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RESEARCH ARTICLE

# Impact of light intensity on the results of rearing juvenile pikeperch, *Sander lucioperca* (L.), in recirculating aquaculture systems

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**Abstract**. The aim of the study was to determine the impact of different light intensities on the results of rearing juvenile pikeperch, *Sander lucioperca* (L.), in recirculating aquaculture systems (RAS). In experiment I, the light intensities applied were 45.1 lx (group LI) and 385.7 lx (group HI) (initial body weight – 6.1 g), while in experiment II they were 1.2 lx (group LII) and 8.0 lx (group HII) (initial body weight – 42.2 g). In both experiments, the fish reared in the tanks with lower light intensity (groups LI and LII) exhibited faster growth rates ($P < 0.05$). In experiment I significant differences were also noted among groups with regard to feed conversion ratio (FCR) and protein efficiency ratio (PER). Fish mortality in both experiments was low, and differences among groups were not significant ($P > 0.05$). The results obtained indicate that the application of low intensity light (< 45 lx) during juvenile pikeperch (body weight > 6 g) rearing is justified since it has a positive impact on the behavior and growth rate of the fish, and the feed conversion ratio, which implies that it is possible to shorten the rearing period of this species.

**Keywords**: pikeperch, light intensity, recirculating aquaculture systems, rearing

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## Introduction

Pikeperch, *Sander lucioperca* (L.), is a typical freshwater fish, although it does inhabit brackish estuarine waters and periodically marine bays of considerable salinity (Klinkhardt and Winkler 1989, Lappalainen and Lehtonen 1995). This species inhabits turbid waters in which transparency ranges from 0.1 to 1.5 m (Brylińska 2000). These waters are also characterized by their substantial productivity, and consequently deliver adequate amounts of food to pikeperch larvae. Until recently, stocking material of pikeperch was reared only in earthen ponds (Korycki 1976, Hilge and Steffens 1996, Wojda 2004). Studies conducted in recent years at the Inland Fisheries Institute in Olsztyn (IFI Olsztyn) led to the development of methods for the artificial spawning and intensive production of stocking material of this species under strictly controlled conditions (recirculating aquaculture systems – RAS) (see Zakęś and Szczepkowski 2004, Zakęś 2007, 2009).

Fish growth rates are regulated by a number of abiotic factors including water temperature (Zakęś 1999), light intensity (Siegwarth and Summerfelt 1992), water oxygen content (Müller et al. 2006), salinity (Ložys 2004), and water pH (Nelson 1982, Gonzalez and Dunson 1989). The light intensity requirements of pikeperch are not well understood.

Since this species prefers turbid waters, it follows that this factor might have a significant impact on rearing results in RAS. It is also known that fish sensitivity to light is not only unique to species, but also to their ontogenetic development stages (Blaxter 1969, 1975, Sandström 1999). Generally, larvae need minimal amounts of light, as is the case with Atlantic herring, *Clupea harengus* (L.), (Batty et al. 1986) and striped bass, *Morone saxatilis* (Walbaum), (Chesney 1989). The larvae of these species require very low light intensity to locate and acquire food. When light intensity is too high the European seabass, *Dicentrarchus labrax* (L.), experiences stress, which can even lead to increased mortality (Barahona-Fernandes 1979). It has also been demonstrated that light conditions have a substantial impact on the pigmentation process of larvae (Bolla and Holmefjord 1988). Thus, the hypothesis can be proposed that light intensity can determine the effectiveness of rearing numerous species of fish, including pikeperch, in RAS. The behavior of this species under natural conditions indicates this since they feed actively at dusk and at night (Ali et al. 1977, Collette et al. 1977, Ryder 1977, Kelso 1978). Additionally, percid fish, including the European pikeperch and the American walleye, *Sander vitreus* (Mitchill), have a specially constructed eye that includes a reflective layer known as the *tapetum lucidum* (Summerfelt 1996, Sandström 1999), which increases the light sensitivity of these species. Reflections from this layer are directed to photoreceptors thus increasing visibility in low light (Braekvelt et al. 1989). Studying the light preferences of pikeperch is potentially important for improving the production methods of this species in RAS.

The aim of the current study was to determine the impact different light intensities had on the results of rearing juvenile pikeperch in RAS. The study included two size groups of fish.

## Materials and methods

### Fish origin and experiment preparations

The experimental material comprised juvenile pikeperch obtained from natural spawning which were reared in earthen ponds until they had attained a total length TL of about 4.0 cm and a body weight of 0.5 g. The fish were transported to the Department of Sturgeon Fish Breeding in Pieczarki (IFI Olsztyn) in synthetic tanks that were oxygenated (water temperature – approximately 19°C; transport time – approximately 2 h). The material was stocked into rearing tanks with working volumes of 2.0 $m^3$ that were part of a RAS. The fish were trained to consume commercial feed according to procedures developed previously (Zakęś 1999). After a 14-day adaptation period during which the fish were acclimated to feeding on commercial feed, the material was reared for the subsequent 45 days until they had attained a body weight of approximately 6 g. Subsequently, the fish were moved to another RAS fitted with six synthetic circulation tanks with a capacity of 1.0 $m^3$ each.

### Experimental procedure

Two experiments were conducted in which material of different initial body weights was reared under different light conditions. In experiment I, the material had a mean body weight of 6.1 g and body length SL of 8.0 cm. Light intensity measured with an L-100 lux meter (Sonopan, Poland) just above the water surface in the center of the rearing tanks was 385.7 ± 36.8 lx (group HI) and 45.1 ± 8.2 lx (group LI). Each group of fish was reared in tree repeats, and the stocking density in each tank was 150 individuals. The length of the experiment was 56 days. After the conclusion of experiment I, the fish were reared for 10 days, and then the second experiment began. In experiment II, the initial pikeperch body weight was 42.2 g, and SL was 15.4 cm. Two light intensities were tested: 8.0 ± 1.2 lx (group HII); 1.2 ± 0.3 lx (group LII) (N = 3). The stocking density of each rearing tank was 75 individuals. The length of experiment II was also 56 days. The water flow rate in the rearing tanks in both experiments was maintained at 18 l $min^{-1}$. During the experiment, the water temperature was monitored daily, and the other water quality parameters were monitored at last once a week (Table 1).

**Table 1**
Physical and chemical parameters of water at the outflows of the rearing tanks during experiments I and II (mean values ± SD)

| Parameter | Experiment I | Experiment II |
|---|---|---|
| Water temperature (°C) | 24.4 ± 0.95 | 23.6 ± 0.52 |
| Oxygen content (mg $O_2$ $dm^{-3}$) | 3.86 ± 0.61 | 4.85 ± 1.41 |
| Maximum CAA (mg CAA $dm^{-3}$) | 0.20 ± 0.09 | 0.19 ± 0.09 |
| Nitrite concentration (mg $NO_2$- $dm^{-3}$) | 0.09 ± 0.06 | 0.04 ± 0.02 |
| pH range | 7.85 ± 0.32 | 7.97 ± 0.08 |

Measurements of water oxygen content and pH were performed with a CyberScan 5500 meter (Eutech Instruments, USA). The concentration of total ammonia nitrogen (CAA = $NH_4^+$-N + $NH_3$-N) was determined with the direct nesslerization method, and nitrite was determined with the sulfanilic method (Hermanowicz et al. 1999) and a spectrophotometer (Carl Zeiss 11, Germany).

The fish were fed 24 hours $day^{-1}$ with automatic band feeders in both experiments. The feed was manufactured by Nutreco (France) (Table 2). In experiment I, the fish were fed Nutra T-1.5 for the first three weeks. In the subsequent week, this feed was mixed with Nutra T 1.9 at a ratio of 50:50. From the fifth week, the fish were only fed Nutra T-1.9. The daily feed ration for the first five weeks was 4.0% of the stock biomass, after which it was reduced to 3.0%. In experiment II, the fish were fed E-1 P Stella, and the daily feed ration was 1.5% of the stock biomass. The tanks were cleaned of feces and unconsumed feed daily in the morning, and fish behavior, condition, and mortality were also observed.

**Table 2**
Proximate composition (% wet weight), energy concentration, and granulation of the feed used in the experiments (manufacturer's data)

| Parameter | Diets | | |
|---|---|---|---|
| | T-1.5 Nutra MP | T-1.9 Nutra MP | E-1P Stella |
| Crude protein(%) | 52.0 | 52.0 | 47.0 |
| Crude fat (%) | 20.0 | 20.0 | 14.0 |
| Ash (%) | 11.0 | 11.0 | 8.5 |
| Digestible energy(MJ $kg^{-1}$) | 19.9 | 19.9 | 18.5 |
| Granule size (mm) | 1.5 | 1.9 | 2.5 |

## Research procedures and statistical analysis

Fish measurements were taken every seven days to determine growth rates, fish condition, the feeding coefficients of the feed, and the daily feed ration. Samples of 30 fish were chosen at random from each tank and their body weights (± 0.1 g) and SL and TL (± 1 mm) were measured. Before all manipulations, the fish were anesthetized in a Propiscin solution (Kazuń and Siwicki 2001) at a dose of 0.7 ml $dm^{-3}$. On the final day of experiment I, 50 individuals were measured from each tank, while 30 individuals were measured from each tank in experiment II. Additionally, the stock biomass was determined in each tank to verify the feed ration by weighing all the individuals in a tank in a container with a known water volume. During this procedure, all of the fish from each tank were counted to determine survival rates and losses caused by cannibalism. Starving individuals were noted in experiment II. Pikeperch with body weights of less than 42.2 g that were in visibly poorer condition were included in this group on the final day of the experiment.

The data collected was used to calculate the values of the following rearing indexes:

- daily growth rate, DGR (g $d^{-1}$) = (final body weight (g) – initial body weight (g)) × rearing $period^{-1}$ (days);
- specific growth rate, SGR (% $d^{-1}$) = 100 × (ln final body weight (g) – ln initial body weight (g)) × rearing $period^{-1}$ (days);
- variation coefficient, CV (%) = 100 × (standard deviation in body weight (g) × mean body $weight^{-1}$ (g));
- condition coefficient, K = 100 × (body weight (g) × body length $SL^{-3}$ (cm));
- stock survival, S (%) = 100 × (final abundance (individuals) × initial $abundance^{-1}$ (individuals));
- feed conversion ratio, FCR = weight of feed consumed (g) × (final stock biomass (g) – initial stock biomass $(g))^{-1}$;

- protein efficiency ratio, PER = (final fish weight (g) – initial fish weight (g)) × quantity of protein fed$^{-1}$ (g).

The results obtained were analyzed statistically using the Statistica 5.0 PL program. Single factor analysis of variance (ANOVA) and Tukey's test (HSD) ($P \leq 0.05$) were used to determine the significance of differences among the mean values of rearing indexes in the groups.

## Results

In experiment I, increases in body weight, both absolute and relative (DGR, SGR), in the fish from group LI (light intensity 45.1 lx) were greater than those noted in HI, in which the highest light intensity was applied (385.7 lx) ($P < 0.05$; Fig. 1; Table 3). In the case of absolute values, the fish from LI attained 13% greater growth. Increases of SL and TL were also statistically significantly different between the fish groups compared ($P < 0.05$). No differences were noted with regard to body weight variation coefficent (CV) ($P > 0.05$). Statistically significant differences between groups were noted in FCR, which was 0.97 in LI and 1.09 in HI ($P < 0.05$; Table 3). The final survival of the fish in the groups analyzed was similar at approximately 97%. No statistically significant differences were noted with regard to losses from cannibalism ($P > 0.05$; Table 3).

In experiment II, the pikeperch from LII (initial body weight – 42.2 g), which were reared in tanks with lower light intensity (1.2 lx), attained significantly higher body weights and TL growth than did the fish from HII (8.0 lx) ($P < 0.05$; Fig. 1; Table. 3). Other parameters such as body length SL, condition coefficient, SGR, CV, FCR, and PER were similar in the groups compared ($P > 0.05$). Losses noted during rearing were not numerous and occurred only in HII. No cannibalism was noted. During this part of the experiment, some of the fish either did not feed or consumed feed only in quantities that met their basic energy needs, which mean that they did not grow. On the final day of he experiment, the group of fish that were starving accounted for 17.3% (LII) to 27.8% (HII) ($P > 0.05$; Table 3) of the experimental material.

## Discussion

The results of the study indicated that pikeperch prefer lower light intensity. In both experiments, more advantageous rearing results were achieved in the groups held in tanks lit with lower light intensities of approximately 45 lx (experiment I; initial body weight of approximately 6.1 g) and 1 lx (experiment II; initial body weight approximately 42.2 g). The

**Table 3**

Final results of rearing two size groups of juvenile pikeperch under different lighting conditions (mean values ± SD). Values with the same letter indexes in the same row (for each experiment separately) do not differ significantly statistically ($P > 0.05$)

| | Experiment I | | Experiment II | |
|---|---|---|---|---|
| Parameter | Group HI | Group LI | Group HII | Group LII |
| Final body weight (g) | $40.6^a \pm 1.1$ | $45.9^b \pm 1.3$ | $108.6^a \pm 0.6$ | $113.0^b \pm 1.4$ |
| Final total length TL (cm) | $16.8^a \pm 0.2$ | $17.5^b \pm 0.1$ | $23.2^a \pm 0.0$ | $23.5^b \pm 0.1$ |
| Final body length SL (cm) | $14.8^a \pm 0.1$ | $15.6^b \pm 0.1$ | $20.9^a \pm 0.03$ | $21.1^a \pm 0.07$ |
| Daily growth rate DGR (g d$^{-1}$) | $0.61^a \pm 0.02$ | $0.71^b \pm 0.02$ | $1.19^a \pm 0.01$ | $1.26^b \pm 0.02$ |
| Specific growth rate SGR (% d$^{-1}$) | $3.37^a \pm 0.03$ | $3.61^b \pm 0.03$ | $1.69^a \pm 0.01$ | $1.76^a \pm 0.02$ |
| Body weight variation coefficient CV (%) | $19.13^a \pm 1.42$ | $21.12^a \pm 1.15$ | $17.4^a \pm 2.2$ | $15.0^a \pm 0.8$ |
| Condition coefficient K | $1.20^a \pm 0.01$ | $1.19^a \pm 0.01$ | $1.18^a \pm 0.01$ | $1.19^a \pm 0.01$ |
| Feed conversion ratio FCR | $1.09^a \pm 0.01$ | $0.97^b \pm 0.01$ | $0.80^a \pm 0.01$ | $0.78^a \pm 0.01$ |
| Protein efficiency ratio PER | $1.78^a \pm 0.02$ | $1.98^b \pm 0.01$ | $2.67^a \pm 0.05$ | $2.73^a \pm 0.01$ |
| Survival (%) | $97.33^a \pm 0.01$ | $97.77^a \pm 0.01$ | $99.1^a \pm 0.4$ | $100.0^a \pm 0.0$ |
| Cannibalism (%) | $0.89^a \pm 0.22$ | $1.78^a \pm 0.59$ | - | - |
| Starved fish (%) | - | - | $27.8^a \pm 4.3$ | $17.3^a \pm 2.8$ |

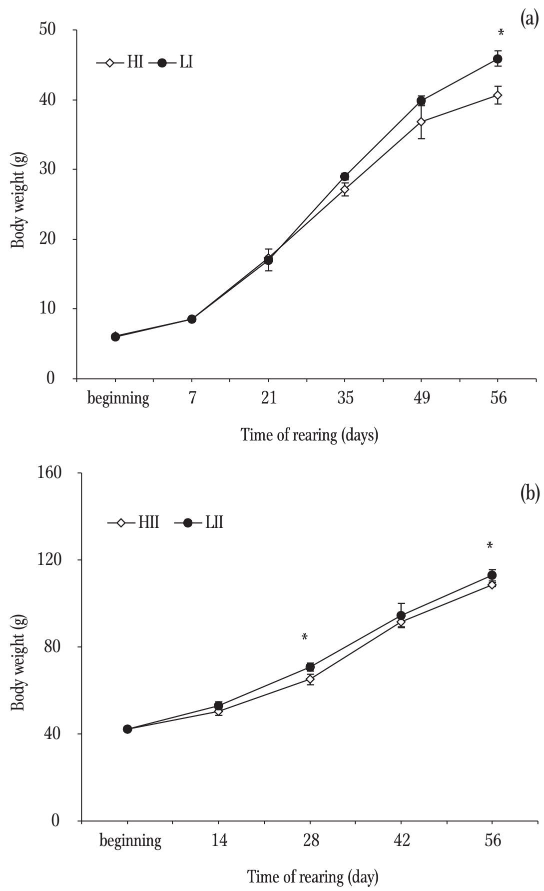


Figure 1. Growth in body weight of juvenile pikeperch during tested experiments. Data are weights in g (± SD), based on tank means, with N = 3 for experiment I (a), and experiment II (b). In experiment I, the light intensities applied were 45.1 lx (LI) and 385.7 lx (HI) (initial body weight 6.1 g), while in experiment II they were 1.2 lx (LII) and 8.0 lx (HII) (initial body weight 42.2 g). Data marked by the asterisk differ significantly statically ($P < 0.05$).

results of the current experiment correspond to those reported by Luchiari et al. (2006), who studied the behavior of pikeperch from two age groups (0+ and 1+) that were reared at various light intensities ranging from 25 to 300 lx and from 1 to 50 lx. Individual pikeperch (1 fish $tank^{-1}$) "lighting" preferences were observed for five days by holding the fish in tanks that were divided into compartments in which different light intensities were applied. The numbers of times the fish visited the different compartments was noted (the fish were not fed). The results of this study indicated that the fish preferred the compartments with the lowest light intensity. The current study confirm these results, but they were conducted under rearing conditions (intense rearing in RAS), and thus provide new knowledge on the influence of light intensity not only on the behavior, but also on the effectiveness of rearing juvenile stages of this species. The results obtained under controlled conditions also reflect the behavior of this species in the natural environment. Pikeperch is a predator that feeds mostly at dusk and at night (Ali et al. 1977).

The study by Marshall (1997) indicated that light intensity preferences of fish from the genus *Sander* change over time, and that during the early stages of individual development they shift from positive phototaxis to negative phototaxis. Bulkowski and Meade (1983) observed that larval walleye preferred high light intensity (7800 lx) from day 1 post-hatch until the eighth week of life (TL from 9 to 33 mm), while individuals older than eight weeks (TL 32-40 mm) exhibited a decided preference for low light intensity (2-4 lx). Differences in light intensity preferences that occur in the species during its ontogenetic development can be attributed to the changes that occur in the eye, especially in connection with the development of the reflective membrane. The *tapetum lucidum* appears in the walleye during the first month of life and is visible in fish 3.7 cm in length; it is fully developed by the time the fish reach about 14.0 cm in length (Braekvelt et al. 1989). Bearing this in mind, it can be assumed that the material used in the current study (by the end of experiment I and from the beginning of experiment II) most probably had well-developed *tapetum lucidum*. It is possible that the *tapetum lucidum* is fully developed in pikeperch that measure about 15 cm. Differences in the degree of eye development in two size groups of fish might explain certain differences in light intensity preferences. This hypothesis can only be confirmed by histological tests of eye development in this species.

Changes in fish behavior prompted by the use of different light intensities were particularly apparent in experiment I in the first week of rearing. Individuals in the tank with higher light intensity (385.7 lx) stayed mainly under and behind the feeder where light intensity was lower. It was apparent that this strategy was motivated mainly by the search for shelter from intense light, and not by finding the most advantageous feeding site. The fish reared in tanks with less intense light (45.1 lx) were distributed throughout the water column and did not form groups. No significant differences in fish behavior were noted in experiment II (light intensities of 1.2 or 8.0 lx). It was evident that the dusk-like conditions in the recirculating system had a more advantageous impact on fish behavior. The fish reared in the tank with the least intense light (1.2 lx) were the least susceptible to stress, as was evident during routine tank maintenance.

Changes in fish behavior that resulted from different light intensities were reflected in growth rate and/or feed conversion ratio. Generally, it can be concluded that the lower light intensity in both the first and second size groups of juvenile pikeperch had an advantageous impact on the results of rearing. It should be noted, however, that the FCR values in all the groups analyzed were positive. The results obtained in experiment II (FCR approximately 0.8 and PER > 2.5) are evidence that the pikeperch assimilated feed well. The rearing results obtained in the current study were similar to those of earlier studies of this species (Zakęś et al. 2003, Kozłowski et al. 2009).

Fish size influenced mortality in the current study. Losses of the smaller fish were higher (2.2-2.7% of the initial stock) and resulted mainly from cannibalism since most of the deaths were caused by the pikeperch inflicting injuries on each other (type II cannibalism; Baras et al. 2000). The fish mostly exhibited injuries to the fins or the tail stem. These results are confirmed by previous studies which indicated that among larger material, which was also of roughly equal sizes, losses from cannibalism were also small (Zakęś 1999, 2009). In experiment II, while cannibalism was not noted, starving individuals were observed. The cause of this phenomenon must be sought in the feeding regime. Such individuals occurred in both experimental groups, thus the influence of the factor being tested (light intensity) can be excluded. In experiment II, the feeding ration of 1.5% of the stock density is appropriate for pikeperch of this size (Zakęś et al. 2003, Kozłowski et al. 2008, Zakęś 2009). It is possible that the cause of this disadvantageous phenomenon was the way the feed was delivered (automatic band feeder that distributed feed at designated points). This could have allowed dominant individuals to monopolize the feed and led to the creation of a distinct hierarchy within the stock (Jobling 1994). As a result, the other fish that were in worse positions in the tanks could have limited access to feed as was reflected in their growth rates. It is also possible that the granulation size of the feed was too large for a certain segment of the fish (smaller individuals), which contributed to the occurrence of starving individuals.

The results of this study indicate that applying low light intensity (< 45 lx) during the rearing of juvenile pikeperch (body weight > 6 g) is justified. Under such conditions this species attains greater growth, more effective feed conversion, and, consequently, it is possible to shorten the rearing period and lower production costs.

## References

Ali M.A., Ryder R.A., Anctil M. 1977 – Photoreceptors and visual pigments as related to behavioral responses and preferred habitats of perches (*Perca* spp.) and pikeperches (*Stizostedion* spp.) – J. Fish. Res. Bd Can. 34: 1475-1480.

Barahona-Fernandes M.H. 1979 – Some effects of light intensity and photoperiod on the sea bass larvae (*Dicentrarchus labrax* (L.)) reared at the Centre Océanologique de Bretagne – Aquaculture 17: 311-321.

Baras E., Ndao M., Maxi M.Y.J., Jeandrain D., Thomé J.P. Vandevalle P., Mélard C. 2000 – Sibling cannibalism in dorada under experimental conditions. I. Ontogeny, dynamics, bioenergetics, of cannibalism and prey selectivity – J. Fish Biol. 57: 1001-1020.

Batty R.S., Blaxter J.H.S., Libby D.A 1986 – Herring (*Clupea harengus*) filter-feeding in the dark – Mar. Biol. 91: 371-375.

Blaxter J.H.S. 1969 – Visual thresholds and spectral sensitivity of flatfish larvae – J. Exp. Biol. 51: 221–230.

Blaxter J.H.S. 1975 – The eyes of larval fish – In: Vision in fishes, New Approaches in Research (Ed.) M.A Ali, Plenum Press, New York, 836 p.

Bolla S., Holmefjord I. 1988 – Effect of temperature and light on development of Atlantic halibut larvae – Aquaculture 74: 355-358.

Braekevelt C.R., McIntyre D.B., Ward F.J. 1989 – Development of the retinal tapetum lucidum of the walleye (*Stizostedion vitreum vitreum*) – Histol. Histopathol. 4: 63-70.

Brylińska M. 2000 – Freswater Fish of Poland – Wyd. PWN, Warszawa, 521 p (in Polish).

Bulkowski L., Meade J.W. 1983 – Changes in phototaxis during early development of walleye – Trans. Am. Fish. Soc. 112: 445-447.

Chesney E.J. 1989 – Estimating the food requirements of striped bass larvae *Morone saxatilis*: effects of light, turbidity and turbulence – Mar. Ecol. Progr. Ser. 53: 191-200.

Collette B.B., Ali M.A, Hokanson K.E.F., Nagiec M., Smirnov S.A., Thorpe J.E., Weatherley A.H., Willemsen J. 1977 – Biology of percids – J. Fish. Res. Bd Can. 34: 1890-1899.

Gonzales R.J, Dunson W.A. 1989 – Differences in low pH tolerance among closely related sunfish of the genus *Enneacanthus* – Environ. Biol. Fish. 26: 303-310.

Hermanowicz W., Dojlido J., Dożańska W., Koziorowski B., Zerbe J. 1999 – Physicochemical testing of waters and wastewaters – Wyd. Arkady, Warszawa: 71-91 (in Polish).

Hilge V., Steffens W. 1996 – Aquaculture of fry and fingerling of pike-perch (*Stizostedion lucioperca* L.) – a short review – J. Appl. Ichthyol. 12: 167-170.

Jobling M. 1994 – Fish bioenergetics – Chapman & Hall, London, 300 p.

Kazuń K., Siwicki A.K. 2001 – Propiscin – a safe new anaesthetic for fish – Arch. Pol. Fish. 9: 183-190.

Kelso J.R.M 1978 – Diet rhythm in activity of walleye, *Stizostedion vitreum vitreum* – J. Fish Biol. 12: 593-599.

Klinkhardt M.B., Winkler H.M. 1989 – Einfluß der Salinität auf die Befruchtungs und Entwicklungsfähigkeit der Eier von vier Süßwasserfischarten Plötz (*Rutilus rutilus*), Barsch (*Perca fluviatilis*), Kaulbarsch (*Gymnocephalus cernua*) und Zander (*Stizostedion lucioperca*) – Wissensch. Zeitschr. Univ. Rostock 38: 23-30.

Korycki A. 1976 – Pikeperch– PWRiL, Warszawa, 224p (in Polish).

Kozłowski M., Szczepkowski M., Wunderlich K., Piotrowska I., Szczepkowska B. 2008 – Impact of using floating feed for rearing pikeperch fry – In: Biotechnology of Aquaculture (Eds) Z. Zakęś, J. Wolnicki, K. Demska-Zakęś, R. Kamiński, D. Ulikowski, Wyd. IRS, Olsztyn: 279-283 (in Polish).

Kozłowski M., Szczepkowski M., Wunderlich K., Piotrowska I., Zakęś Z. 2009 – Results of rearing juvenile pikeperch (*Sander lucioperca*) in various types of tanks – Komun. Ryb. 6: 6-10 (in Polish).

Lappalainen J., Lehtonen H. 1995 – Year-class strength of pikeperch (*Stizostedion lucioperca* L.) in relation to environmental factors in a shallow Baltic Bay – Ann. Zool. Fennici 32: 411-419.

Ložys L. 2004 – The growth of pikeperch (*Sander lucioperca* L.) and perch (*Perca fluviatilis* L.) under different water temperature and salinity conditions in the Curonian Lagoon and Lithuanian coastal waters of the Baltic Sea – Hydrobiologia 514: 105-113.

Luchiari A.C., de Morais Freire F.A.., Koskela J., Pirhonen J. 2006 – Light intensity preference of juvenile pikeperch *Sander lucioperca* (L.) – Aquacult. Res. 37: 1572-1577.

Marshall T.R. 1977 – Morphological, physiological, and ethological differences between walleye (*Stizostedion vitreum vitreum*) and pikeperch (*S. lucioperca*) – J. Fish Biol. 66: 1515-1523.

Müller T., Bódis M., Bercsényi M. 2006 – Comparative oxygen tolerance of pikeperch *Sander lucioperca*, Volga pikperch *S. volgensis* and their hybrids *S. lucioperca* × *S. volgensis* – Aquacult. Res. 37: 1262-1264.

Nelson J.A. 1982 – Physiological observations on developing rainbow trout, *Salmo gairdneri* (Richardson), exposed to low pH and varied calcium ion concentrations – J. Fish Biol. 20: 359-372.

Ryder R.A 1977 – Effects of ambient light variations on behavior of yearling, sub-adult, and adult walleyes (*Stizostedion vitreum vitreum*) – J. Fish. Res. Bd Can. 34: 1481-1491.

Sandström A. 1999 – Visual ecology of fish – a review with special reference to percids – Fiskeriverket Rapport 2: 45-80.

Siegwarth G.L., Summerfelt R.C. 1992 – Light and temperature effects on performance of walleye and hybrid walleye fingerlings reared intensively – Prog. Fish-Cult. 54: 49-53.

Summerfelt R.C. 1996 – Walleye culture manual – NCRAC Culture Series 101. North Central Regional Aquaculture Center Publications Office, Iowa State University, Ames, 416 p.

Wojda R. 2004 – Carp. Breeding and Rearing. A Breeder's Guide. – Wyd. IRS, Olsztyn, 318 p. (in Polish).

Zakęś Z. 1999 – The effect of body size and water temperature on the results of intensive rearing of pike-perch, *Stizostedion lucioperca* (L.) fry under controlled conditions – Arch. Pol. Fish. 7: 187-199.

Zakęś Z. 2007 – Out- of-season spawning of cultured pikeperch (*Sander lucioperca* (L.)) – Aquacult. Res. 38: 1419-1427.

Zakęś Z. 2009 – Pikeperch. Breeding and Rearing. A Breeder's Guide. – Wyd. IRS, Olsztyn, 203 p. (in Polish).

Zakęś Z., Szczepkowski M. 2004 – Induction of out-of-season spawning of pikeperch, *Sander lucioperca* (L.) – Aquacult. Int. 12: 11-18.

Zakęś Z., Szkudlarek M., Woźniak M., Demska-Zakęś K., Czerniak S. 2003 – Effects of feeding regimes on growth, within-group weight variability, and chemical composition of the juvenile zander, *Sander lucipoperca* (L.) body – EJPAU 6(1): http://www.ejpau.media.pl/volume6/issue1/fisheries/art-04.html

## Streszczenie

### Wpływ natężenia oświetlenia na efekty podchowu juwenalnego sandacza, *Sander lucioperca* (L.) w obiegach recyrkulacyjnych

Celem badań było porównanie wpływu różnych warunków świetlnych na efekty podchowu juwenalnego sandacza, *Sander lucioperca* (L.) w obiegu recyrkulacyjnym. W eksperymencie I zastosowano oświetlenie 45,1 lx (grupa LI) i 385,7 lx (grupa HI) (początkowa masa ciała – 6,1 g) a w doświadczeniu II światło o natężeniu 1,2 lx (grupa LII) i 8,0 lx (grupa HII) (początkowa masa ciała – 42,2 g). W eksperymencie I wzrost masy ciała, zarówno wartości bezwzględnych i względnych (DGR, SGR) ryb z grupy LI był większy od odnotowanego w grupie HI, w której stosowano wyższe natężenie oświetlenia (385,7 lx) (P < 0,05). W przypadku wartości bezwzględnych ryby z grupy LI osiągnęły przyrosty o 13% wyższe. Porównywane grupy ryb różniły się również istotnie statystycznie przyrostami długości ciała i długości całkowitej (P < 0,05). Nie zaobserwowano różnic w kondycji ryb i zróżnicowaniu wewnątrzgrupowym masy ciała (CV) (P > 0,05). Istotne statystycznie różnice międzygrupowe stwierdzono w efektywności wykorzystania paszy (FCR). Przeżywalność końcowa ryb w analizowanych grupach była na podobnym poziomie (ok. 97%). W eksperymencie II sandacze z grupy LII, podchowywane w basenach oświetlanych światłem o niższym natężeniu (1,2 lx) osiągnęły istotnie wyższe przyrosty masy ciała i długości całkowitej Lt od ryb z grupy HII (8,0 lx) (P < 0,05). Długość ciała, współczynnik kondycji, SGR, CV, FCR i PER były zbliżone w porównywanych grupach (P > 0,05). Nie zaobserwowano zjawiska kanibalizmu. W eksperymencie tym część osobników nie pobierała paszy lub pobierała ilość zaspokajającą pokrycie jedynie podstawowych potrzeb energetycznych. W dniu zakończenia eksperymentu liczebność ryb głodujących ustalono na poziomie od 17,3% (grupa LII) do 27,8% (grupa HII) (P > 0,05). Uzyskane wyniki wskazują, że stosowanie w podchowie juwenalnego sandacza oświetlenia o niskim natężeniu (< 45 lx) jest uzasadnione, ponieważ wpływa korzystnie na behawior i tempo wzrostu ryb, efektywność wykorzystania pasz, a w efekcie implikuje możliwość skrócenia okresu podchowu tego gatunku.