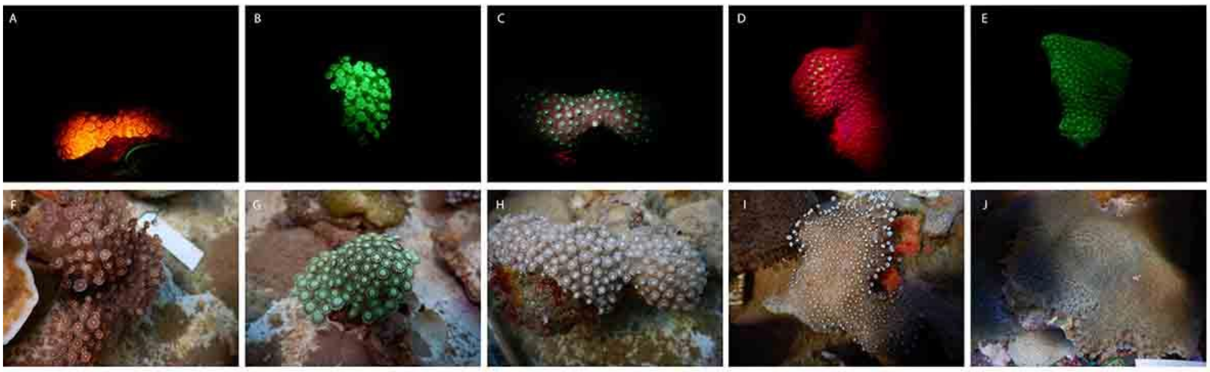


*Figure 1* Fluorescent and non-fluorescent images of mesophotic corals from the Gulf of Eilat/Aqaba. Fluorescent images (A-E) and non-fluorescent images (F-J) of the corals *Goniopora minor* (A-C, F-H) and *Alveopora ocellata* (D-E, I-J).

To test the "sunscreen hypothesis", three fluorescence morphs of the mesophotic coral *Euphyllia paradivisa* were exposed to high-light and ultra-violet radiation, followed by analyses of several stress indices. I found no difference between the fluorescence morphs in either the amount of symbiotic algae (Fig. 2A), chlorophyll a concentration (Fig. 2B), or DNA damage (Figs. 2C, 2D) caused by the light stress. Hence, my findings did not

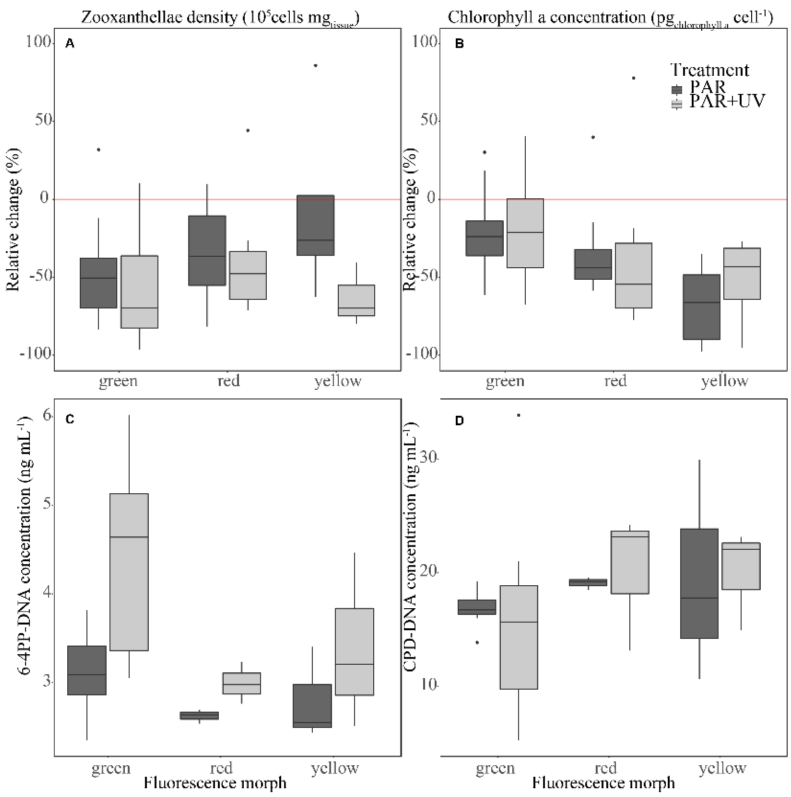


*Figure 2* Stress indices of *Euphyllia paradivisa*. Change (%) in the (A) zooxanthellae density, and (B) chlorophyll a concentration and concentration of (C) 6-4PPs and (D) CPDs under two light treatments: full sunlight ("PAR+UV"; light gray boxes) and PAR only ("PAR"; dark gray boxes), in three fluorescence morphs. Boxes represent the upper and lower quartile, center lines represent medians, and whiskers extend to data measurements that are less than 1.5*IQR away from first/third quartile. Outliers are represented by dots. Red lines represent a reference to the measurements taken prior to the light treatments.

support the suggestion of a protective role of FPs in shallow-water corals under light-stress. However, the mesophotic corals did display defense mechanisms against harmful radiation that had previously only been described in shallow corals, such as the production of protective compounds (mycosporine-like amino acids) and tissue contraction (Ben-Zvi et al. 2019).

When examining the photosynthetic abilities of mesophotic corals, I found no difference between the quantum yields of different fluorescence morphs under changing light intensities (Fig. 3). This indicates that fluorescence may not enhance photosynthesis in a low-light environment in contrast to the role suggested by Schlichter et al. (1994). Additionally, sequencing results revealed that the symbiotic algae (family *Symbiodiniacea*) from all morphs belonged to the genus *Cladocopium*. Consequently, I cannot say that specific fluorescence morph is advantageous in attracting specific *Symbiodiniacea*. Having found no support for the two above-noted major hypotheses in the case of *E. paradivisa*, I am currently exploring a new and exciting hypothesis regarding the potential role of coral fluorescence as prey attractant in the mesophotic environment.

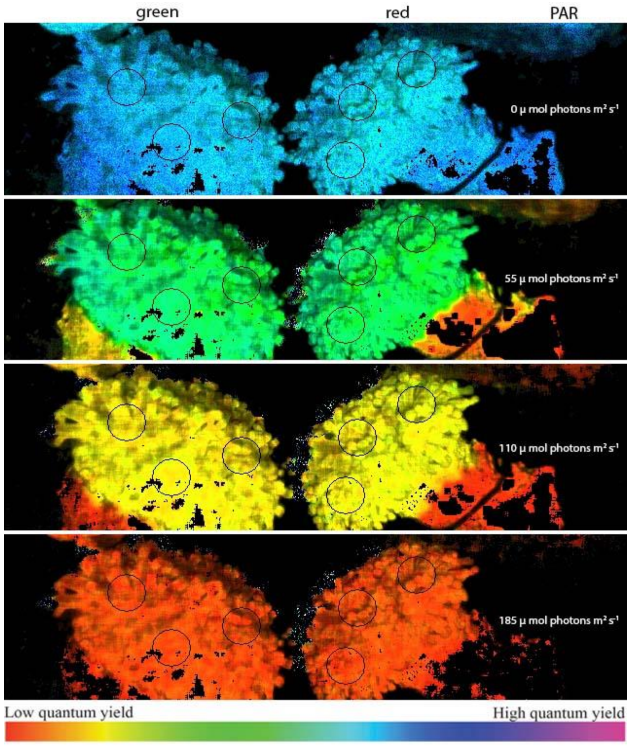


Figure **3** Quantum yield of different fluorescence morphs of the coral *Euphyllia paradivisa* under changing light intensities. Quantum yield of green (left) and red (right) polyps of *E. paradivisa* under increasing photosynthetic active radiation (PAR) intensities of 0, 55, 110, and 185 μmol photons $m^2$ $s^{-1}$ measured with a maxi version Imaging PAM.

## Future implications

Unravelling the mystery of coral fluorescence through an examination of mesophotic corals and the phenomenon of fluorescence polymorphism, may provide us with a non-invasive tool for monitoring coral health; while also explaining some of the unique distribution patterns of corals, and broadening our currently limited understanding of the physiology of corals at the mesophotic depths - a coral habitat that is drawing increasing interest and research.

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