Arch. Pol. Fish.	Archives of Polish Fisheries	Vol. 12	Fasc. 1	71-79	2004

Short communication

EFFECT OF SORTING ON SELECTED REARING FACTORS OF PIKEPERCH *SANDER LUCIOPERCA* (L.)

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ABSTRACT. The aim of the experiment was to determine the effect sorting had on the effectiveness of rearing juvenile pikeperch in recirculation systems. The fish were reared in three groups – small specimens (group S – average body weight (BW) 28.5 g), large specimens (group L – BW 49.6 g), and unsorted specimens (group U – BW 38.8 g). After eight weeks of rearing, the average specific growth rate (SGR) for fish from group S was significantly higher than for those from the groups U and L ($P < 0.05$). A similar pattern was found for the feed conversion ratio (FCR), percentage of stock biomass gain and survival rate. However, there were no statistically significant intergroup differences between values of the rearing factors obtained in group U and in the combined sorted groups (S + L) ($P > 0.05$). Thus, it appears that the sorting of juvenile pikeperch does not improve the rearing effectiveness for this species.

Key words: PIKEPERCH (*SANDER LUCIOPERCA*), SORTING, GROWTH, SURVIVAL, INTERINDIVIDUAL VARIATIONS

Significant size diversity within fish species requires that they be sorted. The main goal of this rearing technique is to obtain maximum weight gain by all individuals and to increase their survival rate, which result in obtaining the maximum biomass (Baardvik and Jobling 1990, Kamstra 1993, Sunde et al. 1998). Sorting separates small and large specimens, thus minimizing the effect of interindividual interaction (Jobling 1995). However, the sorting effect depends on the species, and sometimes it can cause decreased growth rates (Baardvik and Jobling 1990).

Percids are characterized by highly variable individual growth rates. During early developmental stages this leads to intensifying cannibalism (Baras et al. 2003). In order to minimize losses, especially during intensive rearing, the stock must be sorted frequently. The phenomenon of heterogeneous growth is also observed during the rearing of the juvenile stages. Mélard et al. (1996) reported that the body weight of seven-month-old Eurasian perch, *Perca fluviatilis* L. reared in a recirculating system

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ranged from 7 to 89 g (average – 26 g). According to these authors, sorting juvenile perch into three size groups led to the equalization of the growth rates in the reared groups. After some time, the hierarchy phenomenon appeared in all cohorts, and this, in turn, resulted in the faster growth of some specimens. This suggests that the growth rate of particular specimens is not only determined genetically, but that the phenomena of domination and hierarchies in fish stocks might also play roles (Mélard 1995, in Kestemont and Mélard 2000).

Pikeperch, *Sander lucioperca* (L.) is a species, which, in the future, might be able to be reared to commercial size in recirculation systems. During the domestication process of a given species, changes in its behavior can occur, including increased aggression (for a review see Rozzante 1994). Fish are under significant stress during intense production due to increased interindividual interactions (high stock density, competition for food and space), worsening water quality, or procedures linked to cleaning basins, taking fish measurements and sorting (Wedemeyer 1996). The highly variable body sizes attained by individual pikeperch specimens makes sorting them by size necessary. The body weight of a six-month-old pikeperch specimen fed artificial feed in a recirculation system can vary from 6 to 130 g (average – 40 g; Zakęś, unpublished data).

The aim of this experiment was to determine the impact of sorting on the rearing effects (growth, survival rate, stock biomass, intragroup variability) of juvenile pikeperch in a recirculation system.

The material for the study was comprised of summer pikeperch fry reared in earthen ponds and fed artificial feed (Zakęś 1997). In October (fish age about six months), a portion of the material (450 specimens) was measured (total length – Lt ± 1 mm) and weighed (BW ± 0.1 g). The fish body weight distribution was not normal (Shapiro-Wilk test, P = 0.0000, Fig. 1). Individual body weight ranged from 5.8 to 128.6 g (range – 122.8 g; average – 39.0 g; median – 36.4 g; skeweness coefficient – 1.82; variability coefficient CV – 42.03%). The fish were divided into three experimental groups (two replicates of each group): larger (group L; BW > 36.4 g), smaller (group S; BW ≤ 36.4 g) and unsorted fish (group U – 37 and 38 specimens from groups S and L). The fish were placed in 200 l rearing tanks that were part of recirculation systems. The stock density was 75 specimens per tank. The water flow rate was maintained at 3.8-4.0 l min^{-1}. The oxygen concentration at the inlet was maintained at 9.3 mg l^{-1}, while the ammonia level (TAN = NH_4^+-N + NH_3-N) at the outlet did not exceed 0.3 mg TAN l^{-1}. The average water temperature was 22.1 ± 0.1°C. Illumination in the rear-

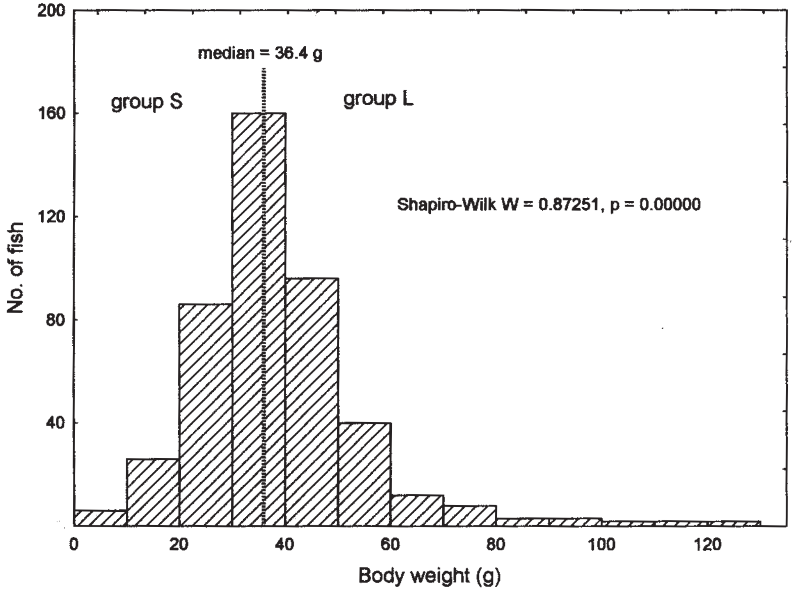

Fig. 1. Distribution of the body weight of juvenile pikeperch (N= 450) used in the current experiment.

ing hall was provided continuously 24 hours per day at an intensity of 30-70 lx. Rearing was conducted for eight weeks.

The fish were fed with the commercial trout granulates NUTRA 1 and NUTRA T (TROUVIT, Nutreco Aquaculture, Holland), which had identical chemical composition (protein 54%, fat 18.0%, carbohydrates 8%, digestible energy 19.5 MJ kg^{-1}). The only difference was the granulate size (Nutra 1 – 1.7 mm, Nutra T – 2.2 mm). The fish in groups S and U were fed with a mixture of NUTRA 1 and NUTRA T at (50/50) and (75/25) proportions, respectively, for the first three weeks. The fish in group L were fed only NUTRA T. Beginning at week four, all the fish were fed NUTRA T. At the beginning of rearing the feed ration was 1.3%; it was later gradually decreased to 1.0% of the stock biomass. Feed was provided continuously by automatic feeders 18 h per day (09:30-03:30).

Measurements of individual fish (BW ± 0.1 g, total length Lt ± 0.1 cm) were taken at the beginning of the experiment and then after four and eight weeks of rearing. The fish were anesthetized with a PROPISCIN (IFI Olsztyn) solution of 1.5-2.0 ml l^{-1} (Kazuń and Siwicki 2001). After weeks one, three, and five, the biomass was determined by weighing and counting the entire stock. This permitted calculating the following rearing factors:

– daily growth rate (DGR, g d^{-1}):

$$DGR = (BW_2 - BW_1)\ \Delta t^{-1}$$

– specific growth rate (SGR, % d^{-1}):

$$SGR = 100\ (ln\ BW_2 - ln\ BW_1)\ \Delta t^{-1}$$

– fish condition coefficient (K):

$$K = 100\ (BW)\ Lt^{-3}$$

– body weight variability coefficient (CV_{BW}, %)

$$CV_{BW} = 100\ (SD\ BW^{-1})$$

– survival rate (S, %):

$$S = 100\ (IN - DN)\ IN^{-1}$$

– feed conversion ratio (FCR):

$$FCR = TFS\ (FB - IB)^{-1}$$

where:

BW_1, BW_2 – initial and final body weights (g); Δt – rearing duration (days); Lt – total lengths (cm); SD – standard deviation of body weight; IB and FB – initial and final stock biomass (g); IN and DN – initial stock numbers and losses (specimens); TFS – total feed weight (g).

In order to determine the differences in intergroup growth rates, condition, intragroup body weight variability (CV_{BW}) and the effectiveness of feed use (FCR), single factor variance analysis (ANOVA) was applied. When statistically significant differences were confirmed ($P \leq 0.05$), the LSD test (STATISTICA PL program) was applied. The percentages were transformed using the *arcsin* function prior to statistical analysis.

No significant intergroup differences in growth rate, expressed in absolute units (g d^{-1}), were confirmed. The average value of the specific growth rate (SGR) for small fish (group S) was significantly higher than for unsorted (group U) and large fish (group L) ($P < 0.05$). There were no statistically significant differences ($P = 0.2448$; Table 1) between the average values of SGR obtained for group U and the sorted groups combined (group S + L). The body weight variability coefficient (CV_{BW}) of the unsorted fish increased throughout the rearing period (from 38 to 45%), while in the sorted groups it did so only in the first four weeks. Over the subsequent four weeks, the CV_{BW} coefficient was stable at ≈ 40% (Fig. 2). Consequently, the CV_{BW} coefficient in group U was significantly higher during the final rearing stage than in groups S

TABLE 1

Pikeperch rearing coefficients at the beginning and end of the experiment
(Group S – small fish, Group L – large fish, Group U – unsorted fish).
Values in rows denoted with the same index do not vary significantly statistically (P > 0.05)

Specification	Experimental groups			
	Group S	Group L	Group U	(Group S + Group L)
Initial body weight (g)	28.5 ± 2.72	49.6 ± 1.8	38.8 ± 0.02	39.1 ± 0.46
Final body weight (g)	67.9 ± 4.92	91.8 ± 3.01	76.0 ± 7.41	79.8 ± 0.92
Daily growth rate (g d^{-1})	0.69^{a} ± 0.04	0.74^{a} ± 0.02	0.65^{a} ± 0.13	0.72^{a} ± 0.01
Specific growth rate SGR (% d^{-1})	1.52^{b} ± 0.04	1.08^{a} ± 0.01	1.18^{a} ± 0.17	1.30^{ab} ± 0.02
Biomass gain (kg m^{-3})	13.4^{a} ± 0.95	15.4^{a} ± 0.78	13.8^{a} ± 2.96	14.4^{a} ± 0.09
Biomass gain (% of initial biomass)	126.9^{c} ± 2.86	83.9^{a} ± 1.33	104.5^{b} ± 6.32	105.4^{b} ± 2.09
Initial condition coefficient – K	0.82^{a} ± 0.02	0.88^{b} ± 0.01	0.86^{b} ± 0.00	0.85^{b} ± 0.01
Final condition coefficient – K	0.89^{a} ± 0.01	0.87^{a} ± 0.02	0.86^{a} ± 0.03	0.88^{a} ± 0.02
Survival (%)	95.4^{a} ± 0.92	100^{b} ± 0.00	98.7^{b} ± 0.00	97.7^{ab} ± 0.46
Feed conversion ratio – FCR	0.82^{a} ± 0.04	1.10^{b} ± 0.03	1.04^{b} ± 0.03	0.96^{ab} ± 0.00

and L, both separately and combined (group S + L) (P < 0.05). The skeweness coefficient in groups U and L was positive (right asymmetry of the fish body weight distribution; the majority of specimens weighed less than the group average). In group S, it was negative (left asymmetry of the fish body weight distribution) and stable throughout the experiment (Fig. 2). At the beginning of the experiment fish from group S were in significantly worse condition than those in groups U and L (0.82 versus 0.86 and 0.88). At the end of rearing no statistically significant differences between groups (P > 0.05) were observed. The fish condition coefficient for groups U and L remained at a similar level, while that for specimens from group S increased from 0.82 (beginning of the experiment) to 0.89 (end of rearing; Table 1). The biomass gain ranged from 13.4 kg m^{-3} (group S) to 15.4 kg m^{-3} (group L) with statistically insignificant differences between the groups. When this was expressed as the percentage of the initial biomass, there were statistically significant differences between the groups (P < 0.05). The value of the feed conversion ratio (FCR) in group S was significantly lower and the most advantageous (P < 0.05; Table 1). It must be emphasized that when the average percentages of biomass gain and FCR coefficients obtained for group U and the sorted groups S and L together were compared there were no statistically significant differences between the groups (Table 1).

During rearing incidental cases of fish death were observed in small specimens

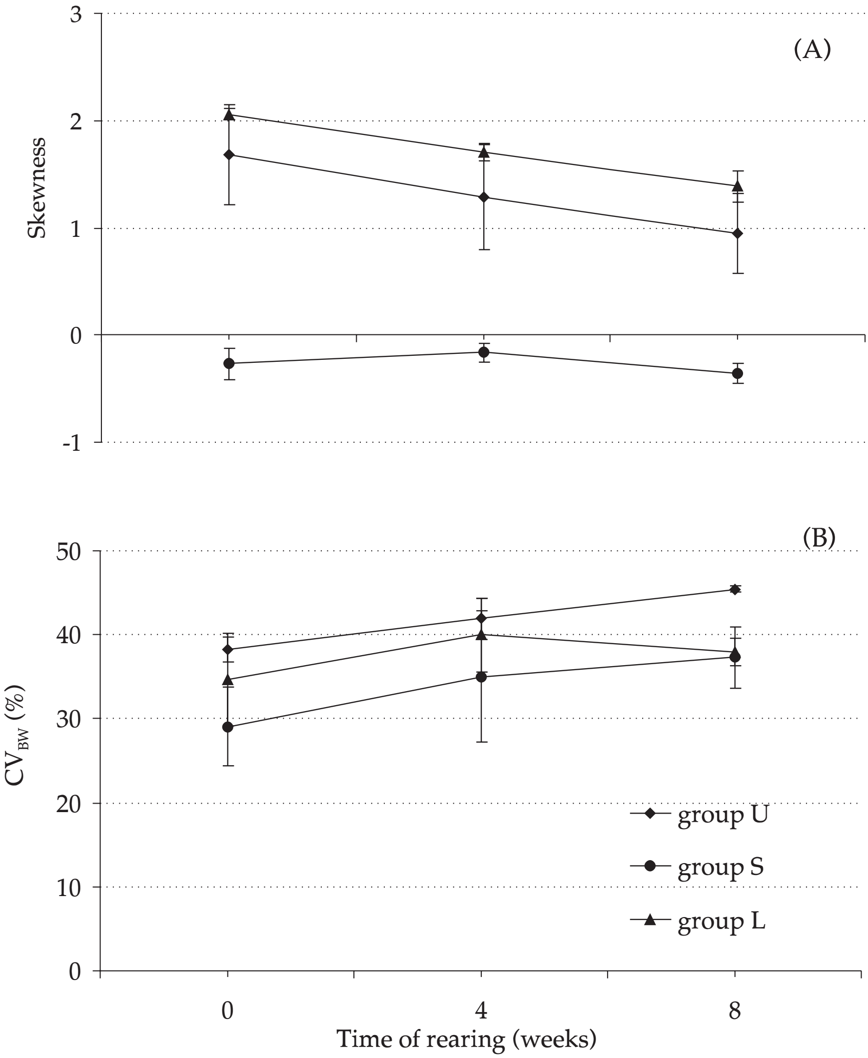

Fig. 2. Skeweness coefficient (A) and body weight variability (B) of juvenile pikeperch in the small (S), large (L), and unsorted (U) groups of fish at 0, 4, and 8 weeks of rearing (average values ± SD).

from groups S and U (BW < 15 g). The survival of smaller fish specimens was significantly lower than in groups U and L ($P < 0.05$). The survival of the groups of unsorted (U) and sorted fish (S + L combined) were compared, but no statistically significant intergroup differences were observed ($P = 0.1168$; Table 1).

Sorting fish according to size is a standard rearing procedure in commercial rearing systems and on fish farms (Popper et al. 1992, Kamstra 1993). Its aim is to simplify feeding (by applying the appropriate feed granulation size and ration) and to limit phenomena of domination and interindividual interaction (Jobling 1985, 1995). The assumption is that separating smaller specimens will protect them from domination by larger specimens, thus improving their growth rates, which results in improved rearing coefficients such as growth rate and increases in stock biomass (production). The results of the current experiment indicated that, in comparison with unsorted (group U) and larger fish (group L), the group of smaller fish (group S) had better SGR values, stock biomass gain (as a percentage of the initial biomass) and FCR. On the other hand, the survival of fish from group S was significantly lower. When the rearing coefficients obtained for the sorted groups were analyzed jointly (groups S + L) and then compared with the results obtained for the unsorted fish, no statistically significant differences between the groups were observed (Table 1). This means that pikeperch sorting did not lead to improved rearing effectiveness. Similar results were obtained when the impact of sorting on the rearing effectiveness of other predatory fish was analyzed (e.g., European eel, *Anguilla anguilla* (L.) (Kamstra 1993); Arctic char, *Salvelinus alpinus* (L.) (Jobling and Reinsnes 1987, Baardvik and Jobling 1990); silver perch, *Bidyanus bidyanus* (Mitchell) (Barki et al. 2000); channel catfish, *Ictalurus punctatus* (Raf.) (Carmichael 1994); turbot, *Scophthalmus maximus* (L.) (Sunde et al. 1998). Studies on perch indicated that sorting causes decreased production. Mélard et al. (1996) also confirmed that the biomass gains in the unsorted fish groups were 5-6% higher than those obtained for the sorted fish.

Dill (1983) proposed the hypothesis that the highest level of interindividual interaction occurs between specimens of similar sizes, and a new hierarchy is established relatively fast in homogeneous (sorted) groups. In effect, this means that sorting does not improve biomass gains in comparison with groups of unsorted fish (Jobling and Reinsens 1987). Baardvik and Jobling (1990) reported that the intensification of interactions between specimens of similar sizes can lead to increased energy expenditure on active metabolism and limit feeding intensity thus reducing growth rates. It was not possible to track the social status of individuals in the current experiment because the fish were not tagged. Conclusions regarding domination phenomena in groups of sorted fish or the stability of the social status of individuals in unsorted groups could only be drawn on the basis of this information.

Intragroup body weight variability in the sorted pikeperch in the large, small and combined (S + L) fish groups was significantly lower than that confirmed on the final day of the experiment in the unsorted group. It should be added that the conditions of the current experiment facilitated a heightened domination phenomenon and intensified size diversity. Such conditions definitely include the relatively small stock size (Abbott and Dill 1989) and the feeding regime based on point delivery (automatic band feeders) and continuous feeding (18 hours per day). These last two factors allow dominant individuals to monopolize the food and can, in effect, over time influence differences in the amount of feed consumed as well as specific growth rates (Houlihan et al. 2001). It is known that phenomena of domination and hierarchies in fish stocks become stronger especially when there is limited food availability (Jobling 1994, Jobling and Koskela 1996, Houlihan et al. 2001). In the current experiment the fish were fed in excess, thus it is highly probable that the impact of food competition resulting from limited food was eliminated. Providing the maximum feed rations might reduce aggression levels and increase interactions between the small and large specimens. As a result, the phenomena of domination and hierarchies in the stock might be significantly masked (Sunde et al. 1998).

The current experiment indicated that sorting juvenile pikeperch did not improve the values of the majority of the analyzed zootechnical indices (e.g., stock biomass gains, feed coefficients). It did, however, limit intragroup variability. Since a full understanding of the impact of the tested factor on interindividual interactions is only possible if the fate of individuals is tracked, future studies must include methods that will allow for this to be done (e.g., testing and choosing the optimum method for tagging pikeperch individuals).

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STRESZCZENIE

WPŁYW SORTOWANIA NA WYBRANE WSKAŹNIKI HODOWLANE SANDACZA *SANDER LUCIOPERCA* (L.)

Celem eksperymentu było określenie wpływu sortowania na efektywność podchowu juwenalnego sandacza w obiegach recyrkulacyjnych. W październiku 2002 r. (wiek ryb około 6 miesięcy), część materiału (450 sztuk) zmierzono (całkowita długość – Lt ± 1 mm) i zważono (BW ± 0,1 g). Rozkład masy ciała ryb nie był normalny (Shapiro-Wilk test, P = 0,0000, rys. 1). Indywidualna masa ciała ryb mieściła się w przedziale od 5,8 do 128,6 g (zakres 122,8 g; średnia – 39,0 g; mediana – 36,4 g; współczynnik skośności 1,82; współczynnik zmienności CV – 42,03%; rys. 1). Ryby podzielono na trzy grupy doświadczalne – ryby małe (grupa S – średnia masa ciała (BW) 28,5 g), duże (grupa L – BW 49,6 g) i niesortowane (grupa U – BW 38,8 g). Sandacza żywiono komercyjnym granulatem pstrągowym NUTRA 1 i NUTRA T (TROUVIT, Nutreco Aquaculture, Holland). W początkowej fazie podchowu dawka paszy wynosiła 1,3%, później zaś była stopniowo redukowana do 1,0% biomasy obsad. Paszę zadawano w systemie ciągłym, za pomocą automatycznych karmników, przez 18 h na dobę (09.30 – 03.30). Po 8 tygodniach podchowu średnia wartość względnego przyrostu masy ciała (SGR) ryb z grupy S okazała się istotnie wyższa od obliczonych w grupie ryb niesortowanych (U) i dużych (L) (P < 0,05; tabela 1). Podobnie korzystniejsze wartości przyjęły: współczynnik pokarmowy pasz (FCR), procentowy przyrost biomasy obsad i wskaźnik przeżywalności. Jednak porównanie wartości tych wskaźników hodowlanych uzyskanych w grupie U i grupach ryb sortowanych S i L potraktowanych łącznie (S + L) nie wykazało istotnych statystycznie różnic międzygrupowych (P > 0,05). Współczynnik zmienności masy ciała ryb niesortowanych (CV_{BW}) wzrastał w czasie całego podchowu (od 38 do 45%), zaś w grupach sortowanych tylko w pierwszych czterech tygodniach. W kolejnych czterech tygodniach współczynnik CV_{BW} utrzymywał się na stabilnym poziomie ≈ 40% (rys. 2). W efekcie, w końcowej fazie podchowu współczynnik CV_{BW} w grupie U był istotnie wyższy niż w grupach S i L traktowanych oddzielnie i łącznie (S + L) (P < 0,05).