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Farming of the Juvenile Narrow-clawed Crayfish *(Astacus leptodactylus)* in Cages and Ponds in Polyculture With Fish in the Heated Waste Water of the Thermal Power Plant[f]

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Experimental research has been carried out on fanning of the narrow-clawed crayfish larvae in ponds and cages in the TPP waste water. It was shown that farming in such conditions during the first vegetation period was more effective, than in water bodies with natural temperature regime. In ponds in polyculture with fish crayfish summerlings reached 4.4-4.6 cm length and 2.69-3.34 g mass; when grown in cages with natural forage resources - 3.4-3.7 cm and 1.25- 1.53 g, accordingly. Survival rate in the ponds amounted to 2.9-3.0%, in cages - 22.0-37.3%. Density of seeding should be about 70 specimens/m^2. Cages of the open-air type have been recommended.

KEYWORDS: *Astacus leptodactylus, breeding survival rate, larva, summerling, heated waste water, Berezovskaya TPS, Belarus.*

Introduction

In Belarus the main commercial species of Crustacean is a narrow-clawed crayfish - *Astacus leptodactylus* Esch. It occurs practically everywhere. As a rule its number is not high (less than 0.5 specimen per 1 trap a day), but in some water bodies catches can amount 10 specimens per 1 trap a day [4],

This product is highly requested in the foreign and domestic markets. Along with exploitation of the natural resources of crayfish, semi-intensive farming is the mostly perspective and economically effective. This method consists of the seeding stock (crayfish summerlings) farming in aquaculture and its settling into the perspective water bodies.

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Use of the waste heated water of the power plants enables to reduce period of larvae development, increase weight-dimensional characteristics of the seeding stock. This is reached by higher temperature and better supply of the natural forage objects [7],

This paper deals with peculiarities of the crayfish larvae growth and survival rate at farming in the cages and in ponds in polyculture with fish using heated waste water of the Berezovskaya TPP.

Material and Method

Water-cooling system of the Berezovskaya TPP (Berezovskiy region, Brest oblast, Belarus) comprises the main pond (the Beloye Lake, water surface 590 ha), one intake channel, two discharge channels and system of the fishery ponds, supplied by heated water from the discharge channels by pumps.

Density of seeding and fish species composition during the period of the juvenile crayfish farminging is presented in the Table 1. Females with eggs were caught by passive catching gear from 16 to 21 May in the Sominskoye Lake (the Brest oblast). Within some hours crayfish were brought to the incubation department of the fish farm "Selets".

Egg-bearing females were kept in the pools (dimensions 6.0 x 0.8 x 0.6 m, density 52 specimens/m^2) with constant water flow. Water temperature varied within the limits 24-25°C, dissolved oxygen content was not below 6.0 mg/1. Period of keeping was 20 days; animals were fed weekly by combined feed for carps. Survival rate until larvae hatching amounted to 97.0%. Dimension of the females (from edge of rostrum to the end of telson) varied from 8.0 to 12.5 cm, on average 10.7 ± 0.7 cm.

Larvae started to hatch on June 9,2008. Quality parameters of water from the discharge channels of the Berezovskaya TPP are presented in the Table 2. Larvae were obtained by the method of M. Keller [18]; they were washed off the females' pleopods by water. In two days larvae of the 2^{nd} development stage were measured, weighted and counted.

Along with egg-bearing females keeping in the incubation department, on May 31 2008 60 females were placed into two ponds (hf® 1, 2) with water area 0.2 ha (30 females in each), in order to obtain crayfish summerlings in pond conditions in polyculture with fish. Calculated density of the obtained crayfish larvae amounted to 1.6 specimens/m^2. Ponds were impounded in the end of April 2008, for this period quiet abundant forage base was formed.

Crayfish larvae of the 2^{nd} development stage, obtained on Junel 1, 2008 in the incubation department, were placed into cages (mesh opening 4.0 mm), which were placed in the pond -N° 1. Open cages (area 0.7 m^2) were placed near the bank at the depth 0.3 cm. Closed cages (area 0.8 m^2) were totally submerged and placed at the depth about 1 m.

Initial settling density in the open cages amounted to 300 specimens/m^2, in the close cages - tc 200 specimens/m^2. Simultaneously with larvae settling 1000 ml of the concentrated *Daphnia* culture (5 thousand specimens/1) from the warm discharge channel and three plants of homwon *(Ceratophyllum* sp.) were added into the cages. Afterwards feeding objects were not added

Table 1

Fish species composition and settling density at farming in polyculture with narrow-clawed crayfish

Ponds	Species	Starting density 15.05-10.06			Final density 30.09 (111-137 days)		
		specimen/kg	specimen/m^2	g/m^2	specimen/kg	specimen/m^2	g/m^2
Ns 1 (2000 m^2)	Catfish *Silurus glanis*	3/10.5	0.0015	5.3	3/12.0	0.0015	6.0
	Carp *Cyprinus carpio*	4/12.0	0.002	6.0	4/15.0	0.002	7.5
	Grass carp *Ctenopharyngodon idella*	40/140.0	0.02	70.0	40/160.0	0.02	80.0
	Amur silver carp *Hypophthalmichthys molitrix*	30/75.0	0.015	37.5	30 / 90.0	0.015	45.0
	Chinese silver carp *Aristichthys nobilis*	70/112.0	0.035	56.0	50/115.0	0.025	57.5
	Catfish summerlings	-	-	-	-500/14.0	- 0.25*	7.0
	Carp summerlings	-	-	-	- 400/30.0	- 0.20**	15.0
	Sub-total (without summerlings)	147/349.5	0.074	174.8	127/392.0	0.063	196.0
	Total	147/349.5	0.074	174.8	- 1027/436.0	-0.51	218.0
No 2 (2000 m^2)	Catfish *Silurus glanis*	5/15.0	0.0025	7.5	4/14.0	0.002	7.0
	Grass carp *Ctenopharyngodon idella*	43 / 146.0	0.022	74.8	43 /172.0	0.022	88.0
	Amur silver carp *Hypophthalmichthys molitrix*	26 / 52.0	0.013	26.0	23 /62.0	0.012	32.4
	Chinese silver carp *Aristichthys nobilis*	70/ 105.0	0.035	52.5	67 /147.0	0.034	74.8
	Total	144/318.0	0.073	160.8	137/395.0	0.070	202.2

* 14 kg of the catfish summerlings, average mass 30.0 g = ~ 500 specimens; ** 30 kg of the carp summerlings, average mass 80.0 g = ~ 400 specimens.

Table 2

Hydrochemical characteristics of water used for the crayfish larvae fanning

Characteristics	June 18,2007	June 10, 2008
PH	8.5	8.3
0_2 content, mg/dm³	10.5	9.3
Total hardness, mgCeq./dm³	4.4	4.9
Fe, mg/dm^3	0.05	0.04
NH“, mg/dm^3	0.15	0.13
NH*, mg/dm^3	0.02	0.01
Ammonia, mg/dm^3	0.20	0.14
Suspended matter, mg/dm^3	5.6	6.6
Solid residue, mg/dm³	333.6	303.0
Calcined residue, mg/dm^3	130.0	138.1
Oxidability, mg $0_2/dm^3$	21.0	20.0
BOD_5, mg 0_2/dm³	2.95	3.6
Ca, mg/dm^3	70.1	66.4
Cf, mg/dm³	40.0	38.1
Carbonates, mg/dm³	90.0	93.4
SO*", ion, mg/dm³	15.7	19.8
Silicates, mg/dm^3	14.0	12.1
Mg, mg/dm^3	10.9	12.8

Breeding of the crayfish larvae in the cages and ponds lasted 108-110 days and ended on September 30,2008. Juvenile crayfish was measured from edge of rostrum to the end of telson.

Variability of the growth indexes was assessed using standard deviation (*sd*). Variation coefficient (cv, %) was used as variability measure. Specific weight growth rate was calculated according to formula:

$$,,_{\wedge W\sim}(\text{in } W_z \text{ -In } JF_0)\text{x } 100 \quad {}^{9} \quad \text{m}$$
$$\text{X} \qquad {}_{4}$$

where W_T– final mass, mg; W_0 - initial mass, mg; x - breeding period, days. Obtained results were processed using «STATISTICA-6,0» software.

Results and Discussion

According to the literature data the narrow-clawed crayfish is able to occur for a long time within the temperature range from 4 to 32°C. It was noted that crayfish adapted to the temperature 26°C are able to stand sharp temperature decrease to 15°C and its increase to 35.8°C [20]. Thus, during our experiment temperature conditions were quite favorable for the crayfish growth and development. Maximal water temperature in the ponds (about 28.0°C) was registered in June-July, only in the middle of September it sharply decreased to 14°C (Fig. 1)

Value of pH was slightly shifted to the alkaline, at this high calcium and low ammonia content was observed, this conditions were favorable for the crayfish growth and development [11, 19]. Somewhat elevated oxidability was a sub-optimal factor, indicating high content of organic matters in the water body, but high oxygen content mitigated limiting effect of the organic pollution [8],

At keeping of the crayfish females in the incubation department, were obtained 105 larvae per 1 female of the average length 10.7 ± 0.7 cm. Effective fertility of the long-clawed crayfish from the Sominskoye Lake on average amounted to 165 eggs [1], Thus, during 20 days of the females keeping and 2 days of the larvae farming survival rate of larvae amounted 65% of the effective fertility. Taking into account average larvae yield per one female (105 larvae), let us suppose that in the ponds, where 30 egg-bearing females were settled, were about 3150 larvae of the second development stage, that is 1.6 speciemnt/m^2.

Average length of the two-day-old larvae of the 2nd development stage amounted to 1.01 ± 0.1 cm, prevailed larvae of the length diapason from 8.0 to 12.5 mm (Fig. 2, *a)*. Average wet mass amounted to 27.89 ± 4.90 mg (min 18.0, max 38.0 mg), prevailed specimens with mass 22.0-34.0 mg (Fig. 2, *b)*. Variation coefficient of the body length and mass amounted to 10.9 and 17.6%, accordingly.

Average body mass of the narrow-clawed crayfish from different habitats is not constant. Thus, average mass of the 2nd age larvae in experiments carried out in Poland amounted to 29.0 ±3.0 mg [21], in England - 36.0 ± 7.1 mg [15]. However in Turkey the 3rd age larvae had average mass 22.4 mg [18], The egg mass in females of the same size can differ 1.4—1.7 times, the tendency was noted: the more female size was, the more egg size was [13].

When larvae were grown in cages of different type, their dimension-weight characteristics also differed even at the first development stages (Table 3). Statistically reliable differences in the crayfish growth rate at the age 19 and 57-58 days were not noted. Reliable differences were noted at the age 34-35 days (t = 2.22; p = 0.03), and in the end of the growth period (t = 2.07; p = 0.04). Significance of differences in this period (110-112 days) was close to threshold, and differences in average size and mass of the crayfish summerlings from different cages were minor. For the crayfish farming we recommend to use open-type cages and to place them within the shallow areas, because in this case it is easier to monitor larvae state, feed and resettle them.

Effect of density and temperature was studied at larvae farming in aquariums at different temperature. It was stated that at the low temperature (15°C) density lost its importance and had no crucial effect on the juveniles' growth. Low feeding activity at these conditions enabled crayfish to survive at relatively higher density. When temperature increased to 25°C growth rate of crayfish statistically reliably depended on density [15].

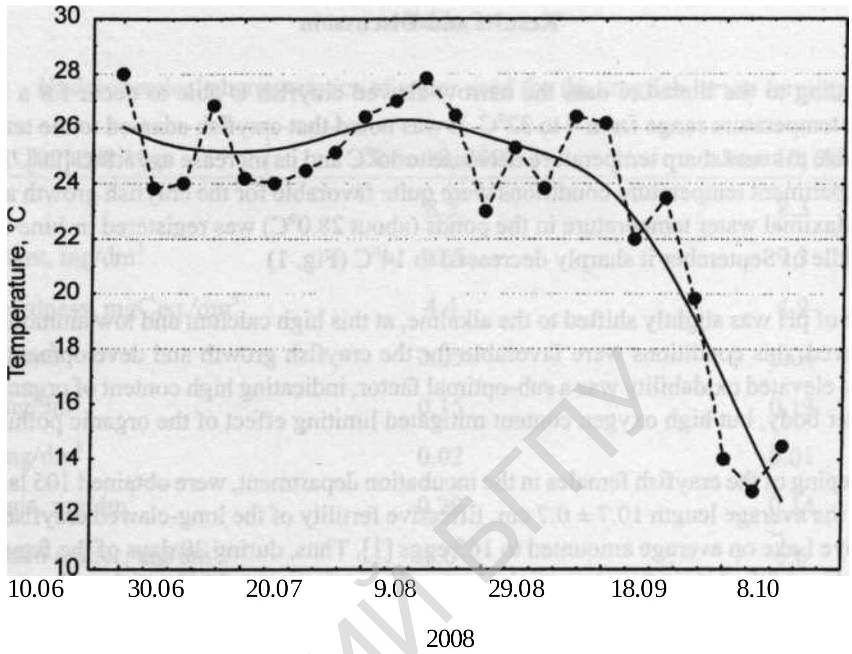


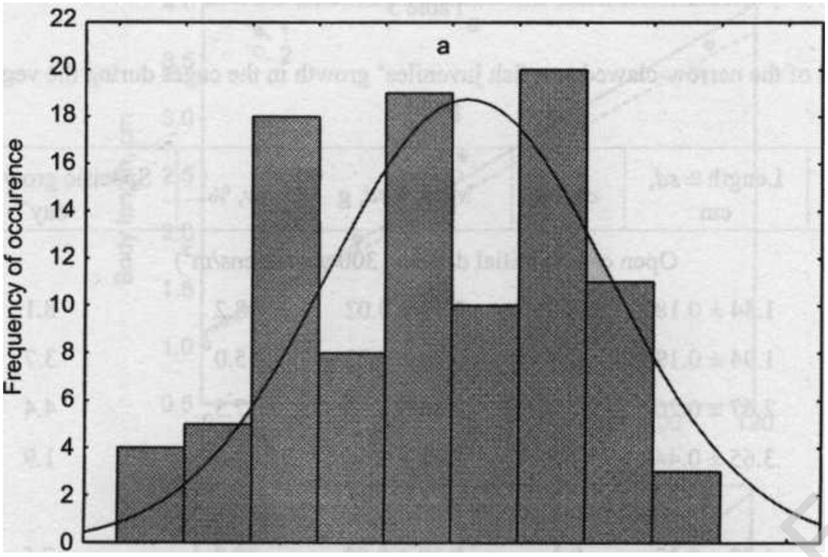
Fig. 1. Water temperature dynamics in the ponds supplied with waste water of the Berezovskaya TPP during the vegetation period 2008.

When the narrow-clawed crayfish larvae were grown in the outdoor concrete pools (density 875 specimens/m^2, temperature about 18°C), in 3 months, from June 23 to September 25, males became 2.7 cm length and 0.51 g mass, and females -2.6 cm and 0.348 g [15], that is significantly less than in our experiments (see Table 3 and Fig. 4).

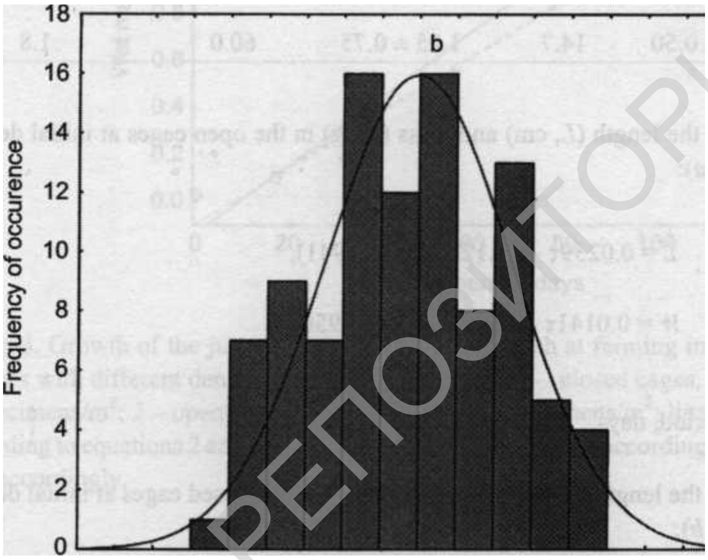
Results obtained in Turkey, when juvenile narrow-clawed crayfish were grown in the plastic pools (density from 50 to 200 specimens/m^2) [18], were close to results obtained in our experiments Crayfish was fed by industrial trout mixed feed, growing duration - 120 day, water temperature - 22.8°C. When density was 100 and 200 specimens/m^2 final length of animals amounted to 3.55 =l 0.53 and 3.33 ± 0.33 cm, accordingly, and at density 50 specimens/m^2 their average lengtl amounted to 3.65 ± 0.29 cm.

Specific growth rates were close in two variants of the juvenile crayfish farming in the cage during all growth period and decreased as larvae became older (see Table 3).

According to the literature data [21], specific growth rate of larvae in aquariums in the firs month amounted to 6.4 and 5.8 day at the density 600 and 1200 specimens/m^2, accordingly. In th second month it amounted to 3.1 and 2.9 day^{-1}, and in the third - 1.3 and 1.4 day^{-1}. Thus, specifi growth rates in the first month were close when the juvenile crayfish were grown in the cages and i: aquariums, at significantly higher densities. However later specific growth rate in the cages wa higher (see Table 3). When juveniles were grown in the concrete pools [15], specific growth rate c males amounted to 2.48 day $^{-1}$, and females - to 2.41 day $^{-1}$.



0.75 0.80 0.85 0.90 0.95 1.00 1.05 1.10 1.15 1.20 1.25 Body length, cm



0.014 0.018 0.022 0.026 0.030 0.034 0.038 0.042 Wet mass, g

Fig. 2. Length (a) and mass (*b*) of the 2nd age larvae obtained in the incubational department.

Growth of the narrow-clawed crayfish at the early ontogenesis stages was well described by the lineal regression equation.

Table 3

Dynamics of the narrow-clawed crayfish juveniles' growth in the cages during the vegetation period

Age, days	Length ± *sd*, cm	*cv*, %	Mass ± *sd*, g	cv, %	Specific growth rate, day^{-1}
		Open cages (initial density 300 specimens/m^2)			
19	1.54 ± 0.18	11.7	0.11 ±0.02	18.2	8.1
35	1.94 ±0.19	9.8	0.20 ±0.03	15.0	3.7
58	2.67 ± 0.26	9.7	0.55 ±0.15	27.3	4.4
112	3.65 ± 0.44	12.1	1.53 ±0.56	36.6	1.9
		Closed cages, (initial density 200 speciemens/m^2)			
19	1.43 ±0.13	9.1	0.10 ±0.02	20.0	7.5
34	1.85 ±0.15	8.1	0.18 ±0.03	16.7	4.3
57	2.51 ±0.28	11.2	0.48 ±0.21	43.8	4.0
110	3.40 ± 0.50	14.7	1.25 ±0.75	60.0	1.8

For calculation of the length (*L*, cm) and mass (*W*, g) in the open cages at initial density 300 specimens/m^2 (Fig. 3, *a*):

$$L = 0.0239\tau — 1.1285\ (R^2 = 0.941), \quad (2)$$

$$W = 0.0141r — 0.1278\ \{R^2 = 0.956), \quad (3)$$

where: τ - farming period, days.

For calculation of the length (*L*, cm) and mass (*W*, g) in the closed cages at initial density 200 specimens/m^2 (Fig. 3, *b*):

$$L = 0.0223r — 1.0952\ (.R^2 = 0.930), \quad (4)$$

$$W = 0.0117x — 0.0890\ (R^2 = 0.966). \quad (5)$$

At higher density (300 specimens/m^2) final dimension-weight characteristics of the summerlings were higher than at lower (200 specimens/m^2). This may be explained by the fact that at the first growth stage in the open cages mortality rate increased (up to 71.4 specimens/m^2) (Fig. 4 *a*), and survival rate decreased to 25% (Fig. 4, *b*). Later density and mortality stabilized, and insig-

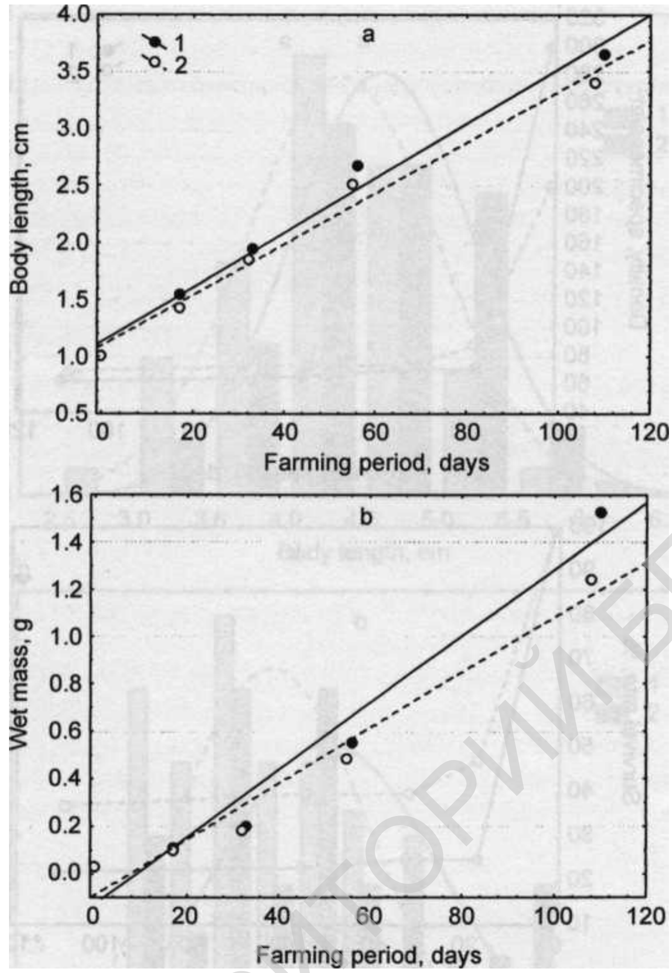


Fig. 3. Growth of the juvenile narrow-clawed crayfish at farming in the different-type cages with different density (*a* - length, *b* - mass); *1* - closed cages, initial density 200 specimens/m^2; *2* - open cages, initial density 300 specimens/m^2; lines (a) - 1 and 2 according to equations 2 and 3, accordingly; lines (*b*) -1 and 2 according to equations 4 and 5, accordingly.

nificantly decreased to the end of farming. In the open and closed cages density and mortality amounted to 62.3 specimens/m^2 and 22.0%; and 70.0 specimens/m^2 and 37.3% .

Similar dynamics of survival rate was noted by other specialists. For instance, mortality of the juvenile narrow-clawed crayfish at cultivation in aquariums (at the density 600 and 1200 specimens/m^2) was maximal in the first month, it amounted to 42.0 and 52.3%, in the second month it decreased to 5.3 and 12.0% and remained at this level during the third month (4.3 and 13.0%, accordingly). In 92 days body length amounted to 3.0 cm. [21]. When summerlings were farmed in the trays [18], survival rate amounted to 67.0-73.8%, that is significantly higher than in the cages in the discharged heated water.

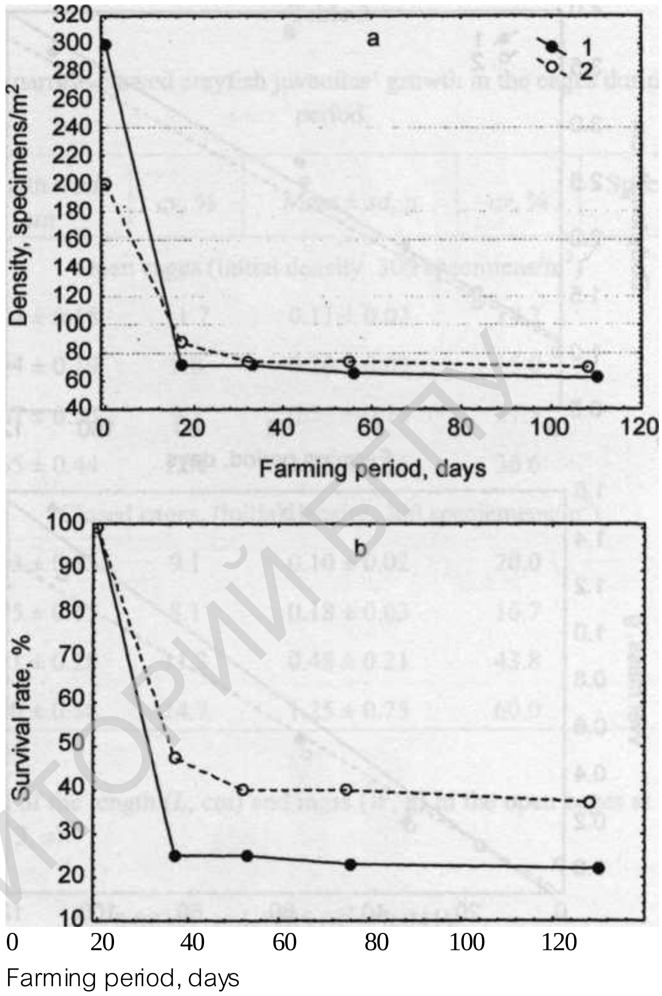


Fig. 4. Dynamics of density (a) and survival rate (*b*) of the narrow-clawed crayfish summerlings at cultivation in cages; *1* - initial density 300 specimens/m^2; *2* - initial density 200 specimens/m^2.

Usually cultivated specimens are sufficiently supplied by forage, but in our case juveniles were supplied only by natural forage base and got any additional feeding. As a result average size of the summerlings was comparable with data of other authors, but survival rate was lower.

Habitat conditions of the juvenile crayfish can be assessed by lost or injuries of the chelipeds. In the end of our experiment number of specimens with lost chelipeds in the open cages amounted to 9.1%, and in the closed cages - 14.5%. According to the literature data [18], at cultivation in the plastic trays at the density 100 specimens/m^2 number of specimens with injured chelipeds amounted to 16.0%. This number increased as density increased [18].

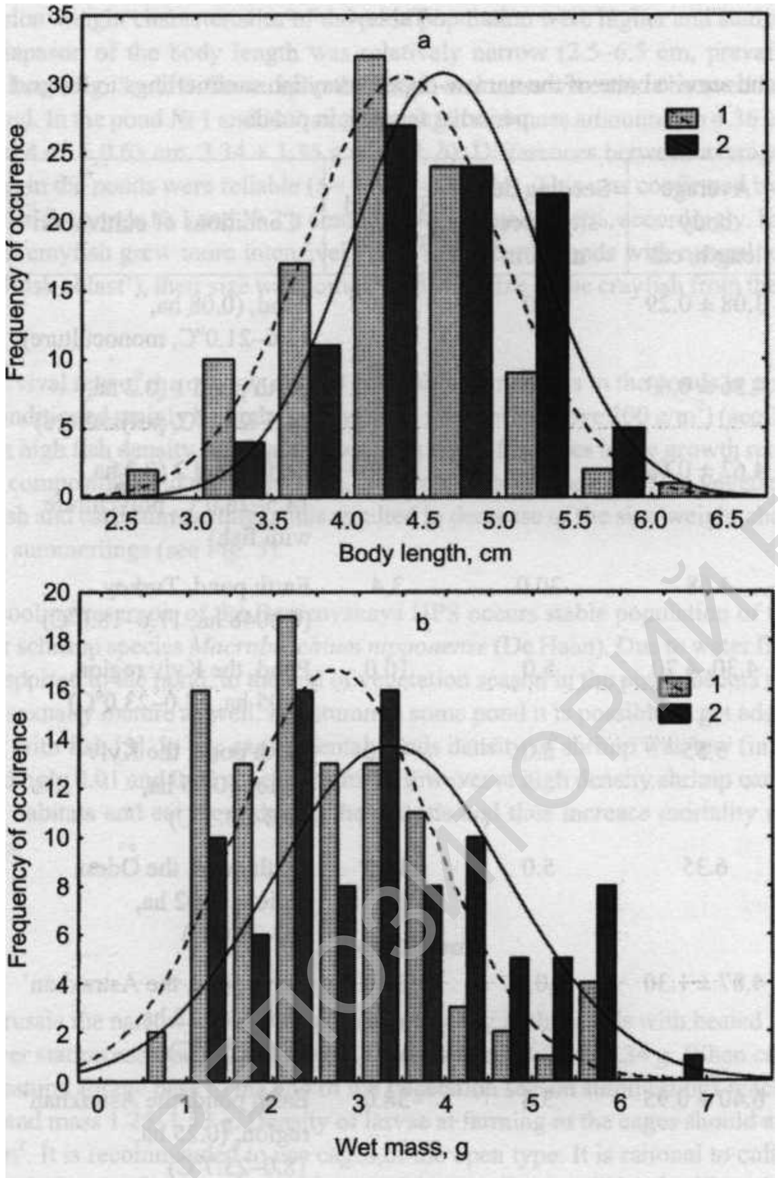


Fig. 5. Length (a) and mass (*b*) of the narrow-clawed crayfish summerlings at cultivation in the ponds with discharged heated water in polyculture with fish; *1* - pond hf° 1; *2* - pond N 2.

Results of our study and literature data enabled to conclude that density in cages, plastic trays and basins should not exceed 70-80 specimens/m^2. At farming of the yearlings to the commercial mass density should be even less. For instance, in order to obtain commercial product, recommended density of the narrow-clawed crayfish summerlings (2.0-5.0 cm long) amounted to 10- 150 specimens/m^2 [14].

Table 4

Dimensions and survival rate of the narrow-clawed crayfish summerlings to the end of vegetation period at farming in ponds

Farming time, days	Average body length, cm	Seeding density, speci- mens/m^2	Survival rate, %	Conditions of cultivation	Literature sources
132	3.08 ± 0.29	6.0	22.0	Pond, (0.08 ha, 12.6-21.0°C, monoculture)	[3]
108	4.36 ± 0.63	1.6	3.0	Earth pond 1 (0.2 ha, 14.5-28.0°C, polyculture)	Original data
108	4.62 ± 0.63	1.6	2.9	Earth pond 2 (0.2 ha, 14.5-28.0°C, polyculture with fish)	Original data
120	4.68	20.0	3.4	Earth pond, Turkey (0.0048 ha, 17.6-18.0°C)	[17]
120	4.30—4.70	5.0	10.0	Pond, the Kyiv region, (0.05 ha, 13.0-23.0°C)	[2]
122	5.55	5.0	10.0	Earth pond, the Kyiv region (0.05 ha, 10.0-23.5°C)	[9]
122	6.35	5.0	16.0	Earth pond, the Odesa region, (0.02 ha, 8.0-28.0°C)	[9]
119	4.87 ± 1.30	10.0	21.0	Earth pond, the Astrakhan' region, (0.25 ha, 17.5-21.4°C);	[5]
128	6.40 ± 0.95	3.8	38.0	Earth pond, the Astrakhan' region, (0.25 ha, 18.0-23.7°C)	[6]
120	5.25 ± 1.93	6.0	30.0	Earth pond, the Rostov region, (0.13 ha, 21-23°C, carp larvae)	[12]
120	5.05 ± 0.86	30.0	75.2	Earth pond, the Rostov region, (0.13 ha, 21-23°C, buffalo larvae)	[12]
160	5.79 ± 1.21	2.1	71.0	Pond, Bulgaria, (0.14 ha, 16.5-24.1°C, grass carp summerlings)	[10]

Dimension-weight characteristics of the pond population were higher and statistically reliably differed. Diapason of the body length was relatively narrow (2.5-6.5 cm, prevailed specimens 4.0-5.5 cm long (Fig. 5, *a)*. Differences in the length and mass were also observed in crayfish from different pond. In the pond JV® 1 and .Ns 2 average length and mass amounted to 4.36 ± 0.63 cm, 2.69 ± 1.15 g and 4.62 ± 0.63 cm, 3.34 ± 1.35 g (Fig. 5, *b)*. Differences between average length of the summerlings in the ponds were reliable *(t = 3.6,p* = 0.0004). This was confirmed by low variation coefficients, in the ponds-N® 1 and-N® 2 it amounted to 14.4 and 13.6%, accordingly. In the pond with heated water crayfish grew more intensively than in the earth ponds with natural temperature regime (the Minsk oblast'), their size was comparable with size of the crayfish from the south regions (Table 4).

Low survival rate of the narrow-clawed crayfish summerlings in the ponds in polyculture with fish were conditioned mainly by high density of the fish stock (above 200 g/m^2) (see Table 2). Probably, at such high fish density survival rate was low and differences in the growth rate depended on fish species composition and their age. Thus, in the pond X® 1 to the end of the vegetation season appeared catfish and carp summerlings, this resulted in decrease of the size-weight characteristics of the crayfish summerlings (see Fig. 5).

In the cooling reservoir of the Berezovskaya HPS occurs stable population of the subtropical eastern river schrimp species *Macrobrachium nipponense* (De Haan). Due to water flow shrimp larvae are transported to the pond, to the end of vegetation season in the ponds occurs certain amount of shrimps, sexually mature as well. In autumn in some pond it is possible to get additional shrimp yield, along with fish [3]. In our experimental ponds density of shrimp was low (in the ponds JV°1 and 2 accordingly 0.01 and 0.02 specimens/m^2). However at high density shrimp can compete with crayfish in habitats and eat them during the ecdysis and thus increase mortality of the crayfish summerlings.

Conclusion

In Belorussia the narrow-clawed crayfish summerling in the ponds with heated waste water of electric power station reached the length 4.4-4.6 cm and mass 2.69-3.34 g. When cultivated in the cages with natural forage base to the end of the vegetation season summerlings reached the length 3.4—3.7 cm and mass 1.25-1.53 g. Density of larvae at farming in the cages should amount to ~ 70 specimens/m^2. It is recommended to use cages of the open type. It is rational to cultivate juvenile crayfish only during the first month. At this material expenditures will be significantly reduced, and lost of number will be minor.

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