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SWIM BLADDER DEVELOPMENT IN VIMBA (*Vimba vimba* L.) LARVAE

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A B S T R A C T. Histological examination revealed that at 18.5^0 C swim bladder inflation in vimba *(Vimba vimba* L.*)* larvae took place between the fourth and fifth day from hatching. Swim bladder is inflated by ingesting the air from above the water surface and transporting it to the bladder via pneumatic duct *(ductus pneumaticus)* connected with oesophagus. Swim bladder inflation takes place simultaneously with yolk sac resorption to about 30% of its volume.

Key words: VIMBA, LARVAL PERIOD, DEVELOPMENT AND INFLATION OF THE SWIM BLADDER

INTRODUCTION AND THE AIM OF THE STUDY

Fish swim bladder develops from the wall of the oesophagus arch. In some teleosts it is connected with the oesophagus. Pneumatic duct develops from that connection and it is present for the entire life of open-bladdered fish *(physostomi)* (Nash *et al.* 1977), such as common carp *(Cyprinus carpio)*, barbel *(Barbus barbus)*, rainbow trout *(Salmo gairdneri)*. Vimba *(Vimba vimba* L.*)* also belongs to this group of fish. Closed-bladdered fish form a separate group. Their swim bladders resemble closed sac, and the pneumatic duct is absent - for example in tilapias *(Tilapia mossambica)* (Doroshev, Cornacchia 1979, Doroshev *et al.* 1981), or is present only in larvae and degenerates later on, as in striped bass *(Morone saxatilis)* (Nash *et al.* 1977).

Swim bladders of various fish species vary considerably as to their shape and morphology. In Cyprinidae it is divided into two chambers. The front chamber is round at both ends, with hind end ovoid, pointed towards the tail. The pneumatic duct *(ductus pneumaticus)* is narrow, and connects the hind part of the bladder with the oesophagus.

In Salmonidae swim bladder resembles an elongated sac, and is connected with the oesophagus by a relatively wide but short pneumatic duct (Grodzinski 1971).

A shift from endogenous to exogenous feeding is one of the most important moments in early larval development. The period preceding the commencement of active feeding is considered to be a critical one. Little active larvae are particularly susceptible to adverse abiotic environmental conditions, and are easily preyed upon by vertebrate and invertebrate predators. Active swimming is in that period essential for survival, enabling the fish to escape, hide, and capture food.

The embryos develop a recess of the oesophagus wall which forms the swim bladder during subsequent development. To fulfil its most important function - enabling the fish to swim freely at various depths - the swim bladder has to be inflated with gas similar to atmospheric air. This usually takes several days, sometimes up to several months from hatching, depending on fish species.

Various species inflate swim bladders for the first time in different ways. Most open-bladdered teleosts *(physostomi)* posses the pneumatic tract during their larval stage, and inflate the swim bladders by ingesting atmospheric air, which is then passed to the bladder via pneumatic duct (Tait 1960).

In closed-bladdered fish *(physoclisti)*, the mechanism of swim bladder inflation is not quite clear. Doroshev and Cornacchia (1979) observed that in striped bass *(Morone saxatilis)*, atmospheric air ingested by the larvae from above the water surface was necessary to initiate swim bladder inflation. In *Tilapia mossambica* larvae, however, gases are transported via gills and blood.

Other authors suggest that physoclisti larvae may inflate their swim bladders by ingesting air bubbles suspended in water or attached to various submerged objects (Mc Elman and Bulon 1979). They are also able to use gas produced during metabolic processes (Johnston 1953), or to produce gas in the gas gland (Schwarz 1971).

Recent studies, however, indicated that in closed-bladdered fish the first swim bladder inflation took place by ingesting atmospheric air from above the water surface (Barrows *et al.* 1993, Chapman *et al.* 1988).

Nash *et al.* (1974, 1977) and Spectarova and Doroshev (1976) found that the result of the first swim bladder inflation determined larval survival until the fry stage. Failure results in reduced ability of free swimming, which causes excessive energy consumption and leads to inceased mortality (Bennett and Kraeuter 1987).

Chapman *et al.* (1988) observed that striped bass *(Morone saxatilis)* larvae that failed to inflate their swim bladder showed reduced growth and were more susceptible to stress, this resulting in increased mortality.

Factors inhibiting swim bladder inflation are not known. They possibly include anomalies in digestive tract development, DO depletion, inhibition of gas excretion, or genetic factors accompanied by skeletal deformities (Bennett and Kraeuter 1987).

The aim of the present study was to follow the swim bladder development in vimba *(Vimba vimba* L.*)* larvae until the inflation.

MATERIAL AND METHODS

The studies were carried out in 1995 and 1996 in the Fishery Experimental Station of SGGW in Łąki Jaktorowskie. Larvae of vimba *(Vimba vimba* L.*)* obtained from the hatchery from an artificially stimulated spawning of riverine fish were used in the experiment.

The experiment was done in three replicates in non-flow aquaria of 25 dm^3. Each tank was stocked with 100 individuals of newly hatched vimba larvae. Water supplying Łąki Jaktorowskie hatchery was used in the experiment. Larval development took place at 18.5°C. Water was mechanically aerated and partly changed. The larvae were sampled daily and fixed for histological examinations. At the same time DO content was monitored using the DO-meter Oxi-96, and pH using the pH-meter N-517. Observations of live larvae were done using a binocular. Larval behaviour was also observed in order to notice the signs of swim bladder inflation.

Fish for analyses were preserved using two different techniques. The larvae for measurements were fixed in formaldehyde. Histological preparations were treated with Bouin-Holland solution, and then embedded in paraffin. Six μm thick cuttings were stained with haematoxyline according to Delafild (Zawistowski 1983). About three thousand preparations were made. Development and level of inflation of swim bladders were observed in the preparations using light microscopy. Measurements of total length of the fish *(longitudo totalis)* and of the yolk sac were carried out using light microscope. Yolk sac volume was calculated according to the formula for an elongated ellipsoid:

$$V = 0.526 \cdot L \cdot h^2$$

where:
L - yolk sac length
h - yolk sac width.

RESULTS

The experiment lasted 6 days. Environmental conditions in the tanks were optimum for the development of vimba larvae. Water temperature was 18.3-18.8°C. DO level fluctuated within 82-92% of saturation, and pH from 7.5 to 7.7. Average length of vimba larvae one day after hatching was 6.08 mm (Tab. 1). Front part of the body was distinctly bent down and touched a large (about 0.58 mm^3) pear-shaped yolk sac. Hind part was erect with clearly visible notochord. There were nuclei of pectoral fins. Eye pigmentation had already started and the eyes were greyish in appearance. Mouth opening was still closed. The larvae were poorly motile, and stayed in the dark, at the bottom of the tank.

TABLE 1

Average body length of vimba larvae (*longitudo totalis*), increments of body length during 6 days of the experiment, and yolk sac resorption rate

24 h after hatching	Average body length mm	Body length increment		Rate of yolk sac resorbtion %			Yolk sac volume mm^3
		mm	%	resorbed	remained	during 24 h	
1	6.08	-	-	-	-	-	0.58
2	6.44	0.36	18.0	38	62	38	0.36
3	7.04	0.60	30.0	45	55	7	0.32
4	7.33	0.29	14.5	72	28	27	0.16
5	7.63	0.30	15.0	76	24	4	0.14
6	8.08	0.45	22.5	81	19	5	0.11
	-	2.00	100.0	-	-	-	-

On the second day, the yolk sacs of the larvae were considerably resorbed (the highest resorption rate in the entire 6 days of the experiment) - on the average in 38%, and mean sac volume was 0.36 mm^3. Front part of the body was still bent downwards, but it was no more attached to the yolk sac. Total body length increased to 6.44 mm (18%). Pectoral fins were well developed. Mouth opening remained still closed. The larvae stayed at the bottom and avoided light.

On the third day after hatching total body length increment was the highest

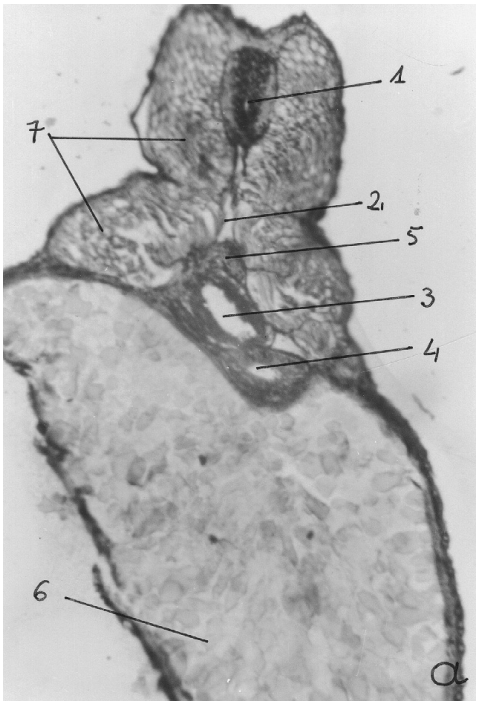
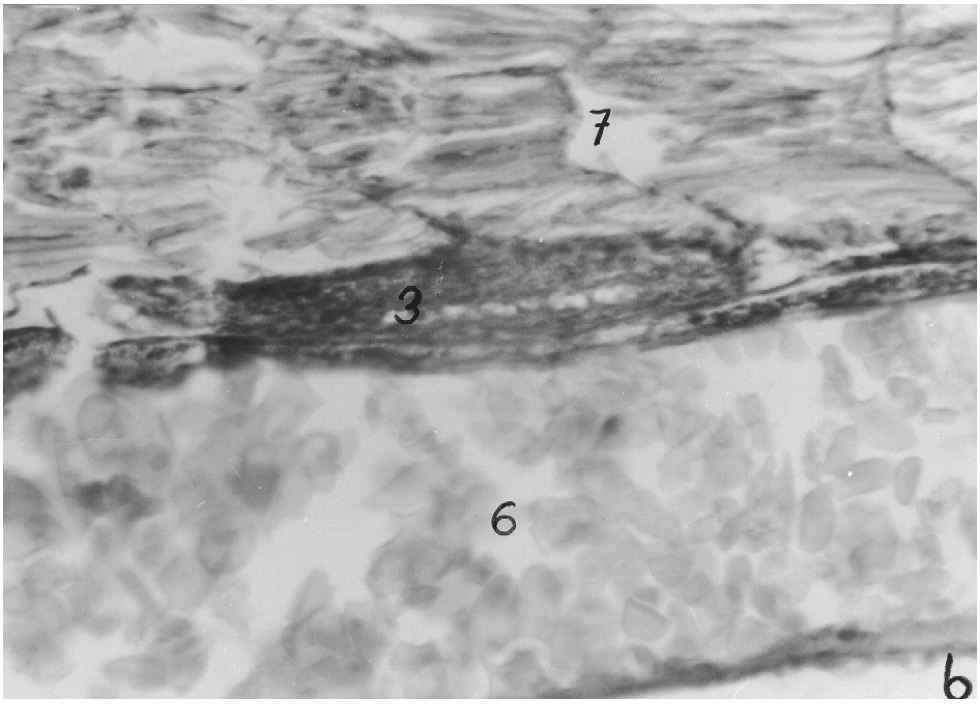


Fig. 1 a, b. Histological section of the larva on the third day after hatching. Non-inflated, flattened swim bladder is present. a. cross-section (x 125); b. longitudinal section (x 250). 1. spinal cord, 2. notochord, 3. swim bladder, 4. intestine, 5. kidney, 6. yolk sac, 7. muscles.



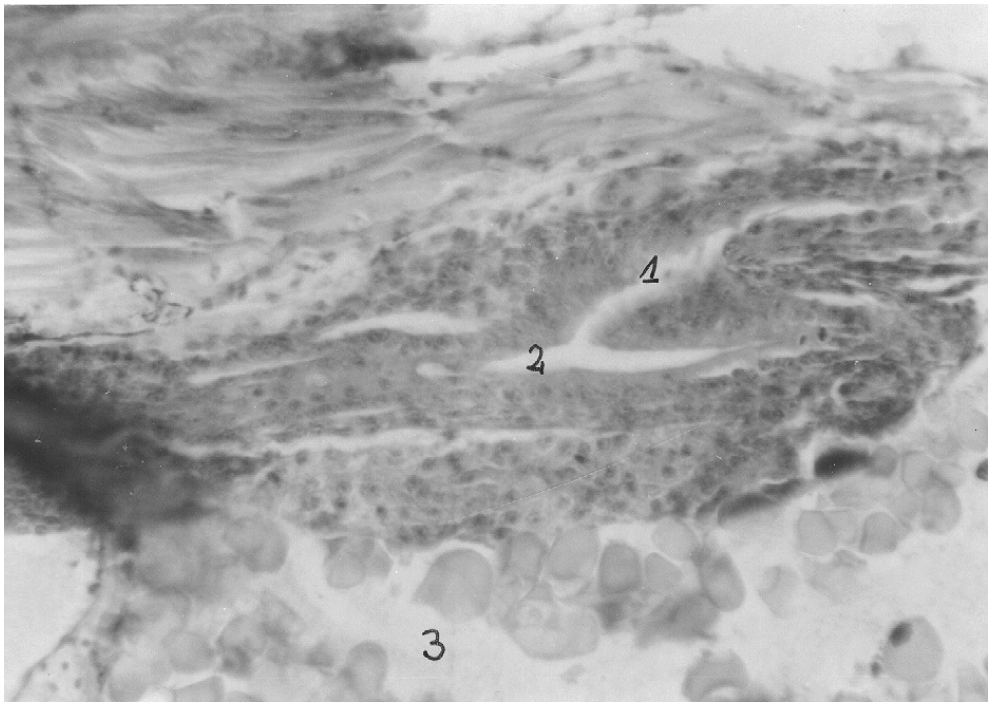


Fig. 2. Longitudinal histological section of the larva on the fourth day after hatching (x 250). 1. pneumatic duct, 2. oesophagus, 3. yolk sac

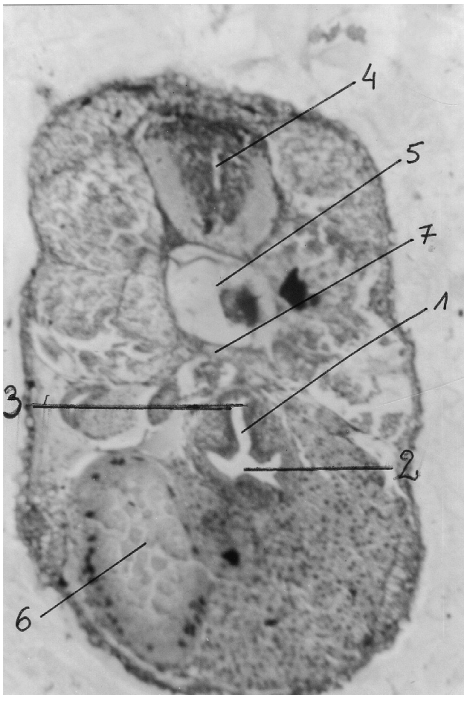


Fig. 3. Histological cross sections of the larva on the fourth day after hatching (x 125). 1. connection between the pneumatic duct and oesophagus, 2. oesophagus, 2a. intestine, 3. pneumatic duct, 4. spinal cord, 5. notochord, 6. yolk sac, 7. aorta, 8. swim bladder.

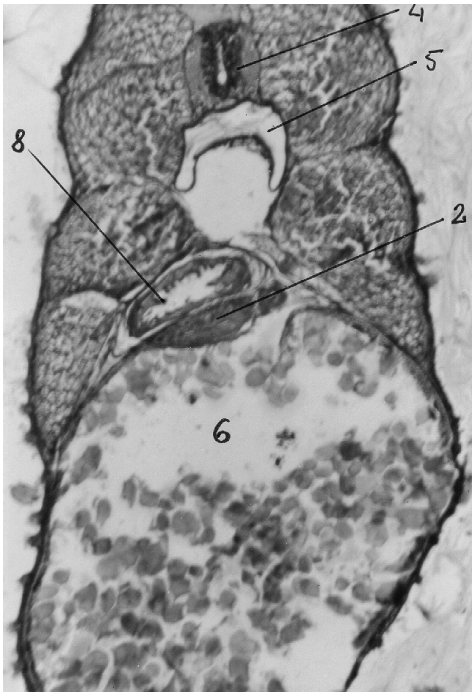


Fig. 4. Histological cross sections of the larva on the fourth day after hatching (x 125). 1. connection between the pneumatic duct and oesophagus, 2. oesophagus, 2a. intestine, 3. pneumatic duct, 4. spinal cord, 5. notochord, 6. yolk sac, 7. aorta, 8. swim bladder.

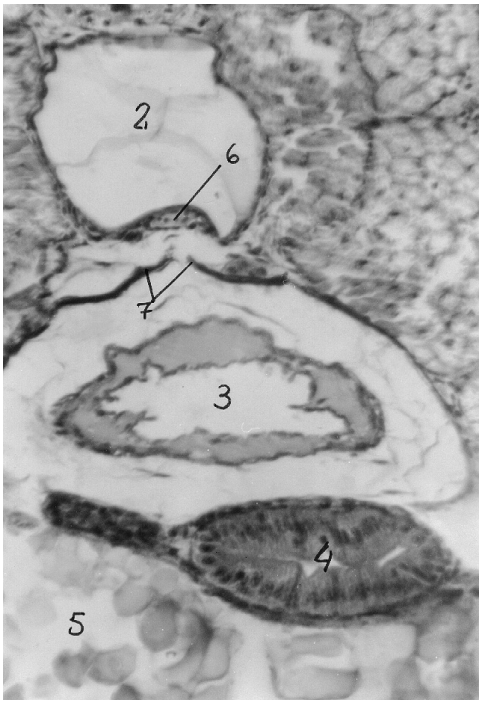


Fig. 5. Longitudinal histological section of the larva on the fifth day after hatching (x 125). 1. swim bladder, 2. intestine, 4. yolk sac, 5. pneumatic duct, 6. melanophores, 7. aorta

vealed the beginning of the swim bladder formation. In this stage, the bladder was flattened.

Considerable changes in the larval development and behaviour took place on the fourth day. Body length increased up to 7.33 mm. Melanophores were arranged in three lines: 1 - lateral, along the lateral line organ, in the inter-muscular septum, 2 - dorsal, on the head and along upper edge of the body, and 3 - ventral, along ventral side of the fin fold somites, at the lower end of the yolk sac, and in the cardiac region. Eyes of the larvae turned goldish. Mouth was open with mobile lower jaw. From time to time the larvae ingested air. In this period they passed from breathing through the vessel system to gill breathing. Yolk sac content was resorbed in about 72 %. Consecutive histological sections (Fig. 2) show connection between the food tract and the pneumatic duct, the latter having irregular walls (Fig. 3), as well as a partly filled swim bladder.

Larvae which had so far been little active changed their behaviour. Many swam towards the surface, tried to break the surface film with their heads and to ingest air. Then, they slowly sunk down to the bottom and laid down on their stomachs. At the end of the fourth day almost 90% of the larvae swam up to the surface and ingested air. Many of them floated for some time in water, and then settled down on the bottom.

On the fifth day, the larvae continued to swim up to the surface and swallow the air, but most of them no more sunk to the bottom, and swam freely in water. Only some larvae remained at the bottom. Subsequent stripes of melanophores appeared in larvae of average body length 7.63 mm, extending from the heart to the swim bladder, and surrounding the latter (Fig. 5). The swim bladder itself appeared as a dark sac filled with liquid. In five days old larvae the yolk sac was resorbed in about 76%. Histological examinations revealed the presence of the pneumatic duct (Figs. 5, 6), and large swim bladder. In the last replicate, six days old larvae of average body length 8.08 mm were extremely skittish and reacted to every motion in the neighbourhood of the tank. Only about 5% of them still stayed at the bottom and were unable to swim. Most of the larvae swam freely in water, had large mobile eyes, and caudal fin developing from the fin fold. Large but not fully developed gills were visible, and rhythmically moving gill covers. These movements were accompanied by movements of the lower jaw and pectoral fins. The yolk sac was in 81% resorbed and its volume was equal to 19% of the initial size.

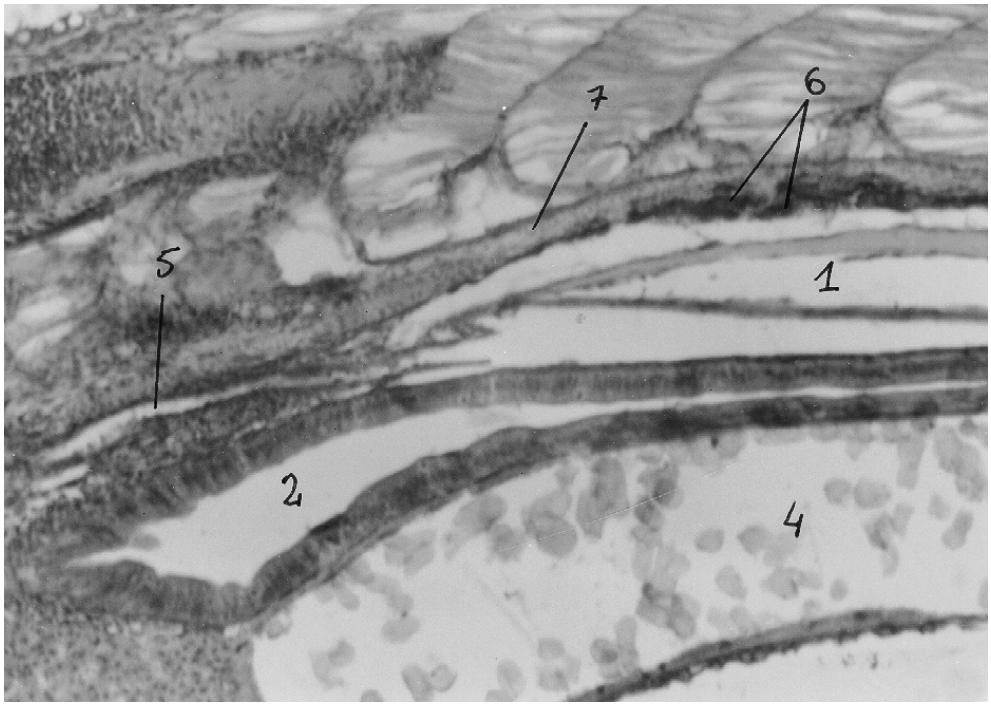


Fig. 6. Cross-section of the swim bladder of a five days old larva (x 250). 2. notochord, 3. swim bladder, 4. intestine, 5. yolk sac, 6. aorta, 7. melanophores.

DISCUSSION

In the present experiment vimba larvae developing at 18.5°C started to inflate the swim bladders between fourth and fifth day after hatching. This confirmed observations by Wolnicki (1996) who noticed that vimba larvae of the same age swam freely with partly inflated swim bladders. Pliszka (1953) observed that vimba larvae on the fourth day from hatching showed the first signs of swim bladder development, and started to swim up to the surface and swallow the air. Kryzanowski (1949), however, noticed that vimba larvae started to inflate their swim bladders and to swim actively as late as at the age of about nine days after hatching. This difference resulted from different temperatures of rearing.

Inflation of the swim bladder in vimba takes place by ingesting the air from above the water surface, and passing it to the swim bladder via the pneumatic duct. This conforms to the observations by Pliszka (1953) of larvae swimming up to the surface.

Many authors reported that the swim bladder inflation coincided with the yolk sac resorption, beginning of active swimming, and exogenous feeding. The present experiment confirmed these observations. On the fourth and fifth day, when the fish started to inflate their swim bladders, the yolk sacs were in 72-76% resorbed. Similar observations were made by Pliszka (1953) and Wolnicki (1996). The rate of yolk sac resorption influenced the increase of body length at that period. Tab. 1 shows the yolk sac volume and total body length of vimba larvae during six days of the experiment. The results of the studies carried out by Doroshev *et al.* (1981) revealed that the larvae of striped bass *(Morone saxatilis)* started to inflate the swim bladders after utilisation of the yolk sac content, on the fifth day after hatching, which coincided with the beginning of active feeding. In the case of *Tilapia mossambica* larvae, swim bladder inflation started on the fourth day of larval life, after resorption of about 50% of yolk sac content. The larvae started to swim on the seventh day, which also coincided with complete yolk sac resorption (Doroshev *et al.* 1981).

Tait (1960) observed that *Salmo trutta lacustris* L., *Salmo gairdneri*, and *Salmo trutta trutta* L. did not inflate the swim bladders and stayed at the bottom of the tank until the yolk sac was almost completely resorbed. The author also noticed that the beginning of the bladder inflation depended on water temperature. Our results confirmed these observations. Larvae of vimba reared at 18.3-18.8°C inflated the bladders on the fourth day and were able to swim actively on the fifth day after hatching, while the fish developing at 25°C (Wolnicki 1996) swam freely and were regularly distributed in water already on the fourth day. This shows that the beginning of swim bladder inflation, which coincides with the yolk sac resorption, also indirectly depends on water temperature. This fact may play an important role in the initial rearing of the larvae under controlled conditions, and make possible forecasting the moment of the start of feeding (Tait 1960, Doroshev *et al.* 1981).

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STRESZCZENIE

KSZTAŁTOWANIE SIĘ PĘCHERZA PŁAWNEGO U LARW CERTY (*Vimba vimba*)

Celem badań było prześledzenie kształtowania się pęcherza pławnego u larw certy. Rozwój larwalny prowadzono w temperaturze 18,5°C. Wyniki badań uzyskano na podstawie obserwacji przyżyciowych larw certy oraz wykonywanych preparatów histologicznych. Stwierdzono, że napełnienie pęcherza pławnego u larw certy (*Vimba vimba* L.) następuje między czwartą i piątą dobą od momentu wyklucia. W tym okresie larwy mają zresorbowany woreczek żółtkowy w około 70% i zaczynają swobodnie pływać.

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