Reproductive Aging of African Catfish in Aquaculture

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Abstract. The work is devoted to the study of reproductive aging of African catfish in the conditions of industrial aquaculture. The problem is urgent, because industrial aquaculture changes the biology of African catfish so much that it loses its ability to reproduce naturally. The offspring of African catfish can be obtained only with the use of hormonal inducers of gametogenesis. Questions of age selection of producers and age composition of breeding stock in this type of fish are still open. In practice, we have to face the facts of poor quality of sexual products in primary spawning or old females and males. The aim of the study was a comparative assessment of age-related variability of reproductive properties of female and male African catfish in the conditions of industrial aquaculture. The results of our study showed the presence of age-related dynamics in the quality of sexual products in African catfish. Age-dependent differences in the quality and fertilization of eggs, the viability of embryos and larvae, their size, and the quality of offspring were established. When studying the properties of sexual products in fish of different ages, differences in morphometric and physiological parameters were found for a complex of indicators such as the size and diameter of eggs, sperm concentration, and the number of viable spermatozoa. Evaluation of the influence of parents age on the viability of offspring in the embryonic and postembryonic periods revealed that this indicator is the lowest in first – spawning fish, and the highest in middle-aged fish. The Russian Foundation for Basic Research has supported our study with the grant No. 18-416-730005.

1 Introduction

An important stage of fish-breeding process is to obtain high-quality reproductive products from producers of cultivated fish species. All further activities of fish-breeding enterprise related to the cultivation of necessary amount of planting material and the manufacture of marketable products depend on this stage [1, 2].

In Russian fish farming, two main methods of forming a breeding stock are used. The first is the import from other farms of fish eggs, larvae, fry or fingerlings obtained from proven (elite) producers of a particular breed. Preference is given to the transportation of fish effs, as the least time-consuming and relatively cheap method. The second way to form a breeding stock is to use own high-quality producers. The positive aspect in this case is the absence of labor-intensive and expensive transportation. At the same time, there is no need to adapt the offspring to new conditions. When using this method of forming a breeding stock, it is necessary to establish strict quality control of reproductive products, as well as control over the development of embryos, larvae, fry and growing juveniles obtained from producers of sexual products [3–5].

Fish producers who plan to select reproductive products must meet the following requirements: be healthy, without injuries and deformities, energetic in movement, have clearly defined reproductive characteristics, undisturbed scales, elastic muscles and, most importantly, have mature and high-quality reproductive products [6, 7].

It is advisable to keep the optimal age composition of producers at a more productive level – as a rule, these are individuals that spawn for the second, third and fourth time. Different types of fish differ in the age structure of breeding herds [8, 9].

Parental forms have different effects on offspring [9]. The predominant role of maternal organism in transmission of a number of traits to offspring is mainly due to the conditions of embryonic development. However, the predominant influence of mothers does not affect all the characteristics of offspring, there are many examples when the offspring, to a greater extent, inherits the characteristics of the father's characteristics [10–12].

The initial indicator for calculating the number of producers is usually the amount of fish eggs expected for sale and laid for incubation. Calculations are carried out taking into account the average working fertility of one female, the survival rate of embryos, larvae and fry [13].

At different stages of life cycle, the structure of body is qualitatively different. These changes also affect the germ cells, which are formed under conditions of different metabolic rates, depending on both the age of the animal and its general condition [14, 15].

Our analysis of literature sources indicates that both too young and old animals whose reproductive system has passed many reproductive cycles are unsuitable for breeding purposes [15–18]. A number of authors note

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that with age, the sex cells of males and females change qualitatively, accumulating age-related disorders that can affect the quality of offspring [18–20].

In fish farming, the issues of age selection of producers are developed relatively recently and have not been sufficiently studied. In practice, we have to deal with the poor quality of reproductive products in too young or old parents. There are data on correlation of age and fertility of fish [21, 22]. The relationship between the age of female, fertility and the size of fish eggs in different fish species was established [22, 23].

A number of studies have noted the influence of the age of producers on the viability of offspring. Fish embryos, depending on the age of their parents, differ in their resistance to the combined effect of increased water temperature and oxygen deficiency in it [25, 26]. The most persistent is the offspring of middle-aged producers of reproductive products.

The aim of the study was a comparative assessment of age variability of reproductive properties of female and male African catfish in the conditions of industrial aquaculture.

2 Materials and methods

Producers of African catfish aged 12, 24, 48, 60 months were selected as research objects, from which 4 experimental groups were then formed, 30 individuals each. The average weight of fish at the age of one year (12 months) averaged 1300–1400 gr., at the age of two years (24 months) – 2100–2200 gr., at the age of four years (48 months) – 4400–4500 gr., at the age of five years (60 months) – 5200–5300 gr.

In the comparative assessment of producers of African catfish of different ages, the following indicators were determined: fertility and quality of reproductive products, linear and weight growth of offspring, its viability at all stages of ontogenesis (from fish eggs to reproductive maturity of fish), as well as some morphophysiological characteristics of offspring.

Hormonal stimulation of producers was carried out using freshly obtained or acetonated pituitary glands, the volume of administered suspension for African catfish weighing up to 5 kg did not exceed 2 ml, which were administered in two doses of 1 ml. The effectiveness of hormones was enhanced by preliminary and permissive injections.

The fish eggs was recorded before being laid for incubation by the weight method, which is suitable for recording fish eggs of any size. To do this, first weighed the entire amount of fish eggs, then took 2–3 servings, weighed and in each piece calculated the number of fish eggs. Then the average number of fish eggs in 1 g was determined, after which it was recalculated for the entire weight of the fish eggs.

The degree of maturity of fish eggs can be determined experimentally by placing its sample in a solution of methylene blue (1 drop of 0.05 % solution per 10 ml of filtered water) in a ratio of 1:5. Discoloration of the solution for 10–15 minutes meant that the fish eggs was mature and high – quality, and within 30–60 minutes-that it was overripe. If the solution does not discolor at all within an hour, the fish eggs is unripe.

The quality of sperm was also determined by external characteristics – color and consistency. If the sperm is yellowish-cream color, thick, has the appearance of condensed milk and flows in a dense stream or falls in thick dense drops – it is of good quality. Milky-white sperm of the density of cream, which flows like ordinary milk, is of medium quality. Bluish-colored liquid sperm, resembling diluted milk, is of poor quality.

The method of assessing the quality of sperm by the ratio of live and dead sperm was used. To determine the motility of sperms, a microscope with a magnification of 400–600 times was used. The obtained result was evaluated on the five-point scale of G.M. Persov.

Score 5. In the field of view, the forward movement of all sperms is noticeable. Their mobility is too great, it is difficult to concentrate on individual spermatozoa.

Score 4. The progressive movement of sperms is well expressed, but in the field of view there is a small number of them (10–15 %) with an oscillatory movement.

Score 3. Sperms with progressive movement predominate, but there is a slightly increased (30–40 %) number of sperms with oscillatory movement. There are immobile sperms.

Score 2. There are almost no sperm with progressive movement. Up to 70–75 % of sperms are immobile. They are unsuitable for fertilization.

Score 1. All sperms are immobile. Not suitable for fertilization.

Important indicators of sperm quality are the activity of sperms and their concentration.

The activity of sperms was determined under a microscope (eyepiece 5x–7x, lens 20–40) using a stopwatch. A drop of sperm was applied to a watch glass placed under the eyepiece of a microscope with a drop of water, and the stopwatch was immediately turned on. They monitored the movement of sperms. The stopwatch was stopped when more than 50–60 % of the sperm went from progressive to oscillatory motion. The determination of sperm activity in each sample was carried out at least three times, and then the average result is calculated. Three samples were taken from each male. The concentration of sperms was determined using a Goryaev counting chamber.

The larvae were recorded at the time of their transfer from the incubation apparatus to the growth tanks and as they grew further. Piece-by-piece counting was carried out with the help of flat gauze nets. To facilitate the counting of the larvae, the nets were divided into 4–8 sectors with a colored thread.

The duration of the experiment was 9 months.

3 Results

For the rational construction of the fish-breeding process, it is important to know the regularities of dynamics of fish fertility. It should be noted that the fertility of fish and the quality of reproductive products

are closely related to the viability of offspring. The decrease in the fertility of aging animals is often accompanied by the death of embryos in the early stages of development. At the first stage of our work, we studied the fertility and quality of the sexual products of female African catfish, as well as the qualitative characteristics of obtained fish eggs.

The analysis of obtained data shows that males and females of the African catfish of different ages differed in their reproductive abilities. As the age and weight of females increased, fertility significantly increased (Figure 1).

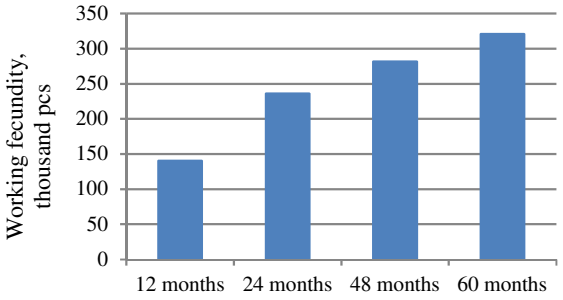

Fig. 1. Working fertility of females of different ages

In the group of twelve-month-old (first spawning) females, the minimum working fertility was recorded, on average in the group it was 140.2±3.02 thousand units. The maximum working fertility was in females at the age of 48 months and averaged 381.2±2.67 thousand units. At an older age, despite the increase in the weight of females, the working fertility decreased and at the age of five it averaged 320.5±3.62 thousand pieces. A comparative analysis of the relative working fertility in different age groups of female African catfish showed that this indicator significantly decreased after 24 months of age (Figure 2).

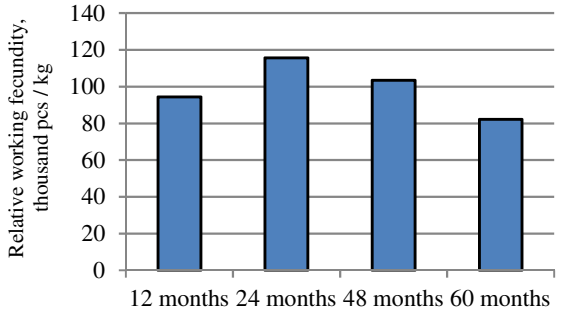

Fig. 2. Relative fertility of females of different ages

Changes in the quality of fish eggs are primarily expressed in the difference in size of fish eggs, which usually corresponds to the difference in the yolk reserves of fish of different sizes and ages. For many fish species, there is a positive correlation between age, size, body fatness, and the average diameter and weight of fish eggs. The results of size characteristics study of fish eggs of females of different ages are presented in the Table 1.

The results of obtained data indicate that the eggs of female African catfish of different ages are of different quality. The smallest diameter and weight were ovulated fish eggs eggs obtained from primary spawning females at the age of 12 months. With the age of the females, these indicators increased. In aging females, there is a slight decrease in the diameter and weight of eggs. A high positive correlation was found between the size of the eggs and the age of the females.

Table 1. Size characteristics of African catfish fish eggs of different ages

Female age, mon.	Fish eggs diameter, mm		Fish eggs weight, mg.	
	M±m	Cv	M±m	Cv
12	1.31±0.0002	3.57	1.302±0.0019	5.25
24	1.48±0.0004	4.41	1.591±0.0017	5.05
48	1.56±0.0001	4.82	1.616±0.0021	5.61
60	1.45±0.0002	4.43	1.581±0.011	5.72

Thus, with each subsequent reproductive cycle, the reproductive potential increased until the number of reproductive products reached a maximum. Then the fertility decreased, the physiological aging of the body began, which is expressed not only in a decrease in the weight and linear gains of the fish, but also in the attenuation of activity of reproductive system.

Studies of the quality of sperm (sperm concentration, number of viable spermatozoa) obtained from males of different ages indicate that the age of males in the conditions of aquaculture affects its quality. The results obtained are shown in figure 3 and 4.

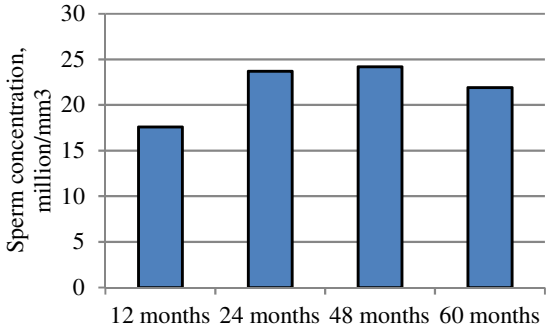

Fig. 3. Sperm concentration in males as a function of age

Studies of the sperm concentration of male African catfish of different ages showed that the lowest sperm concentration (17.6 million/mm³) as observed in the group of individuals of 12 months. In the groups of middle-aged producers, namely, 24 and 48 months of age, the highest concentration of sperm was 23.7 million/mm³ and 24.2 million/mm³ respectively. Analysis of the diagram showed that with increasing age of males, the sperm concentration decreased and at the age of five it was 21.9 million/mm³. The largest number of viable spermatozoa was found in the sperm of middle-aged producers. The dependence of sperm activity on the age of males was revealed.

At the next stage of the research, artificial insemination was performed in groups of African catfish producers of different ages, and the growth and viability of offspring in the postembryonic period were studied.

The size of larvae at hatching depended on the size of the eggs. Thus, with the age of females, not only the size of the fish eggs increases, but also the length and weight

of larvae when hatching. A certain dependence of the growth of larvae during the endogenous feeding period on the age of their parents was also found, the results are presented in the Table 2.

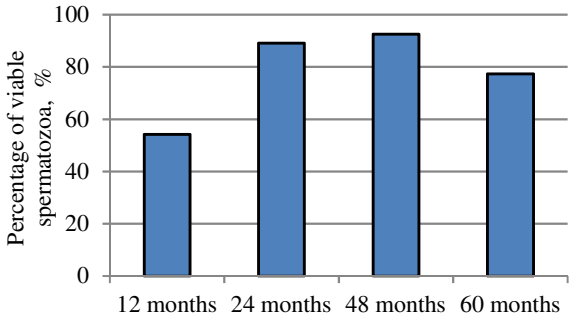

Fig. 4. The proportion of viable spermatozoa in males of different ages

Table 2. Larval growth depending on the age of the parents

Parents age, months.	Larvae weight, mg.		Growth		Losses, %
	hatching	three days	mg.	%	
12	1.03	1.39	0.36	34.9	8.9
24	1.12	2.06	0.94	83.9	7.5
48	1.18	2.24	1.06	89.8	8.0
60	1.21	1.92	0.71	58.6	9.3

Based on the data presented in Table 2, we can say that the highest rates of larval growth were obtained from producers of reproductive products at the age of 48 months, the percentage of growth was 89.8. The lowest percentage of larval growth was observed in the group of young – 34.9 % and old – 58.6 % of producers of African catfish.

As a result, it can be noted that the larvae obtained from producers of different ages differ in nature of the transition to active nutrition. In larvae from middle-aged producers in the conditions of aquaculture, this transition was made synchronously in the main part of the community, and in larvae from aging and old producers, this period was extended.

The advantages in the growth rate were maintained in the subsequent stages of postnatal ontogenesis of the African catfish.

As an example, we refer to the data on biomass set in cultivation of fish from the embryonic to the mature state from producers of different ages. The results are shown in the figure 5.

A comparative evaluation of the results of growing offspring from producers of different ages to the stage of puberty showed that the average weight of offspring at the end of the experiment from middle-aged producers of 24 and 48 months had high indicators and amounted to 1124.5±4.12 g. and 1195.2±3.96 g., respectively. With the increase in the age of producers, average weight of offspring decreased, at the end of the experiment in the group of five-year-old parents, it was 1060.3±05gr. The lowest indicators of the average individual weight 920.3±2.69 g were obtained in the group of producers at the age of 12 months.

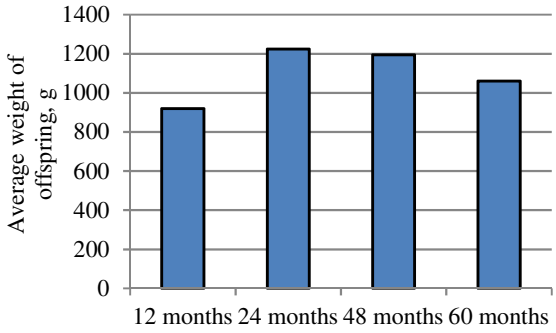

Fig. 5. Weight of offspring depending on the age of the parents

Studies have shown that when selecting producers of African catfish, the best offspring are obtained from middle-aged producers.

4 Discussion

Thus, comparative fish-breeding and morphophysiological studies of individual age groups of producers of African catfish, conducted in the conditions of industrial aquaculture, have shown that the reproductive qualities of males and females do not remain constant throughout their lives and are subject to significant changes. The results obtained by us are in good agreement with the results of studies on other fish species [1, 2].

When studying the fertility of fish of different ages and patterns of fertility changes during life, a clear positive correlation was revealed [1, 7, 8]. The high variability of fertility allows us to conclude that the age, feeding conditions and maintenance of females, as well as their individual characteristics, significantly affect this indicator. These results are consistent with the data of other researchers [7, 13, 14].

The highest working fertility was characterized by middle-aged females (48 months), the highest number of viable spermatozoa was also found in the sperm of middle-aged males.

With a significant increase in the age of parents, the viability of offspring decreased. Thus, the change in the age of parents affects the quality of offspring.

The obtained data on different-quality offspring from producers of different ages are important for the rational management of fisheries [1, 2]. The assessment of age-related reproductive ability of females is necessary for the formation of the breeding core of the breeding stock. No less important is the selection evaluation of males of different ages [13, 14].

These examples reflect a general biological pattern – the influence of the age of the parents on the manifestation of quantitative and qualitative characteristics in the offspring. The correct age selection of producers is an important reserve for increasing the productivity of fish farming.

5 Conclusion

The conducted studies allow us to conclude that when studying the age characteristics of reproductive system

of African catfish, it was found that the qualitative and quantitative characteristics of reproductive products and the quality of offspring are reduced in primary spawning and aging producers.

Differences in the size and fertilization of fish eggs, the viability of embryos and larvae, and the size of larvae obtained from producers of different ages were established. Together, this leads to the conclusion that the quality of offspring decreases with age.

When studying the indicators of the reproductive process in primary spawning producers of African catfish, mature producers and aging producers of different ages, significant differences were found in the complex of such indicators as the size and diameter of eggs, sperm concentration, and the number of viable spermatozoa.

The study of the influence of parents age on the viability of the offspring in the embryonic and larval periods of development showed that this indicator was the lowest in the primary spawning producers, and the highest in the offspring of middle-aged producers.

References

1. A. Abdoli, D. Pont, P. Sagnes, Influence of female age, body size and environmental conditions on annual egg production of the bullhead, J. of Fish Biol., **67(5)**, 1327–1341 (2005)
2. E.M. Romanova, M.E. Mukhitova, V.V. Romanov, V.N. Lyubomirova, E.V. Spirina, Factors for increasing the survival rate of catfish fertilized eggs and larvae, IOP Conf. Ser. Earth and Envir. Sci., **341**, 012197 (2019)
3. E.M. Romanova, V.V. Romanov, V.N. Lyubomirova, L.A. Shadyeva, T.M. Shlenkina, Increase in nonspecific resistance of catfish (Clarias gariepinus) in industrial aquaculture, BIO Web of Conf., **17(1)**, 00122 (2020)
4. J. Ekasari, M.A. Suprayudi, R.F. Hazanah, G.S. Lenggara, R. Sulistiani, M. Alkahfi, M. Zairin, W. Wiyoto, Biofloc technology application in African catfish fingerling production: the effects on the reproductive performance of broodstock and the quality of eggs and larvae, Aquacult., **464**, 349–356 (2016)
5. R.B. Paiva, A. Neves, V. Sequeira, A.R. Vieira, M.J. Costa, L.S. Gordo, Age, growth and reproduction of the protandrous hermaphrodite fish, sarpa salpa, from the portuguese continental coast, J. of the marine biol. Associat. of the UK, **98(2)**, 269–281 (2018)
6. E.A. Trippel, S.R.E. Neil, N.J. Feindel, I.A.E. Butts, A. Babin, T.J. Benfey, Effects of reproduction on growth and survival in atlantic cod, gadus morhua, assessed by comparison to triploids, J. of experim. marine biol. and ecol,. **451**, 35–41 (2014)
7. A.S. Tarkan, J. Cucherousset, M.J. Godard, G.H. Copp, G. Zieba, Growth and reproduction of introduced goldfish carassius auratus in small ponds of southeast england with and without native crucian carp carassius carassius, J. of appl. Ichthyol., **26(suppl. 2)**, 102–108 (2010)
8. C.A. Meyer Ottesen, H. Hop, S. Falk-Petersen, J.S. Christiansen, Reproduction and sexual dimorphism of daubed shanny (teleostei: leptoclinus maculatus) in svalbard waters, Polar biol., **41(9)**, 1867–1880 (2018)
9. J. Žák, M. Reichard, Reproductive senescence in a short-lived fish, J. of animal ecol., **90(2)**, 492–502 (2021)
10. T. Arula, H. Shpilev, T. Raid, M. Vetemaa, A. Albert, Maturation at a young age and small size of european smelt (osmerus eperlanus): a consequence of population overexploitation or climate change? Helgoland marine res., **71(1)**, 7 (2017)
11. A. Folkvord, C. Jørgensen, K. Korsbrekke, R. Nash, J. Skjæraasen, T. Nilsen, Trade-offs between growth and reproduction in wild atlantic cod, Canad. J. of fish. and acquatic sci., **71(7)**, 1106–1112 (2014)
12. E.M. Romanova, V.V. Romanov, V.N. Lyubomirova, L.A. Shadyeva, T.M. Shlenkina, Vectors for the development of high-tech industrial aquaculture, BIO Web of conf., **27**, 00132 (2020)
13. I. Kubinshtein, S. Rothbard, W.L. Shelton, Relationships between embryological age, cytokinesis-1 and the timing of ploidy manipulations in fish, Israeli J. of aquacult. – bamidgeh., **49(2)**, 99–110 (1997)
14. C.L. Gervasi, W.K. Vogelbein, J. Gartland, R.J. Latour, S.K. Lowerre-Barbieri, The reproductive biology of chesapeake bay striped bass with consideration of the effects of mycobacteriosis, Bull. of marine sci., **95(2)**, 117–137 (2019)
15. M.U.S. Nunes, L.F. Fávaro, O.R. Cardoso, M. Soeth, R.A.M. Silvano, Fishers' ecological knowledge on the reproduction of fish and shrimp in a subtropical coastal ecosystem, Hydrobiol. (2021)
16. M. Kesiktaş, E. Yemişken, L. Eryilmaz, T. Yildiz, Age, growth and reproduction of the golden grey mullet, chelon auratus (risso, 1810) in the golden horn estuary, istanbul, J. of the marine biological association of the UK, **100(6)**, 989–995 (2020)
17. E.L. Charnov, Ja.F. Gillooly, Size and temperature in the evolution of fish life histories, Integrat. and comparat. biol., **44(6)**, 494 (2004)
18. I.D. Leonardos, Life history traits of scardinius acarnanicus (economidis, 1991) (pisces: cyprinidae) in two greek lakes (lysimachia and trichonis), J. of appl. Ichthyol., **20(4)**, 258–264 (2004)
19. N. Okuda, T. Takeyama, Ya. Yanagisawa, Age-specific filial cannibalism in a paternal mouthbrooding fish, Behav. Ecol. and sociobiol., **41(6)**, 363–369 (1997)

20. T. Erös, Life history of the stone loach, barbatula barbatula in the bükkös stream (hungary), Folia zoolog., **50(3)**, 209–215 (2001)
21. M. Szczepkowski, B. Szczepkowska, K. Wunderlich, T. Krzywosz, R. Stabiński, Growth rate and reproduction of a brood stock of european whitefish (coregonus lavaretus l.) From lake gaładuś under controlled rearing conditions, Arch. of Polish Fish., **18(1)**, 3–11 (2010)
22. L. Baulier, M. Heino, H. Gjøsæter, Temporal stability of the maturation schedule of capelin mallotus villosus in the barents sea, Aquatic liv. res., **25(2)**, 151–161 (2012)
23. E.A. Trippel, Age at maturity as a stress indicator in fisheries, Biosci., **45(11)**, 759–771 (1995)
24. A. Hurvitz, B. Levavi-Sivan, K. Jackson, S. Yom-Din, G. Degani, Sexual development in russian sturgeon (acipenser gueldenstaedtii) grown in aquaculture, Cybium., **32(2 suppl.)**, 283–285 (2008)
25. E.A. Trippel, Estimation of male reproductive success of marine fishes, J. of northwest atlantic fishery sci., **33**, 81–113 (2003)
26. R.M. Shourbela, A.M. Abd El-Latif, E.A. Abd El-Gawad, Are pre spawning stressors affect reproductive performance of African catfish Clarias gariepinus, Turk. J. of Fish. and Aquatic Sci., **16(3)**, 651–657 (2016)