BKAP718
[1-5]

REVIEW ARTICLE Bhartiya Krishi Anusandhan Patrika

Sexual Dimorphism in Commercially Important Fish Species in India: A Review

Lovedeep Sharma[1], Ranjeet Singh[1]

10.18805/BKAP718

ABSTRACT

Sexual dimorphism in fishes is an important biological aspect, which helps distinguish males and females based on various primary and secondary sexual characteristics. Based on sexual dimorphic characteristics fishes can be categorized as monomorphic, temporary dimorphic and permanent dimorphic. These characters can be either persistent or non-persistent types in fishes. Sexual dimorphism also can be determined using biometric characteristics as well. In fish, males typically display more conspicuous sexual characteristics compared to females, including the development of vibrant colouration, nuptial tubercles, or the formation of accessory organs. Sexual dimorphism is a significant trait helpful in categorizing and classifying fish species more accurately. It also has significant implications for commercial fisheries, which can aid in catch from the wild. This also can contribute to understanding the intricacies of aquatic ecosystems but also underscores the practical applications of studying sexual dimorphism in the context of sustainable fisheries management.

Key words: Carps, Coloration, Dimorphism, Economical, Tubercles.

Sexual dimorphism in animals is a considerable area of interest for many biologists (Shine, 1989; Horne *et al*., 2020). The term sexual dimorphism can be defined as the difference in characteristics between males and females based on primary sexual characteristics like genitalia or secondary sexual characteristics including size, shape, structure, *etc*. and these characteristics differ from species to species. Sexual dimorphism is supposed to develop in two ways *i.e*. natural selection and sexual selection while which one plays a dominant role is not yet clear (Laporte *et al*., 2018).

Sexual dimorphism is influenced by many factors such as niche differentiation, natural selection, evolutionary history as well as sexual selection. Hedrick and Temeles (1989) described three main adaptive mechanisms favouring the evolution of sexual dimorphism: Sexual selection, dimorphic niches and food competition. The majority of studies on sexual dimorphism focused on humans, apes, birds, amphibians and fishes and usually dealt with sexual size dimorphism (SSD) as summarised by Blanckenhorn (2005). Sexual dimorphism is a phenotypic differentiation between males and females of the same species (Dimijian, 2005). Traits such as ornamentation and breeding behaviour found in only one sex imply that sexual selection over an extended period leads to sexual dimorphism (Dimijian, 2005).

Many teleost fishes do not exhibit any sexual dimorphism, even during the spawning season and do not show any sexual characteristics or permanent ornaments. While, some fishes show permanently dimorphic characteristics that are not necessarily associated with internal fertilization (Rapp Py-Daniel and Fernandez, 2005).

Sexual dimorphism in fish can be classified into three categories:

[1]College of Fisheries, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar-263 145, Uttarakhand, India.

Corresponding Author: Lovedeep Sharma, College of Fisheries, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar-263 145, Uttarakhand, India.
Email: lovedeeps18@yahoo.com

How to cite this article: Sharma, L. and Singh, R. (2024). Sexual Dimorphism in Commercially Important Fish Species in India: A Review. Bhartiya Krishi Anusandhan Patrika. DOI: 10.18805/BKAP718.

Submitted: 22-02-2024 **Accepted:** 12-06-2024 **Online:** 25-06-2024

Monomorphic

One is those species in which male and female cannot be differentiated, due to the lack of development of certain secondary sexual characters. It can be termed as Monomorphic.

Temporarily dimorphic

The species, which develop these characteristics only during the breeding season, are categorised as temporarily dimorphic.

Permanent dimorphic

The species included under the permanent dimorphic category are those in which males and females can be distinguished based on certain characteristics always present.

Some other variations occur in the morphology of fish, which helps to distinguish between sexes:

Body shape

In many species, females are heavier and larger as compared to the males because of the ovaries.

Nuptial tubercles

These are thorny-like stunted outgrowths that develop on the snout or head region only in males. Once spawning is over nuptial, tubercles will disappear. *e.g.*, common carp, minnows.

Variation in fin size

Generally, fins are larger in males than the females. In some fishes, pectoral fins can be used to distinguish between males and females. In males, they are rough and grainy while in females they are smooth such as in IMCs. Many studies showed variation in the length of fins between males and females as reported in cyprinids such as *Puntius* and *Pethia sp*. (Gunawickrama 2009; Mieno and Karino, 2017; Sharma and Ali, 2022).

Coloration

Many male fish exhibit vibrant and vivid colours in comparison to their female counterparts, a phenomenon commonly observed in various aquarium species. Examples include parrotfish, *Dawkinsia* sp., *Puntius chola* (Angami, 2012), where the males often display striking and intense hues.

Accessory sexual characters

It Includes modification of the anal fin to an organ called gonopodium (in males) which helps in the transfer of sperm during maturity. *e.g*., guppies and mosquito fish.

Most fish show indeterminate growth, which means it continues indefinitely after maturity, albeit at a decreasing rate (Parker, 1992). Regarding size sexual dimorphism, females are usually larger than males of the same age. In some species, however, males are larger than females (Mann, 1980). The exact reason for the size variation is not clear (Katano, 1998). However, several researchers reported that the evolution of larger body size in males likely results from male-male competition associated with a polygynous mating system (Katano, 1998; Kim *et al*., 2008).

Many have reported that morphological sexual dimorphism in fish ranges from changes in terms of body colouration and banding patterns, rapid growth in the first and second spines of the dorsal fin (Park *et al*., 2001), formation of nuptial tubercles during the breeding season (Ahnelt and Keckeis,1994; Harikumar, 1992) *etc*. Conway and Britz (2007) have described “extreme osteological sexual dimorphism of the axial skeleton, in particular elements of Weberian apparatus”.

Sexual dimorphism in major commercially important fish species in India

Carps (Cyprinids)

In India, major carps including *Labeo catla, Labeo rohita* and *Cirrhinus mrigala*, combinedly known as Indian major carps (IMCs) belong to the family Cyprinidae and are the most economically important fishes. IMCs do not show any difference between sexes (males and females) except during breeding season (Table 1). In the breeding season, the female can be identified by a bulged belly with red round and swollen genital papilla, while in males no such character is present. While the males develop roughness in the pectoral fin. Further, applying gentle pressure on the belly female oozes eggs and the male oozes milt out (Dube, 2002).

In *Labeo dero*, which is a minor carp certain differences between the two sexes were reported. Hora and Misra (1936) described that there are certain modifications in the dorsal fin and snout in the species. The snout of *Labeo dero* (Ham.) bears tubercles commonly termed “pearl organs”. Tubercles are rudimentary in both females as well as males in young individuals in the form of small pores. During maturity, the tubercles become well-defined and more prominent in males. Similarly, males also develop one more distinguishing character *i.e.* elongation of anterior rays of a dorsal fin (Hora and Misra, 1936).

Catfish

The catfishes belong to the order Siluriformes and comprise 39 families and well over 3709 species found worldwide in freshwaters (Fricke *et al*., 2015). Several catfish are important in terms of economic and recreational fisheries such as *Clarias batrachus* (Magur), *Heterop neustes fossilis* (Singhi), *Wallago attu*, *Mystus* sp., *Pangasius* sp. *etc*.

In *Clarias batrachus* commonly known as Magur, in male fish, the anal papilla is long and pointed whereas in females it is round or oval-shaped. In mature females, the vent is reddish in colour, round and bulging but in the male, it is slender and whitish. During the spawning season, the belly of the female is comparatively more swollen. If the belly of a mature female is pressed, ova oozes out through the genital opening but in the case of a male no milt oozes out when the belly is pressed. The anus is flush with the surface of the body and opens in front of the papilla or the urino-genital sinus in the case of the female. Abdominal pores are absent (Kamalaveni, 1961).

Table 1: Sexual dimorphic morphological characteristics of Indian major carps.

Male	Female
Males tend to have a more streamlined and slender body compared to females.	Females often exhibit a rounder, bulged and soft abdomen, especially during breeding season.
Pectoral fins are rough and grainy on the inner surface	They are smooth on the inner surface
Milky white milt extrudes by applying gentle pressure on the abdomen	On applying gentle pressure towards the vent on the belly ova are visible.
The vent is not swollen	The vent is pinkish and swollen.

In *Heteropneustes fossilis*, males have pointed anal papilla and streamlined body while females have swollen abdomen, papilla that is round and blunt (Saurabh *et al*., 2013).

Similarly, the Long Whiskers Catfish, *Mystus gulio* is an edible fish with therapeutic qualities. In this species, males are usually smaller than females in size with a clear white spot on the tip of the fork. Males also have a protuberance with a free tapering end lying further back to the body on the ventral profile. Regarding females, an extra aperture behind the anal opening is present. The generative openings end to this aperture and probably it represents the 'vagina'. During the breeding season, an additional spear-shaped thickening develops on the base of the caudal fin i.e. caudal thickening. These thickenings are absent in females (Lal *et al*., 2016).

Cichlids

Oreochromis mossambicus is one of the 77 species of fish all belonging to the family Cichlidae, popularly known as "tilapia" (George, 2006). Sexually dimorphic traits in tilapia are well established. These traits are often used in aquaculture to separate the sexes. It was noted that mature males have a thicker lip in the upper jaw (Oliveira and Almada, 1995). It was also reported that in the *Oreochromis spp*., males are larger than females and exhibit conspicuous breeding colours (Trewavas, 1982). While in *Oreochromis* (formerly Tilapia) *aureus* and *O. galilaeus*, males can be distinguished from females by the number of openings in their genital papilla (two for males, three for females) and the more pointed shape of the anal fin in males, which is rounded in females (Brzeski and Doyle, 1988; Nacua *et al*., 2011).

Coldwater fishes

In *Tor tor* fleshy protuberance and hypertrophied lips have been reported. The presence or absence of tubercles on the snout is regarded as a secondary sexual character in mahseers. The most noteworthy structures are the gonads, existing in the form of elongated, light-coloured strap-like bodies positioned on either side of the intestine. These structures are nestled within the groove situated between the air bladder and the abdomen. If the abdomen is slightly pressed, the mature females and males 'will discharge eggs and milt respectively.

Hora and Mukerjee (1936) observed sexual dimorphism in *T. putitora*. In males, the lips are fleshy and the lower one is projected backwards into fleshy appendages. In the case of females, the lips are of the normal type, the lower lip does not form an appendage and the snout is rather pointed. Sexual dimorphism is also present in the case of *T. mussullah.* It is found that in the males the tubercles on. The snout is more numerous and prominent, while in the males only a few small tubercles are present on the sides of the snout (Hora, 1943).

In some cyprinids, sexual dimorphism in scales is reported where breeding tubercles develop on the scales of both males and females, but are smaller and unremarkable in females (Ahnelt and Keckeis, 1994). In hill stream fish, *Baralius bendelisis* surface topography of scales in both sexes differs. The mature male scale consists of tubercles while the scales of females are devoid of any tubercles (Hussain and Bordoloi, 2016).

Barbs

In *Pethia ticto* male fish have slight black blotch on the dorsal and ventral fins, which were not found in any of the female fish. Similarly, *Pethia punctata*, possesses three rows of black spots on the dorsal fin and its absence in the female counterparts, is recognized as a persistent character. The males developed a golden yellow nuptial color with slight red coloration on the tips of the anal fin and pelvic fins. At the same time, females retain the natural olive green in color with silvery flanks in mature condition (Sharma and Ali, 2022).

In *Puntius conchonius* commonly known as rosy barb when the male is mature it develops an orange-red colouration with black-tipped dorsal, anal and ventral fins. The female has a silver-greenish colouration without any prominent pigmentation (Mitra *et al*., 2006).

Smiliogastrin cyprinids usually develop secondary sexual dimorphic characters of different types, such as:

Development of nuptial tubercles in *Haludaria melanampyx* (Harikumar, 1992); *Barbodes carnaticus* (Basavaraja *et al*., 2019). In *D. filamentous* prolongation of anterior few rays of the dorsal fin during the spawning season (Mahadevi *et al*., 2020). Development of stripes or bands with intense coloration during the breeding season in *Puntius chola* (Angami, 2012) and *P. parrah* (Vincent, 2013).

Sexual dimorphism can be determined using morphometric methods. Determination of sexual dimorphism, especially sex differentiation based on morphometric characters, has been done with accurate results, for example, the determination of sexual dimorphism on red chick barb or *Puntius orphoides* (Suryaningsih *et al*., 2014).

Importance of sexual dimorphic characters

In many cases, males exhibit exaggerated traits compared to females, such as larger body size, the presence of antlers, longer fins and brighter body colouration (Andersson, 1994). This can help the males to outcompete rival males and attract females for a successful mating process. For example, females prefer male mates that have long fins in some poeciliids, including the green swordtail (*Xiphophorus helleri*) and the guppy (*Poecilia reticulate*) (Basolo, 1990; Karino *et al*., 2011). The study of sexual dimorphism is very significant in biodiversity assessments and very important in taxonomy, bionomics and breeding biology-related research works. Knowledge of sexually dimorphic characters can also be a help for catching fish in commercial fisheries.

CONCLUSION

In conclusion, sexual dimorphism in fishes is a crucial biological trait that facilitates the distinction between males and females through various primary and secondary sexual characteristics. These differences, which may be persistent or non-persistent, include vibrant coloration, nuptial tubercles, and accessory organs, predominantly seen in males. Categorizing fishes as monomorphic, temporary dimorphic, or permanent dimorphic based on these traits enhances species classification and has practical applications in commercial fisheries. Understanding sexual dimorphism not only aids in sustainable fisheries management but also deepens our comprehension of aquatic ecosystems.

Conflict of Interest

Authors declare no conflict of interest.

REFERENCES

Ahnelt, H. and Keckeis, H. (1994). Breeding tubercles and spawning behaviour in *Chondrostoma nasus* (Teleostei: Cyprinidea): A correlation. Ichthyological Exploration of Freshwaters. 5(4): 321-330.

Andersson, M. (1994). Sexual Selection. Princeton University Press, New Jersey.

Angami, V.K. (2012). Studies on the bionomics and breeding biology of *Danio dangila* Hamilton, 1822 and *Puntius chola* Hamilton, 1822, two rheophilic ornamental fishes of Nagaland. Ph.D. Dissertation, Nagaland University, Lumami, Nagaland, India.

Basavaraja, N., Lun, K.P.B., Katare, M.B. and Pinder, A.C. (2019). Hormone induced spawning and embryogenesis of cauvery carp, *Barbodes carnaticus* (Jerdon 1849): Implications on commercial culture and conservation. Indian Journal of Experimental Biology. 57: 86-94.

Basolo, A.L. (1990) Female preference for male sword length in the green swordtail, *Xiphophorus helleri* (Pisces, Poeciliidae). Animal Behaviour. 40: 332-338.

Blanckenhorn, W.U. (2005). Behavioral causes and consequences of sexual size dimorphism. Ethology. 111: 977-1016.

Brzeski, V.J. and Doyle, R.W. (1988). A Morphometric Criterion for Sex Discrimination in Tilapia. In: The Second International Symposium on Tilapia in Aquaculture [Pullin, R.S.V., Bhukaswan, T., Tonguthai, K. and Maclean, J.L. (eds)], Manila: ICLARM Conference Proceedings 15. pp. 439-444.

Conway, K.W. and Britz, R. (2007). Sexual dimorphism of the Weberian apparatus and pectoral girdle in *Sundadanio axelrodi* (Ostariophysi: Cyprinidae). Journal of Fish Biology. 71: 1562-1570.

Dimijian, G.G. (2005). Evolution of sexuality: biology and behavior. Proceedings (Baylor University Medical Center). 18: 244-258.

Dube, K. (2002). Biology, reproductive biology and embryonic development of carps In: Short-term training programme on Carp and catfish breeding and culture. ICAR-CIFE, Mumbai, India. pp 12-29.

Fricke, R., Eschmeyer, W.N. and Fong, J.D. (2015). Eschmeyer's catalog of fishes: Genera/Speciesbyfamily/Subfamily. (http://researcharchive.calacademy.org/research/ichthyology/catalog/SpeciesByFamily.asp).

George, T.T. (2006). The Most Recent Nomenclature of Tilapia Species in Canada and Sudan. AAC Spec. Publ. l0.

Gunawickrama, K.B. (2009). Intraspecific variation in morphology and sexual dimorphism in (Teleostei: Cyprinidae). *Puntius singhala* Ceylon Journal of Science Biological Sciences. 37(2): 167-175.

Harikumar, S. (1992). A monographic study of *Puntius* (*Barbus*) *melanampyx* (Day). PhD Thesis. University of Kerala.

Hedrick, A.V. and Temeles, E.J. (1989). The evolution of sexual dimorphism in animals: Hypotheses and tests. Trends in Ecology and Evolution. 4: 136-138.

Hora, S.L. (1943). The game fishes of India. XVI. The Mahseers or the large-scaled barbels of India. 9. Further observations on mahseers from the deccan. Journal of the Bombay Natural History Society. 44(1): 1-8.

Hora, S.L. and Misra, K.S. (1936). Sexual dimorphism in the carp *Labeo dero* (Ham.). Records of The Indian Museum (A Journal of Indian Zoology). 3: 341-342.

Hora, S. L. and Mukerjee, D. D. (1936). Fish of the Eastern Doons, United Provinces. Rec. Indian Mus., Calcutta. 38(2): 133-146.

Horne, C.R., Hirst, A.G. and Atkinson, D. (2020). Selection for increased male size predicts variation in sexual size dimorphism among fish species. Proceedings of the Royal Society. B. 287: 20192640.

Hussain J.F. and Bordoloi, S. (2016). Breeding tubercles in scales of male *Barilius bendelisis* (Hamilton, 1807) identified as sexual dimorphic character. Current Science. 110(6): 985-986.

Kamalaveni, S. (1961). Morphology of the urinogenital system in some Indian teleostean fishes. Records of The Indian Museum (A Journal of Indian Zoology). 59: 83-118.

Karino, K., Ishiwatari, T., Kudo, H. and Sato, A. (2011). Female mate preference for a costly ornament in male guppies. Behavioral Ecology and Sociobiology. 65: 1305-1315.

Katano, O. (1998) Growth of dark chub, *Zacco temmincki* (Cyprinidae), with a discussion of sexual size differences. Environmental Biology Fishes. 52: 305-312.

Kim, Y.J., Zhang, C.I., Park, I.S., Na, J.H. and Olin, P. (2008). Sexual dimorphism in morphometric characteristics of Korean chub, *Zacco koreanus* (Pisces, Cyprinidae). Journal of Ecology and Field Biology. 31: 107-113.

Lal, S.S., Jaya, D.S. and Sherly, W.E. (2016). Reproductive biology of estuarine catfish, *Mystus gulio* (Hamilton-Buchanan). International Journal of Science and Research. 5(11): 1792-1794.

Laporte, M., Berrebi, P., Claude, J., Vinyoles, D., Pou-Rovira, Q., Raymond, J.C. and Magnan, P. (2018). The ecology of sexual dimorphism in size and shape of the freshwater blenny *Salaria fluviatilis*. Current Zoology. 64(2): 183-191.

Mahadevi, F.S., Ahilan, B., Rajagopalasamy, C.B.T. and Samuel Moses, T.L.S. (2020). Induced breeding and developmental biology of endemic Western Ghats *Dawkinsia filamentosa* (Valenciennes, 1844) under captive conditions. Indian Journal of Animal Research. 54(9): 1069-1077. doi: 10.18805/ijar.B-3874.

Mann, R.H.K. (1980). The growth and reproductive strategy of the gudgeon, *Gobio gobio* (L.), in two hard-water rivers in Southern England. Journal of Fish Biology. 17: 163-176.

Mieno, A. and Karino, K. (2017). Sexual dimorphism and dichromatism in the cyprinid fish. (2): *Puntius titteya.* Ichthyological Research. 64: 250-255.

Mitra, K., Suresh, V.R. and Vinci, G.K. (2006). Captive Breeding and Embryonic Development of a Minor Carp-*Puntius conchonius* (Hamilton). Journal of the Inland Fisheries Society of India. 38(1): 77-80.

Nacua, S.S., Torres, M.A.J. and Demayo, C.G. (2011). Sexual dimorphism in tilapia *Oreochromis mossambicus* (Peters, 1852) from Lake Lanao, Philippines. Research Journal of Fisheries and Hydrobiology. 6(2): 92-99.

Oliveira, R.F. and Almada, V.C. (1995). Sexual dimorphism and allometry of external morphology in *Oreochromis mossambicus*. Journal of Fish Biology. 46: 1055-1064.

Park, I.S., Zhang, C.I. and Lee, Y.D. (2001). Sexual dimorphism in morphometric characters of cocktail wrasse. Journal of Fish Biology. 58: 1746-1749.

Parker, G.A. (1992). The evolution of sexual size dimorphism in fish. Journal of Fish Biology. 41: 1-20.

Rapp Py-Daniel, L.H. and Fernandes, C.C. (2005). Dimorfismo sexual em Siluriformese Gymnotiformes (Ostariophysi) da Amazônia. Acta Amaz. 35: 97-110.

Saurabh, S, Sridhar, N., Barlya, G., Hemaprasanth, Raghavendra, C.H., Ragunath, M.R. and Jayasankari, P. (2013). Sexual Dimorphism in Fishes. Aqua International. 30-32.

Seethal, L.S. and Williams, S. (2016). Sexual dimorphism in *Mystus gulio* (Hamilton-Buchanan). International Journal of Science and Research. 5(11): 1789-1791.

Sharma, L. and Ali, P.H. (2022). Morphometric relationships and sexual dimorphism in *Pethia punctata*, an Endemic barb of Western Ghats, India. Indian Journal of Ecology. 49(5): 1800-1804.

Shine, R. (1989). Ecological causes for the evolution of sexual dimorphism: A review of the evidence. Quarterly Review of Biology. 64: 419-461.

Suryaningsih, S., Sagi, M., Kamiso, H.N. and Hadisusanto S. (2014). Sexing in the red chick barb *Puntius orphoides* (Valenciennes, 1863) by using truss morphometrics method. Biosfera. 31(1): 8-16.

Trewavas, E. (1982). Tilapias: Taxonomy and Speciation, p. 3-13. In: Conservation and Ecological Management of Philippi ne Lakes in Relation to Fisheries and Aquaculture, [Pullin, R.S.V. and Lowe-McConnell, R.H. (eds.) Basiao, Z.U. (eds.)], Southeast Asian Fisheries and Development Center, Aquaculture Department, Iloilo, Philippines. pp: 187.

Vincent, M. (2013). Visual and olfactory perception in the reproduction of a cyprinid fish, *Puntius parrah*. Ph.D. Dissertation, University of Calicut, Calicut, Kerala, India.