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Short Communication

The effect of LED lights on trap catches in signal crayfish fisheries

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Abstract

Signal crayfish (*Pacifastacus leniusculus*) is a freshwater crayfish, originally from the west coast of North America. It is now widespread in Europe and it is listed as a harmful species in the list of invasive species of European Union concern. We tested the effect of LED lights in signal crayfish trapping in a large Finnish lake. Light attraction could be a cost-effective way of increasing crayfish catches in eradication programs and commercial trapping, but research results are largely lacking. Experiments were conducted in Lake Päijänne which has an abundant population of invasive signal crayfish. We tested whether white and green LED lights attached inside the baited traps increase crayfish catch per unit effort (CPUE) compared with baited traps without light. Mean CPUE was higher in traps only baited with a fish (2.7 ind. 24 h^{-1}) compared to traps with a fish bait and a green LED light (1.5 ind. 24 h^{-1}), and traps with a fish bait and a white LED light (1.9 ind. 24 h^{-1}). Our results show that LED lights did not increase signal crayfish CPUE. Instead, lower catches in traps with LED lights indicate that crayfish were not attracted by the light. We observed significant variation in CPUEs, but without interaction between crayfish sex or size and light treatments. We conclude that LED lights do not increase the effectiveness of signal crayfish trapping.

Key words: eradication, invasive species, *Pacifastacus leniusculus,* visual attraction, trapping

Introduction

Artificial light is used as an attractor in fisheries targeting a wide variety of fish (Ben-Yami and Pichovich 1988; Nguyen and Winger 2019). The effects of artificial light is less studied in fisheries targeting crustacea but has proven to be an effective attractor in passive gear fisheries of snow crab (*Chionocetes opilio* Frabricius, 1788) (Nguyen et al. 2017) and shrimp (*Pandalus borealis* Krøyer, 1838) (Bouwmeester 2018). In general, freshwater crayfish are most active during the dark night hours and are commonly thought to be negatively phototactic (Gherardi et al. 2000; Gherardi 2002). Variation in crayfish activity have been linked to lunar cycles, activity being lower during full moon phases (Flint 1977; Somers and Stechey 1986;

Araujo and Romaire 1989). Thomas et al. (2016) and Jackson and Moore (2019) found that freshwater crayfish were negatively affected and less active because of artificial light pollution. These findings pose a question about the usability of light as an attractor.

Some studies, however, have shown that light induced activity and reactions to light stimulus may differ between crayfish species or seasons (Gherardi et al. 2000; Kozák et al. 2009). There is no exact knowledge why light attracts crustacea but it is proposed that attraction could be related to curious behaviour triggered by visual stimulus, or they can see the entrance of trap better, or see conspecifics in the traps which attracts them to enter trap (Nguyen and Winger 2017). Based on structural studies and behavioural empirical research, crustaceans' ability to absorb different wavelengths is limited which may cause differences in attractiveness between different coloured lights (Nguyen et al. 2017; Bouwmeester 2018). Freshwater crayfish are sensitive to polarized and ultraviolet light, and probably could discriminate colours (Vogt 2002; Tuthill and Johnsen 2006). Ahmadi et al. (2008) found that juvenile red swamp crayfish (*Procambarus clarkii* Girard, 1852) were positively phototactic and attracted to traps by white light. They concluded that use of light in the traps might be a feasible way of increasing the crayfish catch in crayfish eradication programs. The results of few published studies on freshwater crayfish are contradictory and mainly from laboratory experiments, so it is difficult to draw general conclusions on the effectivity of light attraction in freshwater crayfish trapping.

Signal crayfish (*Pacifastacus leniusculus* Dana, 1852) is a freshwater crayfish, originally from the west coast of North America. It is now widespread in Europe (Kouba et al. 2014) and listed as a harmful species in the list of invasive species of European Union concern. The EU member states are obligated to minimize the damage by invasive species. Signal crayfish is well established in hundreds of Finnish lakes supporting commercial crayfish fisheries (Erkamo et al. 2010), and its total eradication may be impossible (Ruokonen et al. 2018). However, intensive trapping could decrease the harmful effects on other biota by signal crayfish (McCarthy et al. 2006; Moorhouse et al. 2014; Ruokonen et al. 2016) so all advances which increase trapping effectivity would be beneficial.

The aim of this study was to test the effect of LED lights in crayfish trapping. In the experiment, we used white and green LED lights attached inside traps and control traps without lights, and we compared catch-per-unit effort (CPUE) between treatments.

Materials and methods

The crayfish trapping was conducted at Lake Päijänne (area 1,082 km^2) in Central Finland (Figure 1). Lake Päijänne is the second-largest lake in Finland, with abundant signal crayfish populations supporting commercial crayfish trapping (Erkamo et al. 2010). The water in the northern part of Lake Päijänne

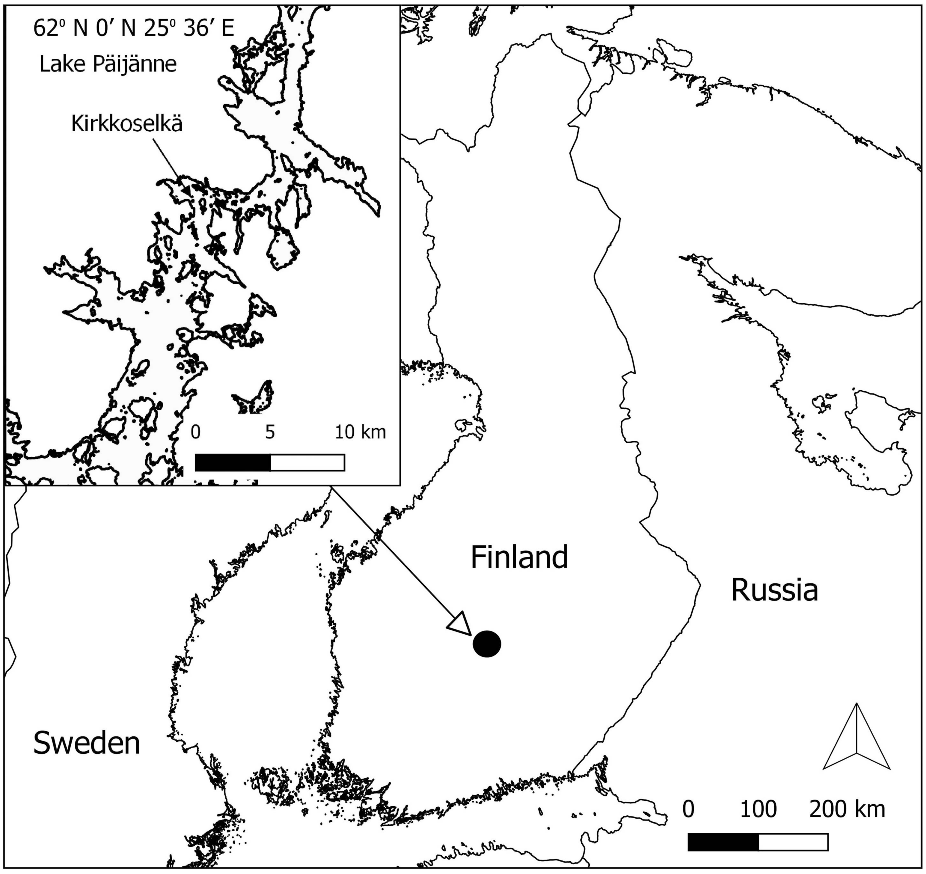

Figure 1. Location of study sites at Lake Päijänne, Finland.

is slightly humic, with 2.7 m mean water transparency (Secchi depth) in the ice-free season (Hertta environmental database, Finnish Environment Institute). Crayfish trapping was conducted in the area of Kirkkoselkä (Figure 1) at the beginning of August 2019 and was repeated at the beginning of September 2019 to investigate whether different natural light regimes influenced the effect of LED lights.

The experiment was conducted at five different sites distributed across the Kirkkoselkä area. The distance between sites varied from 0.5 to 2.5 kilometers. At each study site, 8 cylindrical Evo-traps with two entrances (length 50 cm, diameter 25 cm, entrance width 10 cm, diamond-shaped mesh 15 mm knot-to-knot) were set in the 3–5 m depth zone (mean depth 3.2 m) along the shore during the afternoon and collected the following morning (Figure 2). The traps were attached to a line at 10 m intervals for easier handling. In both periods, trapping was conducted on two successive nights, and the location of each longline (containing 8 traps) was changed within the area to ensure the independence of the results.

Lindgren-Pitman Electralume® fishing LED lights (luminous intensity of 4.7 cd) with white (456 nm and 569 nm) and green (524 nm) lights were used in experiment (Figure 2). The LED lights used emitted light in wavelengths that crayfish should have been able to absorb (Vogt 2002). Wavelengths were measured in the physics laboratory at the University of

Figure 2. Crayfish traps and LED lights used in the experiment. Photo by Timo Ruokonen.

Jyväskylä, Finland. LED lights were hung in the roof of traps, using metal hooks. Traps with inactive LED lights (because of a loss of power) were removed from the data prior to the statistical analyses.

As we were interested in whether LED light could increase the signal crayfish catch, each experimental unit (line of 8 traps) contained baited traps (ca. 50–70 g of fresh fish flesh, *Rutilus rutilus* Linnaeus, 1758) with a LED light of two different colors (2 white, 2 green), two baited control traps without a LED light, and two traps without bait or LED light set in random order (Figure 2). The LED lights we used emitted light in wavelengths (peak in green 525 nm, white 460 nm) that crayfish should have been able to absorb (Vogt 2002). The water temperature (°C) and underwater light intensity (lux) was measured at 30-minute intervals with Hobo Pendant UA-002 lockers attached to the empty control trap in each trap line. The length of the dark period under water (light illuminance < 1 lux) was 10 h 44 min in August and 13 h in September. The water depth for all traps was measured using an echo sounder during trap setting. Crayfish were measured (carapace length in mm), and their sex was determined. CPUE was calculated for the number of crayfish per trap in 24 h^{-1}.

Statistical analysis

We used the generalized mixed effects model (GLMM) with Poisson distribution to estimate the effect of LED lights on crayfish CPUE. In the initial model, we used crayfish CPUE as a dependent factor, treatment and sampling period as fixed factors, and each fleet of traps as a random factor for involving possible differences between sites. Only two crayfish were

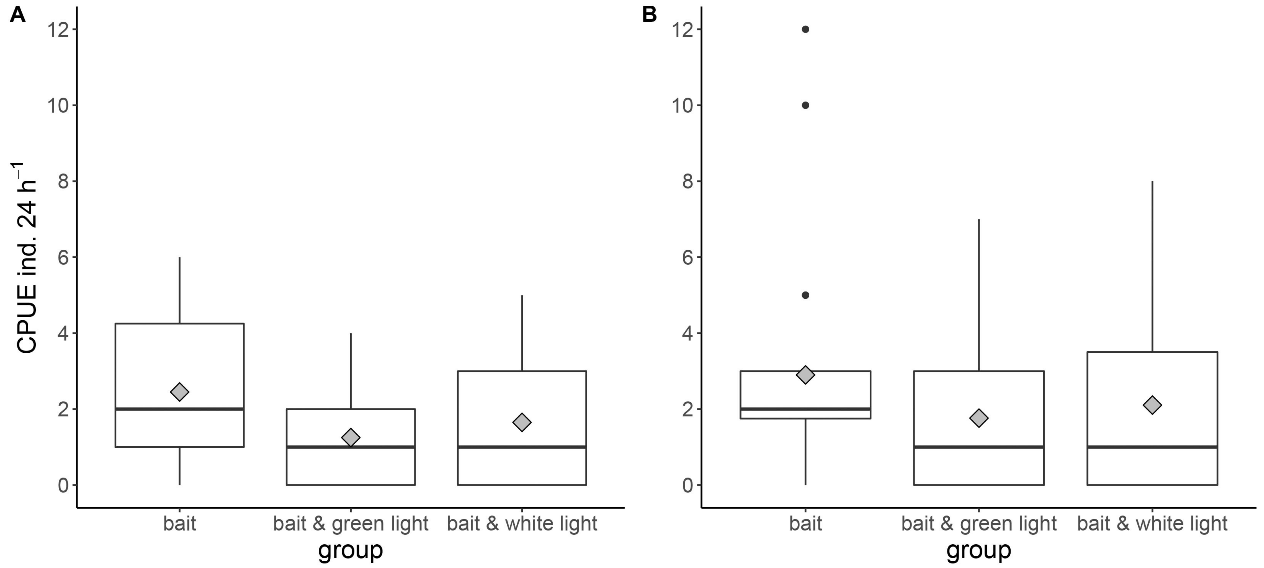

Figure 3. CPUE of signal crayfish in traps with bait, and bait and different colored LED lights A) in August and B) in September at Lake Päijänne. A gray diamond denotes the mean CPUE.

caught in control traps without light and fish bait, which indicated that the empty traps were not attracting crayfish. To simplify analysis, traps without light and fish bait were omitted. We used stepwise model simplification, in which non-significant factors and interactions were dropped. In preliminary data analysis, crayfish CPUE and trap depth showed a significant but weak negative correlation (Spearman correlation, $R = -0.21$, $p = 0.025$), but as no significant interaction between treatments and trap depth on CPUE were found, depth was dropped from the analysis for the sake of clarity. Differences in CPUE between crayfish sexes were tested with the non-parametric Mann-Whitney U-test separately in each treatment. Differences in crayfish length between treatments were tested with ANOVA, using square root transformed crayfish carapace length data.

All statistical analyses were conducted in R (R Core Team 2019), and figures were produced using the ggplot2 package (Wickham 2016). A GLMM model was built using the lme4 package in R (Bates et al. 2015).

Results

The mean crayfish CPUE was higher in traps with only bait (2.7 ind. 24 h^{-1}) compared to traps with a bait and a green LED light (1.5 ind. 24 h^{-1})($z = -3.631$, $p < 0.001$), and traps with bait and white LED light (1.9 ind. 24 h^{-1}) ($z = -2.306$, $p = 0.021$) (Figure 3). The mean crayfish CPUE was similar between traps with different LED lights ($z = -1.235$, $p = 0.431$), and no significant differences were found between sampling seasons (Figure 3A, B).

The mean CPUE was also similar between sexes in all treatments (Figure 4A). The mean crayfish carapace length (mm) was similar between all treatments ($df = 2$, $F = 1.612$, $p = 0.202$), indicating that the effect of LED lights was similar, regardless of crayfish size (Figure 4B).

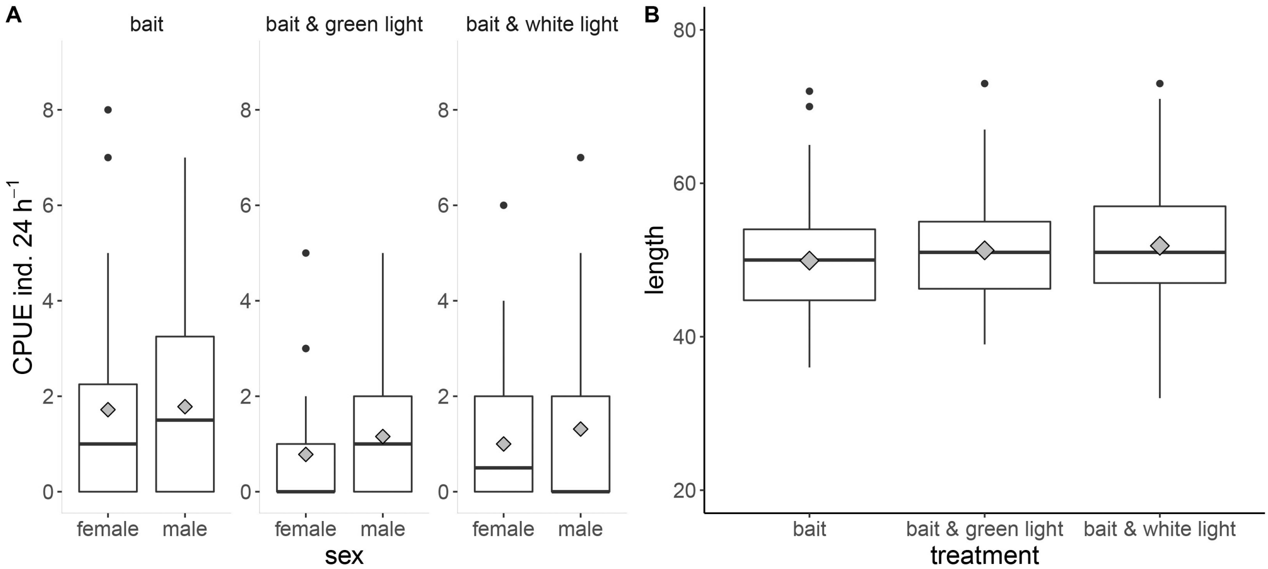

Figure 4. A) CPUE of signal crayfish females and males, and B) mean carapace lengths (mm) in traps with bait, and bait and different colored LED lights at Lake Päijänne. A gray diamond denotes the mean CPUE or the mean length.

Discussion

Previous research has shown that artificial light attracts crustacea in some circumstances, increasing trapping performance (Ahmadi et al. 2008; Nguyen et al. 2017; Bouwmeester 2018). Our results show that LED lights in the traps do not increase crayfish catches, because we observed higher mean CPUEs in traps without light in both sampling seasons. Our finding is not unexpected as most crayfish are nocturnal (Gherardi 2002), and light (e.g. moonlight, artificial lights) may reduce their activity (Flint 1977; Jackson and Moore 2019). Nonetheless, we observed high variation in catches between traps in all treatments. Some lit traps had equal catches with traps without LED lights which indicated that crayfish don't avoid traps with LED lights evenly.

Observed variation in trap catch may be related to differences in light attraction between crayfish specimens' size, life stage, or sex (Ahmadi et al. 2008). Somers and Stechey (1986) found that trap catches were similar during nights with or without full moon, but mean size of crayfish increased on moonlit nights. However, we found no differences in mean crayfish sizes or in sex ratios between treatments. Crayfish show a relatively high individual variation, for example, in boldness and aggressive behavior (Pintor et al. 2009; Vainikka et al. 2011), but there is a lack of research related to light-induced behavior. Juvenile red swamp crayfish are found to be positively phototactic and active during a lit period in aquaculture (Ahmadi et al. 2008). Although signal crayfish juveniles may be attracted by the light, our experiment does not allow us to draw conclusions on the behavior of juveniles, because the traps used are very size-selective for larger crayfish (total length > 60 mm) due to their large mesh size (Westman et al. 2002). Furthermore, small individuals may avoid traps occupied by large individuals.

Ulikowski et al. (2017) showed that signal crayfish can escape Evo-traps which were used in our experiment. They found 30–35% decrease in number of crayfish after 12 h. One possible explanation for lower catches in traps with LED light is that crayfish may be able to escape more easily from the lit traps. However, crayfish catch typically varies considerably, and a low CPUE or totally empty traps are relatively common even in areas with a high crayfish density (T.J. Ruokonen *pers. observation*). Our results clearly indicated that LED lights doesn't increase trapping effectivity in the circumstances our study was conducted. Example UV light could be more attractive or there might variation related to food availability between seasons. Further studies with potentially different approaches are needed, because there is an increasing demand for cost-effective tools to monitor and restrict invasive crayfish species such as signal crayfish (Piria et al. 2017; Ruokonen et al. 2018).

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