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THE EFFECT OF TEMPERATURE DECREASE ON CARP, *CYPRINUS CARPIO* L. CULTURE IN A TEMPERATE CLIMATE PART I. SURVIVAL OF CARP JUVENILE IN PONDS AND SWIM BLADDER INFLAMMATION

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ABSTRACT. The greatest losses in central and eastern European carp culture are caused by the high mortality of juveniles usually during the first three to four weeks after pond stocking in late spring. The pronounced weather fluctuations of this period, including drastic falls in temperature, endanger the survival of this warm-water fish. By quantifying the effect of considerable temperature decreases on the survival of juvenile carp, logarithmic increases in carp survival rate were apparent as favourable thermal conditions extended from 1 to 40 days. Simultaneously, a decrease in carp swim bladder inflammation was observed. The trend toward increasing frequency and amplitude of weather fluctuations might intensify this problem.

Key words: *CYPRINUS CARPIO*, WEATHER COOLING, CARP CULTURE, ICHTHYOPATHOLOGY

INTRODUCTION

One of the chief reasons that carp, *Cyprinus carpio* L. farming in temperate climates has limited success is the poor survival rate of its juveniles. The results of numerous studies (including Krüger 1982, Szumiec 1987, Pilarczyk 1998) show that unfavourable environmental and nutritional conditions and disease eliminate from 50 to 90% of one-year-old carp. Consequently, fish farmers are very interested in the factors which contribute to the poor survival rates of this species in its first year of life, particularly in the first stages of its development since even slight improvement could significantly effect production.

Water temperature, among other factors, plays an important role in fish survival. Both the upper and the lower lethal temperatures depend on a number of factors including the rate and range of temperature fluctuations and the age and condition of the fish (Smišek 1977, Lirski and Opuszyński 1988a, b). As the fish age and grow, their tolerance to low temperatures increases (Dąbrowski 1983, Lirski and Opuszyński 1988a, Hamaćkova et al. 1995).

Farmers sometimes keep nursery ponds very shallow in order to help them heat up quickly. This may, in turn, cause a considerable increase in the diel variations of water temperature. These variations also increase during significant weather changes characteristic during carp juvenile development in late spring (Szumiec 1984).

It is not possible to isolate temperature effects from the complex set of factors which affect the fish in ponds. Therefore, a simple statistical calculation was attempted on the survival rate as a function of the number of days between stocking and the first significant temperature decrease. The effect of temperature decrease on pathological changes in fish were also taken into consideration.

MATERIAL AND METHODS

This work is based on the results of studies on the effectiveness of carp farming in 24 experimental ponds belonging to the Institute of Ichthyobiology and Aquaculture, Polish Academy of Sciences, Gołysz (Szumiec 1987). The area of each pond was 0.15 ha. When stocked with fry, the water depth in ponds was approximately 30 cm; this level was gradually increased. In the 1981-1988 and 1990 seasons, the progeny of a hybrid of females from the Hungarian line W and males from the Polish line 3 (W × 3), which have a pronounced resistance to unfavourable environmental conditions and pathogenic factors (Białowąs 1991), were investigated. The stocks varied from 90 000 to 240 000 fry ha^{-1}, and the fish were fed pellets containing protein whose concentration increased along with stock density from 10 to 40%. The fish survival rate did not show any correlation with stock density. The ponds were fertilised with nitrogen-phosphorus and organic fertilisers.

The dependence of fish survival rate on the number of days between pond stocking and the first rapid temperature decrease from over 20°C to about 14-15°C was calculated using regression analyses (SYSTAT). Equations with the highest correlation coefficient values were accepted. The first 40 days of fish life and the entire season were considered separately. A favourable season was considered to be one when cold occurred no earlier than ten days after stocking, while an unfavourable season was one in which it occurred earlier. Water temperature was monitored in a pond with an average depth of 120 cm and an area of 4 ha and in the shallow (15 and 20 cm deep) nursay ponds located in the vicinity of the experimental ponds.

To determine the period of high fish mortality, the growth of fingerlings measured at about 14-day intervals was compared with the growth calculated from an empirical model based on fish density at the end of the season. The cumulated water temperature affecting the growth of carp (exceeding 14°C), calculated on the basis of the average diel temperature, fingerling density at the end of the season, and the percentage content of protein in the pellets are the variables of the model (Szumiec 1990, 1995, 1998).

Ichthyopathological studies were carried out in 1981-1985. They began with four- to five-week-old fry in 4-16 ponds at two to four week intervals, and 10-20 fish from each pond were investigated. Generally accepted analytical methods were used (Schäperclaus 1979, Prost 1994). The frequency of swim bladder inflammation, a pathological condition which significantly affects fingerling survival (Pilarczyk 1987), was analysed as a function of favourable days using regression analyses.

RESULTS

TEMPERATURE AND FISH SURVIVAL

Thermal conditions favourable for fish larvae occurred in 1982, 1983, 1986, and 1988. In these years, the temperature decreased more than 20 days after pond stocking. The remaining seasons, 1981, 1984, 1985, 1987 and 1990, were unfavourable (Fig. 1). Measurements taken simultaneously in the deep and shallow ponds showed that at 7 am the temperature is approximately 2°C lower in the shallow and small nursery ponds than in the deep one. Moreover, the differences increase as temperature falls (Fig. 2).

Despite considerable disparity, the results show that the juvenile survival rate during the first 40 days logarithmically increases with the number of the favourable days after pond stocking ($r = 0.890$, r corrected $= 0.672$, Fig. 3A). A similar relationship was obtained for the survival rate of one-year-old fish ($r = 0.891$, r corrected $= 0.662$, Fig. 3B). The logarithmic shapes of the curves are the result of significant improvement of fish survival as favourable thermal patterns continue each day after pond stocking. Although, if this period continues for more than 20 days, its significance is slight. Under favourable thermal conditions the highest larvae mortality also occurs shortly after stocking as is indicated by the quasi-parallel pattern of the theoretical and empirical curves (Fig. 4A). However, in this case, the survival rate is much higher. Low survival rates of fish which had favourable conditions at the beginning of the season are usually caused by unfavourable conditions, often insufficient oxygen in the water, in the late season (Fig. 4B).

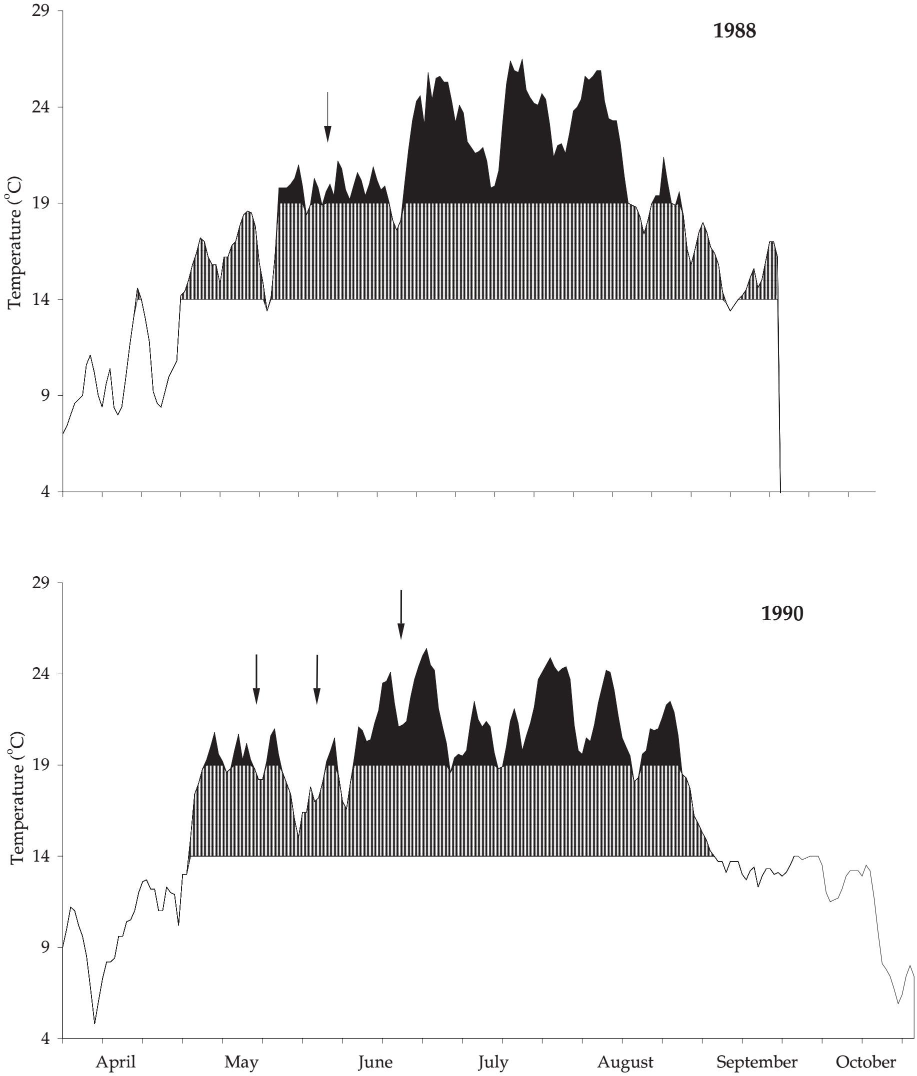

Fig. 1. Examples of average diel water temperature fluctuations during farming seasons. Dark fields present the temperature which is effective for carp body mass growth; the arrow indicates larvae stocking; 1988 favourable and 1990 unfavourable thermal conditions.

PATHOLOGICAL FACTORS

Some species of ectoparasites were found in 10 to 80% of the one-year-old carp, but they did not appear to pose any great threat to their survival. The first signs of life-threatening disease usually appeared after mid-July and persisted with variable

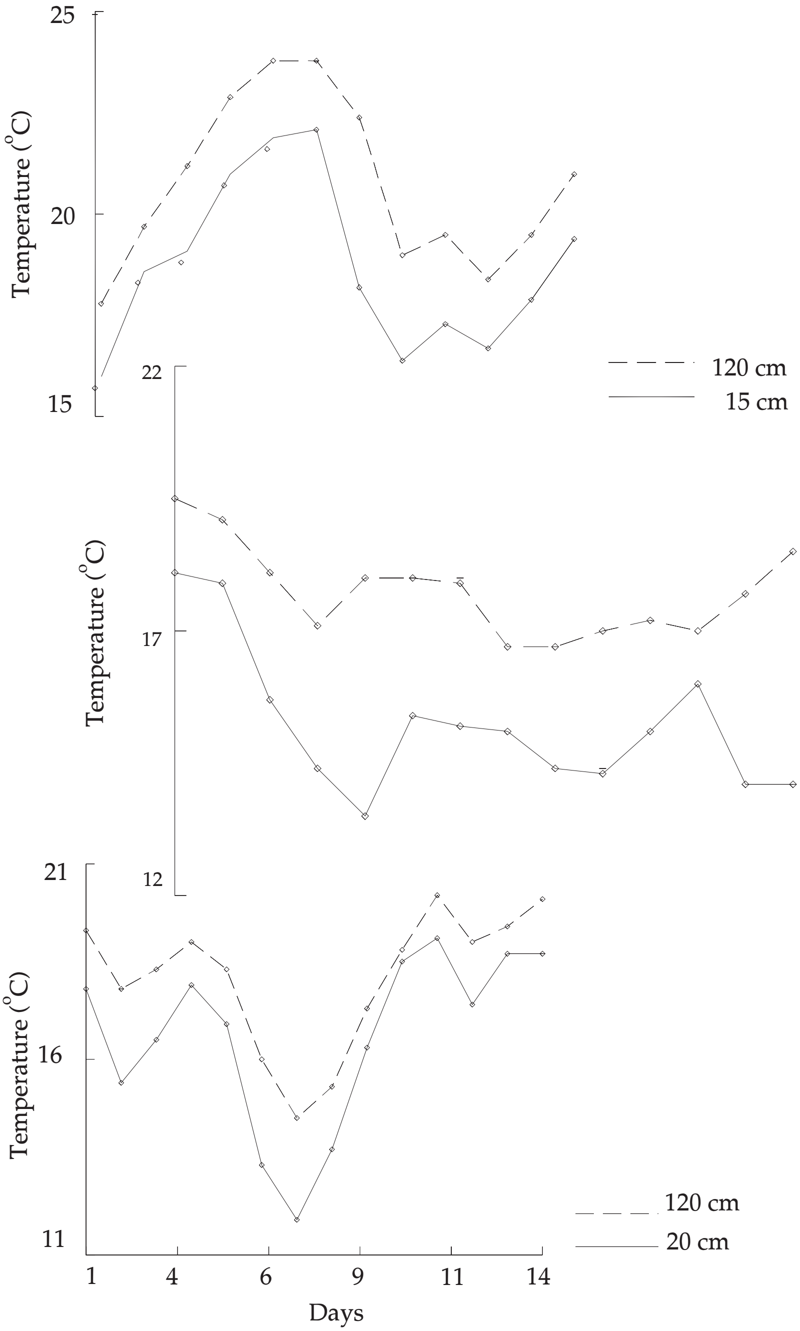

Fig. 2. Examples of diel water temperature fluctuations (°C) in a deep (- -) pond and in nursery (—) ponds at 7 am at the end of May and the beginning of June.

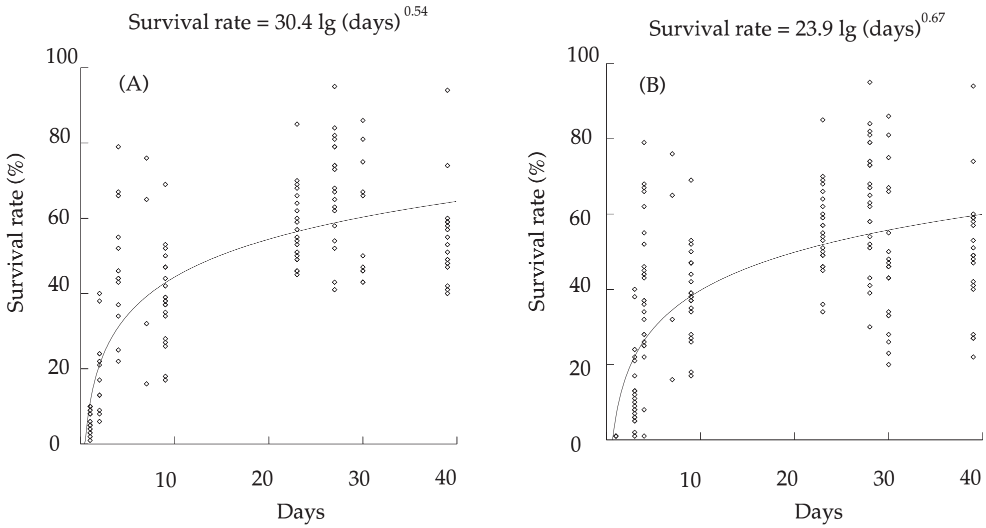

Fig. 3. Survival rate of larvae (A) and one-year-old carp (B) vs. the number of warm days between fish stocking and the first temperature decrease below 20°C.

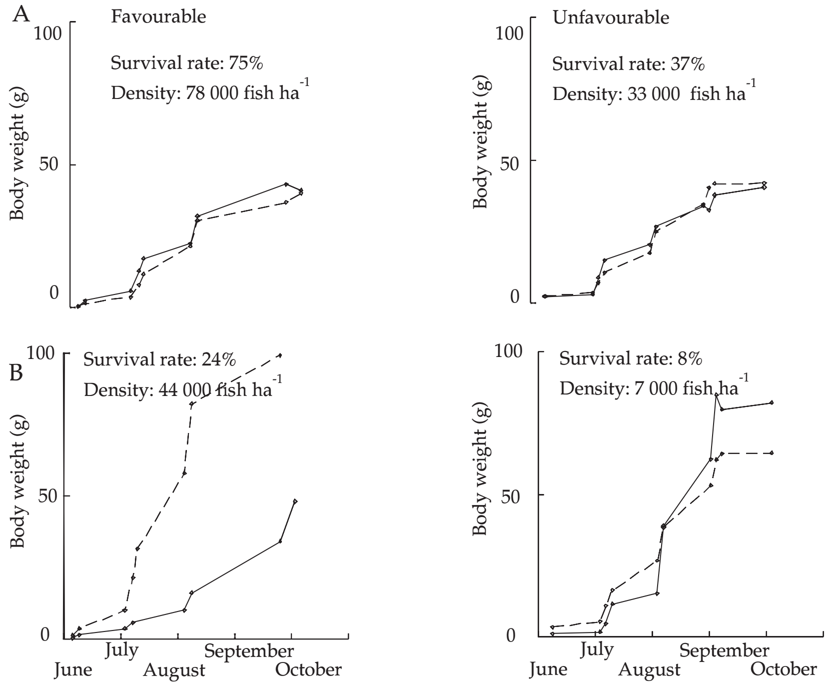

Fig. 4. Empirical (--) and theoretical (—) growth of fingerling body weight in ponds with differentiated survival rates and final fish densities under favourable and unfavourable thermal conditions; A – fish mortality occurred within a few days of larvae stocking, B – in the second half of the season.

intensity until the end of the season. In most cases, these were swim bladder inflammation and gill necrosis, and, more infrequently, infestation by tapeworms of the genera *Caryophyllaeus* sp. and *Bothriocephallus* sp. In spite of the disparity of the results, it can be stated that in the W × 3 hybrid the frequency of swim bladder inflammation decreased as the fish survival rate increased (Fig. 5). When the first drop in temperature occurred later than 10 days post-stocking, the survival rate increased considerably while the swim bladder inflammation frequency decreased considerably (Fig. 6).

DISCUSSION

Under laboratory conditions, it was determined that a drop in water temperature from 25 to 9-6°C at the rate of 0.1°C h^{-1} was lethal (LT_{50}) for carp fry (Lirski and Opuszyński 1988a). Field results showed (Szumiec 1984) that a decrease in pond depth from 30 to 15 cm causes an increase in the diel amplitude of water temperature from approximately 5 to 8°C. In these ponds, momentary temperature decreases to the lethal limits at a dangerous rate higher than 0.5°C h^{-1} may occur in the early morning (Figs. 1 and 2). These allow for the assumption that under unfavourable thermal condition the disparity of the fry survival rate (Fig. 3) resulted from differentiated pond depth.

The inhibitory effect of low temperature on the immunological mechanism of fish has been known for a long time from experiments in aquariums. Various authors have stated that carp are highly sensitive to temperature decreases in the earliest developmental stages, and that such drops inhibit both humoral and cellular reactions in the fish (Avtalion et al. 1980, Avtalion 1981, Rijkers et al. 1980). Still, it is difficult to explain the increasing frequency of swim bladder inflammation, the intensity of pathological changes in the gill system, and the parasite invasion observed in one-year-old fish under unfavourable conditions (Pilarczyk 1987, Pilarczyk 1998). Most data regarding the effect of temperature on immunomodulation address fully-developed fish with efficient immunological competence, which is usually observed in several-week-old carp (van Loon et al. 1981, Manning and Mughal 1985). In the initial stage of growth, however, an unfavourable thermal pattern can affect the development of parasitic diseases and bacterial infections, weakening the fish and possibly leading to swim bladder inflammation (Figs. 5 and 6). According to Manning and Mughal (1985), these conditions affect the resistance of carp by slowing

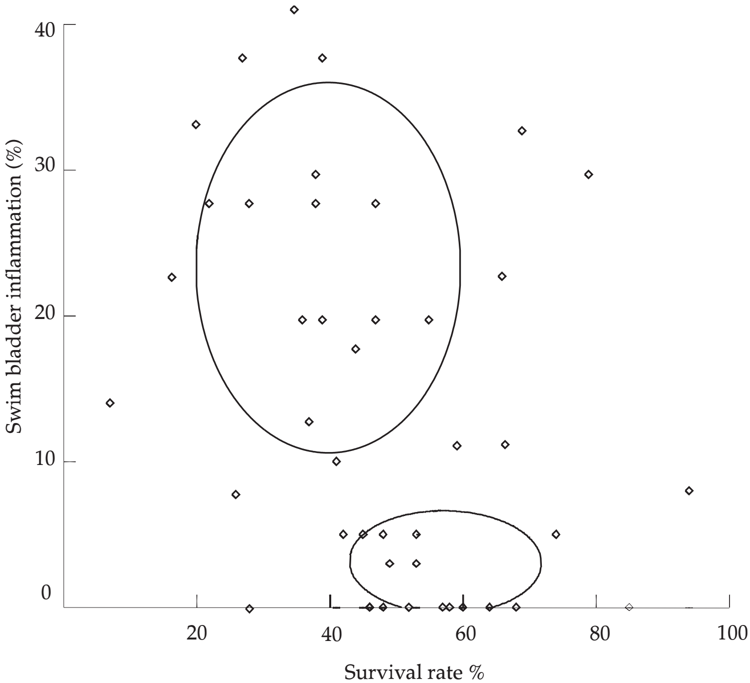

Fig. 5. Frequency of swim bladder inflammation vs. survival rate of larvae; lower ellipse indicates 0.50% confidence region of inflammation in favourable seasons; higher ellipse about 50% (slight asymmetric distribution) under unfavourable thermal conditions.

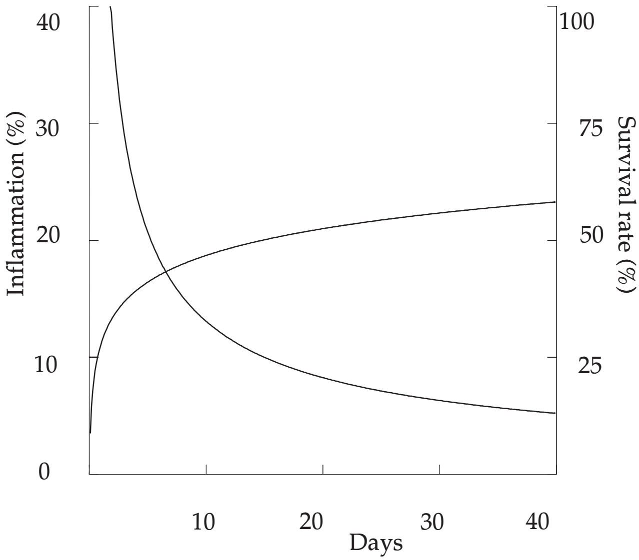

Fig. 6. Survival rate of one-year-old carp and frequency of swim bladder inflammation vs. number of warm days.

down the immunological system and disturbing the development and functioning of the immunocompetent organs more so than by direct inhibitory action on the immunological mechanism.

CONCLUSIONS

In temperate climates, weather cooling, which often occurs in the spring period, may cause the water temperature to fall to lethal levels in ponds shallower than 30 cm. When the temperature decline occurs during the first days of fish life, it is accompanied by a decrease in the survival of larvae and one-year-old carp, and an increase in the frequency of swim bladder inflammation in the fish during the second half of the rearing season.

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STRESZCZENIE

WPŁYW SPADKÓW TEMPERATURY WODY NA EFEKTYWNOŚĆ CHOWU KARPIA, *CYPRINUS CARPIO* L., W KLIMACIE UMIARKOWANYM.
I. PRZEŻYWALNOŚĆ I ZAPALENIE PĘCHERZA PŁAWNEGO U MŁODOCIANEGO KARPIA

Niska przeżywalność młodocianych stadiów jest jedną z głównych przyczyn ograniczenia efektywności chowu karpia w klimacie umiarkowanym, charakteryzującym się znaczną zmiennością pogody w okresie wiosennym (rys. 1). Praca jest próbą statystycznej oceny przeżywalności wylęgu i narybku oraz częstotliwości zapalenia pęcherza pławnego ryb, jako funkcji liczby dni między obsadą a pierwszym spadkiem temperatury wody w stawach odrostowych z ponad 20 do 15-14°C, czyli do wysokości letalnej w stawach płytszych aniżeli 30 cm (rys. 2). Podstawą oceny są wyniki badań nad efektywnością chowu krzyżówki samic linii węgierskiej W z samcami linii polskiej 3 (W × 3) prowadzone w ZIGR PAN w Gołyszu w sezonach hodowlanych 1981-1988 i w 1990. Badania ichtiopatologiczne przy pomocy powszechnie przyjętych metod rozpoczynano u 4-5 tygodniowego narybku w 4-16 stawach i prowadzono w odstępach 2-4 tygodni w latach 1981-1985. Korzystne warunki cieplne (spadek temperatury po 20 dniach) wystąpiły w 1982, 1983, 1986 i 1988, w pozostałych latach były niekorzystne (spadek przed 10 dniami). Określenie momentu największej śmiertelności ryb umożliwiło porównanie empirycznego wzrostu ryb z wynikami symulowanymi (rys. 4).

Przeżywalność wylęgu oraz narybku wzrastała w sposób logarytmiczny wraz z wydłużeniem korzystnych warunków cieplnych (rys. 3), natomiast zapalenie pęcherza pławnego malało (rys. 5 i 6). Przyczyną znacznej dyspersji wyników w latach korzystnych mogło być pojawienie się podczas dobowego minimum (tuż po wschodzie słońca) temperatury letalnej dla wylęgu w przesadkach o głębokości poniżej 30 cm. Natomiast w latach niekorzystnych temperatura letalna, a zwłaszcza letalna prędkość spadku temperatury, mogły się nie pojawić w przesadkach o głębokości większej od 30 cm.

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