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Study of the embryonic period of female crayfish egg development in different species

Mykola Slusar
PhD in Agricultural Sciences, Associate Professor
Polissia National University
10008, 7 Staryi Blvd., Zhytomyr, Ukraine
https://orcid.org/0000-0002-3668-2109

Andrii Muzhenko
Postgraduate Student
Institute of Animal Breeding and Genetics nd. a. M.V. Zubets
of National Academy of Agrarian Science of Ukraine
08321, 1 Pohrebnyaka Str., Chubynske Village, Ukraine
https://orcid.org/0000-0003-1032-7317

Irina Kovalchuk*
PhD in Veterinary Sciences
Polissia National University
10008, 7 Staryi Blvd., Zhytomyr, Ukraine
https://orcid.org/0000-0002-2421-7533

Valeriy Borshchenko
Doctor of Agricultural Sciences, Professor
Polissia National University
10008, 7 Staryi Blvd., Zhytomyr, Ukraine
https://orcid.org/0000-0002-0710-5628

Tetiana Verbelchuk
PhD in Agricultural Sciences, Associate Professor
Polissia National University
10008, 7 Staryi Blvd., Zhytomyr, Ukraine
https://orcid.org/0000-0001-7334-4507

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Abstract. Freshwater crayfish farming is a promising area of production in the food market. This aquaculture industry is currently gaining popularity around the world, but given the high consumer demand, it requires modernisation. The efficiency of aquaculture production is based on the introduction of innovative methods into production processes, which are based on knowledge of biological characteristics, including reproductive capacity and the embryonic period of caviar development. The study aims to assess the

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*Corresponding author

reproductive quality of females and determine the incubation period of caviar, its quantity, weight, and survival rate. The study presents the results of research on the reproductive qualities and embryonic period of crayfish eggs of four species (*Cherax quadricarinatus, Procambarus clarkii, Procambarus fallax forma virginalis, Cherax destructor*) kept in separate closed water supply tanks at an optimal planting density of 4 individuals per 0.45 m^2. Studies have shown that the colour range of caviar and the duration of the incubation period for its maturation varies among different crayfish species. Thus, the first stage of incubation was the shortest and ranged from 2.80 (Florida crayfish) to 3.55 (destructor crayfish) days, while the second stage lasted the longest – from 13.17 to 15.80 days for Australian and broad-toed crayfish, respectively. Based on the analysis of the physiological characteristics of the female crayfish micropopulation, they were divided into quality categories, considering the following indicators: female weight, egg weight, total number of eggs, and number of eggs per 1 g of female. Females of the Australian red snapper of the excellent category was the best among all species in terms of live weight (63.0±0.67 g), egg weight (5.0±0.05 g) and total number of eggs (376.8±16.34 pcs.), the lowest similar indicators were in the marble species (16.8±0.15 g, 1.6±0.03 g, 124.5±2.66 pcs.), respectively. In terms of the number of eggs per 1 g of female weight, Florida crayfish prevailed (7.8±0.19). Instead, the destructor crayfish had intermediate results in these characteristics. The study results can be used in the economic activities of enterprises producing aquatic organisms

Keywords: *Cherax quadricarinatus; Procambarus clarkii; Procambarus fallax forma virginali; Cherax destructor*; reproductive female qualities

INTRODUCTION

Crayfish belong to the aquaculture segment, and their production technologies in artificial conditions are still under development, which requires scientifically sound approaches to keeping, feeding and production systems. The incubation period of female crayfish eggs is no exception, as it determines the size of the future micro-population. Therefore, the selected research topic is relevant. Freshwater crayfish are in great demand around the world. According to the International Food and Agriculture Organisation (FAO), crayfish products were sold for USD 7.6 billion, and it is also noted that the demand for this type of aquatic organism constantly exceeds supply (FAO, 2021).

F. Liu *et al*. (2020) note that the level of production of aquaculture products is negatively affected by the use of traditional, labour-intensive production methods, depending on the season and the effects of inbreeding. According to A. Asher (2020); only traditional caviar production to increase the number of crustaceans requires the use of up to 30% of production tanks, which significantly reduces production efficiency, and the use of the above methods has a direct impact on the industry's ability to meet current market requirements and indicates their unsuitability for intensive production systems. J. Bitomsky (2008) describes that modern technologies of crayfish farming in industrial conditions should be based on a high percentage of preservation of individuals by creating optimal conditions for their reproduction and maintenance, as well as obtaining products in the projected volumes. N.E. Hrynevych *et al.* (2022) indicate that to increase the growth rate and reduce cannibalism in crayfish, it is advisable to use dietary supplements (Spirulina+Chlorella, Digestarom, carotenoids) with extruded feed, which contributes to the production of high-quality protein products, and the process of production of aquatic organisms is determined by their technological level of cultivation and the development of aquaculture as an industry.

J. Patoka *et al.* (2016) believe that out of more than 100 species of Australian freshwater crayfish, only three have the potential for commercial farming, including marron (*C. tenuimanus*), yabby (*C. destructor*), and red-clawed (*C. quadricarinatus*). I. Norshida *et al.* (2021) indicate that the most promising for commercial farming is the Australian red snapper. N.P. José *et al.* (2019) describe that the production of freshwater crayfish products began with the Australian red snapper, as this species has biological characteristics that contribute to its rapid breeding. D. Lodge *et al.* (2012) describe Australian red-claw crayfish as a native species, best suited for aquaculture.

E.I. Fedorovych *et al.* (2022a) note that the average weight gain in the first year of life of red snapper in closed water supply systems is 50-150 g. Up to 70% of the maximum growth can be achieved at temperatures in the range of 23-28°C. For adults, a comfortable level of dissolved oxygen in water is 6-8 mg/l, and the Ph level is 6.0-8.0. M. Amer *et al.* (2015) studied the maturation period of Florida crayfish eggs in the natural conditions of the Nile River basin and proposed to divide them into ten stages of development during maturation. G. Vogt *et al.* (2008) pointed out that the marbled crayfish is the only crustacean in the world that reproduces by apomictic parthenogenesis. In particular, the author notes that there are only females that lay unfertilised eggs, the development of which causes a genetically homogeneous population. C.M. Jones *et al.* (2009), having conducted several studies in laboratory conditions and natural populations, indicate that no males of this species have been found. Females reared at a temperature of 20-25°C began to breed at the age of 141-255 days, their fecundity ranged from 45 to 416 eggs and varied depending on the size of the female. The incubation period was 22-42 days.

Given the above, the issue of studying the growth and development of female crayfish eggs of different species in closed-water supply systems remains relevant. The study was aimed at assessing the embryonic period of development of female crayfish eggs of *Cherax quadricarinatus, Procambarus clarkii, Procambarus fallax forma virginali, and Cherax destructor*.

MATERIALS AND METHODS

The experiment was carried out in the aquaculture laboratory of the Polissia National University (39 B Korolova St., Zhytomyr, Zhytomyr region). The experiment was conducted in the second half of 2021. For the experiment, 70 females of the Australian red snapper, 67 females of the marbled snapper, 64 females of the destructor and Florida crayfish were selected. They were kept in separate breeding tanks measuring 23×35 cm. The water filtration system included three stages of purification: mechanical – using a filtration sponge, biological – using a special biofilter, and bioremediation – purification with plants. The water was saturated with oxygen using an air aerator. The water temperature was maintained at 28°C. The optimum planting density for the breeding stock was 4 individuals per 0.45 m^2.

Before forming a group, each female was weighed, and the stage of egg development was determined. Sampling to determine the number of eggs was carried out immediately after the females laid eggs on the pleopods and at the end of the embryonic period of egg development, just before the larvae emerged. Fecundity was determined by counting all eggs on the female pleopods. To determine the stage of egg development, females were examined weekly. Experimental animals were fed with balanced feed, its nutritional value is indicated per 100 g of product (Table 1).

Table 1. *Feed nutritional value*

Feed	Water, g	Protein, g	Fat, d	Carbohydrate, g	Fibre, g	Calorie content, kcal
Grain crops:						
sprouted wheat	48	7.5	1.3	41.4	2.0	198
non-polished rice	12	7.5	2.7	72.8	3.4	362
oats	14	10	6.2	55.1	12	316
Fish fillet:						
hake	79.7	16.7	2.0	0	0	86
pike	79	18.4	1.1	0	0	84
Oak leaves	0	0.1	0	0.1	0	1

Source*: compiled by the authors*

During feeding, females were observed, and the stage of egg development was determined. When formed fry appeared, the female was removed, and the crayfish were counted. To complete the incubation cycle, the fry was reared to a weight of 0.02 g, and such crayfish were considered formed. However, individuals weighing less than 0.02 g were vulnerable and a significant percentage of mortality was observed among them, which is associated with an increase in the frequency of moulting at small sizes. The reproductive quality of females was assessed by the following indicators: female weight, egg weight, total number of eggs, and number of eggs per 1 g of female body weight. Subsequently, based on the results obtained, the females were divided into quality categories: excellent, good, satisfactory, and unsatisfactory.

All experimental studies were carried out by modern methodological approaches and in compliance with relevant requirements and standards, in particular, they meet the requirements of DSTU ISO/IEC 17025:2005 (2006). The animals were kept, and all manipulations were carried out following the provisions of the Procedure for conducting experiments and experiments on animals by scientific institutions (Law of Ukraine No. 249, 2012), the European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes (European Convention on the Recognition of the Legal Personality of International Non-Governmental Organisations, 1986).

RESULTS AND DISCUSSION

In 3-4 weeks after mating, females begin to lay eggs, releasing them through the anus, the eggs attach to the pleopods under the pond and remain there until the developmental period is complete. This is the most difficult stage in a female's life, as she constantly needs to move her tail, flex and extend her abdomen, creating constant dynamics in the water under the pelvis, as the eggs require continuous flushing with oxygen-enriched water. It has been shown that during this process, some eggs are detached from the pleopods, fall to the bottom and die. In addition, females do not always manage to create the necessary water movement when placing them in hiding places, which contributes to the stagnation of water and, accordingly, a decrease in its oxygen content and an increase in the level of metabolic products, which also contributes to an increase in the percentage of eggs killed. It is worth noting that at this time, the body is forming, and the colour of the eggs is changing.

H. Aydin and M.K. Dilek (2004) provide data on the duration of embryonic development of broad-toed crayfish eggs. They kept females with eggs in cages at a temperature of 10±2°C and then transferred them to incubation pools with temperatures of 11.8°C, 16.0°C, and 20.0°C. The period of embryonic development of eggs under experimental temperature conditions was 120±4, 92±4 and 71±2 days, respectively. According to other scientists, in particular, S. Koca *et al.* (2013), the development of longnose crayfish eggs occurred at an average temperature of 12°C and a period of 134 days. The above studies were performed in vivo. The experiment was conducted in closed water supply systems at a temperature of 28°C, which is optimal for the development of eggs of most species of aquatic organisms.

According to the observations, the colour range of crayfish eggs and their embryonic development varied in the following time intervals: Australian red-clawed crayfish caviar – from 0 to 4 days (olive or dark green shades), from 4 to 17 days (yellow and orange), from 17 to 22 days (eye spots and barely visible limbs), from 22 to 30 days (abdomen is formed and separated from the head and chest), from 30 to 38 days (fry has a formed body structure, limbs are available and is weaned from the female); marble crayfish caviar – from 0 to 3 days (dark grey or pale green shades), from 3 to 15 days (light yellow), from 15 to 19 days (pink colour, eye formation), from 19 to 28 days (abdomen is formed, its separation from the head and neck is observed), from 28 to 35 days (fry is fully formed and weaned from the female); Florida crayfish caviar – from 0 to 3 days (black), from 3 to 13 days (the head is formed, has a black dorsal protrusion containing yolk residues, eye spots are formed), from 13 to 18 days (the abdomen is formed, its clear separation from the head is observed), from 18 to 28 days (the body becomes similar to adults), yambi crayfish caviar – from 0 to 4 days (black in colour), from 4 to 19 days (yellow or light yellow), from 19 to 27 days (orange in colour, eye spots are formed, and the abdominal part of the body is barely visible); from 27 to 39 days (eyes are fully formed, the abdomen is separated from the thorax, there is a dorsal projection containing the remains of the yolk), from 39 to 45 days (anatomically, the body is similar to adults, the presence of limbs is observed). Thus, based on our research, the following division of the embryonic period of development of female crayfish eggs of different species is proposed, in particular:

Australian red snapper. In the first stage – the eggs had a dark green and, in some individuals, olive colour. Olive-coloured eggs gradually changed to yellow, and dark green eggs to orange (second stage). Regardless of colour, as the eggs developed, eye spots appeared (stage 3), and the abdomen formed and was separated from the head and neck (stage 4). At the last stage of development, the tadpoles hatched with a fully formed body (stage 5). Marble crayfish. In the first stage, the caviar had dark grey or pale green shades, by the next stage it changed to light yellow, in the third stage – to pink and eyes formed, in the final stage of incubation the body and limbs began to form (stage 4) and in the fifth stage the crayfish were weaned from the females.

Florida crayfish had one less stage of maturation compared to other crayfish species due to the shorter time of egg maturation. Thus, they were weaned from the female at the fourth stage between the 26th and 28th day. In contrast, the incubation period for yabby crayfish was longer than for the other species studied, with the fifth stage coming to an end on day 45. It is worth noting that unfertilised eggs for all species of females were transparent or light grey in colour. It was located on the outer part of the pleopods in the culled females, was unevenly distributed, and aborted after a while. In other individuals, however, the eggs were tightly adjacent to each other and resembled bunches of grapes.

According to observations, the hatching of crayfish from eggs coincides with the process described by Ya. Tsukerzis (1989). The crustacean, making movements with its abdomen and limbs, breaks the eggshell and hatches out of it, then it hangs on the so-called hyaline threads. The tadpoles stay in this position for 1 to 4 days, feeding on the yolk from the dorsal projection above the thorax. The average incubation time for each stage of caviar is shown in Figure 1.

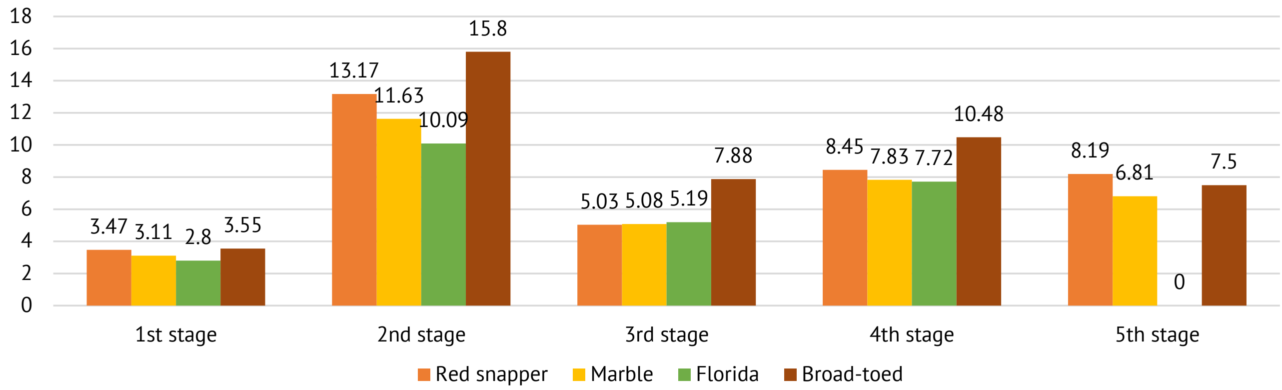

Figure 1. *The average incubation time of eggs of the studied female crayfish*

Source*: compiled by the authors*

The average duration of the 1st stage of caviar incubation for each experimental group was: Australian crayfish females – 3.47 days, marbled crayfish – 3.11 days, Florida crayfish – 2.80 days and yabby – 3.55 days. The longest stage was the 2nd stage, which was 9.70 days longer than the previous one for the Australian, 8.52 for the marbled, 7.29 for the Florida and 12.25 for the destructor crayfish. The third stage is shorter than the second and lasted 8.14 days less in red snapper, 6.55 days in marble, 4.90 days in Florida and 7.92 days in yabby. The last two stages of development were almost the same for the Australian, which was 8.46 and 8.18 days, respectively. In the marbled, the period of these stages was 7.83 and 6.81 days. In the female Florida crayfish, the last-fourth stage lasted 7.72 days. The final - fourth and fifth stages of incubation of caviar in the destructor were within 10.48 and 7.50 days, respectively. As mentioned earlier, the reproductive capacity of female crayfish was assessed throughout the incubation period and during the weaning of fry. Thus, at the final stage of the research, five female groups were formed: culled, unsatisfactory, satisfactory, good and excellent (Table 2).

***Table 2.** Categories of reproductive quality of female crayfish of different species*

Female crayfish species	Quality category				
	Excellent, individuals/%	Good, individuals/%	Satisfactory, individuals/%	Unsatisfactory, individuals/%	Defective, individuals/%
Australian red-bellied shiner	36/51.43	8/11.43	11/15.71	9/12.86	6/8.57
Marbled	22/32.83	16/23.88	18/26.86	5/7.46	6/8.95
Destructor	25/39.06	14/21.88	12/18.75	4/6.25	9/14.06
Florida	27/42.19	13/20.31	14/21.88	3/4.69	7/10.9

***Source**: compiled by the authors*

Australian red snapper females were distributed by quality categories as follows: rejected – 8.57%, unsatisfactory – 12.86%, satisfactory – 15.71%, good – 11.43% and excellent – 51.43%. For marble crayfish, 32.83% were in the excellent category, 23.88% were good, 26.86% were satisfactory, and 7.46% were unsatisfactory, with the proportion of culls being 8.95%. The largest percentage of females in the destructor crayfish was in the excellent category (39.06%), 21.88% were in the good category, 18.75% in the satisfactory category, 6.25% in the unsatisfactory category, and 14.06% in the cull category. The lowest number of Florida crayfish was in the unsatisfactory group and amounted to 4.69%, while the highest rate was in the excellent quality category – 42.19% of individuals, in the good and satisfactory groups the rates were 20.31% and 21.88%, respectively, with 10.9% of females rejected. The following indicators were considered when forming the above groups: weight of females, weight of eggs, total number of eggs, and number of eggs per 1 g of female. The weight of female crayfish of different species according to the quality category is presented in Table 3.

***Table 3.** Weight of female crayfish of different species according to the quality category*

Female species	Quality category and female weight									
	Excellent, individuals		Good, individuals		Satisfactory, individuals		Unsatisfactory, individuals		Rejected, individuals	
	M±m, г	C_v, %	M±m, г	C_v, %	M±m, г	C_v, %	M±m, г	C_v, %	M±m, г	C_v, %
Australian red-clawed	(n=36)		(n=8)		(n=11)		(n=9)		(n=6)	
	63.0±0.67	6.4	57.6±1.01***	4.9	58.3±1.10***	6.3	56.6±1.88**	10.0	56.1±2.34**	12.0
Marbled	(n=22)		(n=16)		(n=18)		(n=5)		(n=6)	
	16.8±0.15	4.2	15.7±0.08***	2.1	14.9±0.09**	2.7	13.7±0.19***	3.2	16.0±0.23*	2.5
Destructor	(n=25)		(n=14)		(n=12)		(n=4)		(n=9)	
	46.9±0.23	7.5	44.4±0.84**	7.2	46.4±1.18	8.8	45.3±2.08	8.0	46.2±0.87	5.7
Florida	(n=27)		(n=13)		(n=14)		(n=3)		(n=7)	
	21.8±0.17	4.1	20.5±0.19***	3.5	20.3±0.17***	3.2	20.9±0.39	3.3	20.8±0.91	7.6

***Note:** difference relevance is shown in comparison with the "excellent" group of females in the quality category: *P<0.05; **P<0.01; ***P<0.001*
***Source**: compiled by the authors*

In particular, among the analysed micro-populations, females of the Australian red snapper had the highest weight. At the same time, 44 (62.8%) out of 70 individuals were of excellent and good quality. The proportion of such individuals among Florida crayfish was also significant – 62.5%. However, weight does not always determine female quality. This is evident among Australian red snappers, where females of satisfactory quality outnumbered those of good quality by weight, although the qualitative difference with the best group was highly significant (p<0.001). This indicates the need for an integrated approach to assessing the quality of females since weight cannot be the only criterion for their quality. The weight of female caviar of different species is presented in Table 4.

Table 4. *Female crayfish egg weight of different species as per quality category*

Female species	Quality category and egg weight									
	Excellent, individuals		Good, individuals		Satisfactory, individuals		Unsatisfactory, individuals		Rejected, individuals	
	M±m, г	C_v, %	M±m, г	C_v, %	M±m, г	C_v, %	M±m, г	C_v, %	M±m, г	C_v, %
Australian red-clawed	(n=36)		(n=8)		(n=11)		(n=9)		(n=6)	
	5.0±0.05	6.4	3.9±0.05***	4.3	3.5±0.04***	3.9	1.7±0.15***	28.5	-	-
Marbled	(n=22)		(n=16)		(n=18)		(n=5)		(n=6)	
	1.6±0.03	10.7	1.5±0.04***	10.9	1.4±0.02***	8.1	0.7±0.04***	15.3	-	-
Destructor	(n=25)		(n=14)		(n=12)		(n=4)		(n=9)	
	3.7±0.02	11.7	3.5±0.12***	13.8	3.0±0.21***	24.7	2.1±0.34***	28.9	-	-
Florida	(n=27)		(n=13)		(n=14)		(n=3)		(n=7)	
	2.1±0.04	12.0	1.8±0.06***	13.5	1.5±0.03***	7.4	1.4±0.10***	13.6	-	-

Note: *difference relevance is shown in comparison with the "excellent" group of females in the quality category: *P<0.05; **P<0.01; ***P<0.001*
Source*: compiled by the authors*

The analysis of Table 4 highlights a clear trend – an increase in the quality category of females to "good" and "excellent", causes an increase in the weight of their caviar. At the same time, there was a highly significant difference in the quality category (p<0.001). The total amount of caviar varied depending on both the type of crayfish and the quality category (Table 5). Thus, the total loss of caviar during sampling during the incubation period was 65%. Such losses were caused, among other things, by the counting process, as the slightest manipulation provoked the development of stress in females, due to which they shed part of their caviar. However, the quality category of females is a crucial factor in caviar production. In particular, in all groups, without exception, a significant amount of caviar production by females of good and excellent quality was recorded, with a highly significant difference within groups (p<0.001).

Table 5. *Total number of eggs of female crayfish of different species as per quality category*

Female species	Quality category and total quantity of female caviar									
	Excellent, individuals		Good, individuals		Satisfactory, individuals		Unsatisfactory, individuals		Rejected, individuals	
	M±m, pcs.	C_v, %	M±m, pcs	C_v, %	M±m, pcs	C_v, %	M±m, pcs	C_v, %	M±m, pcs	C_v, %
Australian red snapper	(n=36)		(n=8)		(n=11)		(n=9)		(n=6)	
	376.8±16.34	26.0	214.3±6.95***	9.2	172.7±4.41***	8.5	80.1±6.92***	25.9	-	-
Marbled	(n=22)		(n=16)		(n=18)		(n=5)		(n=6)	
	124.5±2.66	10.1	101.2±1.51	6.0	87.3±1.81***	8.8	29.2±2.19***	16.8	-	-
Destructor	(n=25)		(n=14)		(n=12)		(n=4)		(n=9)	
	261.8±13.17	14.1	207.9±9.62	17.3	179.9±9.50**	18.3	73.8±8.99***	21.1	-	-
Florida	(n=27)		(n=13)		(n=14)		(n=3)		(n=7)	
	164.9±4.46	14.1	143.5±1.81***	4.6	115.1±1.64***	5.4	71.7±7.51***	18.2	-	-

Note: *difference relevance is shown in comparison with the "excellent" group of females in the quality category: *P<0.05; **P<0.01; ***P<0.001*
Source*: compiled by the authors*

The number of eggs per 1 g of female body weight is presented in Table 6.

Females of all groups of "excellent" and "good" quality produced significantly more eggs per 1 g of body weight compared to the worst quality individuals. Moreover, this difference, compared to the category of females rated as "excellent", was highly significant (p<0.001).

***Table 6**. Number of eggs per 1 g of female weight as per the category of quality*

Female species	Quality category and female weight									
	Excellent, individuals		Good, individuals		Satisfactory, individuals		Unsatisfactory, individuals		Rejected, individuals	
	M±m, pcs.	C_v, %	M±m, pcs	C_v, %	M±m, pcs	C_v, %	M±m, pcs	C_v, %	M±m, pcs	C_v, %
Australian red snapper	(n=36)		(n=8)		(n=11)		(n=9)		(n=6)	
	6.1±0.22	22.0	3.8±0.12***	9.1	3.0±0.06***	7.2	1.4±0.13***	28.1	–	–
Marbled	(n=22)		(n=16)		(n=18)		(n=5)		(n=6)	
	7.7±0.11	7.2	6.8±0.09***	5.6	6.3±0.12***	8.7	2.2±0.16***	16.2	–	–
Destructor	(n=25)		(n=14)		(n=12)		(n=4)		(n=9)	
	5.8±0.05	13.2	4.8±0.20***	16.4	4.1±0.22***	18.8	1.7±0.14***	14.9	–	–
Florida	(n=27)		(n=13)		(n=14)		(n=3)		(n=7)	
	7.8±0.19	12.9	7.2±0.09*	5.5	5.8±0.09***	5.9	3.6±0.41***	19.6	–	–

***Note:** difference relevance is shown in comparison with the "excellent" group of females in the quality category: *P<0.05; **P<0.01; ***P<0.001*
***Source**: compiled by the authors*

Thus, observation of females, the state of caviar (depending on the periods of its development) during the incubation period, and the division of females into quality categories of all studied groups contribute to their selection for the best economically useful traits. In the course of research by C. R. King (1993), conducted at the Queensland University of Technology, a division by stages of incubation of C. quadricarinatus eggs, based on changes in their colour and development: 0 to 3 days (olive or khaki), 3 to 16 days (reddish-brown or orange), 16 to 20 days (formation of the abdomen and its separation from the cephalothoracic region), 20 to 23 days (eyes and barely visible limbs appear on the eggs), 23 to 31 days (limbs and eyes are more distinct), 31 to 41 days (fry are fully formed and released from the female).

In 1997, several studies were conducted at the Southern Regional Aquaculture Centre in Australia to characterise the morphological, functional, and reproductive qualities of red snapper crayfish (Masser & Rouse, 1997). According to these studies, crayfish reach sexual maturity at the age of 6 months; spawning occurs several times a year; the female lays from 100 to 1000 eggs (depending on the size of the latter). The average period from the beginning of spawning to weaning is 6-8 weeks. At the age of 4-5 years, the weight of adults reaches over 400 g.

C. quadricarinatus was first commercially farmed in Australia in 1985. In 1988, this species was introduced to the United States, where it was named the Freshwater Lobster. In 1989, Auburn University began research on the biology of the species, which led to the design of closed-water supply systems. In the same year, several private companies and research institutions, including the Louisiana Agricultural Experiment Station, assessed the potential for farming red snapper and proposed a farming technology. The main disadvantages of this technology were cannibalism, loss of eggs during spawning, diseases (bacterial and parasitic), mortality during moulting, and high energy consumption (Jones, 1998).

P.B. Medley *et al.* (1993) noted that the growth rate and productivity of red snapper are influenced by stocking density and diet. C.M. Jones (1992) studied the fecundity of red snapper crayfish and the factors that affect spawning, namely stocking density, weight of males and females, diet, mortality and its causes, and cannibalism. Y.I. Fedorovych *et al.* (2022b) and A. Radzikhovsky (2017) describe that since the introduction of this species into commercial aquaculture, its cultivation has spread throughout the globe, and the main producers that grow it on a commercial scale are the USA, China, Spain, Israel, and Indonesia. That is why, as noted by R. Hutchings *et al.* (1990), the introduction of innovative methods into production will give an impetus to the intensive development of the aquaculture industry in general and crayfish farming in particular and will allow it to meet significant market needs.

Thus, the most promising for breeding and use is the Australian red snapper, as females of this species significantly outweigh other crayfish species in terms of weight and a set of reproductive traits.

CONCLUSIONS

The embryonic period of egg development in different species of crayfish was studied during the entire period of incubation and weaning, considering the following indicators: change in colour shades of eggs, duration of incubation stages, weight of females, weight of eggs, total number of eggs, number of eggs per 1 g of female weight. According to the results obtained, it was proposed to divide the females of the studied species into five quality categories.

The incubation period of egg development was shortest in Florida crayfish (the fry was separated from the female from day 26 to 28), and the longest in yabby crayfish – the completion of the fifth stage took place on day 45. The colour shades of the eggs were different in all species studied and varied depending on their maturity, while unfertilised eggs were transparent or light grey in females of all species. The quality category of females is a crucial factor in the production of eggs by females, their weight, and the number of eggs per 1 g of female weight, as there is a highly significant difference in all studied crayfish micro-populations between all categories of female quality. Given the research, the most promising for commercial breeding is Australian red snapper and Florida crayfish, as their females are characterised by high reproductive capacity and, accordingly, belong to the "excellent" category.

The results of the research can be used in the educational process, as a theoretical basis for teaching relevant aquaculture disciplines and in the activities of aquaculture farms to improve the artificial breeding of crayfish. Further research will be aimed at determining the dependence of the postembryonic development of individuals on the quality of caviar and the reproductive capacity of female crayfish.

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CONFLICT OF INTEREST

None.

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