# Light Transmission in Turbid Water Environments for Marine Bycatch Technology

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*Abstract*— **Fisheries bycatch is a cause of worldwide risk to marine biodiversity, which is largely detrimental to fisheries and marine environments. Marine megafauna such as sharks, sea turtles, and sea lions are susceptible to entanglement and possible death as incidental bycatch. Previous studies have shown that green lights on fishing gear effectively deter marine species and prevent entanglement in nets and longlines. Various light sources will be placed in turbid marine environments with their transmissivity recorded to find the most effective wavelength of light for a given marine environment.**

**Keywords** - *turbidity, bycatch reduction technology, Lindgren Pitman, light transmissivity, marine conservation*

## I. Introduction

The incidental capture of marine megafauna in fishing gear, termed fishery bycatch, is a direct threat to both individual animals and entire populations [2]. In some cases, bycatch is even more extreme because it largely applies to reproductively mature adults or older juveniles, which would soon begin to reproduce, supporting local populations.

Previous studies in the field of emerging bycatch reduction technologies (BRTs) use green Lindgren Pitman © lights to significantly reduce incidental bycatch without reducing target take [1]. However, these studies have only tested the presence or absence of light and their effect on bycatch. These studies have not tested various wavelengths of light or their effect on bycatch.

The operating principle behind light-based BRTs is that light travels through a marine environment to induce a behavioral response in a marine species, such as a sea turtle, shark, or ray [3]. The ability for light to travel through a marine environment is greatly impacted by the turbidity of said environment as well as the range of sight of marine megafauna, which is largely understudied [4]. Turbidity causes light to scatter/diffuse which is the process of a light beams deflecting into many directions.

Marine environments are turbid due to silt, algae, clay, and other suspended material. Turbidity is the cloudiness of a fluid due to suspended particles. Turbidity can be measured in nephelometric turbidity units (NTU). These units refer to the amount of light scattered 90 degrees from a light source by a turbid medium [5]. Furthermore, turbidity fluctuates in bodies of water, which could change the effectiveness of bycatch reduction technologies [6].

Therefore, this study will assess multiple marine environments with various turbid conditions. A relationship between a light source's transmissivity and an environment's turbidity will be found. These values will be graphed as wavelength v. transmissivity for a given turbid environment. The spectrum of wavelengths will be composed of narrow bands of wavelengths provided by our light sources: green Lindgren Pitman lights, green LEDs, and lasers (red-650nm, green-532nm, blue/violet-405nm).

These findings will help determine the optimal configuration of light-based BRTs. The optimal light source to use in a BRT will be directly related to the light source's ability to transmit through a turbid environment. Sources and intensities of turbidity vary across marine environments and within the same environment based on time of day and time of year. Because of this wide variation in turbidity, an in-the-field experiment is necessary to provide real-world results of how light transmits through turbid water environments.

## II. Methods

### A. Data Collection

Data collection will begin in daytime when the sun is at its apex and is unobstructed by clouds in accordance with conditions in which a Secchi disk can be used to measure turbidity [7]. The turbidity will be measured prior to deploying research equipment into the body of water. Data collection will continue for 12-16 hours with samples collected electronically every 15 minutes for each data treatment: red light, green light, blue light, commercial Lindgren Pitman © green lights, and ASU-developed green lights, used in experiments in Baja, Mexico (Figure 1).

Data will be collected at four different field sites of varied turbidity, which include Papago Park and Tempe Town Lake, Canyon Lake, and Lake Pleasant (Figure 2). A swimming pool or tank of water without organic materials will be used as a control environment for the experimental rig and transmittance measurement. Experiments will occur between July and September of 2019.

*Figure 1: Model of Lindgren Pitman © light used in fisheries and in previous studies as bycatch reduction technology.*

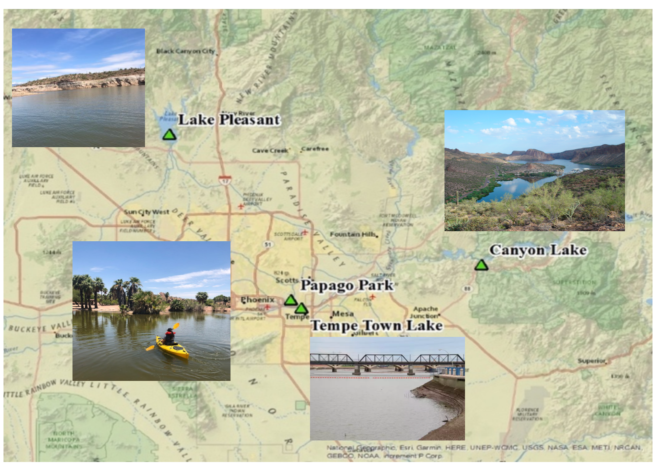


*Figure 2: Bodies of water in Central Arizona used as field sites with varied turbidity.*

### B. Experimental Design

Each experimental setup consists of a pair of submersible electronic packages encased in a clear polycarbonate cylindrical structure. Each package contains a microcontroller, light emitter, photodetector and data storage device to complete the actions of emitting, measuring and recording light signals (Figure 2).

Each device will have its light source aligned with a corresponding photodetector. This configuration will allow us to measure the intensity of light from one device to another (Figure 2). These intensities will be used to find the amount of light transmitted from the corresponding light source and thereby find the transmissivity of that light source's band of wavelengths. These structures will be deployed in varied turbid environments in Arizona as referred to in Figure 1. In order to test each of the 5 variables at both 0.25 meter and 1-meter distances, approximately 4 experimental rigs must be constructed and deployed simultaneously. In this way, the turbidity will be relatively constant for each individual experimental rig.

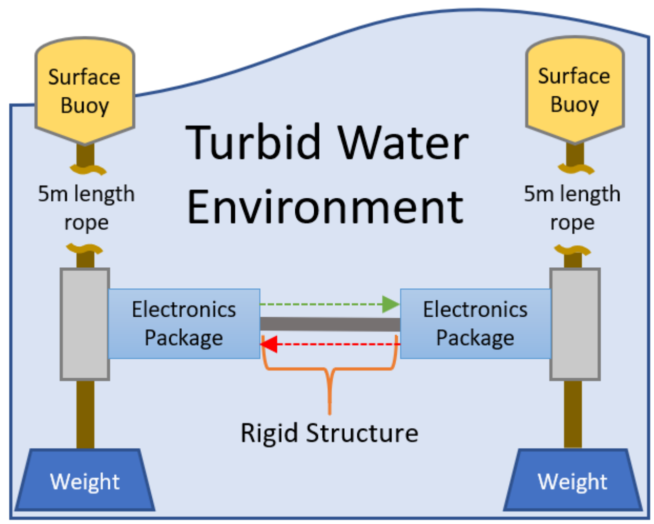


*Figure 3: Example set-up for controlled experiments testing the transmittance of light through different turbid mediums.*

### C. In-lab Experiments

In addition to field experiments, turbid water samples will be collected from various field sites to test the same experiment in smaller, more constant samples of water. These will be tested on the ASU campus.

### D. Data Analysis

After measuring the turbidity using Secchi depth, the bodies of water will be ranked from lowest to highest turbidity and listed as such in any figures. The transmittance of each wavelength will be compared as well as the transmittance of commercial and ASU-developed lights. The difference in transmittance will then be tested for significance with an ANOVA.

## III. Results

### A. Turbidity

Thus far, only the Secchi depth of Papago Park pond has been measured. The Secchi disk disappeared from view at 1.19 m at the deepest point of the pond, meaning the water is highly turbid. Based on observation, it is expected that the turbidity of Tempe Town Lake will be comparable to that of Papago Park Pond, Canyon Lake will be less turbid, and Lake Pleasant will be least turbid. More turbid water is expected to cause an overall decrease in transmittance for each wavelength and light type tested.

### B. *Wavelength*

Green, specifically 532 nm wavelength light, is expected to have the highest transmittance in water considering previous studies have shown that green light transmits best [8]. Red light (650 nm) will likely be the second highest transmittance considering ultraviolet is closest to blue and ultraviolet has been shown to transmit poorly in water [8]. More turbid water is expected to cause an overall decrease in transmittance for each wavelength tested.

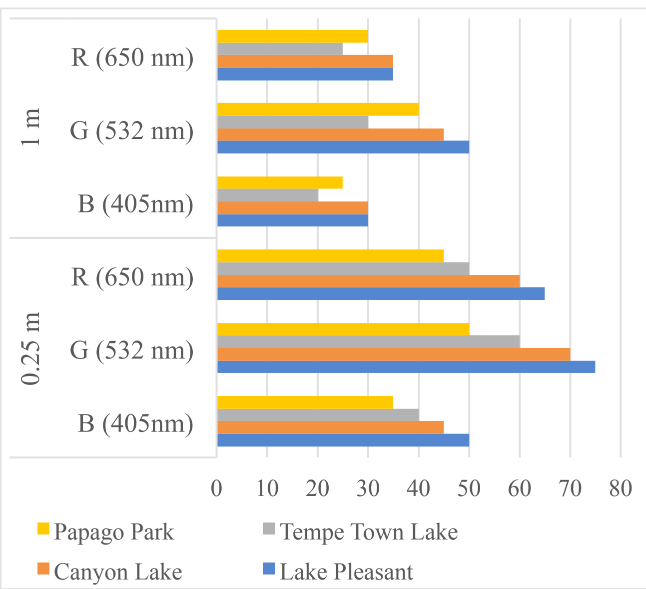


*Figure 4: Projected results for the transmittance of different wavelengths of light through 0.25 m and 1 m of turbid water. The field data was collected in Canyon Lake, Papago Park Pond, Lake Pleasant, and Saguaro Lake, all located in Arizona.*

### C. *Commercial and ASU-Developed Lights*

The ASU and Lindgren Pitman © lights are more difficult to predict the transmittance of due to their similarity in light itself and difference in structure and plastic casing. Therefore, Figure 5 shows an example of what the actual data may resemble after it has been collected.

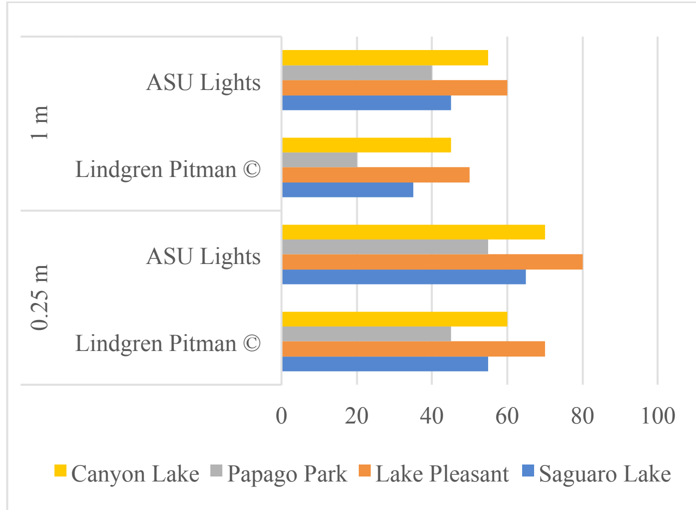


*Figure 5: Projected results for the transmittance of commercial Lindgren Pitman © green lights and ASU-developed green lights through 0.25 m and 1 m of turbid water. The field data was collected in Canyon Lake, Papago Park Pond, Lake Pleasant, and Saguaro Lake, all located in Arizona.*

## IV. Discussion

With little to no data collected at this point in the experiment, it is difficult to analyze the results, however, it is possible to infer the possible outcomes and the causes of such outcomes.

### A. *Wavelength*

If, in fact, one wavelength, such as green light, is proven to be most effective- meaning with the greatest transmittance in the case of this study- in less turbid water while another wavelength, possibly red light, is proven to be most effective in turbid, algae-rich water, then there are two possible methods of optimizing this type of bycatch reduction technology. One way would be to provide fishers with two different buoys to deploy or to allow them to remotely change the settings within a light buoy to use either green or red light, using their own judgement to determine if the water appears more or less turbid and more algae-heavy or devoid of algae. While experienced fishers often have an immense knowledge of the ocean and superior observations of its changing conditions, these judgements may vary fisher to fisher or fishery to fishery [9]. Therefore, it may be more practical to develop a standardized method that would adjust the light on the buoys and nets in accordance with real time measurement.

The Smart Net technology being developed by the BEST Lab at Arizona State University could potentially solve this issue of standardization. Buoys and nets would need to be equipped with technology to measure the turbidity of water in the field in real time, possibly adjusting light wavelength as the tides change, which is a primary driver of turbidity change in marine environments. This method could make the technology more user-friendly and more effective.

However, it is possible that green light continues to transmit most effectively in both highly turbid and less turbid environments, in which case, green light will be used in all further experiments and developed technology. This would simplify the development process as well as the electronics included in the buoys themselves.

### B. Commercial and ASU-Developed Lights

Commercially developed Lindgren Pitman © lights, created for fishery use, have been used in previous studies as bycatch reduction technology that effectively deters marine megafauna such as sea turtles, sharks, and ray [1]. The BEST Lab at ASU has developed adjustable green lights encased in buoys to be used as more sustainable alternatives to the battery-powered Lindgren Pitman © lights. To ensure the success of a more sustainable light, it is important that the newer technology be as effective, if not more effective than previously used commercially sold products. If the Lindgren Pitman © lights transmit more effectively through more turbid mediums, then the lab will have to evaluate the differences in the casing of the two devices and adapt the new technology to be just as effective. Otherwise, if the newer technology is more effective, then this study will provide motivation to move forward with the current technology and focus more on other aspects that will optimize sustainability and deterrence of marine megafauna.

## V. Acknowledgements

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