Analysis of Light Absorption in Underwater Filming: A Methodological and Comparative Approach at Successive Depths

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Abstract

The study conducted in the Red Sea at depths of 10m, 20m, 30m, 40m, and 50m clearly demonstrates the progressive loss of warm colors underwater due to selective light absorption, highlighting the critical role of artificial lighting in recovering these colors. A handmade underwater color scale was created, providing an essential reference for comparative analyses and precise calibration during post-production. Future experiments will expand on these findings by evaluating different types of underwater lamps with varying color temperatures and intensities, testing the effectiveness of color-correction filters (red, magenta, CY) at shallow and intermediate depths, and examining the impact of water turbidity on color visibility. Practical recommendations derived from this study include strategically employing artificial lighting beyond 10–15m depth, consistently applying custom white balance, maintaining close proximity to subjects, and using a color reference within the frame. Technological advancements and improved digital post-processing methods promise to further enhance underwater image accuracy. Nevertheless, a thorough understanding of underwater optical phenomena combined with practical diving experience remains indispensable for achieving visually compelling and scientifically accurate underwater photography and cinematography.

Keywords: underwater, selective absorption, color scale, housing, filters, depth

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1. Introduction

Underwater filming is one of the most fascinating branches of videography and photography, yet it simultaneously presents numerous technical and conceptual challenges. Unlike terrestrial filming, which takes place in the air, capturing images underwater is significantly affected by the density of water, its optical properties, and the presence of suspended particles. Furthermore, the absence of sufficient light at greater depths leads to a radical shift in color perception.

In my doctoral thesis, which focuses on the study of underwater filming methods and the characterization of optical phenomena in aquatic environments, I have created a handcrafted color scale to objectively evaluate how colors change at different depths. I chose to test this scale at depths of 10m, 20m, 30m, 40m, and 50m in the Red Sea, as this maritime space is known for its clear water. Additionally, the Red Sea offers a variety of ecosystems—coral reefs, seagrass meadows, sandy areas—that can highlight differences in light and color under various conditions.

In the following sections, I will discuss, in an integrated manner, some general concepts about color, the importance and specificity of color perception in underwater environments, the methodology used to conduct the experiment, and the resulting observations. The aim of this article is not only to provide empirical data on color loss at depth but also to emphasize the importance of using a reference color scale and calibration tools. Although often underestimated, these approaches can significantly improve the accuracy and quality of underwater images, with relevance both in scientific research and in the media industry (documentaries, feature films, commercials).

2. Notions about Color

2.1 Color Perception

"When we look at the world, we see colors. We tend to think that these colors have to do with light […] If light disappears, color disappears, but if darkness disappears, color disappears as well." (Pastoreau, 2006, p. 67)

Color, in a physical sense, is a property of light that corresponds to a specific region of the visible electromagnetic spectrum (approximately 380–700 nm). The white light we perceive from the sun contains all wavelengths of the visible spectrum, and an object reveals its color because it selectively reflects certain wavelengths while absorbing the rest. For instance, when an object appears red, it means that it primarily reflects light in the 620–700 nm range, which is then perceived by the human eye.

Color perception also depends on the physiology of the eye. The cones in the retina are essentially grouped into three categories: those sensitive to blue (approximately 420 nm), green (530 nm), and red (560 nm). The brain combines the information received from these cones to generate the sensation of color. Therefore, the "truth" of color is a combination of the properties of the light reaching our eyes and the way our visual system processes this information.

2.2. Spectrum Importance in the Underwater Environment

When sunlight penetrates the water, each wavelength undergoes absorption and scattering. It is well known that red, having a relatively long wavelength (approximately 620–700 nm), is absorbed much more quickly than blue (approximately 450–490 nm). Practically, within the first few meters underwater, the red component begins to diminish significantly. This is why, as we dive deeper, colors shift toward cooler tones (greenish or bluish hues).

In the chapter on underwater cinematography from *American Cinematographer*, Pete Romano, one of Hollywood's most renowned cinematographers, emphasizes that: *all water acts as a continuous filter, and the depth of the water, along with the distance between the subject and the camera, adds to the total path that light must travel* (Romano, 2004, pp. 55-76).

However, the absorption rate is not the only relevant factor: the scattering of photons by water molecules and suspended particles can lead to a loss of clarity and contrast. More precisely, light not only "disappears" (through absorption) but also becomes disordered, deviating in various directions, causing the image to appear "milky" or foggy. In extremely clear waters, such as certain areas of the Red Sea, this phenomenon is less pronounced than in murky waters. However, even in the clearest locations, at depths beyond 15–20 meters, the effect becomes noticeable.

3. Color in the Underwater Environment

3.1. Factors Influencing Underwater Filming

• **Visibility Conditions**: The transparency of water depends on salinity, temperature, plankton levels, sediment concentration, and other local factors. In the Red Sea, water tends to be relatively clear, with visibility reaching 30–40 meters on good days. However, seasonal and regional variations may occur, especially near shorelines or at river mouths.
• **Time of Day and Weather**: At noon, the sun is high in the sky, allowing a high level of radiation to penetrate the water. In contrast, during the morning or late afternoon, the angle of sunlight is more oblique, causing a significant portion of the radiation to reflect off the surface or weaken due to its longer path through the atmosphere.
• **Surface Reflections**: If the sea is rough or waves are strong, a significant amount of light can be lost due to multiple reflections. Cloudy skies can also reduce the total amount of light entering the water.
• **Selective Absorption by Wavelength**: The order in which colors disappear is generally red → orange → yellow → green → violet, with blue and a certain range of green lasting the longest.

3.2. The Role of a Color Scale

Why do we need a **color scale**? Simply put, when discussing colors, we need a reference to indicate "how red, green, or blue *should* look." On the surface, color calibrations are commonly performed using commercial *color checkers* (e.g., X-Rite ColorChecker), which contain 24 standardized color patches. In underwater environments, these tools can be just as useful but must be adapted to withstand pressure, corrosion resistance, and handling underwater.

To have a durable and customized version, I crafted a handmade **color scale** containing significant bands from the visible spectrum: bright red, orange, yellow, green, blue, black, white, plus several intermediate shades (cyan, magenta, neutral gray). This panel was made from treated aluminum with matte paint resistant to saltwater, and its dimensions (approximately 30 × 20 cm) are sufficient for clear visibility within the frame.

In this project, the color scale serves a dual purpose:

1. To provide a visual demonstration of how colors fade and transform at 10m, 20m, 30m, 40m, and 50m depths.

2. To serve as a reference point for color corrections in post-production, allowing for the most faithful restoration of lost hues.

4. Methodology and Practical Implementation

4.1 Filming Equipment and Working Conditions

I used a **Sony A7S2** camera, known for its full-frame sensor with high sensitivity to low light, which often delivers excellent results in underwater conditions. This camera was enclosed in a **Subal underwater housing**, designed to withstand significant pressures (over 100m), with all necessary external controls and a **fixed Sigma 20mm F:2 lens**.

For lighting, I had two options:

1. **Natural light**
2. **Artificial light**: I used an underwater video lamp with a luminous flux of **5000 lumens** and a **high CRI (above 90)**. These lamps emitted light with a color temperature close to sunlight (approximately **5000K**) to compensate for the loss of warm tones at greater depths.

The dives were scheduled at noon, in the same location in the Red Sea, to maintain consistent environmental conditions. Visibility ranged between 25 and 30 meters, with relatively calm waters and temperatures around 25–26°C underwater and 28–30°C at the surface. Strong current areas were avoided to stabilize filming and facilitate the handling of the color scale.

4.2 Capture Procedure

At each of the five depths (10m, 20m, 30m, 40m, and 50m), filming and photography were conducted as follows:

1. **Capture with natural light** (without artificial lighting). The color scale was held by an assistant diver, positioned nearly perpendicular to the camera axis.
2. **Capture with artificial light**. Color distortions were significantly reduced when the light source was positioned **0.5–1m** from the subject.
3. **White balance**. A **custom white balance** was performed at each depth using the white section of the color scale. This step was crucial in determining the extent to which the camera could automatically compensate for the loss of warm colors.
4. **Recording conditions**. The following parameters were noted: **exact depth, approximate visibility, exposure settings** (ISO, aperture, shutter speed).

5. Observations at 10m, 20m, 30m, 40m, and 50m Depths

5.1 Depth of 10m

• **Natural light**: At **10m**, red is still quite visible, although not as intense as at the surface. However, when compared to the calibrated color scale at the surface, a slight fading of the red and orange segments is already noticeable. Yellow remains relatively strong, while green and blue appear very close to how they would be seen at the surface.

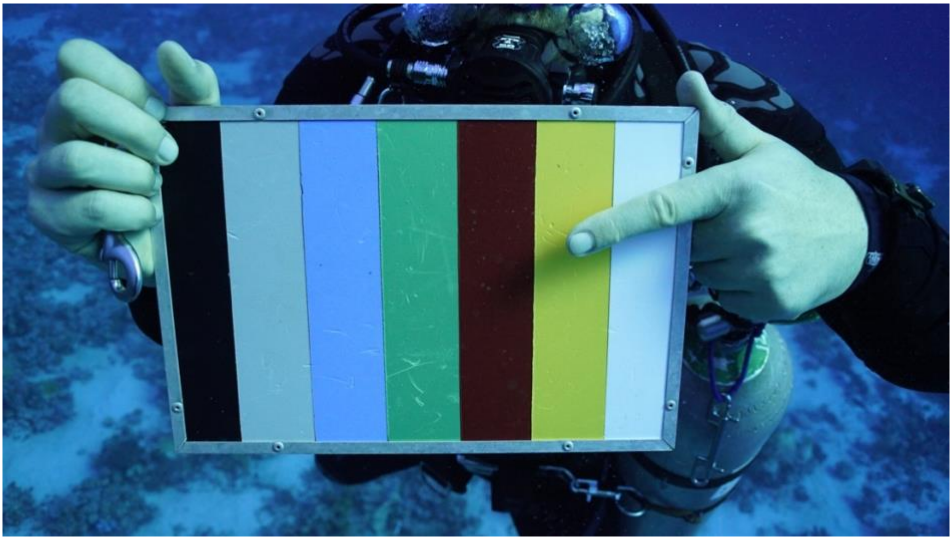

Fig. 1. Photograph at 10m with Natural Light

• **With artificial light**: The color scale appears very close to its "original" state. The differences between the image with and without artificial light are not extreme, indicating that at **10m**, there is still a significant amount of sunlight available. However, the **red band appears more vibrant and accurate** with the lamp turned on, and the **white and gray tones look "cleaner"**, without the slight cyan tint.

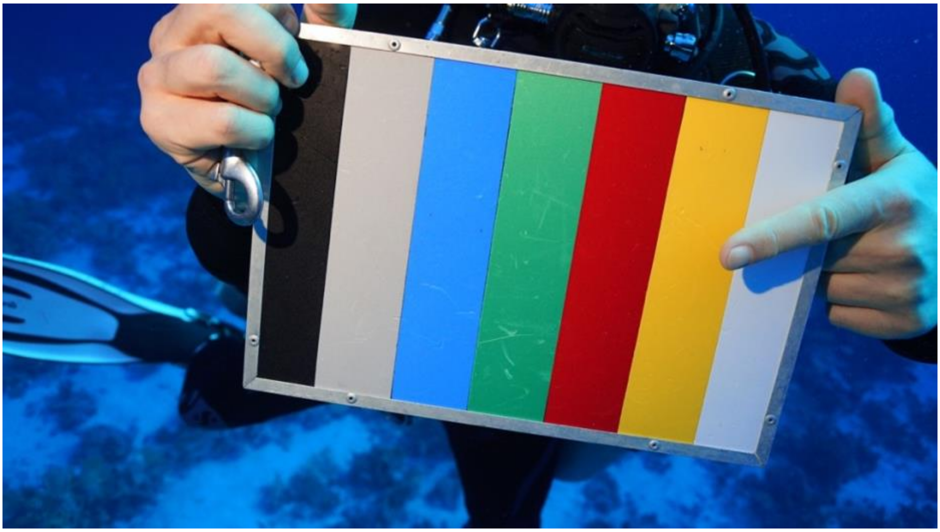

Fig. 2. Photograph at 10m with Artificial Light

• **White balance**: When set to automatic white balance, the camera tends to shift towards slightly cool tones, partially compensating for the lack of red. When a custom white balance was performed using the white section of the scale, warm colors became slightly more pronounced. However, it is still evident that the red section does not receive enough "energy" from natural light.

5.2. Depth of 20m

• **Natural light:** In this image captured at approximately **20 meters** depth, one of the characteristic effects of underwater filming is already visible: the progressive disappearance of warm colors, particularly red. The color scale in the photograph clearly illustrates this phenomenon. The red band (normally located between the white/black and green or yellow segments) no longer has the brightness it does at the surface, appearing reduced to an almost brownish hue or even difficult to distinguish. In contrast, cool colors (such as black, green, and blue) remain much more visible.

The predominant bluish tint of the image is the result of the selective absorption of longer wavelengths (red, orange, yellow) by water, which intensifies with each additional meter of depth. Even the white and gray segments of the scale take on a slight cool tint, indicating that the available natural light at this depth already has a modified spectral composition. This photograph demonstrates how artificial lighting or color correction in post-production becomes crucial for restoring warm colors and accurately depicting the underwater scene.

Fig. 3. Photograph at 20m with Natural Light

• **With artificial light**: The color scale returns to shades that resemble those seen at the surface. Red becomes clearly distinguishable again, orange appears closer to a bright orange, and yellow regains its brightness. However, the rest of the frame retains its bluish dominance if the lamp’s light does not reach far enough. Often, at 20m, the camera needs to increase the ISO if filming with natural light alone.

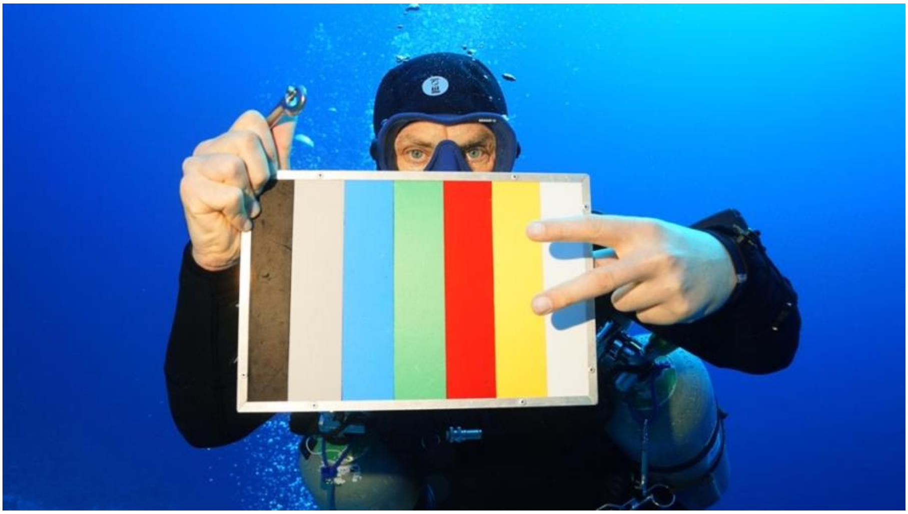

Fig. 4. Photograph at 20m with Artificial Light

• **White balance**: The camera's automatic setting makes the overall image appear less blue, but warm colors are often not accurately represented, appearing dull instead. With a custom white balance set on-site, red becomes slightly more accurate in the foreground, but still weaker than in reality at the surface.

5.3 Depth of 30m

• **Natural light**: At this depth, warm colors fade significantly. The red segment of the color scale is no longer visible as red; instead, it appears almost nonexistent. Orange and yellow have also become highly desaturated. This marked loss of warm hues further highlights the strong blue dominance of the image and the increasing absorption of light at greater depths.

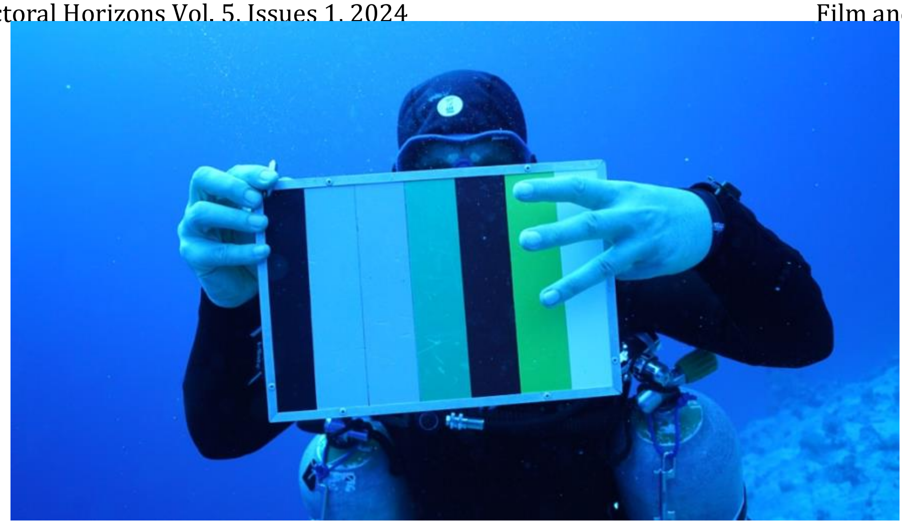

Fig. 5. Photograph at 30m with Natural Light

• **With artificial light**: An underwater lamp or strobe becomes essential for restoring the true appearance of colors. There are significant differences between the directly illuminated areas and the background, which remains bluish. Even with a high-performance sensor like that of the A7S2, the camera starts requiring more aggressive settings (higher ISO) to maintain an appropriate shutter speed for filming (e.g., 1/60s at 30 fps).

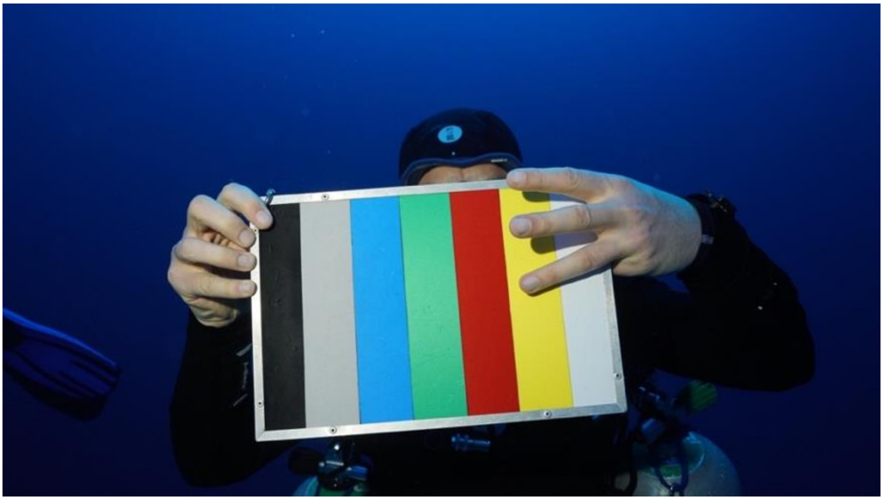

Fig. 6. Photograph at 30m with Artificial Light

• **White balance**: A manually adjusted white balance enhances warm colors only where there is sufficient light. If the subject is too far from the light source (beyond 1.5–2m), red is already “lost”. Therefore, at 30m, it becomes crucial to get closer to the subject to properly illuminate it and achieve vibrant colors.

5.4 Depth of 40m

• **Natural light**: The red region of the spectrum is practically nonexistent. Photos taken at 40m without any artificial lighting exhibit an extremely strong blue dominance. Objects that appear bright red at the surface turn into grayish-blue or dark brown, while yellow is barely recognizable.

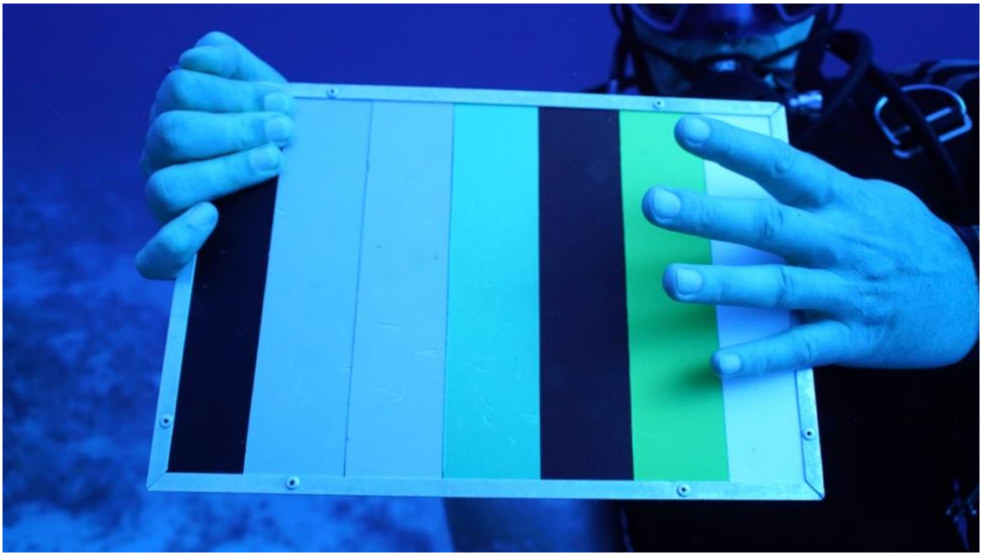

Fig. 7. Photograph at 40m with Natural Light

• **With artificial light**: A significant portion of the color spectrum can be restored in the foreground, but only within a limited range (depending on the power and beam angle of the lights). At this depth, it becomes clear that filming is “selective”—vivid colors are only visible in the directly illuminated area, while the rest of the frame remains in a blue-tinted shadow.

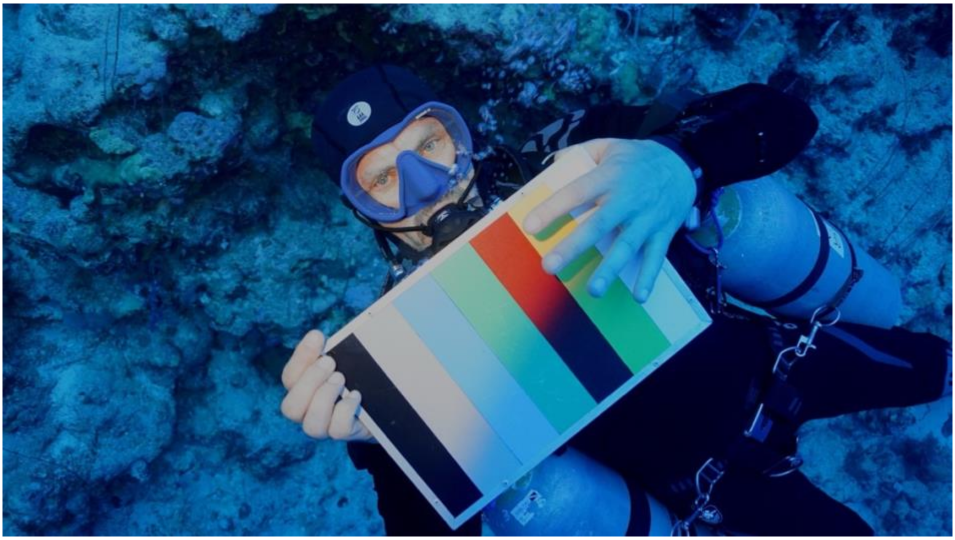

Fig. 8. Photograph at 40m with Artificial Light

• **White balance**: At 40m, the camera's custom white balance cannot fully counteract the spectral loss. However, a reduction in the cool dominance can be observed in the foreground, especially when the subject is illuminated with a lamp. The unlit background still retains a noticeable blue or green tint.

5.5 Depth of 50m

• **Natural light**: At this depth, we have reached the limit of recreational diving for many divers (30–40m already being considered a serious depth). However, for research or technical diving, 50m is still accessible with specialized equipment.

Natural light at 50m is heavily attenuated—everything appears to be "swallowed" into a gradient of blue. The color scale becomes almost monochromatic: red, orange, and yellow are extremely difficult to distinguish, while the white and gray areas take on strong cool tones.

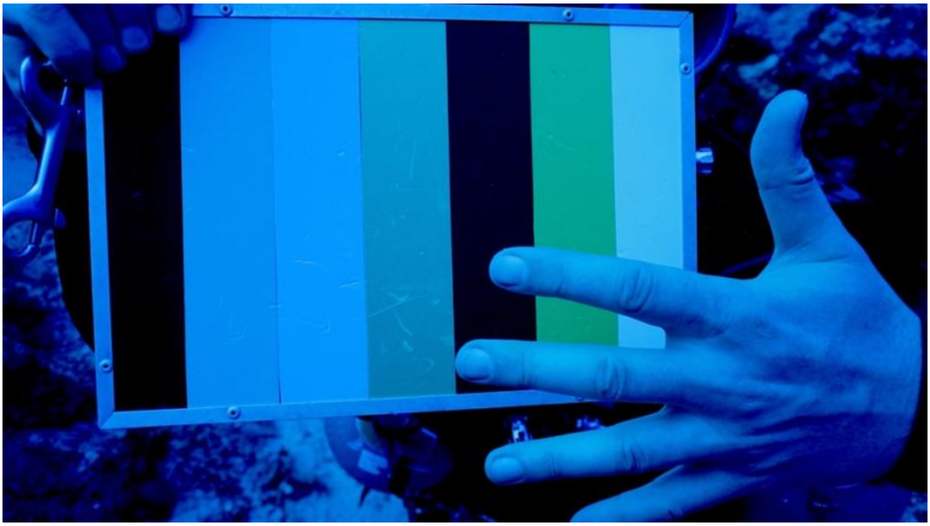

Fig. 9. Photograph at 50m with Natural Light

• **With artificial light**: This is the only way to significantly recover warm colors at this depth. Even so, powerful lights and proper positioning are necessary; otherwise, water absorption immediately “consumes” red light. If the subject is illuminated directly from 50 cm, red and orange can appear almost at their true intensity.

Additionally, at 50m, nitrogen narcosis (for divers using air) and decompression limits become major concerns, significantly reducing the available time for filming and experimentation. Due to these constraints, we had to retreat, and no artificial light photographs were taken at this depth.

• **White balance**: Although the camera can attempt a custom white balance, the available spectral resources are so limited that the effect is minimal. The white balance adjustment will pull the image toward a more neutral tone, but it cannot recreate colors that do not exist as reflected light in the absence of artificial lighting.

6. Conclusions

6.1 Progressive Loss of Warm Colors

The data and images obtained at 10m, 20m, 30m, 40m, and 50m confirm **that red disappears the fastest**—in most cases, it can be considered that after 10m, true red is no longer visible to the human eye without additional lighting. Orange and yellow follow shortly after, and by 30m, the situation becomes critical for objects colored in these shades. By 40m and 50m, it is clear that almost the entire warm spectrum has been eliminated, leaving only cool tones of blue or green.

6.2 The Effectiveness of Artificial Light and the Role of the Color Scale

The use of high-power video lights radically transforms color perception in the foreground. As observed, at 20m, the difference between “without light” and “with light” is already visible, but at 30m and especially 40–50m, artificial lighting becomes practically the only way to accurately reproduce colors.

The handmade color scale provided an objective reference in every situation: it allowed us to visually confirm that the red segment could only be revived in the intensely lit area.

Additionally, in post-production, the color scale played a crucial role: knowing exactly how red, white, or black should look, we were able to apply more precise color adjustments and RGB curve corrections to compensate for the chromatic deficit as much as possible. However, no software can “create” red light if it was not captured by the sensor at all. Generally, color correction involves boosting certain color channels and neutralizing the blue dominance, but this has its limits, especially at great depths.

6.3 Practical Aspects and Depth Limits

Between 10m and 20m, in good visibility conditions (such as those in the Red Sea), it is possible to capture remarkable underwater images even without extensive artificial lighting, especially if the subjects are not bright red. However, below 20–30m, anyone aiming to faithfully capture the beauty of reefs, fish colors, and ambient details must use lamps, strobes, or plan multiple dives to adjust for lighting needs.

At 40m and 50m, the situation becomes even more complex due to diving limitations (bottom time, nitrogen narcosis, decompression), making filming sessions short and technically demanding. The color scale clearly demonstrates that without lighting, the image suffers significantly, and with lighting, proper positioning, beam angle, and distance from the subject must be carefully managed.

6.4 Relevance for Research and Media Productions

The findings presented in this article have significant implications for both the scientific field (marine biology, underwater ecology, oceanography) and the media industry (documentaries, reports, and cinematic productions).

For researchers documenting coral reef conditions, marine habitats, or fish species, it is essential to understand how the actual appearance of organisms changes at different depths. In practice, reef monitoring often involves repeated photography over time, and if colors are not calibrated correctly, it can lead to incorrect conclusions about coral health (e.g., underestimating a bleaching event).

For film, documentary, and TV productions, underwater cinematography can be significantly improved by using a color scale and understanding absorption phenomena. When audiences watch underwater footage, there is always a tendency to “romanticize” the image, with excessive post-production to enhance colors that do not exist in reality. However, a balanced approach between accurate representation and artistic intervention is preferable, especially in documentaries, where scientific accuracy is important.

7. Future Perspectives and Final Conclusions

The study conducted in the Red Sea, at depths of 10m, 20m, 30m, 40m, and 50m, has unequivocally demonstrated the dynamics of light absorption and the critical importance of artificial lighting for recovering warm colors. The handmade color scale has proven to be an essential underwater chromatic reference, both for comparative analysis and for calibration in post-production software.

In my thesis, I plan to further develop these observations and expand the experiments by:

• **Comparing different types of lamps** (with varying color temperatures, CRI values, and intensities) to evaluate how they contribute to the restoration of warm tones.

• **Testing underwater filters** (e.g., red, magenta, CY filters, etc.) that are frequently used at shallow and mid-range depths (10–20m) to compensate for red channel losses.

• **Analyzing turbidity**: In murkier waters, the decrease in visibility and the increased scattering of photons can cause red to disappear even at just 5m.

From a practical perspective, any diving enthusiast passionate about underwater filming—or any professional cinematographer—can benefit from these conclusions. The key is to **understand the limitations** of the underwater environment and carefully **plan** equipment, lighting, subject distance, angles, and time of day. Even the simple use of a color scale can make the difference between a final “dull, blue-dominated” image and one where the true beauty of marine life is faithfully reproduced.

When we ask ourselves why, in some professional documentaries, underwater colors appear so vibrant, the answer is almost always the same: proper lighting was used, everything was correctly calibrated using a color reference, and post-production was handled with care. On the opposite end, photos taken without this knowledge—even at just 10m—can appear lifeless and monotonous.

In conclusion, as we deepen our understanding of light absorption at increasing depths, it becomes clear that specialized tools and techniques are essential for underwater filming. The handmade color scale served as a starting point, providing direct evidence of how much and in what way we lose from the color spectrum at every 10m increment in the Red Sea. Even in this exceptionally clear water, the attenuation of red and yellow components is already significant at 20–30m, while at 40–50m, natural light alone is insufficient for accurate color reproduction. This proves once again that the underwater environment requires a distinct approach, a fine balance between theoretical knowledge of water’s optical properties and practical experience in diving and equipment handling.

Therefore, anyone aiming for spectacular results in underwater photography and filming should consider the following:

• Use **artificial light** strategically, especially beyond 10–15m;

• Test and apply custom **white balance** at each depth (even multiple times during the same dive);

• Get as close to the subject as possible to reduce the distance over which light is lost in water;

• Include a **color scale** or reference object in the frame for accurate calibration in post-production;

• Be aware of diving limitations (time, air supply, nitrogen narcosis, decompression) and carefully plan the shoot—ideally with a team, including one assistant to hold the scale and another to manage the light sources;

• Leverage the power of post-production, but in a conscious and data-driven way, avoiding excessive correction that could result in unrealistic images.

Looking ahead, technological advancements (better camera sensors, higher-intensity lights with longer battery life, smart filters) and new AI-based digital processing methods will continue to bring us closer to the "true" appearance of marine landscapes. However, nothing can replace rigorous documentation and the proper application of light physics principles in water—which is precisely what makes underwater cinematography a field full of mystery, complexity, and beauty.

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