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Some Aspects of the Development of Feeding Relationships in Groups of Young Sturgeons (Acipenseridae) during Artificial Rearing*

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Young sturgeons typically feed on benthos (Shorygin, 1952; Zheltenkova, 1964; Polyaninova, 1968). The search for food and feeding are carried out while in constant contact with the bottom. Therefore it is possible to suggest that under conditions of artificial rearing, particularly at high densities, the size of the feeding area has a great importance in creating optimal conditions for feeding.

Hence a clarification of the effects of the size of feeding areas (also changes in distribution of food in association with these areas) on behavior and on features of growth in a confined space was the goal of the present work.

Materials and Methods

Two series of experiments were conducted. In the first series, young of the sevryuga, *Acipenser stellatus*, 4 months of age, with an average length of 16.5 cm and weight of 12.5 g, were selected; the length of the test was 3 months. Two groups of young, 10 individuals in each, were maintained in aquaria of the same volume (60 liters) which differed by a factor of two in the area of bottom (Fig. 1 (A)).

In the second series of tests, young of the Russian osetr, *A. gueldenstaedti*, at an age of 15 days, average length 30 mm, and weight 0.2 g, were selected. Two groups of these fish, 25 individuals in each, were maintained over the course of 4 months in two identical aquaria (200 liters each). Into one of the aquaria was placed a device (so-called shelving) that enlarged the surface area in comparison with the other aquarium by a factor of 3 (Fig. 1 (B)).

The fish were fed larvae of chironomids two times per day; the daily ration was 4 percent of the weight of the young in each of the groups. We tried to distribute the food uniformly over the entire feeding area. Every three weeks after the beginning of the test, the young of both species were weighed and measured, and the ration computed. According to the results obtained, histograms of the distributions of the young according to size-weight categories were made; this allowed us to trace the dynamics of changes in their indices.

Visual observations were conducted in order to study features of behavior of the young under conditions of provision of feeding area. We determined the relative time spent by the fish on the bottom and in the water column; the number

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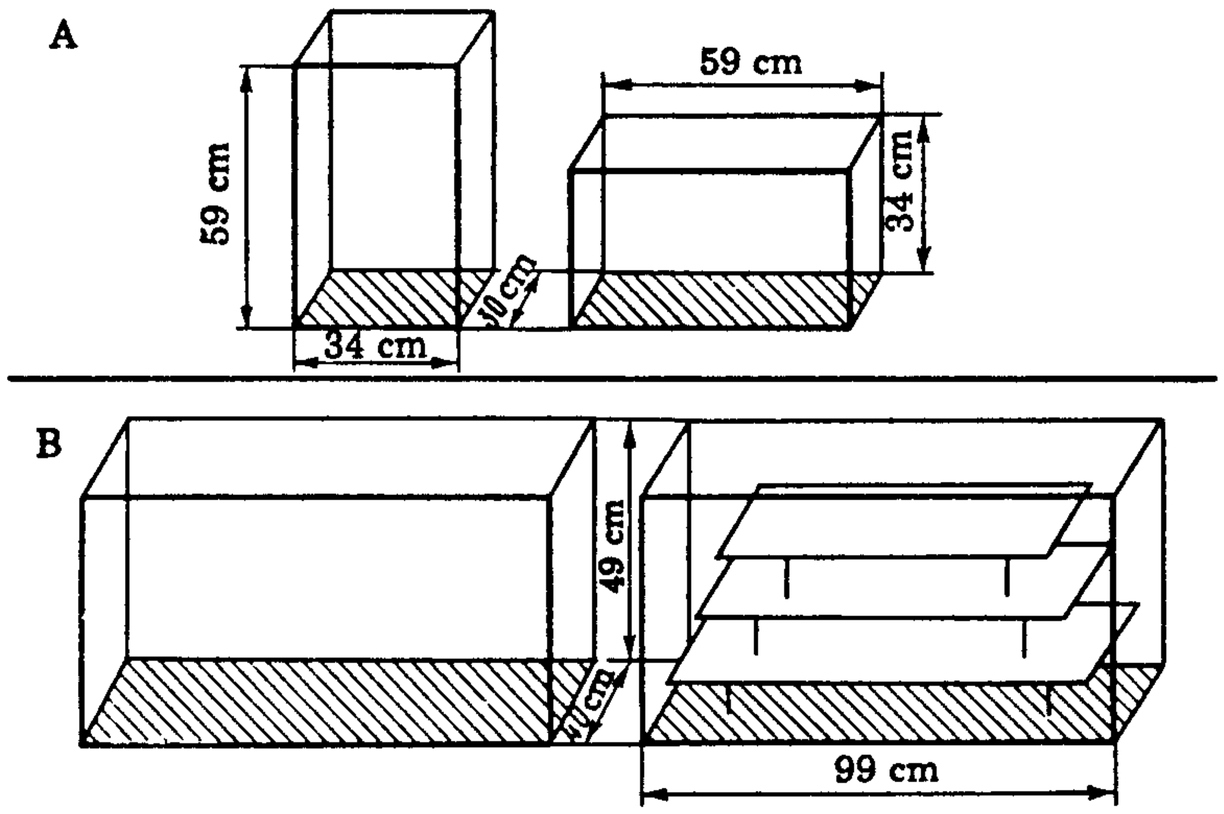

Fig. 1. Schematics of the experimental aquaria: (A) in the tests with young sevryuga; (B) in the tests with young osetr.

of encounters of each individual with another per unit of time was computed. All the observations were conducted on fish of three trophic conditions: starved, feeding, and satiated.

In order to establish whether differences existed in the behavior of the fish, which differed greatly in size, observations were conducted separately on the largest and smallest individuals.

Results and Discussions

Measurements of the weights and lengths showed that length and weight increase of the young in aquaria with different feeding areas differed. Thus, whereas in sevryuga raised in the aquarium with a smaller bottom area the increase in weight at the end of the test was 0.3 g and the increase in length 1.6 cm, for young raised in an aquarium with a larger bottom area, these indices were, respectively, 3.3 g and 3.7 cm. Thus the increase in weight in the first group was 11 times less than in the second group, and the increase in length 2.3 times less (Fig. 2).

Weighing and measurement of young osetr also showed that under conditions of increased feeding area, the fish grew much more rapidly. The increases in weight and length of these fish were, in the smaller feeding area, 6.5 g and 87 mm, and in the larger area 9.7 g and 102 mm. In this case, the differences in weight increase and length increase were, respectively, 1.5 and 1.2 times (Fig. 3).

An analysis of the histogram of the distribution of the young by size-weight categories indicates that the groups of fish raised on large feeding areas differed in the more uniform distribution according to weight and length in the variational series (Figs. 4 and 5).

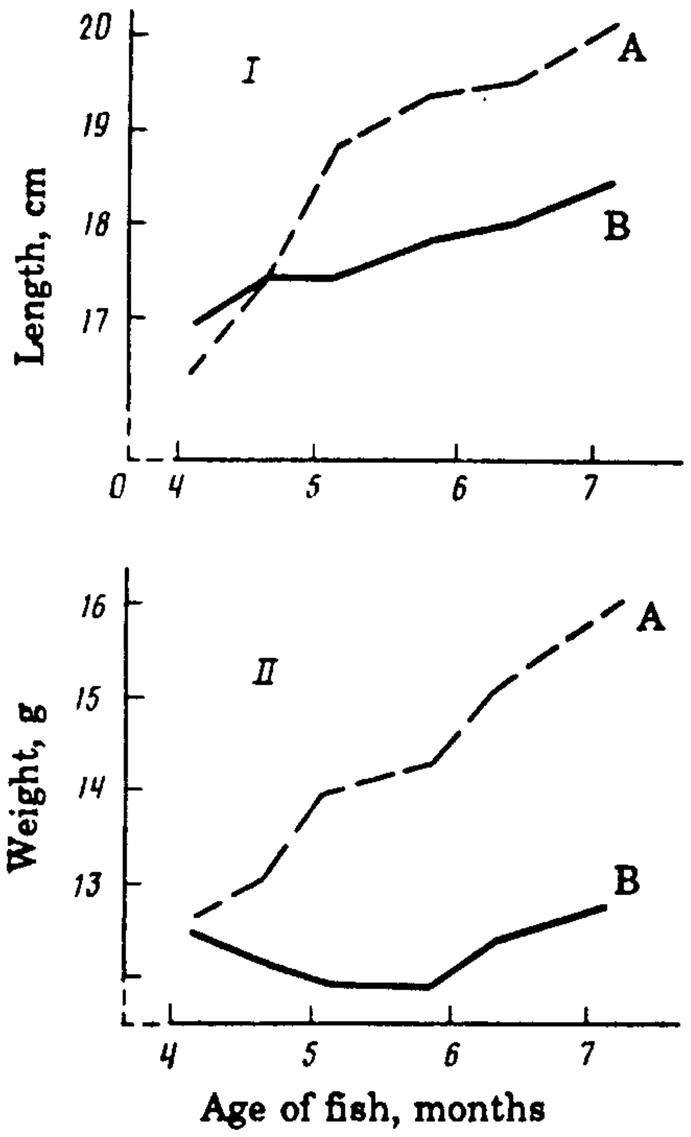

Fig. 2.

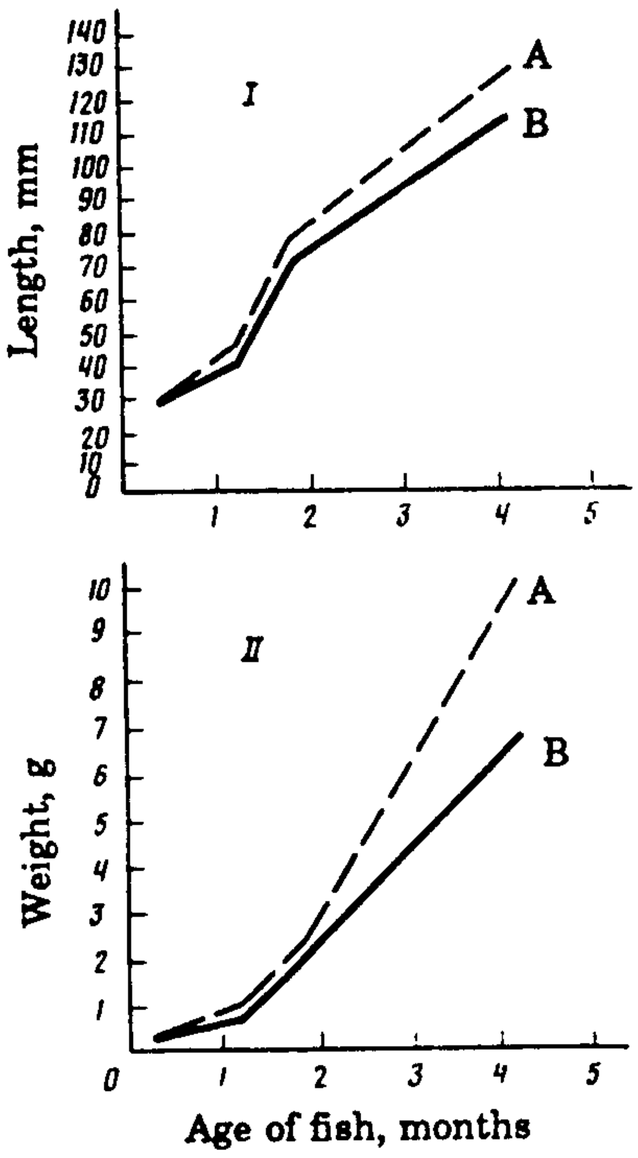

Fig. 3.

Fig. 2. Age-related changes in length (I) and weight (II) of the young sevryuga: (A) as a result of the larger areas; (B) as a result of the smaller areas.

Fig. 3. Age-related changes in length (I) and weight (II) of young osetr: (A) as a result of the larger areas; (B) as a result of the smaller areas.

As the observations on the distribution of the young in the aquaria showed, the fish stayed on the bottom for a considerable part of the time (from 22 to 89 percent). In this case, large differences in these indices were observed as a function of the availability of feeding area and as a function of the trophic condition of the fish. Thus young sevryuga that were maintained on the smaller feeding area stayed on the bottom under starvation condition 1.8 times less (in terms of time) than did the fish on the larger feeding areas; during feeding, 1.1 times less (in terms of time); and in a satiated condition, 1.4 times less (Table 1).

Such phenomena in distribution were also observed in young of the osetr: in all trophic states, they remained on the bottom for considerably less time in the aquarium with smaller feeding area than under conditions of the larger feeding area. In this case, it was determined that the larger individuals spent a larger amount of time on the bottom than did the smaller individuals. This was expressed more strongly on the smaller feeding areas (Table 2).

A count of the encounters between fish showed that the number of these also depended, to a large extent, both on the trophic state of the fish and also on the sizes of the feeding areas. In starved fish, both on the smaller and larger feeding

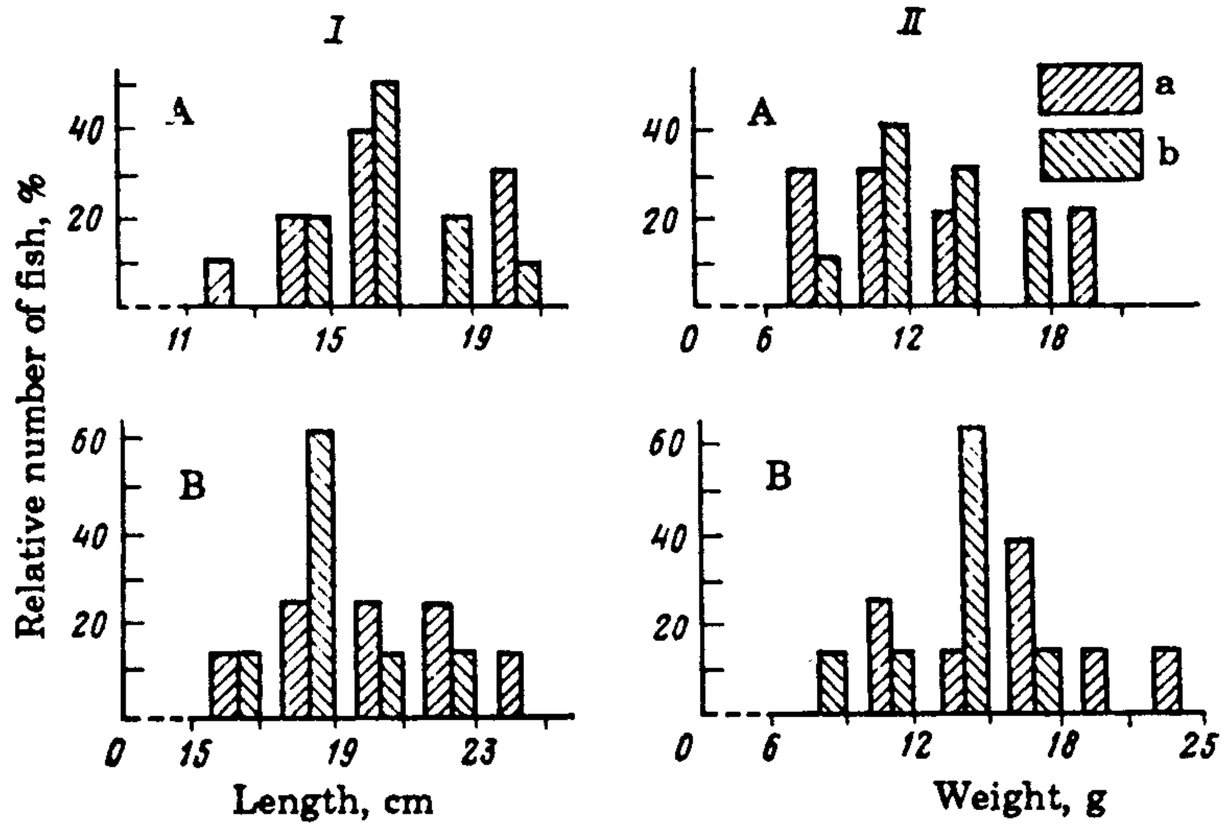

Fig. 4. Size (I) and weight (II) structure of the tested groups of young of the sevryuga at the beginning (A) and end (B) of the experiment: (a) As a result of the larger feeding areas; (b) as a result of the smaller feeding areas.

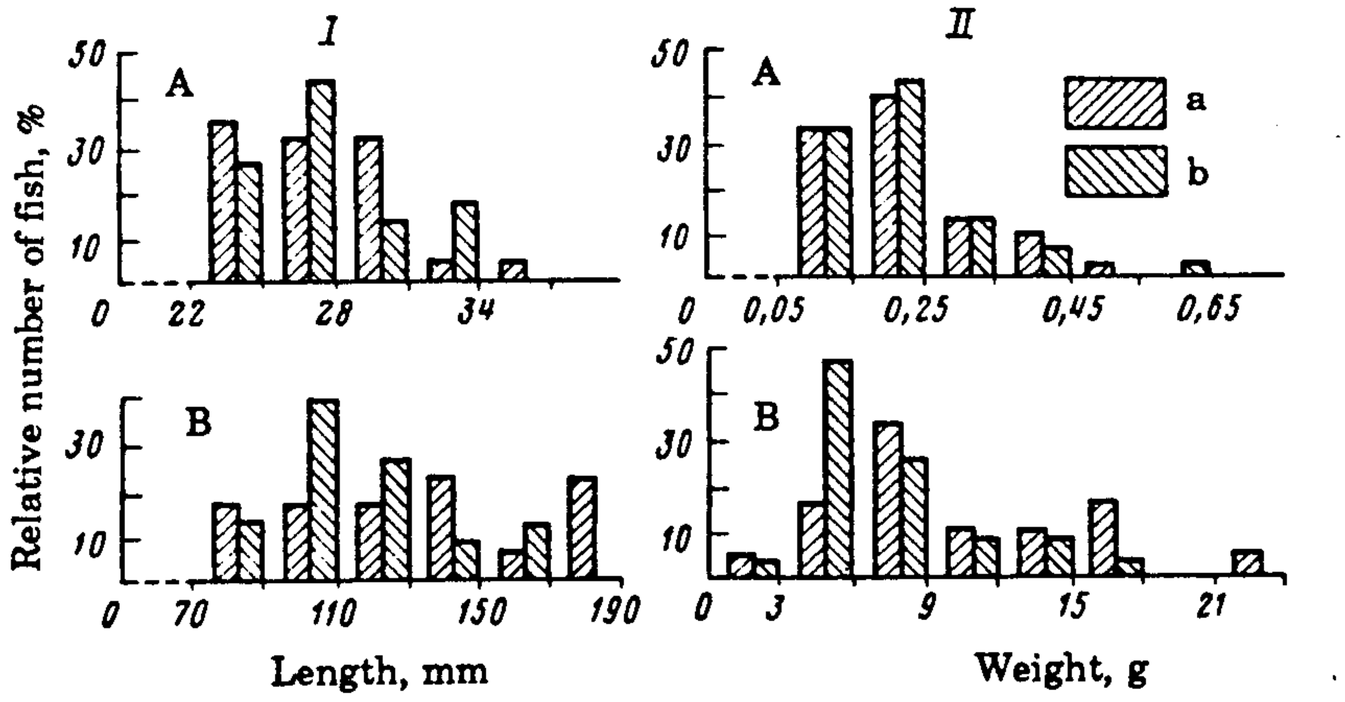

Fig. 5. Size (I) and weight (II) structure of the groups of young osetr at the beginning (A) and end (B) of the experiment: (a) as a result of the larger feeding areas; (b) as a result of the smaller feeding areas.

areas, the number of encounters on the bottom differed slightly, but in the osetr in the aquarium with the shelving encounters were even more frequent in comparison with the aquarium without such a structure. The picture sharply changed as a result of feeding and also later when the young were in a satiated condition. At this time, the number of encounters on the bottom, in comparison with those between the starved fish in the aquaria with smaller feeding areas sharply in-

Table 1

Relative Time (%) Spent on the Bottom by Young Sevryuga

	Area of bottom	
Trophic condition of fish	Small	Large
Starved	22±3	39±3
Feeding	75±2	83±3
Satiated	37±4	52±4

Table 2

Relative Time (%) Spent on the Bottom by Young Osetr

Trophic condition of fish	Size of fish	Area of bottom	
		Small	Large
Starved	Large	47±6*	55±4*
	Small	28±4	46±3
Feeding	Large	82±3	89±1
	Small	79±3*	86±2*
Satiated	Large	55±5	66±2
	Small	46±4	66±3

Note: In this and in the following tables, the asterisk indicates data the differences between which are not statistically significant according to the Student's test.

creased (by 1.5–4 times), whereas in the aquaria with large feeding areas, this increase was not as considerable (1–1.5 times (Tables 3 and 4).

On the basis of the data in the literature (Lagunova, 1979; Khodorevskaya, 1981; Levin, 1984), it is possible to confirm that, under natural conditions, the young of the sturgeons do not form any kind of social groupings and that neutral intraspecific contacts are characteristic of them (Sbikin, 1984). As a result of maintenance in a confined space, groupings of increased densities are artificially created, which are uncharacteristic for these fishes. Under these conditions, one may observe a deficit of feeding areas, and, with respect to this factor, competitive interrelationships develop among the young. This in turn leads to the fact that the availability of food in such groupings becomes uneven for discrete individuals.

In the fundamental work of Ivlev (1947), in addition to other questions, feeding relationships of fishes were examined. According to the position and the terminology of this author, feeding relationships among the groups combined in the tests at the beginnings of our experiments may be considered as homocompet-

Table 3

Number of Encounters (per minute) of One Sevryuga with Another

Trophic condition of fish	Place of residence	Area of bottom	
		Small	Large
Starved	Bottom	20±2*	23±1*
	Water column	17±1*	19±1*
Feeding	Bottom	43±2	34±1
	Water column	10±1*	9±2*
Satiated	Bottom	30±1	21±2
	Water Column	17±1*	18±2*

Table 4

Number of Encounters (per minute) of One Osetr with Another

Trophic condition of fish	Place of residence	Area of bottom	
		Small	Large
Starved	Substratum	8±1*	10±1*
	Water column	5±1	12±1
Feeding	Substratum	34±3	16±1
	Water column	6±2*	8±1.3*
Satiated	Substratum	25±2	14±1
	Water column	13±1*	11±1*

itive—that is, when the discrete individuals in a group are more or less similar among themselves and exert on one another approximately the same influence.

However, even at the beginning of the tests, the young had different qualities, which placed the discrete individuals in different positions in the group. In proportion to growth, the deficit of feeding area and, along with this, competition during feeding increased. This led, on the whole, to large discrepancies in size and also to discrepancies in the behavioral characters of the individual fish; and the relationships of the young acquired the characteristics of heterocompetition, where the individuals in a group, as a result of their influences on each other, obtain different feeding opportunities.

Heterocompetition is seen particularly clearly in those tests where the feeding areas were the smallest. In these groups, differences in time spent in the near-bottom area by the largest and smallest individuals were the greatest. and the histograms of the distribution of the young according to size differed most asymmetrically. A similar picture of nonuniform growth of discrete individuals

under conditions of increased feeding competition is known also for other fishes with difference ecologies (Ichmanski, 1985; Pitcher, 1986).

An analysis of the features of behavior and distribution of the the young in the aquaria allowed us to reveal some of their ethological mechanisms. As a result of natural tendencies of the young for contact with the bottom and the near-bottom layers of the aquaria, an elevated density of fish was created, and here at the bottom, due to their high level of swimming activity, a large number of collisions of a random nature were observed. As a result of this, the larger, stronger, and more active individuals displaced the weaker individuals into the middle and upper water layers. As a consequence, in the artificial group, two categories of fish were formed: one that spent a large amount of time on the bottom, and another that was forced to spend a considerable amount of time in the water column. The first category found itself in a favorable feeding situation; the second was, to a large degree, isolated from the feeding area, and the availability of food for them was reduced. This factor and also the elevated energy expenditure caused by swimming in the water column led to a progressive retardation in the growth of the fish in the second category.

Thus the interrelationships developing in the groups under conditions of inadequate feeding areas may be considered also as intraspecific competitions for resources (Odum, 1975) with the manifestation of immediate effects of the individuals on one another. In this case, it is necessary to emphasize that the described "stratification" in the tested groups took place with the preservation of different relationships with each other, which is characteristic of the young of sturgeons, and with an absence of any kind of specialized behavioral acts directed toward maintenance of the existing situation. Therefore, from the point of view of ethology, similar interrelationships in these groups may be characterized as "pseudo-hierarchic."

Increasing the sizes of the feeding areas in the tests, we ensured that food became more available for all individuals in the group. This was particularly important for the smaller fish, the ration for which, in this way, was considerably increased; this made possible the acceleration of their growth. A decrease, in association with this, of the ration of the larger fish had a weak effect on the rates of their growth. As a result, the average increases of weight and length became much greater.

In conclusion, it is necessary to call attention to the fact that, during the cultivation of young sturgeons under artificial conditions, it is necessary to calculate not only the volume of the nursery tank (as is most frequently done), but also the area of its bottom, the size of which exerts a significant influence on the final results. An increase of the feeding area may serve as one of the means of increasing the effectiveness of cultivation of sturgeons in confined spaces.

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