Red Light, Green Light: How Lighting Can Improve Hatchling Survival

Project Summary

Hatchling sea turtles are highly phototactic, a trait that is instrumental in the process of seafinding after emergence from a nest. However, anthropogenic lights can cause hatchlings to misorient towards human developments rather than towards the ocean. To combat this misorientation while still providing adequate lighting for human properties, turtle-safe lights are employed. These lights cause minimal misorientation in hatchlings by employing wavelengths least attractive to hatchlings; however, what "turtle-safe" is, may be species specific. Greens, loggerheads, and leatherbacks have been investigated for threshold of detection, or the lowest intensity light to still illicit a phototactic response, showing higher thresholds for longer wavelengths of light (such as orange or yellow) and lower thresholds for shorter wavelengths (blue or indigo). Hawksbill turtles are underrepresented in the literature of phototactic studies, having never been investigated for thresholds of detection. They may prove more sensitive to light due to their preference for nesting in dense vegetation where light levels are low. Hatchlings for our experiment were collected from fourteen nests over two field seasons (with multiple clutches generally being necessary to determine a threshold intensity) and were kept in ambient climatic conditions for no longer than one hour before testing. To determine the hawksbill hatchling detection threshold for visual light, we used a Y-maze choice experiment where hatchlings were presented with a single-wavelength LED source at one end of the maze and no light source at the other end of the maze. Wavelengths tested were 415 (violet), 470 (blue), 535 (green), 555 (green), 590 (yellow), 601 (orange), and 660 nm (red). The intensity of light was controlled using a series of neutral density filters. Light intensity was measured pre-experimentation using a S400 Optical Meter and S247 Flat-Response Sensor Head situated at the decision point of the maze. Each hatchling was chosen randomly for experimentation and tested

only once. To determine threshold intensities, hatchlings were tested using the up-down staircase statistical method, using 1.0 log steps down and 0.3 and 0.7 log steps up. A one-tailed binomial test was used to determine if a significant number of hatchlings were attracted to a specific intensity of light (**Table 1**). Hawksbill hatchlings displayed detection thresholds intermediary to those studied in other species at most wavelengths (i.e., they had less or equal sensitivity as greens or loggerheads, and equal or more sensitivity as leatherbacks; **Figure 1**). The exceptions to this were at 555 nm and 470 nm. Hawksbills were more sensitive to green light of 555 nm than any previously tested species. They were less sensitive to blue light (470 nm) than any previously tested species. Hawksbill sensitivity to blue light was on the same order of magnitude as that of red light. Red light required the highest intensity to illicit a phototactic response, while green light of 555 nm could illicit a response at the lowest intensity (**Figure 2**). The data presented here represent the first threshold of detection for any species of sea turtle for light in the red spectrum and indicate that hawksbills can perceive red light but require a higher intensity to do so. Our results may be critical for informing standards for beachfront lighting, as we illustrate that even at very low intensities, light across the visual spectrum may still attract hawksbill hatchlings, causing them to misorient, making them easier prey, and thereby having a potentially lower survivorship.

Tables and Figures

Table 1: List of detection thresholds by wavelength for hawksbill hatchlings with distributions. Detection thresholds varied by a factor of a thousand between the light the hatchlings were most sensitive to and the light hatchlings were least sensitive to. Distributions are the number of hatchlings that went toward the threshold intensity (+) and those that did not (-) during the determinative step of the up-down staircase statistical method. A total of 344 hatchlings were used from 23 clutches for the purposes of this experiment with an average 43.6 ± 4.9 hatchlings to find the threshold of detection.

Wavelength (nm)	Threshold (photons/cm²/s)	Distribution (+/-)	Hatchlings Used	Clutches Used
415	3.17E+8	9/2	53	4
470	1.90E+10	10/0	40	3
535	3.67E+8	9/2	51	5
555	3.41E+7	9/1	20	1
590	2.73E+8	9/1	60	3
601	1.70E+8	10/0	40	2
660	8.72E+10	9/2	41	5

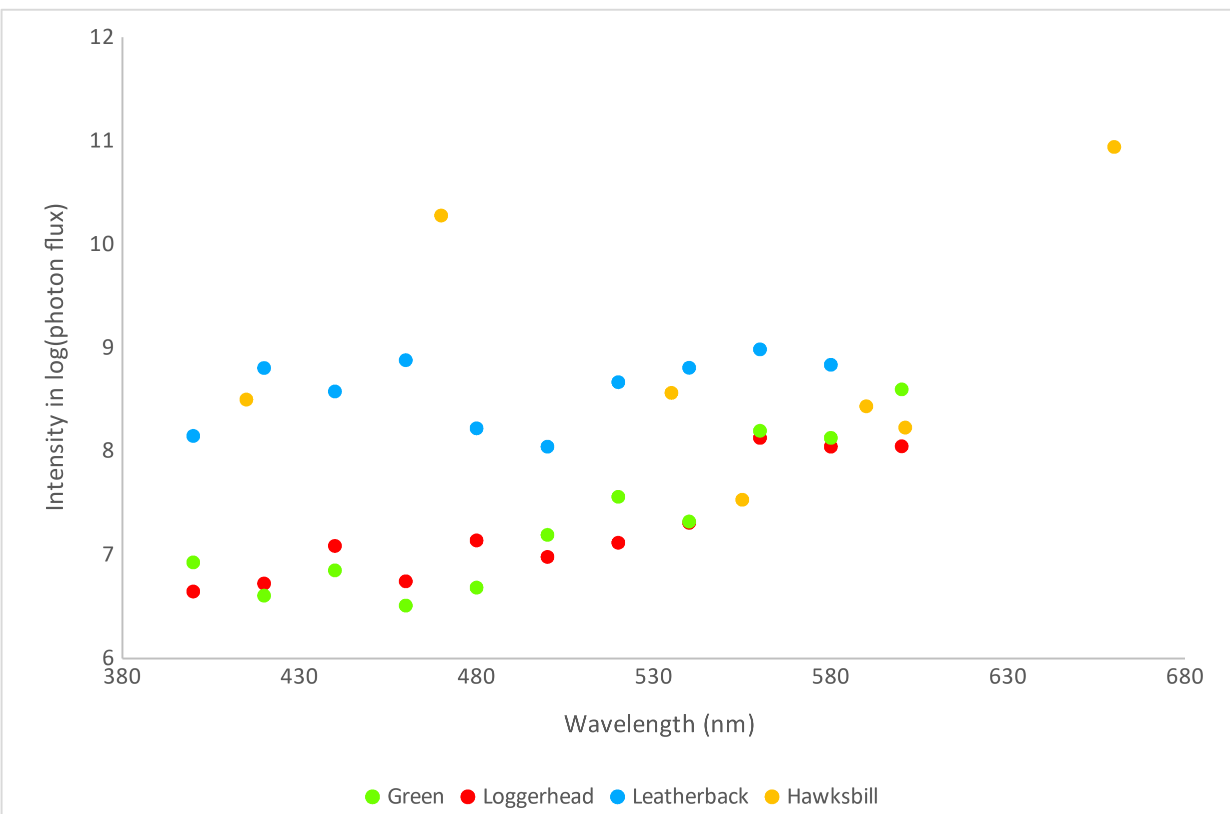

Figure 1: Hawksbill detection thresholds compared to other species of sea turtle. Hawksbills largely display an intermediate sensitivity compared to other species, being neither more sensitive to most visual light than greens and loggerheads (Celano et al. 2018), nor less sensitive than leatherbacks (Trail & Salmon 2022b). Exceptions: hawksbills were more sensitive to 555 nm light than any other species; hawksbills were less sensitive to 470 nm than any other species.

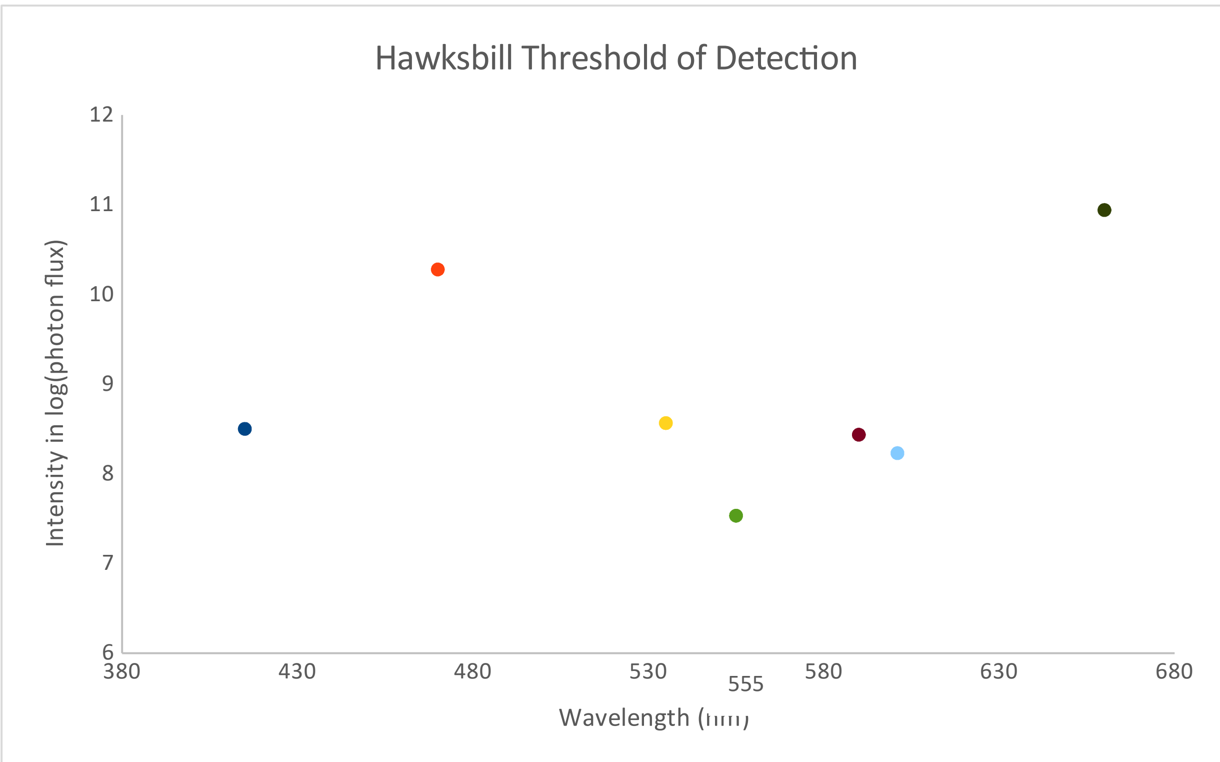

Figure 2: Hawksbill hatchling detection thresholds by wavelength. Hatchlings were most sensitive to green light of 555 nm and least sensitive to red light of 660 nm, representing a 1000-fold difference in sensitivity between these wavelengths. The color of the dots above is the color of the light presented to hatchlings.