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POSTEMBRYONIC DEVELOPMENT, SURVIVAL AND GROWTH RATE OF SIBERIAN STURGEON (*ACIPENSER BAERI* BRANDT) LARVAE

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ABSTRACT. Studies were carried out on postembryonic development of Siberian sturgeon (*Acipenser baeri* Brandt) during 27 days after larvae hatching, in the temperature of 17°C. Critical periods of postembryonic development were observed, in which larvae mortalities increased. These periods were: beginning of active respiration by the fish and beginning of active feeding on exogenous food resources. Prelarvae metamorphosis took place during the period of 27 days post hatching, and the fish became like adults.

Key words: SIBERIAN STURGEON, POSTEMBRYONIC DEVELOPMENT, PRELARVAE

INTRODUCTION

It was concluded based on the observations carried out for a few years during sturgeon larvae rearing that larvae losses usually took place in the first four weeks after hatching (Kolman et al. 1996). It was also observed that mortality dynamics were not uniform, and that periods of increased losses were the same in particular stages of sturgeon larvae development. To confirm these observations it is necessary to obtain comprehensive knowledge on the processes of postembryonic development, with special attention given to organogenesis and transformations of life processes. Such studies were performed on a number of sturgeons, in this Russian sturgeon (*Acipenser gueldenstaedti* Brand, Detlaf et al. 1981), but there is no comprehensive review of these problems in Siberian sturgeon, i.e. the most frequently cultured species. Moreover, to be able to interpret our results, there is a need for such studies in the conditions of standard aquaculture technology, i.e. in definite constant temperature and feeding regimes, these factors having a significant effect on the character and rate of larvae development (Kolman 1999).

MATERIALS AND METHODS

Materials consisted of the larvae of Siberian sturgeon (*Acipenser baeri* Brandt) obtained after incubation of fertilised eggs. The larvae were stocked to one rearing tank (2m x 2m x 0.9 m) in water recirculation system, at the rate of 8152 fish (2038 ind. m^{-2}). Mean water temperature during the study was 17^0C. Oxygen content in water was 6 mg dm^{-3} at the outflow, pH was 7.80 - 7.95. Sturgeon larvae during exogenous feeding were given food in 24-h cycles using conveyer belts. Trout feeds ASTA-AC were used (Kolman et al. 1996). Food was given *ad libitum*. Fish tanks were cleaned twice a day, dead fish were removed, counted, and a random fish sample was weighed to determine individual weight. Larvae samples were collected each day at 13.30 hours, in the same place, using a small dip net. 30 larvae were collected each time during the period between hatching and day 13, and 20 fish were taken in the subsequent period i.e. from day 14 to day 27. Samples were preserved in Bouin solution and then in 70 % ethanol alcohol. Analyses of postembryonic development were performed using these materials and based on the observation of live fish behaviour in course of rearing. Periods of attaining particular stages of development were determined in degree-days (^{0}D) based on the scheme for sturgeons (Detlaf et al. 1081). Statistical analysis of the growth rate was performed taking advantage of the programme „Statgraphics 4.0".

RESULTS

POSTEMBRYONIC DEVELOPMENT

HATCHING (^{0}D) - STAGE 36 ACCORDING TO DETLAF ET AL. (1981)

Length of hatching larvae was about 8 mm. The larvae were visibly rounded, with fin lobe running from the posterior part of the yolk sac along the trunk and caudal part (Fig. 1a). Eye nucleus was in form of a small dark spot and a small hollow could be noticed in place of the future mouth. Brain was well visible through transparent body covers, myomers were noticeable almost to the end of the caudal part. Body pigmentation could be seen over the whole yolk sac and fish head.

APPEARANCE OF THE NUCLEI OF PECTORAL FINS (16^0D) - STAGE 37

Primordial pectoral fins appeared at the upper front part of the yolk sac. Nuclei of gill blades developed in two rows. Four small papillary formations appeared

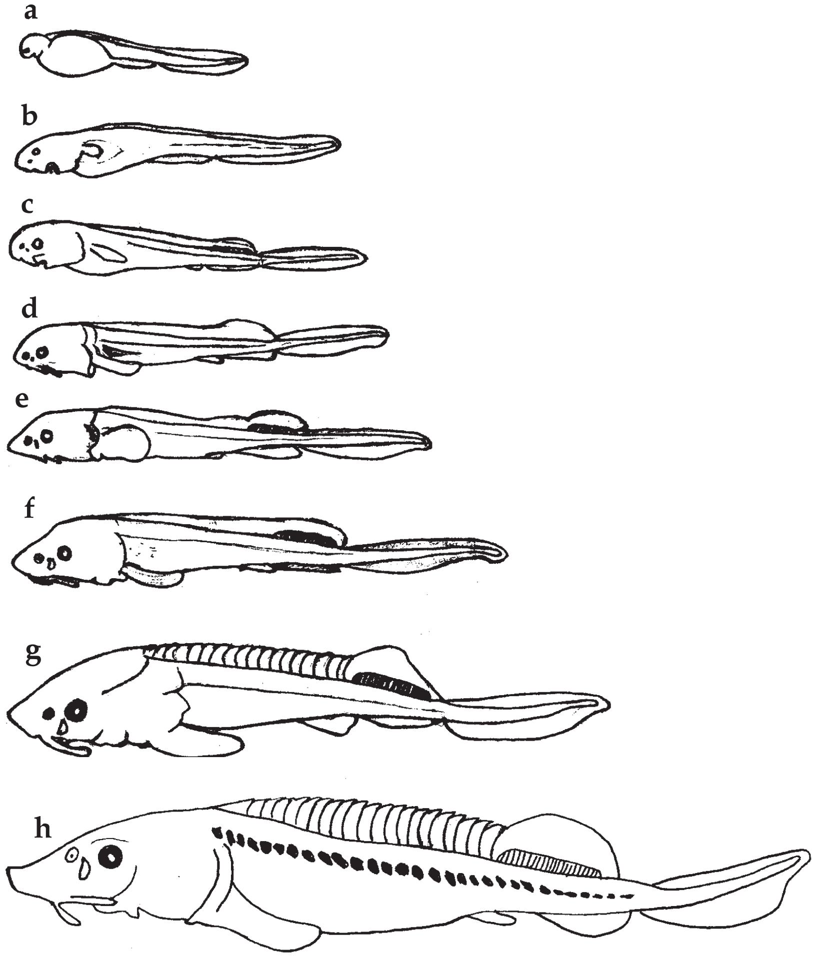

Fig. 1a - 1h. Changes of body proportions and shape in Siberian sturgeon (*Acipenser baeri* Brandt) during postembryonic development. a - hatching 0°D, b - hatching 67°D, c - 135°D, d - 168°D, e - 219°D, f - 287°D, g - 321°D, h - 458°D

underneath the head (two at each side); these were primordial barbs. Head cover viewed from the above was still transparent, so hearing vesicles were well visible. Majority of the pigmentation was found at the bottom of the eye nuclei and over the yolk sac (at the sides and front). Pigmentation of body sides appeared first just behind the yolk sac and did not reach the end tip. Yolk sac was white underneath; heart could be seen in its front part, and Cuvier ducts which reached it at the sides. Larval blood was yellowish. A small narrowing was formed over the fin lobe, close to the anus.

Intestines were in form of a twisted tube, filled with melanin in the section between the yolk sac and the beginning of cloaca, more condensed in the middle part. Small hollows could be found in place of the future olfactory openings.

TOTAL OPENING OF THE MOUTH (33^{0}D) - STAGE 38

Olfactory opening increased and a dividing wall began to form across it. Gill blades elongated, but still remained in two rows. Myomers increased and so did body pigmentation, so that larvae became less transparent. Caudal part bending slightly upwards; its cod end was still without pigmentation. Two parts should be distinguished in the digestive tract: stomach in front and intestine in the posterior part. Cloaca formed and fin bend became very narrow in this place. Subintestine vein ran along lower part of the gall bladder and joined the right Cuvier duct just in front of the heart. The larvae showed positive reaction to light - they gathered in open places. Respiration took place in this stage only in the anterior part.

STAGE OF INITIAL RESPIRATORY MOVEMENTS (51^{0}D) - STAGES 39-40

Larvae commenced respiratory movements with lower jaw, rare at first and rather irregular. Third row of gill blades and nuclei of the dorsal fin rays appeared. Body pigmentation extended over the caudal part. Melanin cork formed in the intestine. Fin band narrowed in the upper and lower part of the body, at mid-section between cloaca and tail end. Subintenstine vein could not be seen any more. Body shape changed - the larvae became slimmer and body length amounted to 10-19.5 mm.

CHANGE OF OLFACTORY OPENING SHAPE (67^{0}D) - FIG. 1B.

Olfactory opening had at this time noticeable narrowing in the middle part and was oval-shaped. Primordial barbs were still in form of small bulbs. Gill blades became much longer than before. Upper lip got bipartite. Lower part of the fin lobe was noticeably wider in the caudal part compared to its upper section. Pectoral fins moved towards lower body part. Respiratory movements were more rhythmical.

LARVAE SETTLING AT THE TANK BOTTOM (84^{0}D) - STAGE 41.

Further row of the gill blades was formed. Their particular rows were very differentiated, with the longest blades of the first row sticking out from under the not fully formed gill cover. Partitioning of the olfactory opening began to grow. Complete body pigmentation formed. Eye lenses began to form, at first as protrusions surrounded with pigment. Respiratory movements and blood flow in the gills became rhythmical, weak and irregular respiratory movements being observed in single larvae only. Semicircular canals of the labyrinth could be seen. Fin band became still narrower.

APPEARANCE OF THE NUCLEI OF VENTRAL FINS (118^{0}D)

These were formed just in front of the cloaca. Pectoral fins continued to move downwards. Partitioning of the olfactory opening was fully formed. Barbs became longer, reaching the mouth. Rays of the anal fin became visible.

REDUCTION OF THE YOLK SAC (135 - 151^{0}D) - FIG. 1C.

Nuclei of ventral fins became longer, reaching anterior part of the fin fold. Melanocytes appeared on the lower part of the intergill partitioning. Points of the seismo-sensoric system became visible on the lower part of the head, in form of two lines running between the barbs. Body pigmentation continued to increase; only the part behind the head, towards ventral fins, was still poor in melanophores. The larvae were 14-14.5 mm long.

EXPULSION OF MELANIN CORKS (168^{0}D) - STAGE 44 (FIG. 1D)

Melanin corks were expelled by the fish. Barb bases moved forwards. Four fully shaped gill arcs were well visible. Gill blades stuck out from under gill covers, almost reaching the level of pectoral fins. These were located just below mid-height of the body. Ventral fins reached the anal opening. Length of the larvae was about 15 mm.

BEGINNING OF EXOGENOUS FEEDING (185^{0}D) - STAGE 45

Majority of the fish expelled melanin corks from the intensities and commenced exogenous feeding. Melanin corks could be seen at the tank bottom as narrow, dark cylinders. Full alimentary tracts were visible in feeding fish through their abdominal covers.

FILL-BLADE COVERING BY GILL COVERS (201 - 219^{0}D) - FIG. 1E

Gill covers over the gill blades changed their shape. Caudal fin was at first of a protoceral type, gradually assuming shape typical of adult fish i.e. with upper part narrowed and bending upward. Only single larvae still possessed melanin corks. Fish body continued to elongate. The larvae were 15 - 15.5 mm long.

CHANGE OF LARVAE SHAPE (236 - 253^{0}D)

Head and anterior body part became relatively broader in relation to the posterior and caudal parts. Larvae abdomen became more and more flat, expressing fish adaptation to benthic feeding. Fish in tanks swam not only close to the bottom, but also with their abdomen close to tank walls, and sometimes even up-side-down, with the abdomen directed towards water surface. Pectoral and ventral fins were shaped and located as in adult fish. Lateral barbs were noticeably longer than middle ones. Middle barbs reached upper lip. Pigmentation of the abdominal part appeared first behind the ventral fins. Some pigment appeared also near gill covers and over pectoral fins. Upper part of the fin fold was strongly reduced; it began at the height of the front part of pectoral fins. This was also most strongly pigmented part of the band. Body length was 15 - 16 mm.

BEGINNING OF SIZE DIFFERENTIATION (270 - 304^{0}D) - FIG. 1F.

Rapid growth of the larvae resulted in noticeable differentiation of their size. Head and anterior part of the body in intensively feeding larvae became much broader and wider than their caudal part, while they remained of the same size in the larvae which did not feed. Lower part of the fin fold divided in places where the fins grew: between ventral and anal fins, and between anal and caudal ones. Larvae length amounted to 15.5 - 19 mm. All fins were well developed; caudal fin less than others. No rays were noticed as yet in the caudal fin.

APPEARANCE OF THE LATERAL AND DORSAL BONY PLATES (321^{0}D) - FIG. 1G

Bony plates of lateral rows could be seen behind the head, at the height of the caudal edge of the gill covers. They looked like small protrusions and ran from the head towards the tail. Anterior plates were bigger than posterior ones. Nuclei of dorsal plates, in form of a uniform segment, became visible in bigger fish, some 20 mm long.

INTENSIVE INCREASE OF LARVAE WEIGHT (338-406^{0}D)

Growth in length was relatively slow (larvae were now 20-21 mm long), but fish weight increased and gradually differentiated more and more. Rays of the anal and pectoral fins attained about 1/4 of the fin height. Larvae were 20 mm long (length of the fish given further on refers to fish which feed in a normal way). Pigmentation increased rapidly; only the larvae abdomen still had little pigmentation. Dorsal segment of the bony plates was noticeable in all fish; its posterior part broadened possibly through dorsal fin. By the end of this period there were some 8-12 plates in the lateral rows, depending on fish size. Larvae attained 20-26 mm.

BEGINNING OF BONY PLATE FORMATION IN LOWER ROWS (424 - 458^{0}D) - FIG. 1H.

Bony plates of lower rows began to form as small granules over the abdomen and lateral body parts. Larvae length increased to 26 - 30 mm. Rows of the later plates (16 at each side) ended between ventral and anal fins. Here nuclei of ventral bony plates were formed. A small keel could be seen between ventral fins and anal fin, at the fish abdomen. It represented the disappearing embryonic fold. Fish resembled adults very much: they had heterocercal caudal fin, flat abdomen, dorsal and lateral plates, and nuclei of lower plates.

GROWTH RATE AND LARVAE MORTALITIES

Larvae mortalities were observed 3 days after hatching. They reached a maximum of 23.4 % on day 6 (Fig. 2) and decreased rapidly after this period. Another maximum occurred between days 16 and 19, but it did not exceed 2.2 % of the stock. Since day 23 losses decreased to less than 1 % of the stock. Overall mortality during the entire rearing period reached 52.7 %.

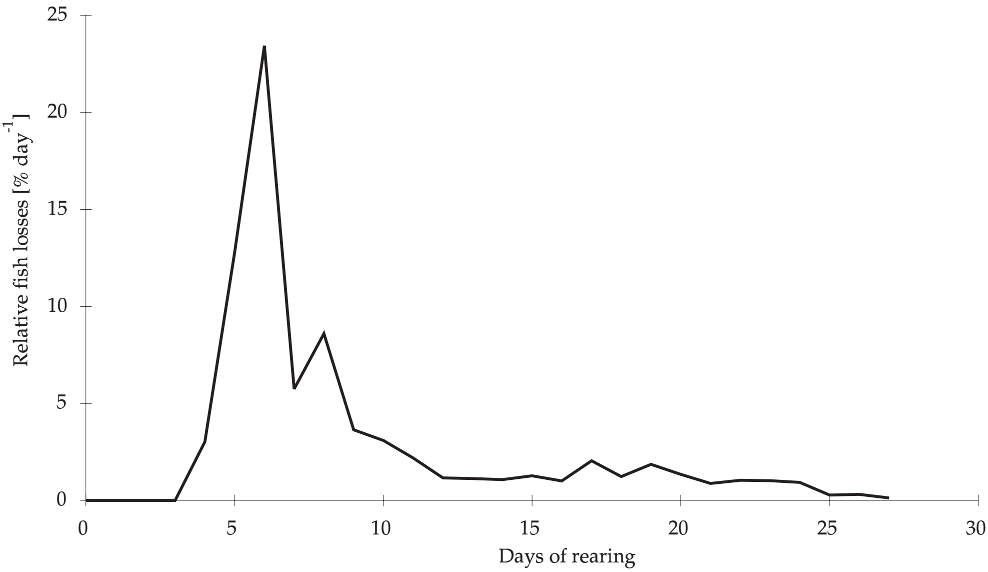

Fig. 2. Relative losses of Siberian sturgeon (*Acipenser baeri* Brandt) during 27 days of rearing

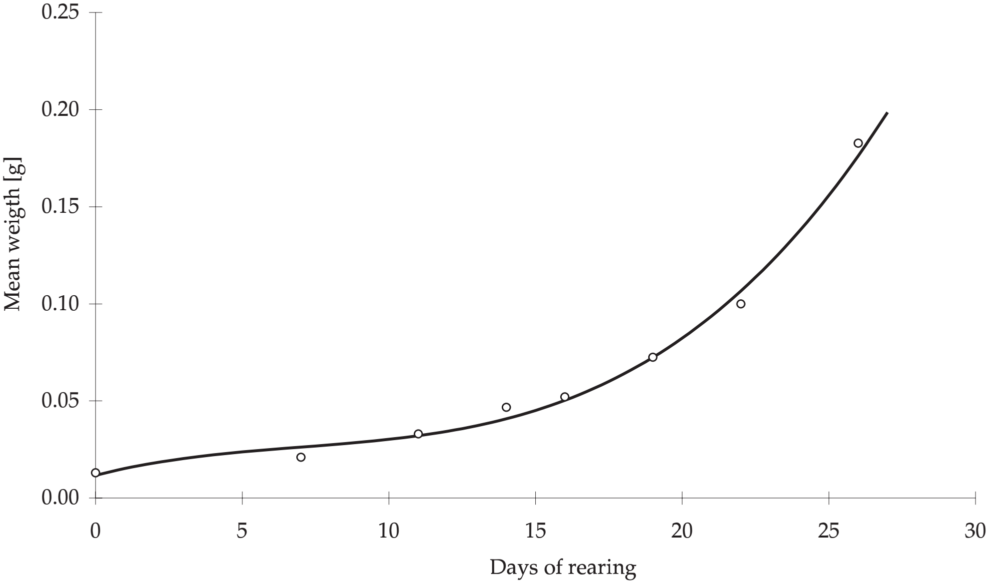

Fig. 3. Increase of the mean weight of Siberian sturgeon (*Acipenser baeri* Brandt) larvae during 27 days of rearing

Growth rate of sturgeon larvae during 27 days post-hatching is described by the equation:

$$W = 0.0000186 \times D^3 - 0.00039 \times D^2 + 0.003892 \times D + 0.0117$$

With $R^2 = 0.99$, SE = 0.002,

Where:

W - fish weight (in g), and D - day of rearing.

DISCUSSION

Observations on postembryonic development of Siberian sturgeon and peaks of larvae losses (Fig. 2) reveal that there are some critical stages in the first period of this development, namely:

– larvae hatching,
– period when larvae commence breathing with gills, 84-101^{0}D,
– period of commencing exogenous feeding, about 185-201^{0}D,
– period of intensive growth and differentiation of individual size - until 270^{0}D.

Hatching period is usually quite extended in time and may last even 2 days at water temperature 13-14^{0}C. Losses in this period are related mainly to egg quality, this being affected by genetic factors, method of fish stripping, fertilisation techniques as well as conditions of egg incubation (Igumnova 1985). In case of our studies there was a yet another negative factor affecting egg incubation i.e. egg transportation.

Larvae of Siberian sturgeon are relatively small. Total length at hatching is up to 8 mm. They are smaller than e.g. larvae of Russian sturgeon (10-11 mm, Detlaf et al. 1981); the latter length is attained by Siberian sturgeon only after about 50^{0}D. This difference is maintained throughout the entire period, until the larvae commence exogenous feeding.

At first the larvae were indifferent to light, but then (about 35^{0}D) they showed positive phototaxy. This was a different reaction than of *Acipenser stellatus* Pallas and *Huso huso* L., which showed positive response to light just after hatching, as well as than of Russian sturgeon larvae which were indifferent to light from hatching until the beginning of active feeding (Baburina 1972, Detlaf et al. 1981).

Larvae commencing active gill breathing lasts a few days. It begins when the larvae commence to move their lower jaws (about 50^{0}D). Breathing apparatus is not fully formed as yet; there are only 3 rows of gill blades, differing as to the degree of development, so that breathing is not regular. Due to this the breathing process is mostly passive, taking place through body surface, most of all through the yolk sac which is well supplied with blood, and through the surface of pectoral fins (Chikhachev et al. 1981). The process is favoured by the lack of fully developed gill covers, so that water can freely flow over the gills. As the yolk sac decreases and vessel net reduces, share of body surface in breathing decreases as well. Increased losses on days 5-6 (the first peak) suggest that mortalities are observed mostly in case of individuals with deficient breathing apparatuses. Decreasing breathing through blood vessel system is not sufficient to supply enough oxygen and the larvae die. This is confirmed by the fact that as a rule there are hardly any losses in the first two or three days after hatching. They increase only since day four, reaching a peak on day five or six. Literature on the subject does not mention larvae losses in the first days of rearing. Such losses, however, have been reported in consecutive days in the Dgał hatchery during rearing the larvae of different sturgeons (Kolman and Szczepkowski 1995, Kolman et al. 1996). These losses were usually due to the quality of sex products, as well as to frequently unfavourable conditions during transportation of fertilised eggs.

Sturgeon larvae in the period of commencing exogenous feeding begin to actively look for food items; they use chemoreception to achieve this (Pavlov and Kasumian

1990, Devitina and Kazhlaev 1992, Kasumina et al. 1992). Due to this composition of artificial feeds should fulfil two basic conditions: it should be acceptable to the fish and ensure their rapid growth. When these two conditions are not met, size of larvae will become highly differentiated. This is very dangerous as the sturgeons often consume large food items and smaller fish may be eaten. In these cases both the pray and the predator usually die because sturgeons consume their prey beginning from „the tail", are then unable to swallow prey's head and choke. To decrease losses related to the beginning of active feeding, feeds should be given in small amounts even before the fish start to consume them (beginning from day 4-6 after hatching). This way the fish become used to food smell and this decreases the adaptation period to artificial feeds. Consequently, less larvae starve and fish size is less differentiated. Some of the larvae (less than 2-3%) do not uptake artificial food; they swim up-side-down close to water surface, looking for natural food. These larvae are not suitable for rearing and are usually characterised by slower growth than fish consuming artificial feeds. In cases when improper or too little food is given, the pectoral fins may become injured as the fish attack each other (Chikhachev et al. 1981, Semenkova 1983). Occurrence of increased losses (about 30 % of the initial stock) in the period when larvae commence active feeding were also described by Chikhachev et al. (1981) for different hybrids of *Huso huso* L. (*Huso huso x Acipenser rhuthenus, BBS, Huso huso x Acipenser stellatus).* According to the authors losses in this period were noted mostly as regards the larvae having anomalies in the smelling and breathing apparatuses. In dead fish the yolk sac was less used. In addition to this, the mentioned authors noted increased losses during intensive fish growth (similarly as in our study) i.e. 7 days after the start of active feeding. Smaller fish dominated among dead larvae; they were probably unable to effectively compete for food and became preys.

In assessing larvae development attention should be given to external factors. These can sometimes disturb life processes. They comprise temperature, pH, oxygen content, level of ammonia and nitrites in water. In our study water quality parameters corresponded to the standards worked out in the Inland Fisheries Institute for sturgeons (Kolman 1998). Dissolved oxygen content was above 70%, and levels of undissociated ammonia and nitrates did not exceed 0.012 and 0.15 mg l^{-1} respectively.

Other factors that might cause improper larvae development are some chemicals, e.g. phenols (Detlaf et al. 1981). Sanitary conditions (bacterial and parasitic infections) are also important. It has been noted earlier that larvae attacked by protozoans (*Trichodina* sp.) had less pigmentation than healthy fish.

CONCLUSIONS

1. In course of postembryonic development of Siberian sturgeon there are some critical stages in which higher losses may occur.
2. Critical periods in postembryonic development of Siberian sturgeon related to the highest losses are: the beginning of gill breathing (84-101 ^{0}D) and the beginning of exogenous feeding (after 185 ^{0}D).
3. During 27 days after hatching the larvae become like adults and get adapted to bottom life patterns

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STRESZCZENIE

ROZWÓJ POSTEMBRIONALNY ORAZ PRZEŻYWALNOŚĆ I TEMPO WZROSTU WYLĘGU JESIOTRA SYBERYJSKIEGO (*ACIPENSER BAERI* BRANDT).

Badano rozwój postembrionalny jesiotra syberyjskiego (*Acipenser baeri* Brandt) w czasie 27 dni po wykluciu przy średniej temperaturze 17°C. Stwierdzono występowanie okresów krytycznych, w czasie których obserwowano nasilenie śnięć larw. Okresy te to rozpoczęcie przez ryby aktywnego oddychania i ich przechodzenie na odżywianie pokarmem egzogennym. W omawianym okresie 27 dni po wykluciu następuje przeobrażenie prelarw i ich upodobnienie się do ryb dorosłych.

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