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Impact of Coloured LED lights and Lunar Phase on Catches of Selected Shrimp Species in a Filtration Field at Kudappuram, Vembanad Lake

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Abstract

This study examined the influence of using LED lights and moon phase on shrimp caught in filtration field with respect to three shrimp species; *Metapenaeus dobsoni, Metapenaeus monoceros* and *Fenneropenaeus indicus*. A total of 849 kg of shrimp comprising three species were collected during the six months (60 trials) of study period from January 2022 to June 2022. The results revealed a significant difference in catch between red light (474.05 kg) and green light (375.40 kg) (LR Chisq = 4.902, df = 1, $p < 0.05$). Shrimps caught using red light (15.8 ± 7.27 kg/ sampling) were significantly higher compared to those caught under green light (12.5 ± 8.84 kg/ sampling). Moon phase also significantly affected total shrimp catch per day (LR Chisq = 20.016, df = 5, $p < 0.01$). Pairwise comparisons indicated significant differences in catch quantities between specific moon phase combinations. It was found that there was significant difference in catch of *M. dobsoni* in different moon phase. (LR Chisq = 12.103, df = 5, $p < 0.05$). The catch of *M. monoceros* were higher under red light than green light, and moon phase significantly affected catches (LR Chisq = 18.319, df = 5, $p < 0.01$). The catch quantities of *F. indicus* showed no significant difference associated with lighting conditions or moon phase. These findings emphasize the importance of considering lighting conditions and moon phase when assessing shrimp catch, from filtration fields as they can influence catch outcomes which may be due to increased visibility or changes in species behaviour.

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Introduction

Organisms heavily rely on visual signals as they provide immediate and direct information. These visual cues enable individuals to assess their surroundings, identify potential mates or prey, recognize and avoid predators, and make informed decisions based on visual stimuli (Cronin & Jinks, 2001; Medina & Tankersley., 2010). Light is employed in fishing to entice and gather commercially valuable species, such as pelagic fish and cephalopods, near fishing vessels (Parrish, 1999; Kim & Wardle, 2003; Geraci et al., 2021). In recent years, a significant upswing in the usage of lights for different types of active and passive fishing gear is observed and aims to enhance the overall efficiency and success of fishing operations by attracting the resource to the gear (Arimoto et al., 2010; Nguyen & Winger, 2019; Yamashita et al., 2012).

The lunar cycle, also known as the synodic month, occurs approximately every 29.5 days as the moon completes its orbit around the Earth, transitioning from one full moon to the next. This leads to changes in tides and moonlight intensity that can impact various aspects of earth's natural systems, including the behaviour of aquatic organisms. Multiple research studies have been undertaken to explore the influence of the lunar cycle on fishing operations such as longline fishing (Poisson et al., 2010), fish traps (Vergara et al., 2017), and sport fishing (Ortega-Garcia et al., 2008). These studies have observed that the composition of catches and the efficiency of fishing differ across various phases of the lunar cycle.

Vembanad Lake, the largest brackish water body in South India, is located in the state of Kerala, between latitudes 9°28' and 10°10′N and longitudes 76°13' and 76°31′E. The area around the lake has flat fields, called Pokkali fields, that are used for catching and growing fish and shrimp larvae obtained from the wild during specific times of the year. Pokkali cultivation is a traditional and widespread agricultural practise in the coastal regions of central Kerala. This integrated system entails concurrent rice and fish cultivation during the kharif season (June to October), followed by prawn culture during the summer months (January to April). This strategy enables farmers in the coastal belt to maximise land productivity by combining rice and fish production during one season and prawn farming during another, capitalising on the region's unique ecological conditions and the availability of saline-tolerant crops (Sasidharan et al., 2012). These Pokkali fields, are famous for a fishing method called prawn filtration, where light is employed to attract juvenile shrimp and fish during high tide as they enter the farm via the generated flow. Subsequently, water is drained out through a sieve installed at the sluice during low tide. The average shrimp production in the traditional filtration systems, is reported to the around 800 kg ha^{-1}, where *M. dobsoni* is the major species, contributing about 35 % of the total catch and generating about 21 % of the total revenue. The other major species, *F. indicus* and *M. monoceros* contribute about 17 % and 3.5 % to the total production (Sahadevan & Kumar, 2021).

In the past, traditional lamps were used for lighting, but they have been largely replaced by LED lights. These LED lights, which are predominantly white in colour, have gained widespread usage. Studies have revealed that crustaceans possess a visual system that differs from that of fish and is notably more intricate. Extensive research has been conducted on the effects of light on crustaceans, demonstrating their visual capabilities and responses to various light stimuli (Barlow, 1982; Gaten, 1998; Barlow et al., 2001; Luque et al., 2019). Due to the highly developed visual capabilities of the prawn resources targeted by this filtration system, it is hypothesised that there could be a significant change in the capture profile if lights of various colours are employed. Therefore, the study was conducted to determine the effect of colour of light on the catch profile of three main shrimp species, obtained in filtration system considering the various phases of the moon, which are known to influence the behaviour and consequently the catch rate of shrimps in this system.

Materials and Methods

The study area encompassed a 1.62 hectare filtration field at Kudappuram (90°49′42.33′′N and 76°19′38.27′′E), situated in the Vembanad coastal area, where seasonal prawn filtration follows paddy harvest (Fig. 1).

Fig. 1. Set up of Kudappuram Paddy filtration field at Vembanad lake

The behavioural assessment study utilised two colour of LED lights, red and green. A red coloured LED light of wavelength, 630-660 nm (1.8v) and green LED lights of wavelength, 550-570 nm (3.5v) was alternatively installed at the centre of one sluice gate as part of the experiment. The lunar phases were documented as per Moon Phase and Libration, 2022, NASA in accordance with the sampling days.

The total catch per sampling and catch per sampling effort for each species were analysed separately.

Non-parametric tests were decided after checking the normality of the distribution of the subject data using the Shapiro-Wilk test. All statistical analyses were done in R version 4.3.0. The influence of LED light colour and moon phase on the total catch per sample was analysed by implementing a negative binomial generalised linear model (GLM) with light colour and moon phases as fixed factors using the MASS package version 7.3-58.4 (Venables & Ripley, 2002). A type II Analysis of Variance (ANOVA) of the fitted model was done using car package version 3.1-2 (Fox & Weisberg, 2018).

The influence of light colour and moon phase on the weight per operation of the three species was analysed separately by implementing a generalised linear model (GLM) with light colour and moon phases as fixed factors. A type II Analysis of Variance (ANOVA) of the fitted model was done using car package version 3.1-2 (Fox & Weisberg, 2018). The least likelihood ratio test was performed to check the goodness of fit between different models using lmtest package version 0.9-40 (Zeileis & Hothorn, 2002). The quasi-poisson error distribution was used in the GLMs done on the species separately to consider the mean-variance relationship of the data. Model assumptions were verified by plotting residuals versus fitted values in the model. The interaction plots of lights and moon phases of the model were displayed using effects package version 4.2-2 (Fox, 2003) and sjPlot package version 2.8.14 (Lüdecke, 2023). Pairwise Tukey's Honest Significant difference test with bonferroni correction was used to conduct pairwise comparisons following the GLMs using the multicomp package version 1.4-23 (Hothorn et al., 2008).

Results and Discussion

The Kudappuram filtration field yielded 849 kg of shrimp belonging to three species during the study period of six months (January 2022-June 2022). Out of which, 474.05 kg and 375.40 kg were caught under red and green LED light sources, respectively. The shrimp species *M. dobsoni* dominated the overall catch throughout all moon phases when samples collected under red and green light were combined, with an average proportion of 80.34 ± 7.77 % (mean weight), which was significant than catch of *F. indicus* (11.77 ± 5.38 %) and *M. monoceros* (7.88 ± 11.97 %) (Fig. 2).

M. dobsoni (76.11 ± 8.23 %) was the major catch within the samples in every lunar phase collected under red light, followed by *M. monoceros* (13.58 ± 14.21 %) and *F. indicus* (10.31 ± 6.87 %). Across all lunar phases collected under green light, *M. dobsoni* accounted for an average of 85.28 ± 3.05 % of the catches, the proportion of *M. monoceros* (1.24 ±1.69 %) was lower than that of *F. indicus* (13.48 ± 2.47 %). It was also noted that catch was high when high tide and low tide were almost of the same duration.

The results of the type II analysis of deviance performed on the GLM fit to total weight per catch of all species combined showed significant differences among lights (LR Chisq = 4.902, df=1, $p < 0.05$) and moon phases (LR Chisq = 20.016, df=5, $p < 0.01$). The weight of shrimps caught under red light (15.8 ± 7.27 kg, mean ± SD) was significantly higher than the weight caught under green (12.5 ± 8.84 kg) light source (Fig. 3). The use of two lights yielded different catch outcomes, implying the importance of lighting conditions in influencing the overall catch. Additionally, the moon phase was found to have a significant effect on the total shrimp catch per day. Pairwise comparisons of total catch between moon phases showed significant differences ($p < 0.05$) between Waxing crescent-Waning gibbous (20.78 [15.56, 27.75, 31], mean (95 % confidence interval) and 6.47 [3.35, 12.49] Kg respectively) and

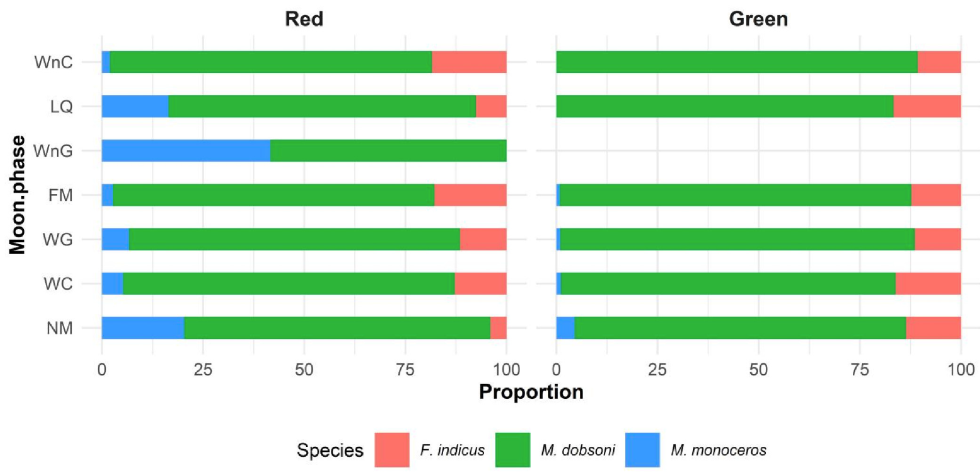

Fig. 2. The average proportions of species of shrimp caught during various lunar phases under red and green LED lights in the Kudappuram filtration fields. Abbreviations: NM-- New moon, WC-Waxing Crescent Moon, WG-Waxing Gibbous Moon, FM-Full Moon, WnG-Waning Gibbous Moon, LQ- Third Quarter Moon, WnC- Waning Crescent Moon.

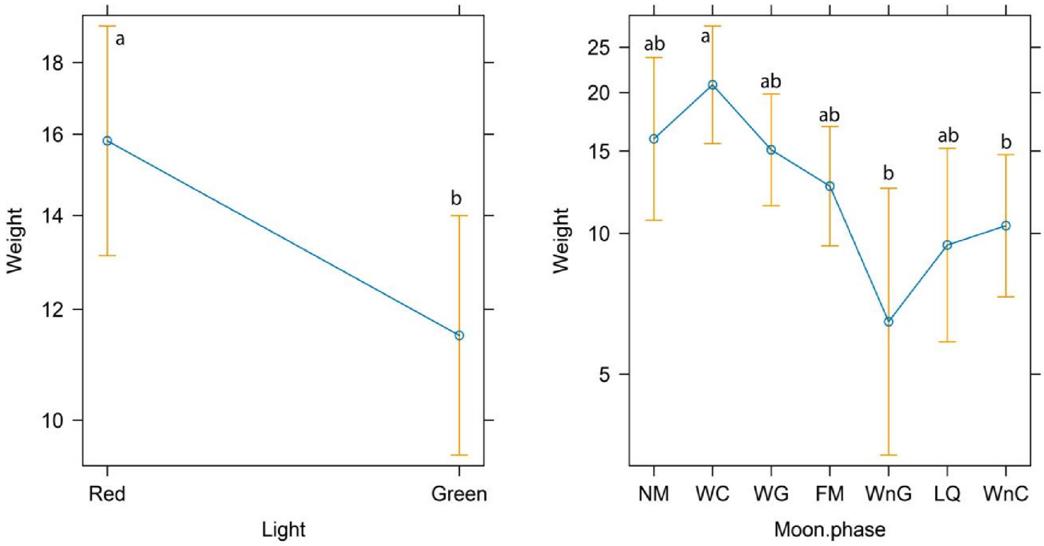

Fig. 3. Effect of light and moon phases to the total catch per day of shrimps at Kudappuram filtration field in GLM (with 95 % confidence intervals) fit

Waxing crescent-Waning crescent (20.78 [15.56, 27.75, 31] and 10.38 [7.31, 14.73] Kg, respectively) (Fig. 4). This finding suggests that the use of different lighting conditions and moon phases can have an impact on the overall catch of shrimps comprising all three species, potentially due to factors such as increased visibility or changes in the behaviour of the target species.

The results of the type II analysis of deviance performed on the GLM fit the weight per catch of *M. dobsoni* showed that there were significant differences in the catches among moon phases (LR Chisq = 12.103, df = 5, $p < 0.05$) but not significant among the lights (LR Chisq = 2.778, df = 5, p = 0.09). However, the mean catch of *M. dobsoni* under green light (10.7 ± 7.44, mean ± SD) was lower compared to that under red light (13.3 ± 5.51 kg). Pairwise comparisons of catch per unit effort of *M. dobsoni* between moon phases showed significant differences between full moon-waxing crescent (10.40 [7.44, 14.55] and 16.74 [16.74, 22.11], $p < 0.05$), last quarter-waxing crescent (7.32 [4.02, 13.36] and 16.74 [16.74, 22.11], $p < 0.01$), waning crescent-waxing crescent (8.71 [5.71, 13.28] and 16.74 [16.74, 22.11], $p < 0.01$) and last quarter-waxing gibbous (7.32 [4.02, 13.36] and 12.81 [9.59, 17.11], $p < 0.05$). Similarly, for *M. monoceros,* the weight per catch under the green light (0.13 ± 0.28) was negligibly lower than that caught under the red light (1.65 ± 2.04), and it was present only during 7/30 days of sampling under the green light. The type II analysis of deviance performed on the GLM fit to the weight per catch of *M. monoceros* captured under red light showed that there were significant differences in the catches among moon phases (LR Chisq = 18.319, df = 5, $p < 0.01$). However, the bonferroni corrected Tukey HSD results did not show any significant difference between moon phases (Fig. 5).

The results of the type II analysis of deviance performed on the GLM fit to the weight per catch of *F. indicus* showed no significant differences in the catches among light colours (LR Chisq = 0.620, df = 1, p = 0.43) and moon phases (LR Chisq = 5.917, df = 5, p = 0.31). The analysis revealed that the catches of *F. indicus* did not show variations associated with either light conditions or different phases of the moon, suggesting that these factors may not play a significant role in influencing the catch quantities of this species.

The study also found a significantly higher number of *M. dobsoni* in all the samples compared to the other two species and was found to be influenced by the factors considered in this study. The study found evidence of the considerable influence of light colour and moon phase on the total catch per day of three shrimps during a period of six months (60 days trial).

Vision plays a fundamental role as a sensory input essential for the daily survival of the majority of aquatic vertebrates (Atema, 1980). Developing com-

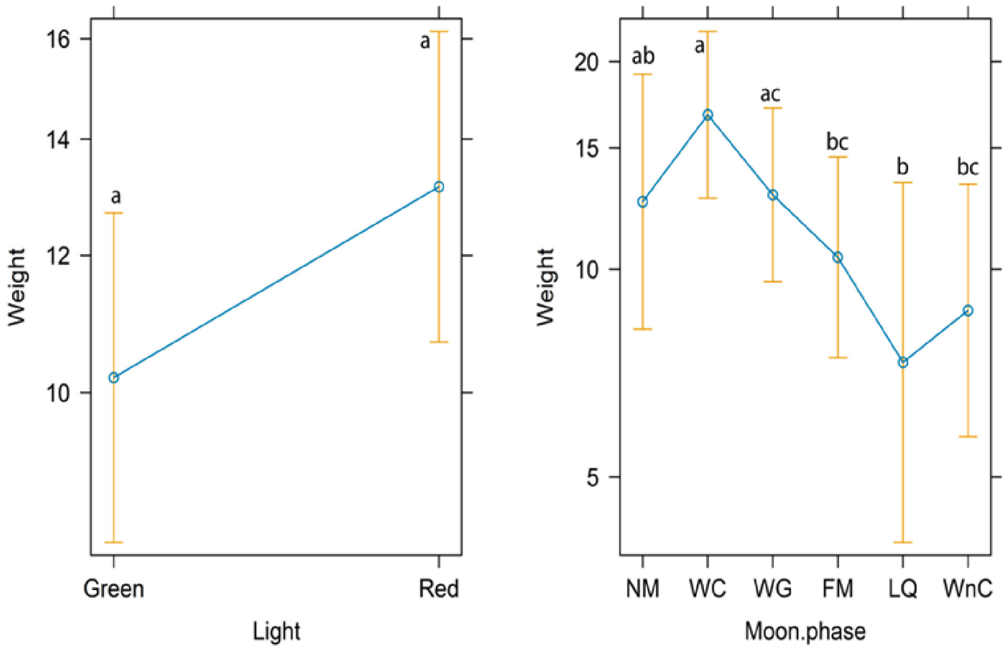

Fig. 4. Effect of light and moon phases to the catch per unit effort of *M. dobsoni* at Kudappuram filtration field in GLM (with 95 % confidence intervals) fit

prehensive knowledge about the visual systems of aquatic species, especially those that hold commercial value, is of utmost importance in driving the advancement of sustainable and up-to-date fishing techniques and practices. The field of aquatic vertebrate vision has witnessed substantial exploration and research over the past few decades (Arimoto et al., 2010; Sokimi & Beverly, 2010; Arimoto, 2013; Land & Nilsson, 2012). A wide array of fish and crustacean species demonstrate the capacity to recognise colours, showcasing variations in sensitivity and resolution across the colour spectrum (Swimmer & Brill, 2006; Arimoto et al., 2010). Artificial lighting has been recently adopted in trawl fisheries, specifically on vessels that focus on deep-sea shrimps, such as *Palaemon longirostris* (Geraci et al., 2021). The study which involved gathering insights from fishermen, it was found that there was higher catch rates of *P. longirostris* during night-time trawling. Increasingly, artificial lights were being employed on the trawl head rope to enhance the catch per unit effort (CPUE) of *P. longirostris* and the giant red shrimp, *Aristaeomorpha foliacea*, during night-time trawling.

The relationship between different moon phases and total catch per unit effort indicates the importance of understanding the moon's role in influencing invertebrates like shrimps. The fluctuations in the catch frequencies of shrimps during various moon phases could be attributed to factors such as improved visibility or alterations in the behaviour of the targeted species. The results of the study show that the waxing crescent and new moon phases exerted a notable influence on the total catch, resulting in higher numbers being recorded.

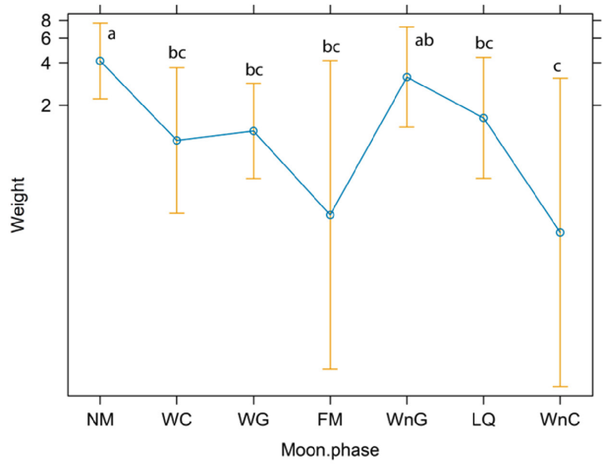

Fig. 5. Effect of moon phases to the catch per unit effort of *M. dobsoni* under red lights at Kudappuram filtration field in GLM (with 95 % confidence intervals) fit

The lunar cycle potentially influences the behaviour, abundance, or distribution of species, such as *M. dobsoni* and *M. monoceros.* Several studies have demonstrated the influence of moon phase on aquatic fauna, particularly crustaceans. DeCoursey (1983) observation on the biological rhythms of crustaceans, revealed that the lunar phase is one of the five environmental cycles that have an impact on animal periodicity. According to a study conducted by Courtney et al. (1996), it was observed that the catch rate and reproductive condition of eastern king prawns, *Penaeus plebejus*, in coastal waters off Southeastern Queensland, exhibited variations based on the periodicity of the lunar cycle. A study conducted by Harman (2001) to evaluate the effect of the moon phase on the daily catch rate of king, tiger and endeavour prawns in the Shark Bay and Exmouth Gulf fisheries revealed a clear and significant impact of the lunar cycle on the daily catch rates of king prawns in both fisheries and endeavour prawns in Exmouth Gulf. The observations revealed a consistent pattern of decreased catch rates during the full moon and increased catch rates during the new moon. The analysis of stow net catches conducted during the full-moon and full-dark-moon phases highlighted a significant difference in catch quantities for species such as pepay shrimp, thorn shrimp, lomek, white shrimp, and cuttlefish. The findings suggested that the lunar cycle had a notable influence on the weight of these caught species between the two moon phases (Brown et al., 2020).

The study conducted in a Kudappuram filtration field revealed significant differences in catch quantities among different lighting conditions and moon phases. The total weight of shrimps caught under red LED light was significantly higher than under green LED light, indicating the importance of colour of light in influencing the overall catch. The moon phases also had a significant effect on the total shrimp catch per day, with specific moon phase combinations (waxing crescent-waning gibbous and waxing crescent-waning crescent) showing significant differences in catch quantities. However, for the *M. dobsoni* species, while significant differences were observed among moon phases, the impact of light on catches was not statistically significant. Similarly, for *M. monoceros*, the weight per catch under green light was negligibly lower than under red light, but there were significant differences in catches among moon phases. However, for *F. indicus*, no significant variations were observed in catches associated with light conditions or moon phases. These findings suggest that different lighting conditions and moon phases can have an impact on the overall catch of shrimps, but their effects may vary depending on the species.

Additional studies are required to investigate the influence of various light features, including colour, intensity, and wavelength, as well as different moon phases, on shrimp behaviour and their consequent effects on catch outcomes. This enhanced knowledge will improve the comprehension of the intricate relationship between shrimp, light conditions, and moon phases, potentially leading to more effective management strategies in the future.

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