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Light intensity preference of juvenile pikeperch *Sander lucioperca* (L.)

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Abstract

Light intensity preference of the pikeperch was tested in 1-m^2 tanks divided into four lateral compartments with a hole in the middle to allow the fish to move between compartments. Two experiments were carried out with both 0+ and 1+ pikeperch: one testing intensities from 25 to 300 lx and the other from 1 to 50 lx. Light preference was observed individually for 5 days at 8, 11, 14 and 17 h. On the first and fifth day, the preference was tested without differences in light intensity (control). In both experiments, both age groups showed preference for the lowest available light intensity. Preference for low light intensity in pikeperch may be related to innate activity and feeding behaviour and to avoidance of harmful effects of light. It is suggested that under aquaculture operations, pikeperch should be reared under very dim conditions.

Keywords: light intensity, preference, percid, pikeperch, *Sander lucioperca*

Introduction

Pikeperch (*Sander lucioperca* L.) is a highly valued freshwater table fish distributed in the Baltic Sea and lakes and large rivers in Europe (Lehtonen, Hansson & Winkler 1996; Craig 2000). Pikeperch has primarily been cultivated for stocking and conservation purposes (Hilge & Steffens 1996; Ruuhijärvi & Hyvärinen 1996). Under cultivation, they are usually raised in natural ponds and are then released as one-summer fish. Over the last 10 years, the interest in food fish cultivation of perciform fish has increased and research has been carried out to develop more intensive production methods for walleye (*Sander vitreum* M.), perch (*Perca fluviatilis* L.) and, to some extent, also for pikeperch (Summerfeld 1996; Kestemont & Melard 2000; Barry & Malison 2004).

Light intensity is an important factor affecting many behavioural and biological processes in fish, such as foraging (Fraser & Metcalfe 1997), growth (Trippel & Neil 2003), onset of sexual maturity (Porter, Duncan, Mitchell & Bromage 1999), feeding of larval fish (Huse 1994) and learning ability (Noble, Mizusawa & Tabata 2005). Light intensity may be an important environmental factor in the cultivation of *Sander* species as in the wild they are usually found under dim light conditions and they are actively feeding during dusk and at night (Ali, Ryder & Anctil 1977; Collette, Ali, Hokanson, Nagiec, Smirnov, Thorpe, Weatherley & Willemsen 1977; Kitchell, Johnson, Munns, Loftus, Greig & Olver 1977; Ryder 1977). Moreover, pikeperch and walleye have a specialized retina that improves vision under dim light conditions and may also influence the light preference of the fish. The tapetum lucidum is a light-reflecting layer of the retina that increases retinal sensitivity by reflecting light back and forth with additional absorption by the rods after each reflection (Aynor & Ali 1975). Furthermore, in the retina of walleye, the photoreceptor cells aggregate into groups of 20–30 to form macroreceptors, which are believed to increase acuity to dim light (Braekevelt, McIntyre & Ward 1989; Vandenbyllaardt, Ward, Braekevelt & McIntyre 1991).

Preference tests have been used widely to study the environmental conditions that may promote an animal's welfare (Gonyou 1994). Preference for a certain environmental feature suggests that the animal is able to discriminate between desirable and undesirable conditions. Thus, when given a choice, the increasing time spent in a particular environment indicates a positive preference for that environment in comparison with the others that can be selected. The aim of the present study was to obtain detailed information on the possible light intensity preferences of juvenile pikeperch, which could further be used for improving the productivity of pikeperch aquaculture.

Materials and methods

Fish, experimental design and sampling

One (0+) and two-summer-old (1+) pikeperch used in the experiment originated from stocks housed in a private fish farm (Hankataimen, Hankasalmi, Finland). The stocks were established in 2004 and 2005 by transferring juvenile fish in August from a natural rearing pond to the fish farm and habituated there to a commercial salmon dry diet. About 2 months before the experiment, approximately 100 0+ and 1+ fish were transported to the fish laboratory of the University of Jyväskylä. Until the start of the experiment, the fish were held in two flowthrough stock tanks (water volume 500 L) supplied with fresh, heated (22 °C) and aerated water and exposed to continuous light (100 lx at the water surface) provided by fluorescent tubes. Fish were fed to excess on a commercial salmon dry diet (Royal Response, Raisio Feed, Raisio, Finland) by belt feeders for 15 min every 3 h.

For light preference trials, three 1 m^2 (100 × 100 cm) light yellow plastic tanks were divided into four lateral compartments of similar size (50 × 50 cm) with a 15 cm hole in the central region to allow the fish to move between the compartments. Water depth was 20 cm, and one air stone supplied oxygen in the middle of each tank. The laboratory was illuminated with fluorescent daylight tubes (Airam 5000 deluxe, L58W950, 3300 lumen, Airam Electric, Helsinki, Finland) for 24 h. To obtain desired light intensities inside each compartment, they were covered with different amounts of white paper. Light intensities inside compartments were measured by a luxmeter (HD 9221, Delta OHM, Padua, Italy).

To test the light intensity preference, two experiments were conducted: one testing intensities from 25 to 300 lx and the other testing intensities from 1 to 50 lx. In experiment 1, the room illumination was set at approximately 300 lx right above the tank and each compartment of the experimental tanks was covered with layers of white paper to obtain mean light intensities of 304.3, 149.0, 92.0 and 25.7 lx at the water surface. In this experiment, we tested the light preference of six 0+ (mean ± SD: 8.75 ± 0.41 cm; 6.68 ± 1.26 g) and six 1+ (mean ± SD: 14.95 ± 1.59 cm; 36.90 ± 10.89 g) pikeperch. In experiment 2, room illumination was set at approximately 60 lx above the tank, and the mean light intensity in each compartment of the experimental tanks was 55.3, 21.3, 11.7 and 1.2 lx. The light preference of nine 0+ (mean ± SD: 11.54 ± 0.88 cm; 19.97 ± 3.31 g) and nine 1+ (mean ± SD: 14.56 ± 1.4 cm; 30.19 ± 4.45 g) pikeperch was observed.

The light preference was observed individually (1 fish $tank^{-1}$) for a period of 5 days. Each fish was introduced into the experimental tank 1 day before the observations started. During the first and fifth day of the 5 days, all compartments had equal light intensities (304 and 55 lx in trials one and two respectively). During these days, fish visit frequency in each compartment was observed to find out possible preference differences between equally illuminated compartments. On days 2, 3 and 4, observations were made with compartments set at the light intensities stated earlier. Visiting frequency was observed throughout the 5 days and the data were collected every 2 min during a 20-min period at 08:00, 11:00, 14:00 and 17:00 hours, yielding a total of 40 observations per day. Food was not offered during the experimental days. The water temperature was 20 °C.

Mathematical calculations and statistical analysis

Visit frequency in each compartment during the experiment and a light intensity preference index, which indicates the light intensity preference of the individual fish, were calculated for each day. The light intensity preference index was calculated as $p = \sum_{i=1}^{4} I_i \times n_i/N$, where I_i is the light intensity and n_i is the number of visits in a certain compartment (1–4) and N is the total number of daily observations (40).

For statistical analysis of visit frequency, the non-parametric procedure of Friedman ANOVA was used for multiple group analyses of visit frequency. The Friedman test was used because fish preference for one compartment instead of others provides dependent data. In cases where the Friedman test was significant ($P < 0.05$), the appropriate non-parametric post hoc test of Dunn's was used (Zar 1999) to determine significant differences among compartments.

To compare *p*, we used two-way RM ANOVA, followed by Student–Newman–Keuls post hoc test. The distribution pattern of the fish among compartments was analysed by second-grade polynomial functions, estimated by the minimum squared method. To contrast the two functions of each experiment, we used Dummy regression analysis, followed by the qualitative parameter confidence interval comparison.

Results

During the first day of experiment 1 (control day, all compartments around 300 lx), fish showed equal distribution among the compartments (Fig. 1a and f), which indicates that no particular compartment was preferred. On the second day, when the fish experienced differences in light intensity for the first time, they did not show preference for any light intensity (Fig. 1b and g). However, both age groups showed a significant preference for the 25.7 lx compartment during the third and fourth days (Friedman ANOVA; 0+ fish: $\chi^2 = 10.2$, $P = 0.017$ for the third day and $\chi^2 = 8.79$, $P = 0.03$ for the fourth day; 1+ fish: $\chi^2 = 18$, $P = 0.0004$ for the third day and $\chi^2 = 18$, $P = 0.0004$ for the fourth day; Fig. 1c, d, h and i). On the fifth day, again without differences in light intensity among compartments, the 1+ pikeperch showed a significant preference for the compartment where the lower light intensity (25.7 lx) was offered on earlier days (Friedman ANOVA; 0+ fish: $\chi^2 = 5.6$, $P = 0.13$; 1+ fish: $\chi^2 = 10.9$, $P = 0.012$; Fig. 1e and j).

Light intensity preference index (lipi) did not differ between 0+ and 1+ pikeperch. However, light intensity preference was affected by time, as on the third and fourth days the fish preferred lower intensities than on the second day (two-way RM ANOVA, $F = 55.27$, $P = 0.0001$). Comparison between the two polynomial functions showed no statistically significant differences in the compartment distribution pattern between 0+ and 1+ pikeperch (Dummy regression; 0+ fish: confidence interval (CI) -10.15 to 3.82; 1+ fish: CI -122.17 to -3.57; Fig. 2).

In experiment 2, for both first (control day, all compartments at 55.3 lx) and second days (four different light intensities), all age groups showed an equal distribution among the compartments (Fig. 3a, b, f and g). On the third and fourth days, all fish showed preference for the lowest light intensity (1.2 lx) (Friedman ANOVA; 0+ fish: $\chi^2 = 24.9$, $P = 0.0001$ for the third day and $\chi^2 = 27$, $P = 0.0001$ for the fourth

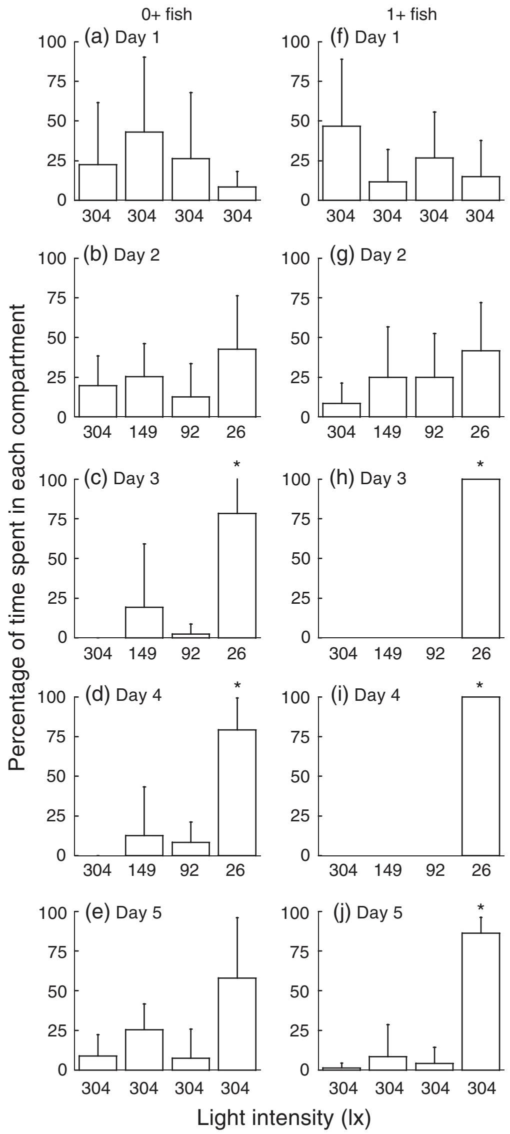

Figure 1 Preference for light intensities from 1 to 55 lx of pikeperch (*Sander lucioperca*). Graphs a–e depict the preference of 0+ pikeperch ($n = 6$), and graphs f–j depict the preference of 1+ pikeperch ($n = 6$). The first and fifth days were the control days; thus, no differences in intensity were offered (all compartments were at approximately 300 lx). Bars represent the mean (+ SD) visit frequency of 40 observations, at 8:00, 11:00, 14:00 and 17:00 hours each day. Statistical differences among compartments are indicated by * (Friedman's ANOVA, $P < 0.05$).

day; 1+ fish: $\chi^2 = 12.4$, $P = 0.006$ for the third day and $\chi^2 = 14.6$, $P = 0.002$ for the fourth day; Fig. 3c, d, h and i). On the last experimental day, again with 55.3 lx in all compartments, pikeperch

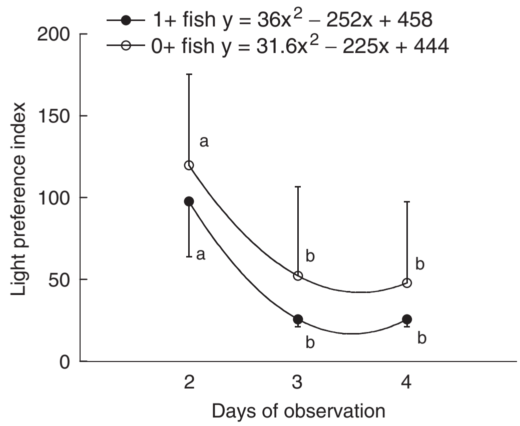

Figure 2 Light intensity preference index (*p*) of pikeperch (*Sander lucioperca*) during those experimental days when different light intensities were offered (days 2–4). Light intensities tested were 304.3, 149.0, 92.0 and 25.7 lx. Curves represent the distribution pattern of pikeperch among different light intensities offered during 3 observation days. The polynomial functions are considered similar as there is an intersection between their confidence intervals. Statistical differences in the *p*-values between the days (two-way RM ANOVA, $P<0.05$) are denoted by letters.

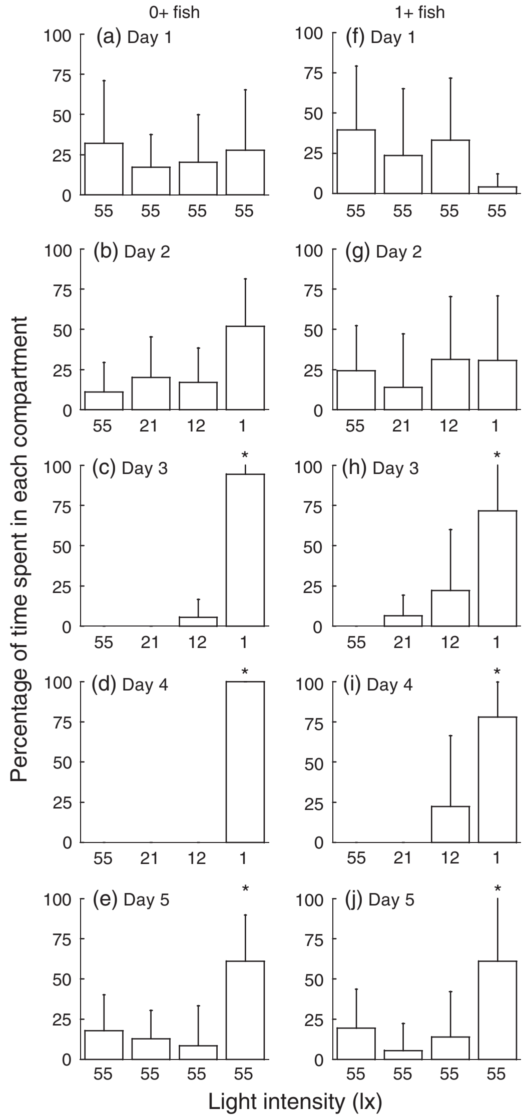

Figure 3 Preference for the light intensities from 1 to 55 lx of pikeperch (*Sander lucioperca*). Graphs a–e depict the preference of 0+ pikeperch ($n=9$), and graphs f–j depict the preference of 1+ pikeperch ($n=9$). The first and fifth days were the control days; thus, no differences in intensity were offered (all compartments were at approximately 55 lx). Bars represent the mean (+ SD) visit frequency of 40 observations, at 8:00, 11:00, 14:00 and 17:00 hours each day. Statistical differences among fish visit frequency in each compartments are indicated by an asterisk (Friedman's ANOVA, $P<0.05$).

preferred the compartment where the lowest light intensity had been offered (Friedman ANOVA; 0+ fish: $\chi^2=12.3$, $P=0.006$; 1+ fish: $\chi^2=7.43$, $P=0.05$; Fig. 3e and j).

The light intensity preference index showed the same distribution pattern as in experiment 1. Pikeperch of the two age classes did not differ in their preference among the days, but the fish showed a lower light intensity preference in the third and fourth days compared with the second day (two-way RM ANOVA, $F=22.0$, $P=0.0001$). Polynomial function analysis also indicates that there were no differences in light preference between 0+ and 1+ pikeperch (Dummy regression; 0+ fish: CI -2.82 to 3.57; 1+ fish: CI -6.72 to -0.41; Fig. 4).

Discussion

This study shows that pikeperch prefers low light intensity environments. Fish in both age groups, in the two experiments testing light intensities from 25 to 300 lx and from 1 to 50 lx, showed a preference for the lowest available light intensity. The present results are in agreement with the finding of Bulkowski and Meade (1983), who reported that 0+ juvenile walleye prefer light intensity around 2–4 lx, which was the lowest light intensity in their experiment. Also, these results are in agreement with the behaviour of juvenile and adult pikeperch in natural environments where this species is considered a crepuscular predator that is actively feeding during

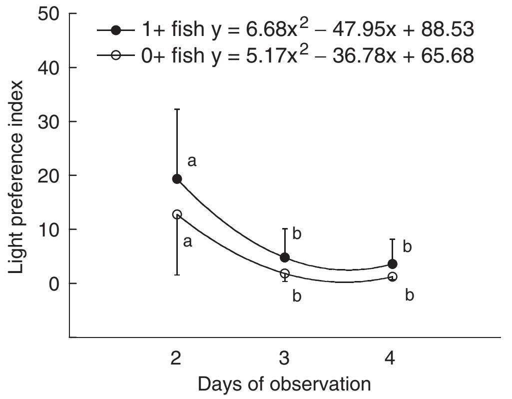

Figure 4 Light intensity preference index (*p*) of pikeperch (*Sander lucioperca*) during those experimental days when different light intensities were offered (days 2–4). Light intensities tested were 55.3, 21.3, 11.7 and 1.2 lx. Curves represent the distribution pattern of pikeperch among different light intensities offered during 3 observation days. The polynomial functions are considered similar as there is an intersection between their confidence intervals. Statistical differences in the *P*-values between the days (two-way RM ANOVA, $P<0.05$) are denoted by letters.

dusk and night (Ali *et al.* 1977; Collette *et al.*, 1977; Kitchell *et al.* 1977; Ryder 1977).

In the present trial, there were no differences in light preference between the two tested size groups of fish (0+ fish 88–115 mm and 1+ fish approximately 150 mm total length). In walleye and pikeperch, the light preference changes during the first months of life (Marshall 1977) from positive to negative phototaxis. Bulkowski and Meade (1983) reported that walleye larvae from 1 to 8 weeks old (from 9 to 32 mm total length) were attracted to the highest light intensity (7800 lx) offered, whereas juveniles older that 8 weeks (32–40 mm total length) preferred the lowest intensities used (2 and 4 lx). The ontogenetic changes in light preference may be related to the ontogenetic changes of the eye structure. In walleyes, the tapetum lucidum appears during the first months of life and it is observed in fish of 37 mm and it is fully developed when the fish are about 140 mm long (Braekevelt *et al.* 1989; Vandenbyllaardt *et al.* 1991). Other structural changes, which enhance scotopic vision, the aggregation of macroreceptors, begin when walleyes are approximately 60 mm long (Braekevelt *et al.* 1989; Vandenbyllaardt *et al.* 1991). Based on the observations in the congener, in the present trial the 0+ pikeperch probably already had a well-developed tapetum lucidum and macroreceptors and therefore the light preference was similar in both age groups.

It is possible that preference for low light intensity in pikeperch may be related to an innate behaviour to avoid harmful effects of light in the light-sensitive eye, and this should be taken into consideration when setting up conditions for pikeperch aquaculture. In other words, the present results suggest that pikeperch should be reared under very dim light conditions.

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