# FISH ATTRACTING EFFECTS OF LED LIGHT OF DIFFERENT COLOURS

Makoto SAKAMOTO[1], Yasuzumi FUJIMORI[2], Naoto MATSUBARA[1], Hiroki YASUMA[2], Susumu SHIMIZU[2], and Seiji KATAKURA[3]
1, Graduate School of Fisheries Sciences, Hokkaido University, Hakodate, Japan
2, Faculty of Fisheries Sciences, Hokkaido University, Hakodate, Japan
3, Mombetsu City, Mombetsu, Japan

## Abstract

There are many fisheries that use artificial lights to attract fish, such as the squid-jigging and seine net fisheries. There are also fisheries that use lights to prevent bycatch. Relationships between the characteristics of light used to attract fish and the behaviours of fish to those lights have been investigated, but most of those experiments occurred in indoor water tanks under controlled conditions. The aim of this study was to investigate the effect of using LED lights of different colours (wavelengths) to attract fish in a natural (nearshore, coastal) environment. The experiment was conducted at an underwater observation window on the coast of Mombetsu in Hokkaido, Japan. LED lights were positioned on the inside of the window and the number of fish that appeared at the window during the night (from evening to morning) was recorded at 5-min intervals using a video camera. The colour of the light (red, 633 nm; green, 514 nm; cyan, 490 nm; blue, 465 nm) was changed every day for about one week. White-edged rockfish (*Sebastes taczanowakii*), threestripe rockfish (*Sebastes trivittus Hilgendorf*) and black rockfish (*Sebastes schlegelii Hilgendorf*) were the most common species observed during the experiment. Among these species, white-edged rockfish was most commonly observed. Blue light (465 nm) attracted the most fish, while red light (633 nm) attracted the fewest. The relationship between the wavelength and the number of fish was inversely proportional to one another.

**Keywords** fish attracting, LED light, colour, wavelength

## Introduction

The collapse of fisheries resources, mostly due to over-fishing that exceeds recruitment, is a global concern (FAO, 2016). Therefore, technical and institutional measures to maintain recruitment of fishery resources are under consideration worldwide. Since the 2000s, selective fishing in commercial fisheries, with respect to size and species, has been advanced globally by implementing improved fishing techniques and gear, such as the use of BRDs (By-catch Reduction Devices) (Garcia-Caudillo et. al., 2000; Graham, 2003; Fonseca et. al., 2005). As a result, over-fishing declined during this period. However, further development of bycatch reduction practices is required because the aforementioned methods have not been effective in all fisheries. In this study, we investigated the influence of artificial LED lights on fish behaviour to determine if such a device can be used to selectively fish particular species. Several studies have shown that a fish's reaction to light varies depending on its species, even when the same light source is used. In addition, it has been confirmed that the reaction of any given fish species varies, depending on the optical specifications of the artificial light, such as its intensity and wavelength (Marchesan et. al., 2005, Ryer and Olla, 2000). It has been suggested that fish reactions differ depending on both the ecological characteristics of the species and the physical characteristics of the light source. Several recent trawl fishing experiments achieved a drastic reducing in by-catch by using a codend containing an escape hole with an attached light (Lomeli and Wakefield, 2016, Hannah et. Al., 2015). Based on these studies, we might be able to greatly to improve selective fishing technology using artificial light. However, most such studies on this subject have been conducted in indoor laboratories. Furthermore, more studies are needed on the effects of lights of various colours and intensities. Therefore, in this study, we examine the effects of light on fish under natural conditions by recording the number of fish attracted to artificial light over time, by light colour (wavelength).

## Material and methods

*Experiment*

Our experiment was conducted from evening to early morning (3-11 August) using an observation window in the Okhotsk tower, which is located on the sea side of the third breakwater at Port Mombetsu, on the Okhotsk coast of Hokkaido. There are many observation windows in the underwater floor of this tower. The windows used in the experiment were 1 m × 1 m in size. LED light that has capable of changing color by RGB value was set in front of the window. We chose to use red, green, cyan and blue colours in our experiment. Table 1 shows the wavelengths of each colour, measured with an irradiance meter (USB4000, OceanOptics). The artificial lighting was provided from 30 minutes before sunset to sunrise at a constant colour. A video camera (GoPro HERO3+) was installed to record fish attracted to the artificial light in the window (Fig. 1). Each image was recorded with a resolution of 1920 × 1080 p, 30 fps, with the camera angle of view set to 'narrow'.

*Image analysis and statistical method*

To count the number of fish attracted to the window by the artificial light, static images were extracted from the video data at intervals of one frame per 9000 frames (i.e. at 5 min intervals). Further, underwater brightness was obtained by converting the colour of each image to grayscale, which was then classified into 255 brightness levels using image analysis software (Photoshop CC, Adobe). From these data, we determined the change in the number of fish attracted over time, and the relationship between light condition and the number of fish attracted.

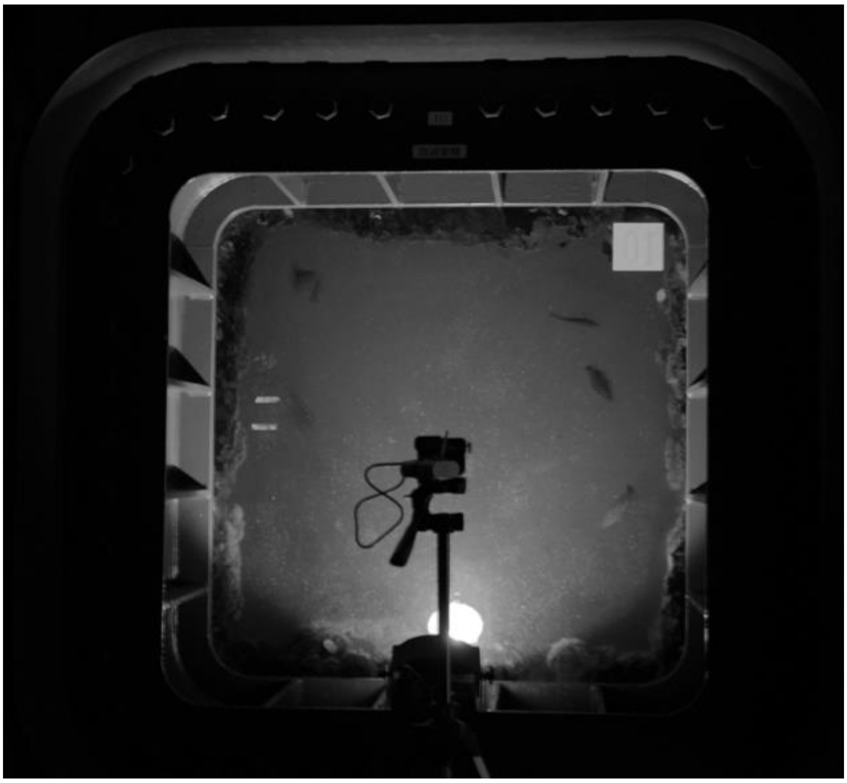

**Figure 1**
The observation window of the Okhotsk tower used in the experiment.

We used a generalized linear model (GLM) with Poisson distribution to investigate the relationship between the number of fish attracted to the light and the influence of underwater brightness, light colour, water temperature, light intensity and weather. The data from 18:30 to 24:55 was employed in or calculations because this time period was not affected by natural sunlight.

**Table 1**
Specification of light source used in the experiment

| Color | Wavelength peak (nm) | Intensity (lx) | Experiment date |
|---|---|---|---|
| Red | 633 | 70 | 2016/8/5-6 |
| Green | 514 | 122 | 2016/8/3-4 |
| Cyan | 490 | 36 | 2016/8/4-5 |

## Result and Discussion

*Attracting effects of different colours*

White-edged rockfish (*Sebastes taczanowakii*), threestripe rockfish (*Sebastes trivittus Hilgendorf*) and black rockfish (*Sebastes schlegelii Hilgendorf*) were observed during the experiment. Among these species, white-edged rockfish was the dominant species attracted to the light. The total number of fish attracted to the light from 18:30 to 07:00, by colour, is provided in Fig. 2. The number of fish attracted varied widely by colour. Blue light attracted the most fish (N = 1119); red attracted the fewest fish (N = 101). In addition, the number of fish attracted decreased as wavelength was increased (Table 1).

*Change of attracting effect with time*

The number of fish attracted over time did not differ among colours (Fig. 3). The number of fish attracted increased from 02:00 to 04:00, except to red light; in addition, the number of fish attracted to red light declined precipitously after 04:00. The number of fish attracted to our lights began to decline around sunrise regardless of the colour of the artificial light we provided. We believe that this behaviour was in response to a weakening of the artificial lighting effects in response to an increase in underwater (background) light intensity. That is, during this period, the intensity of the artificial light became lower than the intensity of the underwater (background) lighting. The results of a GLM are shown in Table 2. Underwater brightness, light intensity and light colour were all determined to be factors influencing the number of fish attracted to the artificial lights ($p < 0.05$). Among these, light colour was the factor that most influenced the number of fish attracted. Also, the coefficient for the colour variable was negative, which means that fewer fish were attracted to our lights as wavelength was increased (Table 2).

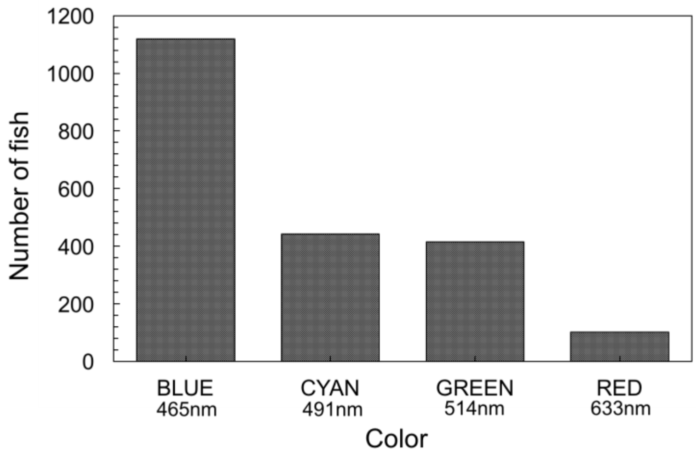


**Figure 2**
The total number of fish attracted to artificial LED light, by wavelength, dur-ing the 18:30 to 06:00 time period.

Only a few fish species were attracted to our lights in this experiment. According to a previous study, fish response to short-wavelength light varies widely among fish species (Marchesan et. al., 2005). Therefore, it will be necessary for us to run this experiment during a different season because fish species composition changes seasonally in the vicinity of Port Mombetsu. In addition, to more quantitatively study the effects of light as attractants, laboratory experiments should be conducted in parallel with an experimental design similar to this one.

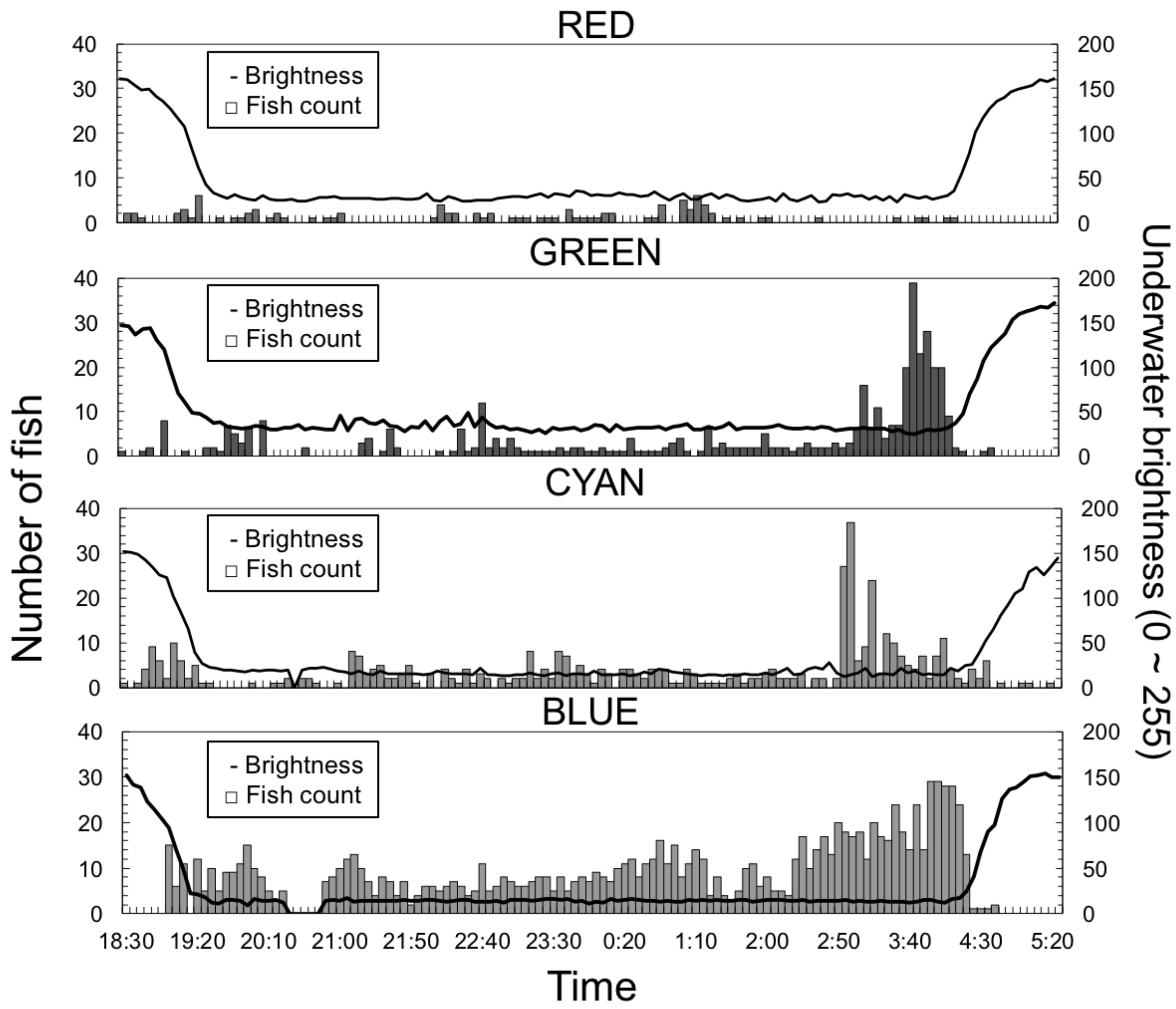


**Figure 3**
The number of fish attracted to artificial LED lights from 18:30 to 05:30, by colour, at 5 min intervals.

**Table 2**
Estimated coefficients using a GLM for the data collected from 18:30 to 24:55

| | Estimate | Std.Error | z value | Pr (>\|z\|) |
|---|---|---|---|---|
| Intercept | 0.603864 | 1.243301 | 0.486 | 0.6272 |
| Tempature | 0.091412 | 0.058916 | 1.552 | 0.1208 |
| WaterBrightness | 0.002565 | 0.001182 | 2.171 | 0.0299 * |
| Color | -0.67208 | 0.053637 | -12.53 | < 2e-16 *** |
| LightIntensity | 0.004487 | 0.001769 | 2.536 | 0.0112 * |

signif. codes 0 '***' 0.001 '**' 0.01 '*' Null deviance : 582.05 on 220 degrees of freedom
Residual deviance : 280.14 on 216 degrees of freedom
AIC : 953.94

## References


1. FAO Fisheries Depatment. The State of World Fisheries and Aquaculture (2016). The state of fishery resources. 38
2. Garcia-Caudillo, J.M., Cisneros-Mata, M.A., Balmori-Ramirez, A. (2000): Performance of a bycatch reduction device in the shrimp fishery of the Gulf of California, Mexico. Biological Conservation, 92, 199-205.
3. Norman, G. (2003): By-catch reduction in the brown shrimp, *Crangon crangon*, fisheries using a rigid separation Nordmøre grid (grate). Fisheries research, 59, 393-407.
4. Paulo, F., Aida, C., Beatriz, M., Roger, B. L. (2005): Potential use of a Nordmøre grid for bycatch reduction in a Portuguese bottom-trawl multi-species fishery. Fisheries Research, 73, 49-66.
5. Marchesan, M., Spoto, M., Verginella, and 2 others (2005): Behavioural effects of artificial light on fish species of commercial interest. Fisheries Research, 73, 171-185.
6. Ryer, C. H., Olla, B. L. (1999): Light-induced changes in the prey consumption and behavior of two juvenile planktivorous fish.
7. Lomeli, M.J.M. and Wakefield, W.W. (2014): Examining the potential use of artificial illumination to enhance Chinook salmon escapement out a by-catch reduction device in a Pacific hake midwater trawl. NMFS Northwest Fisheries Science Center Report, 1-15.
8. Hannah, R. W., Lomeli, M. J., and other (2015): Tests of artificial light for bycatch reduction in an ocean shrimp (Pandalus jordani) trawl: Strong but opposite effects at the footrope and near the bycatch reduction device. Fisheries Research, 170, 60-67.