Eco. Env. & Cons. 29 (3) : 2023; pp. (1452-1459)
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ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2023.v29i03.068

Reproductive characteristics of wild and captive Scale carp, *Cyprinus carpio* var. *communis* in Kashmir, India

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(Received 10 February, 2023; Accepted 4 April, 2023)

ABSTRACT

Cyprinus carpio var. *communis* is a widely distributed fish throughout the world. The fish has also got well adapted in various water bodies of Kashmir and constituted a major fishery here. The demand of the seed of Common carp has been increasing over the years. Domestication of fish seems to be an effective tool to meet the seed demand. However, domestication represents the challenges for aquaculture causing reproductive dysfunctions as per the earlier studies. In this background, current study was undertaken to evaluate the reproductive characteristics of both male and female Common carp, *Cyprinus carpio* var. *communis* in farmed and wild environment of Kashmir. Gonad somatic index (GSI) in both the sexes was found higher in wild fishes (female GSI=13.7±3.605; male GSI=7.403±2.01) compared to farmed fishes (female GSI=8.6±3.52; male GSI=6.37±1.5. Significant difference were found in the male GSI ($p<0.05$) and female GSI ($p<0.05$) between the two groups (wild and farmed). The average values of absolute and relative fecundity of fish in wild environment were recorded as 68864±35950.29 and 185.96±45.7 respectively. Whereas, in farmed environment, the absolute and relative fecundity was 44533±28572.59 and 115.98±49.25 respectively. Both absolute and relative fecundity significantly varied between the two environments ($p<0.01$). The results showed that cultured brooders produced more dense milt than wild individuals. In contrast, the milt volume was found higher in wild brooders than in cultured individuals.

Key words: *Common carp, Wild, Farmed, Gonadosomatic index, Sperm density*

Introduction

Normal gonad growth and effective reproduction require a favourable environment. Temperature and photoperiod influence fish reproduction in the majority of teleosts, including cyprinids (Lam, 1983). The majority of research found that gonad cyclical variations are influenced by environmental factors like as temperature, photoperiod, rainfall, and spawning substrate. A fish's natural environment is never completely replicated in captivity. Some fishes ecobiology is unknown, therefore simulating the essential environmental factors for natural reproductive performance is difficult, if not impossible (i.e., spawning migration, depth, riverine hydraulics, etc.). Stress on captive fish can have a negative impact on reproductive function and gamete quality (Schreck *et al.,* 2010). Fish confinement and overstocking in captivity may have an impact on egg quality. Chronic confinement throughout the final stages of reproductive development, along with periods of acute stress, have been shown to disturb the endocrinology that underpins normal ovary growth and development in trout, potentially leading to significantly reduced progeny survival rates (Campbell *et al.,* 1994). Humans handle reproduction in captivity, and there is no mate selection as there is in the wild world. Concerns regarding the impact of domestication on fish have risen in response to the significant increase in worldwide aquaculture production (Naylor *et al.,* 2005). The aquaculture setting provides a very different environment for fish compared to the wild, resulting in changes in the selective pressures that can lead to fundamental genetic changes at the population level (Skaala *et al.,* 2004; Jonsson and Jonsson, 2006). Farming practices often result in a reduction in genetic diversity due to genetic bottlenecks, as well as the divergence of farmed stocks from wild populations as a result of novel selective pressures associated with domestication (Einum and Fleming 1997; Norris *et al*., 1999; Skaala *et al.,* 2004).

The demand of the seed of common carp has been increasing over the years. Domestication of fish seems to be an effective tool to meet the seed demand. However, domestication represents the challenges for aquaculture causing reproductive dysfunctions as per the earlier studies. In this background, current study was undertaken to evaluate the reproductive characteristics of scale carp, *Cyprinus carpio* var. *communis* in farmed and wild environment. Studies on the influence of wild and farmed environments on reproduction characters is meagure so it is absolutely necessary to evaluate the reproductive parameters of fish. Understanding the difference in reproductive characteristics of both sexes in farmed and wild conditions will help in an identification of good quality males and females in particular environment that would significantly improve brood stock management, discarding nonproductive individuals.

Materials and Methods

The investigation was carried on 240 samples of common carp from the wild (120; Dal lake) and the farmed environment (120; Pandach fish farm) during 2020.The fishes were dissected and sex was determined. Gonads of both the sexes were collected and weighed to nearest gm and Gonadosomatic index (GSI) were calculated using the gonad weight body weight ratio given by Desai (1970) Fig. 1. Fecundity was estimated by Gravimetric method (Polder and Zystra, 1959) by placing the ovaries in 10% formaldehyde for at least 24 hours to bring hardness of eggs, so as to make easy and accurate calculation of sticky eggs. This was followed by drying of eggs on blotting paper for 1-2 hours, three subsamples of one gram each from anterior, middle and posterior region were weighed and then eggs were counted carefully by gravimetric method. The mean numbers of eggs were multiplied by gonad parts of ovary weighed on a sensitive mono-pan weighing balance and the total number of eggs per gonad was obtained, i.e fecundity of fish. The absolute fecundity and relative fecundity was calculated as per the formula given by (Bagenal, 1978):

$$\text{Absolute fecundity} = \frac{\text{No. of ova in the subsample} \times \text{total ovary weight}}{\text{Weight of subsample}}$$

$$\text{Relative fecundity} = \frac{\text{Absolute fecundity}}{\text{Weight of fish}}$$

To determine the milt volume in fishes, each male was stripped once only and the total amount of expressible milt was collected individually by gently pressing the abdomen. The semen was collected directly into clean 15 ml graduated centrifuge tubes. The tubes were covered and immediately transported on ice (4 °C) to the laboratory for analyses. The sperm density was estimated by haemocytometer counting chamber. Milt was diluted at ratio of 1:1000 with Hayem solution (5g

A B

Fig. 1. Reproductive system of *Cyprinus carpio* var. *communis* (A) Ovary (B) Testis

Na2SO4, 1g NaCl, 0.5g $HgCl_2$ and 200ml double distilled water) and mean spermatozoa count was calculated from three replicate samples for each fish at magnification of 40X. A haemocytometer counting chamber (Gem Industrial Corporation, Noida, India) was used to determine the spermatozoa density. A droplet of the diluted milt was placed on a haemocytometer slide (depth 0.1 mm) with a cover slip and counted using light microscopy. After 3-5 min (to allow sperm sedimentation), the number of spermatozoa was counted (Rainis *et al*., 2003) Fig. 2.

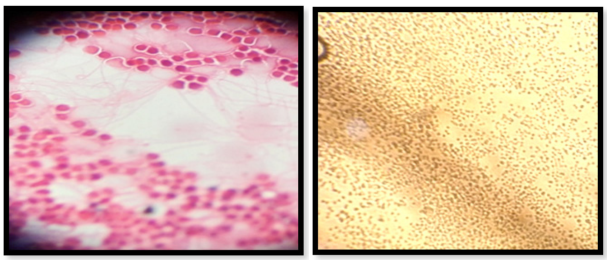

Fig. 2. Observation of spermatozoa of *Cyprinus carpio* var. *communis* under light microscope at 40 X

Statistical analysis

Results were presented as mean±SD. Statistical significant differences were determined by T-test using, Microsoft excel, PAST 3 software, Spss Window (Version 16).

Results and Discussion

The results of reproductive biology of fishes is presented in Table 1. The mean GSI of the female fishes in wild and farmed conditions was 13.7±3.605 and 8.6±3.52 respectively (Fig. 3). The Gonadosomatic index in wild fish of both the sexes (Fig. 3 and 4) during the present study was found significantly higher than the farmed one. Similar findings were reported by Kouril *et al*. (1997a) they reported superior development of gonads in wild perch under natural conditions. Fontaine *et al.* (2008) has also reported the lower quality of reproduction under controlled conditions in farmed perch. Kristen *et al.* (2012) observed the GSI of wild fish of both the sexes higher than the farmed one while comparing the GSI of wild and farmed perch. This differences between farmed and wild Common carp may be mainly by unsuitable feed for the farmed fish as suggested by Izquierdo *et al*. (2001); Bell *et al*. (1997); Henrotte *et al*. (2010); Kestemont *et al*. (1999); Kestemont *et al*. (2008b). The significant difference in GSI between wild and farmed conditions during the present study indicated that culture system has an influence on GSI.

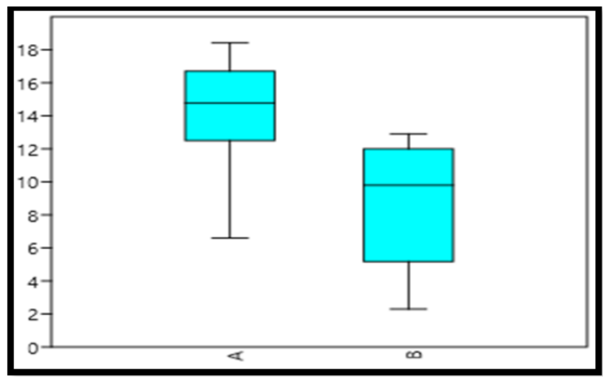

Fig. 3. Box plot depicting GSI of wild (A) and farmed (B) *Cyprinus carpio* var. *communis* (female)

Fecundity (Absolute) of farmed fish observed (44533±28572.59) was significantly lower than that of the wild fishes (68864±35950.2). Similar to the absolute fecundity, relative fecundity was found significantly higher in wild fishes (185.96±45.7) than farmed (115.98±49.25.Similar results have been observed by Kouril and Hamackova (2000) and

Table 1. Comparative analysis of reproductive parameters of Scale carp in farmed and wild conditions

Parameters	Habitat (Mean±SD)		t value	P value
	Wild	Farmed		
Weight	435.1±364.889	375.2±261.32	0.731	>0.05
Length	301.43±76.32	280.77±74.51	1.0612	>0.05
Ovary weight	48.96± 22.745	33.68±21.65	2.6	<0.01
No. of ova	1362.6±106.18	1339±148.28	0.707	>0.05
Absolute fecundity	68864±35950.29	44533±28572.59	2.85	<0.01
Relative fecundity	185.96±45.7	115.98±49.25	5.7	<0.01
Female GSI	13.7±3.605	8.6±3.52	5.5	<0.01
Sperm volume (ml)	2.393±1.64	1.486±0.88	2.62	<0.05
Sperm density ($\times 10^9$/ml)	3.534±.272	3.84±0.181	-5.148	<0.01

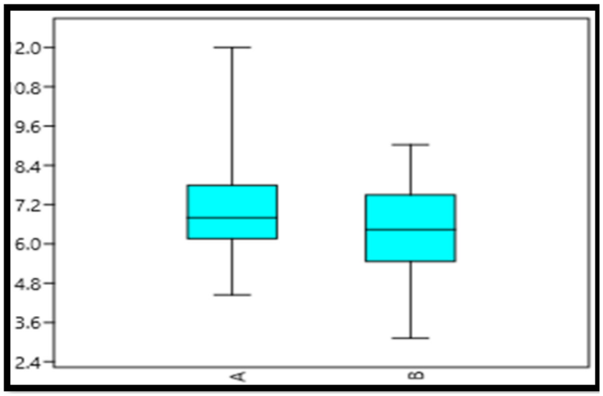

Fig. 4. Box plot depicting GSI of wild (A) and farmed (B) *Cyprinus carpio* var. *communis* ((male)

Kristen *et al.* (2012) who reported the fecundity in wild condition was significantly higher than the farmed conditions. However, Kjesbu *et al.* (1991) reported captive Cod had higher potential fecundity than wild cod. Thorpe *et al.* (1984) observed that cultured salmon had smaller but higher numbers of eggs per unit weight than wild sh. Contreas Sanchez *et al.* (1998) reported that when the fishes were subjected to stress in the form of confinement, significant differences in relative fecundity were found but absolute fecundity were not significantly affected. Randak *et al.* (2006) while studying the effect of captive conditions on reproductive traits of brown trout *Salmo trutta* reported no difference in the fecundity (absolute, relative) between the farmed and wild fish. The reason for such a difference in the results from the above work may be there is the difference in species, age, size and environment conditions between the present study and the study done earlier. According to Simpson (1951) the fecundity of an female fish varies in relation to many factors including size, age, species and environmental conditions, such as water temperature, food availability, and salinity. It may be believed that the lower fecundity in farm conditions during the present study might be due to the improper and underfeeding of fish or genetic makeup of fish stock or overstocking in pond which affected the growth of fish and indirectly the gonadal development which are similar to the findings with Billard (1995) who reported that the fish in pond show low fecundity and fail to spawn due to the stress of confinement, insufficient food and over stocking density.

In the present study mean sperm volume was higher in wild brooder (2.393±1.64ml) than in farmed individual (1.486±0.88 ml). Comparison of wild scale carp with farmed fishes revealed a significant difference in sperm volume ($p<0.05$)Fig. 5. Mean sperm volume in farmed and wild fish was found similar with the finding of Belova (1981) that indicated sperm volume in the range of 1-9 ml for scale carp. Mean seminal volume was also similar with the results reported by Nahiduzzman *et al.* (2014), who reported the sperm volume of Scale carp as 2 ml during the spawning season. Bozkurt (2006) also reported the volume of milt in scaly carp as 2.75 ml. Thamizhselvi and Thirumathal (2016) also reported the range of volume of milt in the *Cyprinus carpio* from 1.83 to 1.98 ml.

Higher sperm volume of wild fish than farmed has also been reported by Hajirezaee *et al.* (2011). Morisawa *et al.* (1979) reported that the cultured fish spent their entire life (fry to adult) in a hypotonic medium contrary to wild males of Caspian brown trout. The hypotonicity of freshwater environment establishes the hydration of testis, possibly causing the dilution of milt and leading to a higher milt volume which is contrary to the results reported by Hajirezaee *et al.* (2011). It is likely that cultured males of Scale carp with the application of an effecient osmoregulation, excrete the excess water of the body in response to hypotonicity of freshwater environment as reported by Hajirezaee *et al.* (2011) in Caspian brown trout while studying the milt quality in the cultured and wild stocks on comparative basis. It is essential to say that the weight of wild males was higher than cultured individuals during the present study. Suquet *et al.* (1994; 1998) have reported that milt volume increases with increase of weight in turbot (*Scophthalmus maximus*). Thus the higher weight of wild fish seems one of the reasons for the higher milt volume of wild males than cul-

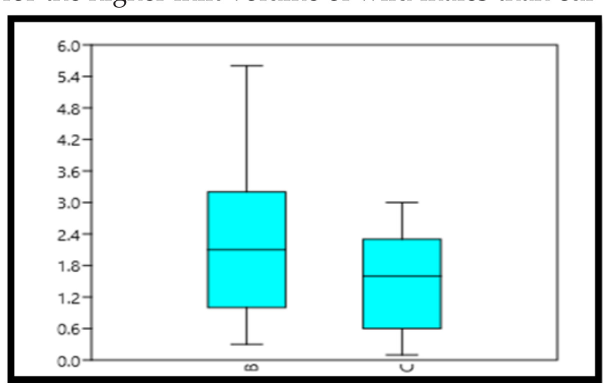

Fig. 5. Relative sperm volume (mean) of *Cyprinus carpio* var. *communis* in wild (B) and farmed (C) conditions

tured fishes. The sperm volume has also been found higher in wild European flounder (0.7ml; Sahin *et al*., 2012) than in cultured ones (0.2 ml; Aydýn *et al*., 2011). Cabrita *et al.* (2006) has found a low sperm quality and volume of stocked animals.

In the present study, the average sperm density of 3.534±0.27 x10^9 mL-^{1}in wild and 3.8415×10^9 ± 0.18ml-^{1} in farm (Fig.6) was recorded for the fish which are in conformity with the results sof Bozkurt *et al*. (2009) for grass carp (2.87-33.914 x10^9 mL-^{1}). Chutia *et al*. (1998) have reported the sperm density of 6.6x10^9 sperm cells/ml in *C. carpio*. Thamizhselvi and Thirumathal (2016) recorded the average sperm density of 2.25x10^9 sperm cells/ml in *C. carpio* from January to March, 2013. Lahnsteiner *et al*. (2000) found that the sperm density of *C. carpio* as 0.5 to 1.0×10^{11} cells per mL of milt. Comparison of farmed fish with wild revealed that sperm density of farmed fish was higher than wild individual. Similar results have been reported by Hajirezaee *et al.* (2011).

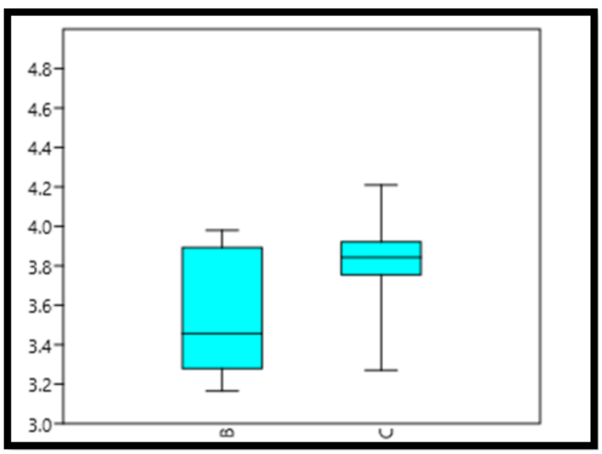

Fig. 6. Relative sperm density (mean) of *Cyprinus carpio* var. communis in wild (B) and farmed (C) conditions

Relationship between fish body weight, body length, ovary weight, absolute fecundity and relative fecundity

Table 2 shows the relationship between body weight, body length, ovary weight, absolute fecundity and relative fecundity in case of wild condition. The data reveals that significant positive correlation was found between fish weight and fish length (r=.878, p<0.01), fish weight and ovary weight (r=.888, p<0.01), fish weight and absolute fecundity. (r=.907, p<0.01. Furthermore significant positive correlation was formed between fish length and ovary weight (r=0.981, p<0.01), fish length and absolute fecundity (r=.976, p<0.01), Ovary weight and absolute fecundity (r=.998, p<0.01). Relative fecundity showed a significant negative correlation with weight, length and absolute fecundity(r=-0.747, p<0.01; r=-0.419, p<0.05and r=-0.460, p<0.05 respectively).

Relationship between body weight, body length, ovary weight, absolute fecundity and relative fecundity in farmed Scale carp

Table 3 shows relationship between body weight, body length, ovary weight, absolute fecundity and relative fecundity in case of farmed condition. The data shows a significant positive correlation between fish weight and fish length (r=.877, p<0.01), fish weight and ovary weight (r=0.860, p<0.05), fish weight and absolute fecundity (r=0.813, p<0.01). Also significant positive correlation existed between fish length and ovary weight (r=0.988, p<0.01), fish length and absolute fecundity (r=0.959, p<0.01). Ovary weight and absolute fecundity r=0.974, p<0.01). Relative fecundity showed the significant negative correlation with weight, length and absolute fecundity (r=-0.081, p<0.05; r=-0.488, p<0.05;

Table 2. Pearson correlation between fish body weight, body length, ovary weight, absolute fecundity and relative fecundity in wild Scale carp

Parameter	Weight	Length	Ovary weight	Absolute fecundity	Relative fecundity
Weight	1	0.878**	0.888**	0.907**	-0.747**
Length		1	.981**	0.976**	-0.419*
Ovary weight			1	0.998**	-0.419*
Absolute fecundity				1	-0.460*
Relative fecundity					1

**correlation is significant at 0.01 level (2 –tailed).

* correlation is significant at 0.01 level (2 –tailed)

Table 3. Pearson correlation between body weight, body length, ovary weight, absolute fecundity and relative fecundity in farmed Scale carp

Parameter	Weight	Length	Ovary weight	Absolute fecundity	Relative fecundity
Weight	1	.877**	.860**	.813**	-0.081*
Length		1	.988**	.959**	-0.488*
Ovary weight			1	.974**	-0.530
Absolute fecundity				1	-0.610*
Relative fecundity					1

**Correlation is significant at 0.01 level (2 –tailed).
* Correlation is significant at 0.01 level (2 –tailed)

p<0.05 and r=0.610, p<0.05 respectively).

Absolute fecundity has been usually related to fish or gonad length and weight (Bagenal, 1966). A relationship has been found to exist between fish length and fecundity in different species of fishes. Length has an advantage over other factors in that the fish does not shrink significantly although it can lose weight during the spawning season (Bagenal, 1967). Clark (1934) suggested that the fecundity of a fish increases in proportion to the square of its length. Simpson (1951) pointed out that the fecundity of plaice was related to the cube of its length. The close relationship between absolute fecundity and fish length demonstrated here is supported by the works of Treasurer (1990); Joshi and Khanna (1980) and Dobriyal (1988) and many others. Fecundity generally increased with total length in several fishes. A positive correlation has been observed between total length of females of *Mugil parsia* (Sarojini, 1957), *Osteogeneiosus militaria* (Pantulu, 1963), *Polynemus paradiscus* (Gupta, 1968), and *Labeo rohita* (Varghese, 1973) and their fecundity. In the mosquito fish *Gambusia affinis*, the maximum average monthly fecundity has reached when the length of the mother was at its highest (Fernandez-Delgado 1989).

A direct proportional increase in the fecundity with the increase in fish weight has been reported by Dobriyal (1988) and Lehman (1953). During the present study an increase in the number of ova was found with the increase in body weight in both the groups (wild and cultured). Absolute fecundity of *Cyprinus carpio* var. *communis* under both wild and farmed condition had a strong correlation with ovary weight than body weight and Total length. These results are in conformity with the results obtained by Khan *et al.* (1992) for *Mystus tengra* and Nabi *et al.* (2007) for *Glossogobius giuris.* According to Smith (1947), the fecundity has been more related to the fish weight than to the length in *Salvelinus fontinalis.* Same has been reported for *Liza parsia* by Rheman *et al*. (2002). However, the 'r' value, the correlation between fecundity and total weight was higher than that of fecundity and total length, suggesting that total weight is a better predictor of fecundity in the present study than total length. Similar finding have been reported by Ikomi and Odum (1998) in *Chrysichthys auratus.* Varghese (1961) has found a reduction in the rate of egg production with the increase in ovary weight in *Coilia ramcarati*. But in present study a corresponding increase in the number of eggs with the increase in the weight of ovary has been found, as in *Tilapia nilotica* (Soliman *et al.,* 1986), *Labeo gonius* (Joshi and Khanna, 1980), *Esox lucius* (Treasurer, 1990) and Chinese silver carp (Dobriyal, 1988).

Conclusion

The fish showed better reproductive characteristics in wild than farmed environments interms of GSI, fecundity and sperm volume. The finding of the present study indicated that the type of environment (wild and farmed) has significant impact on the reproductive characteristics of both the sexes of fish.

Acknowledgement

Authors are highly thankful to the faculty of fisheries Rangil Ganderbal and Fisheries department for proper assistance during this experiment

References

Aydin, I., Sahin, T., Polat, H. and Kuçuk, E. 2011. A study on the spermatological characteristics of hatchery-reared flounder (*Platichthys flesus luscus* Pallas, 1814). *Journal of Fisheries Sciences Com.* **5**(4): 270-278.

Bagenal, T. 1978. Methods of assessment of fish production in fresh waters. IBP handbook No. 3. Black well Science Co. p. 365.

Bagenal, T. B. 1966. The ecological and geographical aspects of the fecundity of the place. *Journal of Marine Biological Association United Kingdom*. 46: 161-186

Bagenal, T. B. 1967. A short review of fish fecundity. In: *The biological basis of freshwater fish production* (Ed. S. D. Gerking), Blackwell Scientific, Oxford pp. 89-111.

Bell, J. G., Farndale, B. M., Bruce, M. P., Navas, J. M. and Carillo, M. 1997. Effect of brood stock dietary lipid on fatty acid compositions of eggs from sea bass (*Dicentrarchus labrax*). *Aquaculture*. 149: 107-119.

Belova, N. V. 1981. The ecological and physiological peculiarities of sperm in pond cyprinids. Communication I. Production and ecological and physiological peculiarities of the sperm of cyprinids. *Journal of Ichthyology.* 21: 90-102.

Billard, R. 1995. Carp*:* Biology and Culture. Springer-Praxis. Chichester. UK.

Bozkurt, Y. 2006. Relationship between body condition and spermatological properties in scaly carp (*Cyprinus carpio*) semen. *Journal of Animal and Veterinary Advance.* 5(5): 412-414.

Bozkurt, Y., Ogretmen, F., Secer, F. S. and Ercin, U. 2009. Effects of seminal plasma composition on sperm motility in mirror carp (*Cyprinus carpio*). *Israeli Journal of Aquaculture-Bamidgeh.* 61: 307-314.

Cabrita, E., Soares, F. and Dinis, M. T. 2006. Characterization of *Senegalese sole*, *Solea senegalensis*, male broodstock in terms of sperm production and quality. *Aquaculture.* 261: 967-975. 2.

Campbell, P. M., Pottinger, T. G. and Sumpter, J. P. 1994. Preliminary evidence that chronic confinement stress reduces the quality of gametes produced by brown and rainbow trout. *Aquaculture.* 120: 151-169.

Chutia, I. P., Krishna, G.,& Chaudhary, A. 1998. **In**: *Fish genetics and Biodiversity conservation,* (Eds. A. G, Ponniah, P. Das and S. R. Verma), Nature conservators, Muzaffarnager pp. 205-213.

Clark, F. N. 1934. Maturity of California sardine *Sardinella caerulea*, determined by ova diameter measurement. *Fishery Bulletin.* 42: 1-49.

Contreras-Sanchez, W. M., Schreck, C. B., Fitzpatrick, M. S. and Pereira, C. B. 1998. Effects of stress on the reproductive performance of rainbow trout (*Oncorhynchus mykiss*). *Biology of Reproduction*. 58(2): 439-447.

Desai, V. R. 1970. Studies on the fishery and biology of *Tor Tor* (Hamilton) from river Narmada. *Journal of Inland Fisheries Society of India*. 2: 101-112.

Dobriyal, A. K. 1988. Fecundity of the Chinese silver carp *Hypophthalmichthys molitrix* (Val.) from Gujartal fish farm. Jaunpur, UP. *Proceeding Indian Academy of Sciences.* 97(2): 169-173.

Einum, S. and Fleming, I. A. 1997. Genetic divergence and interactions in the wild among native, farmed and hybrid Atlantic salmon. *Journal of Fish Biology.* 50: 634-651.

Fernández-Delgado, C. 1989. Life-history patterns of the salt-marsh killifish *Fundulus heteroclitus* (L.) introduced in the estuary of the Guadalquivir River (South West Spain). *Estuarine, Coastal and Shelf Science*. 29(6): 573-582.

Fontaine, P., Kestemont, P. and Mélard, C. 2008. Broodstock management. In: C. Rougeot and D. Torner (Eds.), Farming of Eurasian Perch, Special Publication BIM no. 24, Dublin, Ireland: 16-22.

Gupta, M. V. 1968. Observation on the fecundity of *Polynemus paradism* L from the highly estuarine system. *Proceeding of National Institute Science India.* 34(B): 330-345.

Hajirezaee, S., Rafiee, G. R. and Hushangi, R. 2011. Comparative analysis of milt quality and steroid levels in blood and seminal fluid of Persian sturgeon males, *Acipenser persicus* during final maturation induced by hormonal treatment. *Biologia.* 66(1): 160-169.

Henrotte, E., Mandiki, R. S. N. M., Prudencio, A. T., Vandecan, M., Melard, C. and Kestemont, P. 2010. Egg and larval quality and egg fatty acid composition of Eurasian perch breeders (*Perca fluviatilis*) fed different dietary DHA/EPA/AA ratios. *Aquaculture Research.* 41: 53-61.

Izquierdo, M. S., Fernández-Palacios, H. and Tacon, A. G. J. 2001. Effect of broodstock nutrition on reproductive performance of fish. *Aquaculture.* 197(1-4): 25-42.

Joshi, S. N. and Khanna, S. S. 1980. Relative fecundity of *Labeo gonius* (Ham.) from Nanak Sagar reservoir. *Proceeding of India Academic Science Animal Science.* 89(5): 493-503.

Kestemont, P., Cooremans, J., Abi-Ayad, S. M., & Melard, C. 1999. Cathepsin L in eggs and larvae of perch *Perca fluviatilis:* variations with developmental stage and spawning period. *Fish Physiology and Biochemistry*. 21: 59-

Kestemont, P., Henrotte, E., Wang, N., Hamza, N., Paulsen, H. and Overton, J. 2008. Feeding and nutrition of European percid broodstock and early life stages. In: *Proceeding of Abstracts and Short Communications of the Workshop Percid Fish Culture From Research to Production*, (Eds. P. Fontaine, P. Kestemont, F. Teletchea and N. Wang), *Namur* pp. 28-34.

Kjesbu, O. S., Klungs, K., Kryvi, H., Witthames, P. R. and Walker, M. 1991. Fecundity, atresia and egg size of captive Atlantic cod (*Gadus morhua*) in relation to proximate body composition. *Canadian Journal of Fisheries Aquatic Sciences*. 48: 2333-2343.

Kouril, J. and Hamackova, J. 2000. The semi artificial and artificial hormonally induced propagation of European perch (*Perca fluviatilis*). In: *Proceeding Aquatic 2000. Responsible Aquaculture in the New Millennium*, (Eds. R. Floss and L. Creswell) Spec. Publ. No. 28, Oostende, Belgium pp. 345.

Kouril, J., Hamackova, J., Lepic, P. and Mares, J. 1997. Semi-artificial and artificial spawning of Eurasian perch and rearing of fingerlings. *Research Institute of Fish Culture and Hydrobiology Vodnany*. 22: 31.

Kristan, J., Stejskal, V. and Policar, T. 2012. Comparison of reproduction characteristics and brood stock mortality in farmed and wild Eurasian perch (*Perca fluviatilis* L.) females during spawning season under controlled conditions. *Turkish Journal of Fisheries and Aquatic Sciences*. 12: 191-197.

Lahnsteiner, F., Berger, B., Horvath, A., Urbanyi, B. and Weismann, T. 2000. Cryoperservation of spermatozoa in cyprinid fishes. *Theriogenology*. 54: 1477-1498

Lehman, B. A. 1953. Fecundity of Hudson River Shad. US Fish Wild Serv. Res Rept. pp. 8.

Morisawa, M., Hirano, T. and Suzuki, K. 1979. Changes in blood and seminal plasma composition of the mature salmon (*Oncorhynchus keta*) during adaptation to freshwater. *Comparative Biochemistry and Physiology*. 64: 325-329.

Nabi, M. R., Rahman, H. A., Mustafa, S. and Kader, M. A. 2007. Population dynamics of estuarine set bag net fishery of Bangladesh. *Chiang Mai Journal of Science.* 34(3): 355-365.

Nahiduzzaman, M., Akter, S., Hassan, M. M., Azad Shah, A. K. M. and Hossain, M. A. 2014. Sperm biology of artificially induced Common carp, *Cyprinus carpio* (Linnaeus, 1758*) International Journal of Fisheries and Aquatic Studies*. 1(6): 27-31.

Naylor, R., Hindar, K., Fleming, I. A., Goldburg, R., Williams, S., Volpe, J., Whoriskey, F., Eagle, J., Kelso, D., and Mangel, M. 2005. Fugitive salmon: assessing the risks of escaped fish from net-pen aquaculture. *Bioscience*. 55: 427-437.

Norris, A. T., Bradley, D. G. and Cunningham, E. P. 1999. Microsatellite genetic variation between and within farmed and wild Atlantic salmon (*Salmo salar*) populations. *Aquaculture* 180: 247-264.

Rainis, S., Mylonas, C. C., Kyriakuo, Y. and Divanach, P. 2003. Enhancement of spermiation in European sea bass (*Dicentrachus labrax*) at the end of reproductive season using GnRHa implants. *Aquaculture*. 219: 873-890.

Randak, T., Kocour, M., Zlabek, V., Policar, T. & Jarkovsky, J. 2006. Effect of culture conditions on reproductive traits of Brown trout, *Salmo trutta l Fr. Peche Piscic.* 383: 1-12.

Rehman, S., Islam, M. I., Shah, M. M. R., Mondal, S. and Alam, M. J. 2002. Observation on the fecundity and gonadosomatic index (GSI) of *Liza parsia* (Ham.). *Journal of Biological Science.* 2: 690-693.

Sahin, T., Gunes, E., Aydin, I. and Kurtoglu, Z. I. 2012. Sperm characteristics of wild European flounder (*Platichthys flesus luscus*) *The Israeli Journal of Aquaculture - Bamidgeh I JA*: 64: 796.

Sarojini, K. K. 1957. Biology and fisheries of the grey mullets of Bengal. I. Biology of *Mugil parsia* Hamilton. *Indian Journal of Fisheries.* 4(1): 160-207.

Schreck, C. B. 2010. Stress and ûsh reproduction, the roles of allostasis and hormesis. *Gen. Comp. Endocrinol*ogy 165: 549-556.

Simpson, A. C. 1951. The fecundity of the plaice. *Fish Invest. Min. Agrl. Fish U K* Series II: **17(**5): 1-27.

Simpson, A. C. 1951. The fecundity of the plaice. *Fish Invest. Min. Agrl. Fish U K* Series II: **17(**5): 1-27.

Skaala, O., Hoyheim, B., Glover, K. and Dahle, G. 2004. Microsatellite analysis in domesticated and wild Atlantic salmon (*Salmo salar* L.): allelic diversity and identification of individuals. *Aquaculture*. 240: 131-143.

Smith, O. R. 1947. Returns from natural spawning of cutthroat trout and Eastern brook trout. *Transactions of American Fish Society.* 74: 281-96.

Soliman, A. K., Jauncey, K. and Roberts, R. J. 1986. The effect of dietary ascorbic acid supplementation on hatchability, survival rate and fry performance in *Oreochromis mossambicus* (Peters). *Aquaculture.* 59: 197-208.

Suquet, M., Billard, R., Cosson, J., Dorange, G., Chauvaud, L., Mugnier, C. and Fauvel, C. 1994. Sperm features in turbot (*Scophthalmus maximus*): a comparison with other freshwater and marine fish species. *Aquatic Living Resources.* 7: 283-294.

Suquet, M., Dreanno, C., Dorange, G., Normant, Y., Quemener, L., Gaignon, J. L. and Billard, R. 1998. The ageing phenomenon of turbot spermatozoa: effects on morphology, motility and concentration, intracellular ATP content, fertilization and storage capacities. *Journal of Fish Bio*logy. 52(1): 31-41.

Thamizhselvi, N. and Thirumathal, K. 2016. A study of interrelationship between physico-chemical characteristics of water and spermatological qualities of *Cyprinus Carpio. International Journal of Fisheries and Aquatic Studies*. 4(3): 621-625.

Thorpe, J. E., Miles, M. S. and Keay, D. S. 1984. Developmental rate, fecundity and egg size in Atlantic salmon, *Salmo salar* L. *Aquaculture*. 43: 289-305.

Treasurer, J. W. 1990. The annual reproductive cycle of pike, *Esox lucius* L., in two Scottish lakes. *Journal of Fish Biology.* 36: 29-46.

Varghese T. J. 1961. Observation of the biology of *Raconda russeliana. Indian Journal of Fisheries*. 8: 96-106.

Varghese, T.J. 1973. The fecundity of the rohu, *Labeo rohita* (Hamilton). Proceedings of the Indian Academy of Sciences - Section B. May 1973. 77(5): 214-224.