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Comparison of Different Light Spectra in Fishing Lamps

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ABSTRACT

It is widely recognized that some fish species are attracted to light. Thus, the use of artificial light in some fisheries has been one of the most advanced and successful methods to control fish behavior for capture purposes. In Thailand, fishing with lights utilizes metal halide, incandescent or fluorescent bulbs with various colors. The type of lamp depends on the engine due to the light output requirement for the underwater light intensity. The color of light used differs for different fishing grounds, with the main colors being white, red, green and blue. This research investigated the light spectrum of three types of fishing lamps using a profiling reflectance radiometer system (PRR2006). The lamps tested were: 1) a metal halide light with a spectrum and radiation of about 0.1–0.8 $W.cm^{-2}$ and the main direction of the light was 90°–120° and 240°–270°, 2) an incandescent lamp with the spectrum and main direction of the radiation about 0.2–2.0 $W.cm^{-2}$ and 120°–240°, respectively, and 3) A fluorescent bulb with a spectrum that ranged from 0.8 to 2.0 $W.cm^{-2}$ depending on the color and the radiation surrounding the cylindrical bulb. The main light color radiated by the metal halide lamp was red and by the incandescent lamp was yellow and orange. The results determined that with metal halide and incandescent, lights, the long wavelength had a high intensity although it was diminished to nearly 0 $W.cm^{-2}$ at 10 m below the sea surface. Only the 500–600 nm range of the spectrum could radiate into deeper waters.

Keywords: fishing light, incandescent, metal halide, fluorescent, radiation

INTRODUCTION

Fishing with lights is one of the most advanced and successful methods to control the behavior of fish and squid for capture purposes. In the past, fishermen aboard small engine-powered boats or sailboats used a torch or acetylene gas (C_2H_2) to lure squid before capture using cast nets (Ben-Yami, 1976). In 1962, cast net operators started using 500 W gas lamps aboard engine-powered boats that were 5–7 m in length. Up until 1978, fishermen used a 3 kVA electric dynamo in small fishing boats that utilized three to five 500 W lamps. Nowadays, the dynamo power, the number of bulbs used and the size of the cast net have increased (Department of Fisheries, 1969; Iamsa-ard, 1985).

In Thailand, the major fishing methods that utilize light are known as the surrounding net, lift net and falling gear methods. The bulbs used

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are metal halide (250 and 500 W), incandescent (500 W), and blue, green or red fluorescent lamps (36 and 40 W). Fishermen use these lamps to produce artificial light to lure fish at night until the fish have condensed into a school. Target fish are barracuda, ponyfish, squid and anchovy (Iamsa-ard, 1985).

During the period 1981 to 2007, the total number of fishing boats that were registered by the Thai Government as fishing with lights increased from 235 to 3,100. In 2007, the percentages of small fishing boats by size were: less than 14 m in length (58%), 14–18 m in length (32%) and 19–25 m in length (10%); most used squid falling nets and anchovy falling nets.

The process of using a light is rather simple as it is expected that the fish will gather under the light when it is turned on. It is not clear, however, whether the effect of the light attracts the target species directly, or indirectly through attracting phytoplankton which are then a source of attraction for the target species that feed on the phytoplankton (Ben-Yami, 1976). When the light is turned on, fish gather in schools near the surface around the boat so that they are easily caught by a falling net.

In order to understand the penetration of light from a fishing lamp into the sea, the angular distribution and intensity of light in the air should be determined. The spectra of the fishing light in a dark room and the spectra that can penetrate through a water column and create an illumination zone around the boat during fishing were investigated.

MATERIALS AND METHODS

Fishing with lights uses bulbs that can be metal halide, incandescent or fluorescent and also many different colors. The type of bulb depends on the engine and size of the boat. The main light colors used are white, red, green and blue.

A metal halide lamp (Figure 1A) consists of a glass outer envelope and a quartz arc tube. Metal atoms move from the hot electric arc towards the cooler arc tube wall. Near the wall, the temperature and vapor pressure allow the metals and halides to form a stable molecule that will not corrode the arc tube. When the metal halides approach the hot arc, the molecules break apart. The halides move away from the arc, while the metals are energized and radiate light (Bunjongjit, 1995).

An incandescent light (Figure 1B) is composed of inert gas, a tungsten filament, a glass support and a fuse (Bunjongjit, 1995). In a fluorescent lamp (Figure 1C), the low-pressure mercury discharge produces radiant energy within the ultraviolet part of the spectrum. By coating the inside of the arc tube with a fluorescent coating or phosphor, this UV radiation is converted to visible radiation (Bunjongjit, 1995).

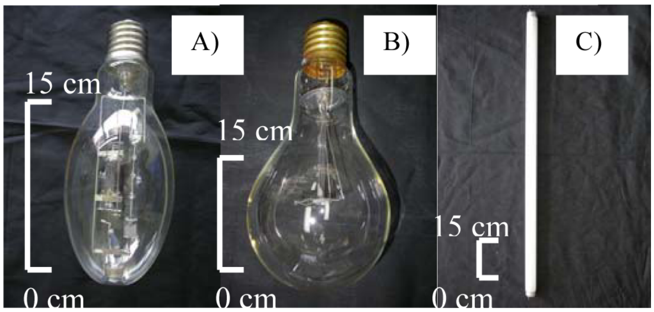

Figure 1 Types of fishing lamps used in Thailand: A) Metal halide lamp (250 W); B) Incandescent lamp (500 W); and C) Fluorescent lamp (36 W).

The current research investigated the light spectra of three types of fishing lights: 1) a 250 W metal halide bulb, 2) a 500 W incandescent lamp, and 3) a 36 W (red), a 40 W (blue) and a 40 W (green) fluorescent lamp. The light spectra were detected by a profiling reflectance radiometer system (PRR2006) with wave lengths of 412, 443, 490, 510, 555, 625 and 665 nm. The radiation of the bulbs which were rotated was investigated using PRR2006 at a distance of 1 m in a dark room (Figure 2) at the Southeast Asian Fisheries Development Center/TD.

The radiation from a metal halide and an incandescent lamp in seawater at night was measured by PRR2006 at 1–10 m depth during fishing operations (Figure 3). The attenuation of light in seawater was considered. The spectra of the different fishing lights during fishing operations were investigated aboard a fishing boat 10 m in length at latitude 10°44.532 N, longitude 99°26.462 E, at 11:00 pm (high tide period) on 27 July 2006. The average water depth was 15 m. The high tide and low tide as reported by the Hydrographic Department of the Royal Thai Navy 2006 at Ko Mattaphon, Chumphon province (10° 26′ 40″ N, 99° 15′ 25″ E) were at midnight and 10:00 a.m., respectively. The F factor, which was computed by the amplitude of the tidal constituents, was 3.72. The suspended solids on the seawater surface were 0.0126–0.0174 g/L, the temperature was 29 °C, the pH 7.9 and the salinity 34 psu.

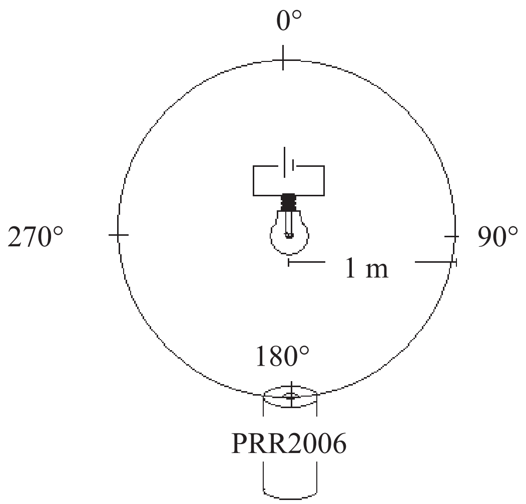

Figure 2 Measurement of light spectrum in a dark room by PRR2006.

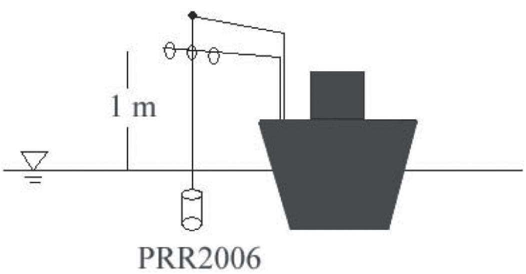

Figure 3 Measurement of light intensity in seawater.

RESULTS

The radiation outputs of each bulb at different angles from 90°–270° at a 1 m radius from the bulb in a dark room are shown in Figure 4. The spectrum of a 250 W metal halide bulb ranged from 0.1 to 0.8 $W.cm^{-2}$; the main directions of the radiation were about 90°–120° and 240°–270°. The spectrum of a 500–W incandescent bulb ranged from 0.2 to 2.0 $W.cm^{-2}$; the main direction of the radiation was about 120°–240°. The main colors radiated by the metal halide bulb were red and by the incandescent bulb were yellow and orange. The spectrum of the fluorescent bulbs ranged from 0.8 to 2.0 $W.cm^{-2}$ depending on the bulb color and the radiation surrounding the bulb since it was cylindrical in shape. There seemed to be special spectra produced for the mono colors such as blue (412–555 nm), green (490–625 nm) and red (555–665 nm).

The metal halide and incandescent bulbs produced red, yellow and orange as the main color spectra. The metal halide and fluorescent spectra had spikes or peak irradiances of certain

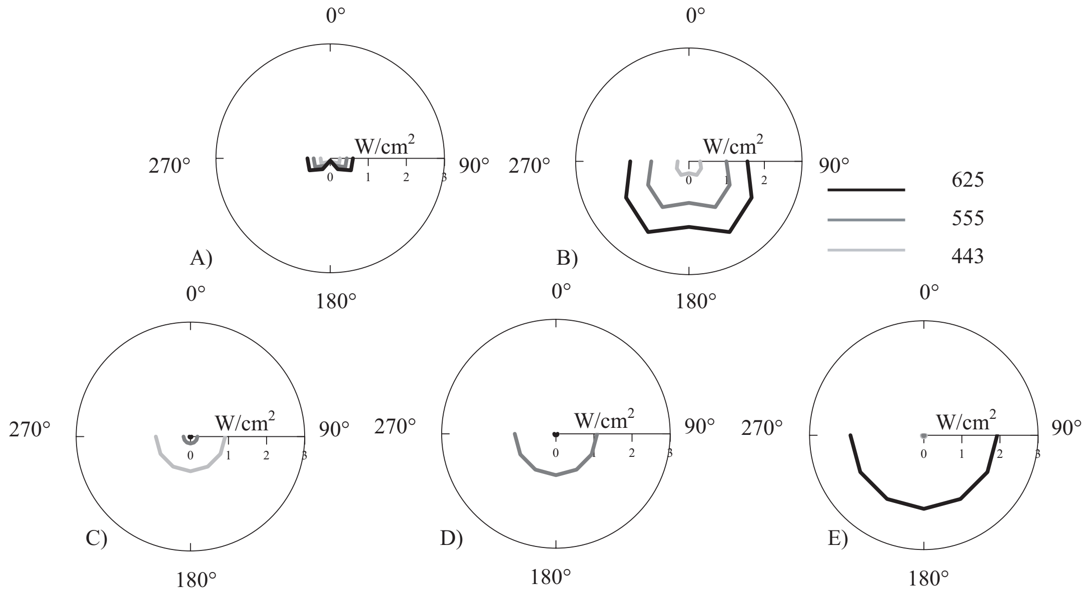

Figure 4 Spectrum radiation at 1m for different bulb types: A) Metal halide 250 W; B) Incandescent 500 W; C) Blue fluorescent 40 W; D) Green fluorescent 40 W; and E) Red fluorescent 36 W. Radius indicates the magnitude of each light color (W/cm^2).

wavelengths (Bunjongjit, 1995). The metal halide spectrum was comprised of several peaks that resembled sunlight. The incandescent spectrum appeared as a continually distributed wavelength. The special peaks of the fluorescent bulb varied according to the color of the bulb as shown in Figure 5.

DISCUSSION

The spectrum radiation from each bulb has special characteristics which depend on its shape and purpose. Fishermen carried out empirical trials using common, readily available bulbs to determine which ones produced a good catch. However, they didn't know which ones were suitable based on a commercial decision. The fishermen believed that a higher lamp power evidently attracted fish from a wider radius and increased the fishing area.

The illumination of the bulb decreased rapidly with the distance from the light source. The decrease in the intensity of light with distance depends on the optical properties of the medium

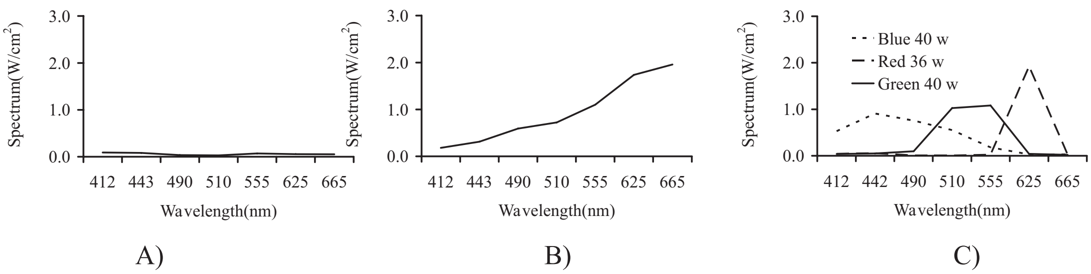

Figure 5 Distribution of light spectrum of A) Metal halide, B) Incandescent lamps and C) fluorescent lamps (from Anongponyoskun and Arnupapboon, 2006).

and these optical conditions vary widely in natural water. Illumination decreases in proportion to the square of distance from the light source. The surface fishing light loses a part of its useful illumination in water due to reflection at the surface and additional losses can be attributed to increased attenuation in the very top water layer where concentrated air bubbles, floating particles, foam and waves (especially in a choppy sea) absorb, scatter and reflect more of the light (Jerlov, 1968).

Bunjongjit (1995) reported the highest efficiency of production in visible rays occurred with a fluorescent tube with about 22% of the energy source. The incandescent bulb in the infrared lost more than 70% of the energy source. The metal halide lamp lost energy during the arc process resulting in about 70% of the energy source being available. If an incandescent or metal halide bulb were used to attract squid or anchovy by placing it in the air, less than 1% of the whole radiant energy would contribute to the attraction of fish and most of the input energy is converted into heat. According to Masyahoro (1998), an appropriate increase in light intensity combined with the light color could obtain a better catch. On the other hand, a higher output in the visible region could be obtained by increasing the voltage, which merely produces more heat and results in a shorter life span of the lamps. Metal halide and incandescent lamps utilize only a narrow band of energy as visible light and the majority of energy is consumed as unnecessary heat.

The fishing ground also contributes to the optical aspects, as the color of the seawater may differ and the underwater pattern of light intensity of light fishing also differ according to the fishing time, season and ground. The effectiveness of light attraction depended on factors such as the power and the color of the lamp, the weather, the temperature, the phase of the moon and the abundance of fish (Arimoto *et al*., 2001). The proper specification for spectrum radiation can be important to fit in with the sea conditions, and to fit the spectrum sensitivity to the vision of the target species (Arimoto *et al*., 2001).

For sunlight, longer wavelengths such as red are diminished in the shallower layers due to attenuation by suspended particles in the water (Kirk, 1994). Light is better able to pass through clear rather than turbid water. In the upper Gulf of Thailand, during the dry season, the seawater near the shore was well mixed and not affected by water draining from land; suspended particles were about 0.02–0.06 g/L while during the rainy season, suspended particles increased to about 0.02–0.2 g/L (Anongponyoskun and Chuchit, 2006). The attenuation coefficients and spectrum fishing light source compared at depth are shown in Figure 6.

It is known that long wavelengths cannot penetrate very far into the shallow layers of water, so the attenuation coefficient is very high (Kirk, 1994). Metal halide and incandescent bulbs radiate mostly long wavelengths and heat. The intensity

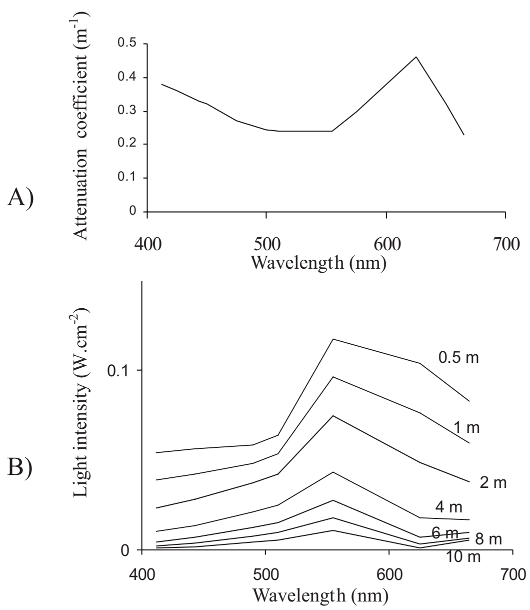

Figure 6 Attenuation coefficients A) and penetration of spectra B) in the fishing area at 10°44.53′N, 99°26.46′E, at 11:00 pm on 27 July 2006.

of long wavelengths at 10 m below the sea surface was diminished to nearly 0 W.cm^{-2}. Only the 500–600 nm range of the spectrum could radiate into the deeper areas.

Moreover, most fish perceive light in the 400 to 750 nm spectrum range, with different fish species possessing different orders of light perception (Kawamura, 1986). Thus, blue light penetrates deeper and farther than light with longer wavelengths and is considered to be the most attractive to fish. Consequently, marine fish perception should be shifted to the blue part of the spectrum. Since the fluorescent tube has a special blue spectrum, this explains why fishermen are still using blue fluorescent tubes for fishing. Wijopriono (1993) reported that blue light yielded a larger catch of ornamental fish in Citereup waters, West Java. Mahfud (1995) showed that the use of an underwater blue fluorescent lamp caught significantly more Indian mackerel than a kerosene lamp. However the higher light intensity near the source does not permit many fish species to approach and concentrate close to it and it is believed that most fish species keep a distance from the light source in a zone of given light intensity (Blaxter and Parrish, 1957; Kumagi 1958; Protasov, 1968).

CONCLUSION

The main light color radiated by the metal halide lamp was red and by the incandescent lamp was yellow and orange. The spectrum of the metal halide lamp was about 0.1–0.8 W.cm^{-2}. The main direction of the radiation was about 90°–120° and 240°–270°. The spectrum of the incandescent bulb was about 0.2–2.0 W.cm^{-2} and the main direction of the radiation was about 120°–240°. The spectrum of color from the fluorescent tube was about 0.8–2.0 W.cm^{-2} and depended on its color and the radiation surrounding the bulb due to its cylindrical shape. The use of metal halide and incandescent lamps to attract squid or anchovy utilizes only less than 1% of whole radiant energy while most of the input energy is converted into heat. At 10 m below sea surface during fishing operations, the intensity of long wavelengths produced by the lamp diminished to nearly 0 W.cm^{-2}. Only the 500–600 nm spectrum range could be radiated into deeper waters.

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