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EFFECTS OF FEEDING REGIMES ON GROWTH, WITHIN-GROUP WEIGHT VARIABILITY, AND CHEMICAL COMPOSITION OF THE JUVENILE ZANDER, *Sander lucioperca* (L.), BODY

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ABSTRACT

The study was aimed at determining effects of feed ration on growth, within-group variability, and chemical composition of the body of juvenile zander (*c*. 25 g initial individual weight) grown out in a recirculation system for 42 days. The fish were fed a commercial pelleted trout feed offered at three rations (Group L: 1.2% of stock biomass; Group M: 1.6% of stock biomass; and Group H: 2.0% of stock biomass). Each experimental treatment involved two replicates. The feed rations used were found to significantly ($p < 0.01$) affect fish growth: the mean body weight on termination of the experiment was 47.9, 60.3, and 69.4 g in Group L, M, and H, respectively. Statistically significant differences were revealed also in SGR and fish condition. The most favourable food conversion ratio (FCR) and protein efficiency ratio (PER) were found in Group M, the between-group differences being significant as well ($p < 0.05$). The feeding rations applied did not produce a significant effect ($p > 0.05$) on the within-group variability in body weight (CV_{BW}). However, it was only in Group L that the within-group variability was observed to increase, a tendency to decrease being observed in the remaining two groups. The feed

rations applied were found to significantly affect the chemical composition of the entire body, muscles, and viscera of the juvenile zander. The largest differences ($p < 0.01$) involved fat content, the highest contents being recorded in Group H.

Key words: zander (*Sander lucioperca*), feed ration, growth, within-group variability of body weight, body chemical composition.

INTRODUCTION

Knowledge on food requirements of a species is one of the basic determinants of using that species in a broadly-understood aquaculture. Previous research has demonstrated the fish growth rate to depend not only on the feed chemical composition, but also on the manner the food is administered (manual, automatic), feeding frequency, feeding period, and feed ration [9, 12, 13, 14]. Not only does the feeding regime affect the growth rate, but it may also influence the within-group size variability in fish [6, 7, 11, 20]. From the standpoint of fish culturist, it is very important that growing-out techniques be developed such that the within-group variability of stocks is maximally limited. Low variability reduces the time necessary to sort the fish, thereby limiting effects of stress. Handling stress is known to considerably reduce the time of effective feeding, and thus to reduce the fish growth rate and to extend the duration of the production cycle [1, 25]. Effects of restrictive feeding on within-group variability depend obviously on the level of the restrictions, but are also dependent on fish species, and even on the individual development stage. Research on salmonids showed restrictive feeding to increase the within-group variability. Feeding restriction result in increased inter-individual competition [15, 19]. Under such conditions, some individuals may monopolise the available food and consume it at amounts sufficient for their maintaining a fast growth rate. Most individuals then have to take up small amounts of food only, some being forced to starve and loose weight as a result. As the duration of feeding restrictions is increased, the fish size variability increases progressively [8, 15].

The zander, *Sander lucioperca* (L.), is a species that can be successfully grown out in recirculation systems, the cultures involving commercially available pelleted trout feeds [28]. Research on the effects of feeding regime on metabolic rates of the juvenile zander showed the factor in question to significantly affect ammonia excretion and oxygen demand of the species. Variations in feed rations were reflected in changes of the ammonia quotient (AQ), i.e., they affected the contribution of protein to the total energy expenditure [27]. The experiment described in this paper was aimed at determining feeding regime effects on growth rate, within-group variability, and chemical composition of the body of juvenile zander grown out in a recirculation system.

MATERIALS AND METHODS

Materials and conditions of culture

The experiment involved juvenile European zander of *c.* 25 g individual body weight and 14.3 cm total length (TL). The initial stocking density was 57 individuals per tank (stock biomass: 7.24 to 7.28 kg m^{-3}; Table 1). The fish were grown out in two recirculation systems, each consisting of three 0.2 m^3 grow-out tanks. The tank water flow rate during the six weeks of the experiment was gradually increased from 3 l min^{-1} (1.2 exchange h^{-1}) to 6 l min^{-1} (1.8 exchange h^{-1}). Water temperature oscillated around values optimal for zander, i.e., 22.3 (± 0.2)°C in the inlet and 22.2 (±0.1)°C at the outlet. Contents of total ammonia nitrogen (TAN = NH_4^+-N + NH_3-N) and nitrites (NO_2-N) were determined in the intake to and at the outlet from the tanks at two-day intervals. Water samples were collected 5-6 hours after the feeding had started, i.e., during a period of a substantial feeding-related increase in metabolite contents during the 24-h cycle [27]. The total ammonia nitrogen and nitrite contents did not exceed 0.09 mg TAN l^{-1} and 0.015 mg NO_2-N (in the inlet) and 0.39 mg TAN l^{-1} and 0.025 mg NO_2-N l^{-1} (at the outlet), respectively. Dissolved oxygen contents (DOC) were measured with a computer-interfaced (RS-485 Serial Interface) Model 9100 Dissolved Oxygen Analyzer (Roice Instrument Corporation, LA, USA). In each tank, DOC was recorded in the inlet and at the outlet every 15 min. DOC values in the inlets and at the outlets did not decrease below 7.3 and 4.6 mg l^{-1}, respectively. Water pH was 7.8 and 7.6 in the inlet and at the outlet, respectively. The culture room was lit, at a stable intensity, round the clock. The light intensity just above the tank water surface was 40 - 80 lx. The tanks were cleaned once a day, an hour before the feed was to be offered (at 08:00).

Table 1. Growth, condition, size variability, and protein utilisation efficiency of juvenile zander fed different feed rations (Group L: 1.2; Group M: 1.6; Group H: 2.0% of stock biomass) (mean ± SD); data in a row, marked with identical index, are not statistically different (p > 0.05)

Parameter	Experimental treatment		
	L	M	H
Initial body weight (g)	25.4^{a} (± 0.32)	25.5^{a} (± 0.03)	25.6^{a} (± 0.09)
Final body weight (g)	47.9^{a} (± 0.26)	60.3^{b} (± 0.45)	69.4^{c} (± 0.29)
Body weight gain (g d^{-1})	0.53^{a} (± 0.01)	0.83^{b} (± 0.01)	1.04^{c} (±0.03)
Specific growth rate, SGR (% d^{-1})	1.52^{a} (± 0.04)	2.05^{b} (± 0.02)	2.38^{c} (± 0.01)
Initial biomass (kg m^{-3})	7.24^{a} (± 0.09)	7.26^{a} (± 0.01)	7.28^{a} (± 0.00)
Final biomass (kg m^{-3})	13.63^{a} (± 0.07)	17.03^{b} (± 0.08)	19.79^{c} (± 0.08)
Biomass gain (kg m^{-3})	6.39^{a} (± 0.16)	9.76^{b} (± 0.07)	12.50^{c} (± 0.07)
Initial condition coefficient, K	0.85^{a} (± 0.01)	0.86^{a} (± 0.00)	0.86^{a} (± 0.04)
Final condition coefficient, K	0.82^{a} (± 0.00)	0.89^{b} (± 0.01)	0.92^{b} (± 0.01)
Initial body weight coefficient of variation, CV_{BWi} (%)	29.02^{a} (± 4.45)	27.32^{a} (± 2.74)	29.89^{a} (± 0.38)
Final body weight coefficient of variation, CV_{BWf} (%)	33.03^{a} (± 5.87)	25.82^{a} (± 3.70)	27.08^{a} (± 2.45)
CV_{BWf} / CV_{BWi}	1.14^{a} (± 0.03)	0.94^{b} (± 0.04)	0.91^{b} (± 0.06)
Food conversion ratio, FCR	0.77^{ab} (± 0.02)	0.75^{a} (± 0.01)	0.79^{b} (± 0.00)
Protein efficiency ratio, PER	2.39^{a} (± 0.06)	2.49^{b} (± 0.02)	2.34^{a} (± 0.01)

Feed and feeding

The fish were fed a 2.2 mm pellet diameter commercial pelleted trout feed NUTRA T (TROUVIT, Nutreco Aquaculture, Holland). According to the manufacturer's data, the feed contained 54% protein, 18% fat, and 8% carbohydrates, its declared energy content being 19.5 MJ kg^{-1} (digestible energy). The feed was administered with timed conveyor feeders operated for 19 hours each day (from 09:00 until 04:00). The following three feed rations were used: 2.0% of stock biomass (Group H): 1.6% of stock biomass (Group M); and 1.2% of stock biomass (Group L). Each experimental treatment (group) involved two replicates. As of the second week of the experiment, the feed rations were increased each day by an amount equal to the fish weight gain, as calculated from the average gains obtained the previous week.

Growth data collection and chemical analyses

The fish were individually weighed (body weight, BW; to ± 0.1 g) and measured (total length, TL; to ± 0.1 cm) at the beginning of the experiment and after 2, 4, and 6 weeks of culture. The fish were anesthetized in a 1.5 - 2.0 ml l^{-1} PROPISCIN (IFI Olsztyn) solution [18]. After 1, 3, and 5 weeks, the biomass was determined by weighing the entire stocks.

The data were used to calculate:

- 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):
  $K = 100\ (BW)\ TL^{-3}$
- coefficient of variation of body weight (CV_{BW}, %) at the beginning (CV_{Bwi}) and on termination (CV_{BWf}) of the experiment:
  $CV_{BW} = 100\ (SD\ BW^{-1})$
- food conversion ratio (FCR):
  $FCR = (FB - IB)\ TFS^{-1}$
- protein efficiency ratio (PER):
  $PER = (FB - IB)\ FPS^{-1}$

where:

$BW_{1,2}$, initial and final body weight (g); Δt, duration of the experiment (days); TL, total length (cm); SD, standard deviation of mean body weight; IB and FB, initial and final stock biomass (g), respectively; TFS, total feed served (g); FPS, feed protein served.

On the day the experiment began, a sample of 20 fish (=initial sample) was collected to determine the body chemical composition. On termination of the experiment, samples of 10 fish (final samples) each were collected from each tank. The fish were put to sleep with a 4 ml l^{-1} PROPISCIN solution and decapitated. Each sample was divided into two equal sub-groups (initial sample: 2 x 10 fish; each final sample: 2 x 5 fish). Each fish was separately minced, homogenised, and freeze-dried. Contents of total protein (Kjeldahl technique), raw fat (Soxhlet technique), water, and raw ash were determined [22]. Chemical composition of each of the 10 individuals in the initial sample and of 5 individuals from each final sample was determined. The remaining fish sub-groups provided muscles and viscera for relevant chemical analyses.

Statistical treatment

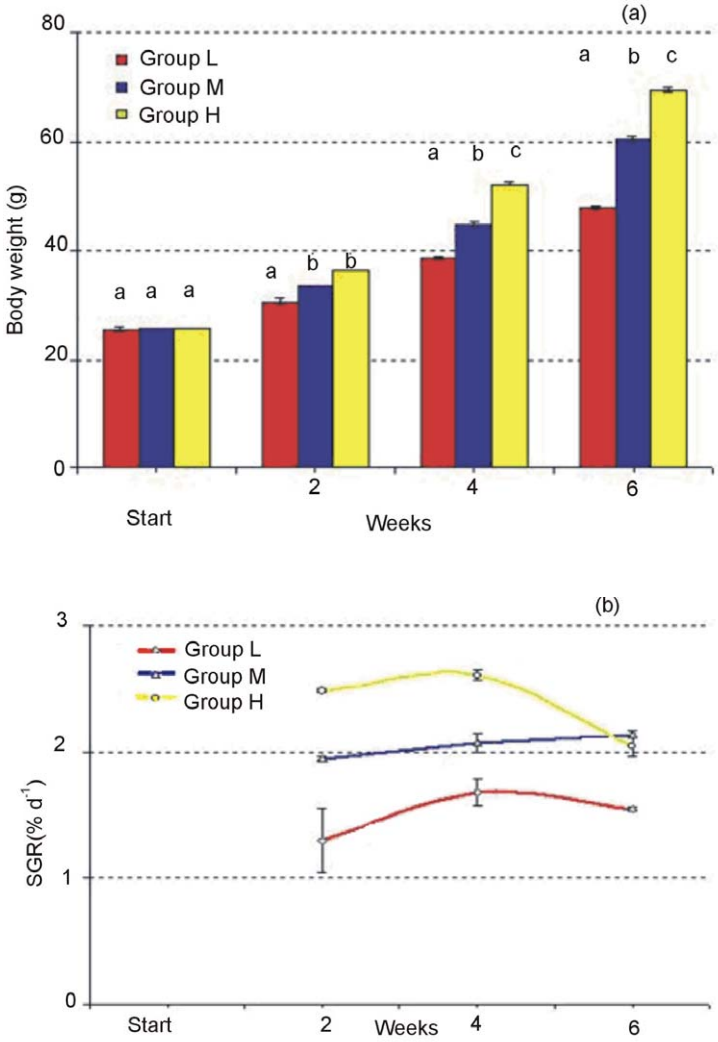
One-way analysis of variance (ANOVA) was used to test for statistical significance ($p \leq 0.05$) of differences in growth rate, condition, within-group body weight variability (CV_{BW}), and chemical composition of the body of fish fed different rations of the feed. Whenever significant differences were revealed, Duncan's multiple range test was applied. The statistical treatment involved the use of STATISTICA PL computer software. Mean values of each parameter for each replicate were determined and used in subsequent statistical analyses (N = 2). Data expressed as percentages (SGR, CV_{BW}, contents of protein, fat, ash, and water) were *arcsin*-transformed prior to statistical testing. Linear regression was used to analyse changes in CV_{BW} during the experiment.

RESULTS

Fish growth and efficiency of feed utilisation

Different feed rations were found to significantly affect growth of the zander (Table 1; Fig. 1). After two weeks, the Group M and H fish attained significantly ($p < 0.05$) higher weight gains. After four weeks, highly significant differences ($p < 0.01$). were recorded between all the groups. On termination of the experiment, the Group M and H fish showed their mean weight to be higher than that of Group L fish by 26 and 45%, respectively.

Fig. 1. Weight gain (a) and specific growth rate (b) of juvenile zander (mean ± SD) grown out for 42 days in recirculation system and fed feeds applied in three rations (Group L: 1.2; Group M: 1.6; and Group H :2.0% of stock biomass). Data in panel (a), marked with identical letters are not significantly different (p > 0.05)



The specific growth rate (SGR) depended on feed rations used. Throughout the experiment, SGR values were found to range from 1.52% (Group L) to 2.38% (Group H), the between-group differences being statistically significant (Table 1). In Groups L and M, SGR values were uniform, while in Group H (the highest feed ration) SGR significantly decreased during the last two weeks (Fig. 1).

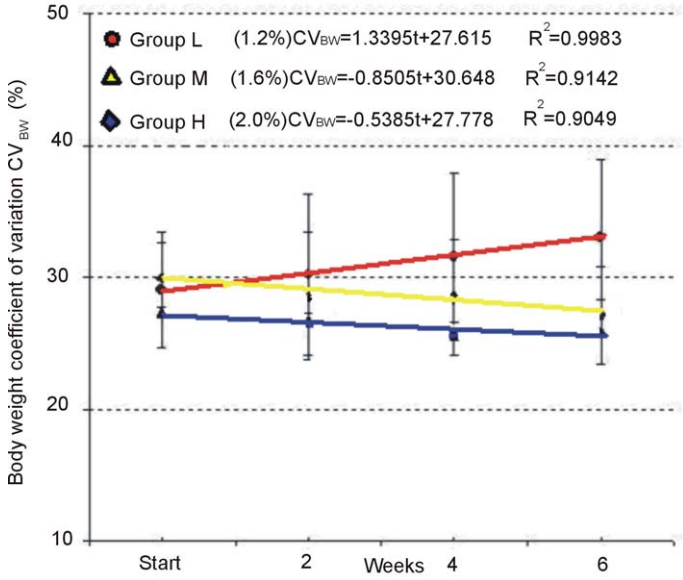
During the experiment, it was only the Group L fish that showed their condition to deter-iorate. As a result, during the final stage of the experiment, the condition coefficient K was significantly higher in Groups M and H, compared to Group L (Table 1).

The food conversion ratio (FCR) was close to 0.8 in all the groups. The differences between them, however, proved statistically significant ($p < 0.05$): FCR was significantly lower in Group M than in Group H (Table 1). This was also reflected in PER, most favourable and significantly ($p < 0.05$; Table 1) higher in that group.

Within-group variability of fish body weight

Different feed rations proved to exert no statistically significant effect on the coefficient of body weight variation, CV_{BW} ($p > 0.05$, Table 1). However, the coefficient was observed to have increased (by about 4%) in Group L and to have decreased in the two remaining groups (M and H). Linear regression equations describing trends of CV_{BW} changes in time were highly significant ($R^2 > 0.9$; Fig. 2). The increase in within-group variability among the fish fed the lowest feed ration was confirmed by the CV_{BWf}/CV_{BWi} ratio, higher than 1 and significantly higher than the values calculated for the two remaining groups ($p < 0.05$; Table 1).

Fig. 2. Changes in coefficient of body weight variation in juvenile zander (mean ± SD and trends) grown out for 42 days in recirculation system and fed feeds applied in three rations (Group L: 1.2; Group M: 1.6; and Group H :2.0% of stock biomass). (*t* in regression equations = weeks of rearing)



Body composition

The protein level in the entire fish body was, in all the groups, significantly higher on termination of the experiment than at its start. The highest value was recorded in Group L, the between-group differences being statistically significant ($p < 0.05$; Table 2). No effect of feed ration on the muscle protein content was found, while the differences between the viscera protein level were significant ($p < 0.05$). The protein content was inversely proportional to the feed ration and formed the following series: Group L > Group M > Group H (Table 2).

Table 2. Table 2. Chemical composition of juvenile zander body (% wet weight; mean ± SD; N = 2) at the beginning of the experiment and after 42 days of grow-out in recirculation system, fed feed applied in three rations (Group L: 1.2; Group M: 1.6; Group H: 2.0% stock biomass). Data in a row, marked with identical letters, are not significantly different (p > 0.05)

Initial sample		Experimental treatments		
		L	M	H
Total protein				
Entire fish	15.2 (0.3)^{a}	18.3 (0.4)^{c}	17.3 (0.3)^{b}	17.2 (0.1)^{b}
Muscles	16.2 (0.2)^{a}	19.2 (0.3)^{b}	19.3 (0.4)^{b}	19.3 (0.0)^{b}
Viscera	10.9 (0.1)^{b}	15.0 (0.2)^{d}	11.5 (0.3)^{c}	9.9 (0.1)^{a}
Fat				
Entire fish	9.9 (0.4)^{a}	9.8 (0.5)^{a}	10.1 (0.2)^{a}	12.2 (0.1)^{b}
Muscles	8.4 (0.3)^{b}	7.9 (0.2)^{ab}	7.7 (0.3)^{a}	7.6 (0.4)^{a}
Viscera	34.6 (0.4)^{c}	19.2 (0.2)^{a}	32.8 (0.5)^{b}	44.0 (0.3)^{d}
Water				
Entire fish	72.2 (0.5)^{a}	68.4 (0.3)^{b}	68.5 (0.3)^{b}	68.0 (0.2)^{b}
Muscles	73.3 (0.4)^{a}	69.7 (0.5)^{b}	69.8 (0.4)^{b}	70.1 (0.4)^{b}
Viscera	52.2 (0.3)^{b}	62.7 (0.5)^{a}	51.8 (0.2)^{b}	43.6 (0.4)^{c}
Ash				
Entire fish	2.8 (0.1)^{a}	3.2 (0.3)^{b}	3.2 (0.2)^{b}	3.4 (0.3)^{b}
Muscles	2.1 (0.1)^{a}	2.9 (0.2)^{b}	2.9 (0.0)^{b}	2.7 (0.2)^{b}
Viscera	2.1 (0.1)^{a}	2.8 (0.1)^{b}	2.8 (0.1)^{b}	2.6 (0.3)^{b}

The highest fat content in the entire fish body was recorded in Group H. The content differed significantly from that revealed both in the initial sample and in Groups L and M ($p < 0.05$; Table 2). The fish muscle fat content

was similar in all the groups and ranged within 7.6 - 7.9% ($p > 0.05$). The largest differences in fat content involved viscera, the fat content of which increased with increasing feed ration: Group H showed twice as much fat in the viscera as Group L (Table 2).

DISCUSSION

Increase in feed ration results in acceleration of fish growth which is limited by the maximum ration, i.e., the maximum amount of food the fish are capable of taking up [14]. This generalisation is borne out by the results of the experiment described. The highest growth rate (SGR of 2.38% d^{-1}) was observed in the group fed a ration equal to 2.0% BW d^{-1}. A feed ration guaranteeing optimal feed utilisation is, however, lower than a ration necessary for the maximum growth [23]. In the present study, the feed was most efficiently utilised by the fish fed an intermediate ration (1.6% BW d^{-1}), as evidenced by the best FCR and PER values (Table 1). The ration in question may be regarded as optimal for the juvenile zander of 25 - 70 g individual body weight. FCR < 1 and PER > 2.5 obtained in this experiment confirm that zander assimilated commercial pelleted feeds well. Efficiency of utilisation of those feeds is not basically different than that shown by juvenile salmonids and is better than in other percids, e.g., the European perch (*Perca fluviatilis* L.) [6] and the yellow perch (*P. flavescens* Mitch.) [2]. Thus the species tested in this work is potentially amenable to being , in the near future, an object of intensive production in recirculation systems. This prediction is supported by the fast growth rate observed. During the period of study, the specific growth rate (SGR) of fish fed rations equal to 1.6 and 2.0% BW d^{-1} was higher than those fed rations of 2% d^{-1}. Other experiments aimed at exploring possibilities of rearing the species in recirculation systems and with commercial pelleted trout feeds produced fish weighing 1 kg after about 700 days (fish age: 700 days post hatch, D700). Mean FCR, daily weight gain, and SGR during the grow-out phase of culture (D151 - D800) were 1.6, 1.6 g d^{-1}, and 0.75% d^{-1}, respectively [28].

Condition of the fish in the lowest ration group (1.2% BW d^{-1}) was significantly lower than that shown by the fish fed rations of of 1.6 and 2.0% BW d^{-1}. Changes in the condition coefficient K are reflected in the body chemical composition; this is particularly pronounced in the fat content [10]. The pattern was confirmed by the results of the present experiment. The fat content in the fish showing the lowest K was significantly lower than the value recorded in the group with the best condition (Tables 1, 2). A feeding regime is one of the major determinants of fish body composition, the most significant effects being those of the fat content [3, 24]. This pattern was borne out by the present study. It should be, however, emphasised that no significant differences in muscle fat content were revealed between the groups, the largest differences involving the viscera. The viscera fat content in the fish fed the ration equal to 2.0% BW d^{-1} was more than twice that of the fish fed 1.2% BW d^{-1} (Table 2). The fat storage process is species-specific. This specificity involves both profiles of the fatty acids stored and the storage sites (tissues, organs) [12]. As shown by this study, the excess of fat in zander, as in the juvenile perch fed artificial feed [26], is stored mainly in the viscera.

A tendency towards large variations in growth rate between various individuals, resulting in a large size variability, is not favourable for the aquaculture outcome. Appropriate manipulation of external factors, i.a., feed ration, feeding frequency, and stock density allows to compensate, to some extent, for intra-individual size variability [14]. Effects of various external factors on stock heterogeneity are, however, seen in every species [6, 17, 19, 21]. The feed rations applied in this experiment did not produce any significant effect on the within-group variability of body weight. It may be presumed that, to some extent, the lack of significant effect was a result of a wide scatter of the coefficient of body weight variation (CV_{BW}) between replicates in each experimental treatment (Table 1). It should be, however, stressed that it was only in the group fed the ration equal to 1.2% BW d^{-1} that the CV_{BW} value increased ($CV_{BWf} / CV_{BWi} > 1$), a decrease being observed in the remaining groups fed rations equal to 1.6 and 2.0% BW d^{-1} ($CV_{BWf} / CV_{BWi} < 1$, Table 1). This means that restrictive feeding enhanced competition for food. The amount of food taken up by various individuals varied and the stock evolved a domination structure and hierarchy. As a result, the within-group variability tended to intensify. A full picture of restrictive feeding effects could be obtained in a study designed to follow fish growth and evolution of the stock hierarchy structure by following fates of individual fish. Such studies, however, bear certain constraints which usually involve a lower stock density; it is known that stock hierarchy establishment and within-group variability is related to stock density through the so-called group effect [8, 14]. It can be generally contended that zander responds to feeding restrictions in a manner similar to responses observed in most salmonids [4, 7, 16, 17, 19]. A completely different nature of the feed ration-intra-group body weight variability was observed in juvenile perch of *c*. 10.5 g initial individual body weight [6]: during an 84-day-long grow-out period: the fish fed lower feed rations (1 and 2% BW d^{-1}) showed a decrease in CV_{BW} , while in the group fed the ration of 3% BW d^{-1} the coefficient was maintained at a stable level and was significantly higher on termination of the experiment. Reduction of the within-group variability in perch stocks fed with lower intensity could be, according to the authors referred to, explained by sexual dimorphism observed in the species

growth. A higher feed ration (3% BW d^{-1}) allowed the females to attain the maximum potential growth rate, which resulted in maintenance of a higher within-group variability. No sexual dimorphism in growth rate was observed in juvenile zander (BW of 20 - 55 g), kept in an intensive culture [5]. This perhaps is the reason why the nature of the relationship between feed ration and within-group variability in body weight is different in the species. It should be, however, remembered, that the differences observed could have been related to different feeding schedule (continuous feeding in this study *vs*. 4 rations per day in the perch). It has been assumed that point-source feeding with automatic feeders, as used in this experiment, favours resource (food, space) appropriation by the dominant individuals. This phenomenon is particularly pronounced when the resource in question is scarce; under such conditions, the fish size variability is observed to increase with time [4, 7, 8, 14, 15].

CONCLUSIONS

The study described demonstrates that the growth, body chemical composition (particularly fat content), and within-group variability of zander kept in a recirculation system can be modelled by appropriate manipulation of feed rations. It may be presumed that, should a more restrictive feeding regime be applied, certain processes would be expressed with a higher intensity. In this experiment, it was only the lowest feed ration (equal to 1.2% BW d^{-1}) that could be considered restrictive. It is therefore purposeful to analyse a wider spectrum of feeding restriction effects, particularly with respect to the within-group variability and stock hierarchy establishment.

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