CHAPTER 2

CHAPTER 2

Morphology and Morphometric characterization of genus *Tor*

2.1. INTRODUCTION

Taxonomy is the science of description and classification of organisms which is essential to the inventory of life on earth (Lincoln *et al*., 1998; Wägele, 2005). It is very important to know the living organisms around us, and also their accurate identification and classification are of vital importance (Kapoor, 1998). Around 1.7 million species have been named since Linnaeus and it is estimated that about 90% of the world's biota are still undescribed (Wilson, 2000; Garcia, 2008).

The interest in the taxonomic study of fish is as old as Vedic times in India. The ancient Indians classified fish, based on shape and structure and their knowledge from keen observations are remarkable as seen from Kautilya's Arthashasthra (300 B.C.), King Someswara's Manasallosa (1127 A.D.) etc. More scientific and accurate taxonomic studies start only from the 19th Century. Hamilton- Buchanan's (1822) "An Account of the fishes of the Ganges", followed by McClelland (1839), Sykes (1839) have contributed more and all these pioneer researchers laid a solid foundation for Indian systematic ichthyology. Francis Day's "Fishes of India" was published in 1875-1878 and he documented 1418 species of fishes from Indian region. Dr. S.L. Hora was an eminent ichthyologist in the 20th century and his revisionary studies brought new dimensions in the field of fish taxonomy. He is well known by his Satpura hypothesis, by which he attempted to explain the origin and faunistic similarity with the Malayan Archipelago with that of Peninsular India (Jayaram, 1999). After Hora, the two eminent researchers A.G.K Menon and K.C. Jayaram have contributed more to the systematics of Indian ichthyology.

Genus *Tor* exhibits much taxonomic uncertainty in the classification and identification of species, especially while the morphological characters are looked into. According to Thomas (1897) 'if attention is given to Mahseers as it given to the family *Salmonidae* in the west, the Mahseers of India would also grow in numbers'. His view was surprisingly accurate because more and more species are being added to this genus.

2.1.1 Taxonomic review of *Tor*

Many authors have critically analyzed and described the systematic position of the various species of Genus *Tor* (Gray, 1834; Day, 1873, 1878; Hora and Mukherji, 1936; Misra, 1959; David, 1953; Sen and Jayaram, 1982; Menon, 1992; Molur and Walker, 1998; Jayaram, 1997; Jayaram, 1999, 2013; Mirza and Bhatti, 1996; Nautiyal, 1994; Gopalakrishnan and Basheer, 2000; Silas *et al.*, 2005; Kurup and Radhakrishnan, 2010). Hora (1939-1944) dealt the detailed work on the species of Mahseer in a series of articles under the title of "Game fishes of India". Sen and Jayaram (1982) reviewed the literature on Mahseer in India and restricted the term 'Mahseer' to the members of the genus *Tor*. Thomas (1879) reported in his historical account entitled "Rod in India", about the complete account on the biology and sporting qualities of Mahseer species.

In earlier days, the mahseer group was assigned under the genus *Cyprinus* (Hamilton), *Tor* (Gray), *Labeobarbus* (Ruppell) and *Barbus* (Jerdon, 1849; Day, 1878). Hora (1939) used the generic name, *Barbus* and erroneously recognized *Tor* Gray as its subdivision. Later workers again assigned this group under the genus *Tor* (Misra, 1959; Menon, 1992). Sen and Jayaram (1982) reviewed the literature on the Mahseers in India and identified six valid species under the genus *Tor*. They are *Tor tor* (Hamilton), *Tor putitora* (Hamilton); *Tor mussullah* (Sykes); *Tor khudree* (Sykes); *Tor mosal* (Hamilton); and *Tor progeneius* (McClelland). They also described three sub species also- *T. khudree longispinis*, *T. khudree malabaricus* and *T. mosal mahanadicus*. Talwar and Jhingran (1991) also followed Sen and Jayaram (1982) by supporting the opinion of six valid species of genus *Tor.* Menon (1992, 1999) described five valid species of genus *Tor (T. tor, T. putitora, T. khudree, T. progenius and T. kulkarni*) from different parts of India. *T. kulkarnii* (Menon) is a new species described by Menon (1992) from Darna river of Godavari drainage. The Conservation Management Assessment Plan workshop (Molur and Walker, 1998) on Freshwater fishes of India has listed eight species of Mahseer, *Tor khudree (*Sykes, 1839), *Tor khudree malabaricus* (Jerdon), *Tor kulkarni* (Menon, 1992), *Tor mosal* (Hamilton, 1822), *Tor mussullah* (Sykes, 1839), *Tor progenies* (Mc Clelland, 1839), *Tor putitora* (Hamilton, 1822) and *Tor tor* (Hamilton, 1822). Jayaram (2004) reported five species (*T. khudree, T. mussullah, T. progenies, T. tor* and *T. putitora*). He revised this genus and added *Tor macrolepis, Tor mosal, Tor malabaricus,* and *Tor neilli* (Jayaram, 2013). *Tor remadevii* (Madhusoodana Kurup and Radhakrishnan, 2011) and *Tor barakae* (Arunkumar and Basudha, 2003) are the newest species added to the genus *Tor*.

Desai (2003) stated that the carps with big scales, fleshy lips continuous at the angles of the mouth with uninterrupted fold or groove across the lower jaw, two pairs of big barbels, lateral line scales ranging from 22 to 28 and length of head equal to or greater than the depth of the body are considered as 'true Mahseer' and are included in the genus *Tor*. Taxonomy and systematic of genus *Tor* is more confusing due to the morphological variation and lack of uniformity in diagnosis of species. As mentioned in the previous chapter the generic position of *Tor mussullah* (Sykes) and its existence in Western Ghats as well as validity and distribution status of *T. malabaricus* (Jerdon) are some of the major taxonomic ambiguities of genus *Tor.*

Genus *Tor* shows more ambiguity with other Mahseer groups Neolissochilus and Naziritor in diagnosis. Fishes of the genus *Tor* are considered as ''true

Mahseer" with the presence of the median lobe, as opposed to Neolissochilus and Naziritor, where the median lobe is not present. The shape, size and length of the median lobe, the features that have often been used to distinguish species of *Tor* (Zhou and Cui, 1996), are highly variable (Roberts, 1999) and are also being influenced by environmental factors, leading to confusion and as such its reliability as an indicator of species is questionable (Ng, 2004). The systemaic status of *Tor chelynoides*, commonly known as dark Mahseer, is in a great debate. Talwar and Jhingran (1991) have considered this species as *Tor chelynoides* while Jayaram (1999, 2010) and Menon (1999) considered as *Naziritor chelynoides*. Later, it was shifted to the genus Puntius (Goswami *et al.,* 2012) and again it is placed under *Nazirator* and known as *Naziritor chelynoides (*Froese and Pauly, 2013).

2.1.2 Morphology of Mahseer

The head length related to body length ratio is a taxonomic character of high value for distinguishing the species of *Tor* (Beavan, 1877). Cylindrical body, powerful muscular tail and hypertrophied lips are some of the important characters that enable Mahseer to live in fast flowing streams (Menon *et al*., 2000). According to the requirements, fins of Mahseer are more osseous and strongly built compared to other carps (Pisolkar, 2000). Mahseer have bigger scales than any other fresh water Indian cyprinids and can easily identify this group. A fully grown Mahseer may have scales as big as the palm of one's hand. The scales are reported to be used as playing cards in some part of India (Hora, 1953).

Mac Donald (1948) noted that its fin area is greater than the total superficial area of the rest of the body. The upper lip is protrusible so as to form a cup on the bottom of the stream and cover any small body. The molluscs thus get covered and detached and are readily drawn up in to the mouth by suction. Mahseer does not possess teeth in the jaws as in the case of carnivorous fishes, but the fifth branchial arch bears the pharyngeal teeth for tearing and masticating the food materials. Hora (1940) reported that the anglers in India often preserve the pharyngeal teeth of Mahseer as trophies since they provide a reliable evidence of the size of the specimens. Another aspect of interest is the presence of hypertrophied lips in the group. Thomas (1897) explained that this is a taxonomic character which can be used for differentiating a species.

2.1.3 Morphometric and Meristic

Morphometric and meristic analysis can be a first step in the characterization of species with large population sizes (Turan, 1999). Meristic characters originally referred to characters that correspond to body segments (myomeres), such as number of vertebrae and fin rays. Now meristic is used for almost any countable structure, including numbers of scales, gill rakers, cephalic pores, and so on (Helfman *et al*., 1997).

Among the European herring populations, significantly different vertebral counts was discovered by Heincke (1898), which was the earliest report on study of morphometric variability among fish populations (Mohandas, 1997). Jayasankar *et al.* (2004) observed morphological homogeneity in Mackerals from Indian coasts. Manimegalai *et al.* (2010) performed morphometric analysis to identify the different variants in a fish species *Etroplus maculates*.

Quilang *et al*. (2007) reported the significant morphologic heterogeneity in silver perch (*Leiopotherapon plumbeus*) populations in the Philippines. The studies of Klingenberg and Ekau (1996) in Antarctic fishes (Perciformes:Nototheniidae); Elvira and Almodovar (2000) in *Acipenser sturio*; Smith *et al.* (2002) in black (*Allocytus niger*) and smooth oreos (*Pseudocyttus maculates*); Turan (2004) in Mediterranean horse mackerel (*Trachurus mediterraneus*); Turan *et al.* (2005) in African catfish (*Clarias gariepinus*); Pollar *et al*. (2007) in *Tor tambroides*; Mazlum *et al*. (2007) in eastern white river crayfish (*Procambarus acutus acutus*) are some other classical examples for morphological study.

Multivariate techniques such as principal component analysis, factor analysis, cluster analysis, and discriminant are the most powerful tools in the analysis of morphology and population structure of fishes (Ihssen *et al*., 1981; Surre *et al*., 1986; Hedgecock *et al*., 1989; Melvin *et al*., 1992; Mamuris *et al*., 1998; Trapani, 2003; Quilang *et al*., 2007; Nowak *et al*., 2008). Sokal and Rinkel (1963) described that geographic variations is not likely due to the adaptation of a few characters to single environmental variable but a multidimensional process involving the adaptation of many characters to a myriad of interdependent environmental. Hence a better understanding of morphological variations may be achieved by thoroughly examining the patterns of variance and co-variance among as many characters as possible in a data set using multivariate statistical analysis (Gould and Johnston, 1972; Reyment *et al*., 1981; Thorpe, 1976, 1983, 1987).

The morphometric analysis can be used to understand the relation between the body parts, to assess the well-being of individuals and also to determine the possible differences between separate unit stocks of the same species (Carpenter, *et al.,* 1996; King, 2007). Sharp *et al.* (1978) and Costa *et al.* (2003) have shown that morphometric characters are often more suitable than meristic characters for describing intra-specific differences. In another study Ihssen *et al.* (1981) stated that the discrete nature of meristic data contributed to low ability to discriminate among *Halobatrachus didiactylus* populations. Naeem *et al.* (2011) studied the external morphometry of the hatchery reared Mahseer, *Tor putitora* in relation to body size and condition factor. Studies of Day *et al. (*1994) and Robinson and Wilson (1996) proved that the body shape in fishes has been influenced by the type of food or feeding mode. Morphology in teleost fish is depends on the response to different types of habitat effects (Kinsey *et al.,* 1994, Corti *et al.,* 1996).

De Silva *et al.* (2006) studied the morphometric and meristic features of the three freshwater fish species namely *Puntius dorsalis, P. vitatus* and *P. bimaculatus* and shows that the morphology of a species in the same river but different localities could differ. Sometimes this may lead to the formation of different populations as the movement of individuals among the most localities is difficult. The local selection pressures leading ultimately to the increased adaptations (Carvalho, 1993) and this could even result genetic divergence of populations. The present study also shows some interesting findings that the individuals sampled from the same altitude range of different rivers clustered together indicating the considerable effect of altitude on the morphology of the species. Jerry and Cairns (1998) explained the individuals that develop and mature in common environmental conditions may share a similar phenotype and when the movement between the riverine populations is limited they develop population specific phenotypes.

As per the Genus *Tor* concern there is more Taxonomic ambiguities and there is no uniformity in diagnosis of genus *Tor*. Only few detailed taxonomic reviews are available but these reviews are also not very clear. There are several gaps in our current knowledge on the evolutionary history and distribution of the *Tor*. Most of the survey checklists of fishes often misidentify as different species or carry over the mistakes of previous workers and it creates further confusion. There is no proper type specimen for the *Tor* species which was discovered and described several years ago this lacks for comparison.

2.3 OBJECTIVES

The present study was carried out to resolve the taxonomic ambiguities of *Tor* species using morphometric and meristic characters.

2.4 MATERIALS AND METHODS

At each sampling site *Tor* species were collected using gill nets of different mesh size ranging from 8 mm to 22 mm, cast net and dip nets depending upon the depth and water velocity. The fishes were identified using the keys described by Talwar and Jhingran (1991), Menon *et al.* (1992) and Jayaram (2013). Further the specimens were labeled and preserved in 10% formalin as voucher specimen for future reference. Twenty three morphometric and fifteen meristic characters were taken from the head and body for the analysis following Rainboth (1996). Principal component analysis (PCA) was performed to know the morphometric characters differ from each species. Cluster analysis was performed to know the similarities and dissimilarities between the species using XLSTAT.

Morphometric and meristic characters were measured based on the following description (Figure 2.1).

2.4.1 Morphometric Characters

Standard length: Measurement from the anterior most portion of the snout to the base of the middle caudal rays.

Total length: Extends from the anterior most portion of the snout to the posterior tip of the caudal fin.

Head length: Measured from the anterior most portion of the snout to posterior end of operculum.

Body depth: It is the maximum depth of the body near the base of the dorsal fin to the insertion of the pelvic fin.

Pectoral fin length: It is the greatest extension of depressed fin from insertion, measured over the outer surface.

Pelvic fin length: It is taken as the greatest extension of depressed fin from insertion, with the longer of the two pelvic fins being used.

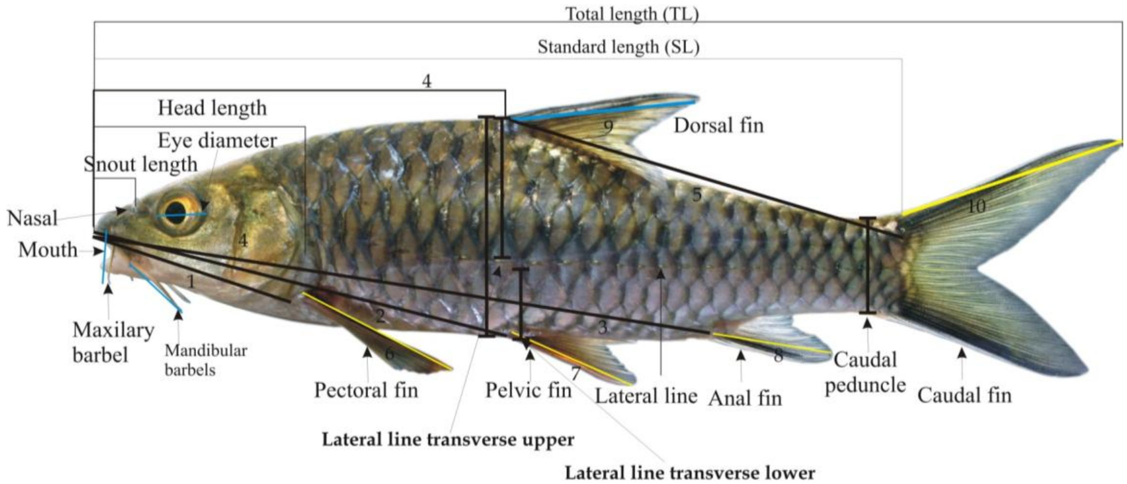

Figure 2.1. Schematic representation of *Tor* indicating the positions of the superficial points used to measure the morphometric variables

Dorsal fin length: It is the length of the last anterior unbranched dorsal ray.

Anal fin height: It is taken as the total length of the last anterior unbranched anal ray.

Prepectoral length: It is the distance from snout tip to the point of pectoral fin insertion.

Prepelvic length: It measures from the anterior most point of the unbranched pelvic rays to the tip of the snout.

Pre dorsal length: It measures the body length to the anterior most base of the unbranched dorsal fin rays (origin of dorsal fin).

Preanal length: It measures the body length to the anterior most base of the unbranched anal fin rays (origin of anal fin).

Post dorsal length: It measures from the point of pectoral fin insertion to the tip of the caudal fin.

Pelvic axillary scale length: It is taken from the point of pelvic fin insertion to the posterior tip of the axillary scale.

Head depth: It is taken from the posterior margin of the cranium at the dorsal midline on a vertical axis.

Snout length: It measures from the anterior bony rim of the orbit to the tip of the snout, not including lips.

Upper jaw length: It measures the distance from the anterior edge of the pre-maxilla to the posterior edge of the maxilla.

Maxillary barbell length: It measures the length of the barbel at the angle of the gape from the anterior edge of the oftern bulbous base to its full posterior extension.

Rostral barbel length: It is the measure of the anterior barbel found at the junction of the lacrimal groove with the maxillary groove.

Gape width: It is taken with the mouth shut and width compressed even if the mouth has been preserved in an expanded position.

Eye diameter: Measured from the widest horizontal plane from edge to edge of the eye ball.

Interorbital width: It is the width measures from the plane passing through the center of the pupil.

2.4.2 Meristic Characters

Dorsal fin spines: It is on the anterior margin of the fin articulate with the first two pterygiophores of dorsal fin.

Anal fin spines: It is on the anterior margin of the fin articulate with the first two pterygiophores of the anal fin.

No. of pelvic fin spines: The total number primary pelvic fin spines.

No. of pectoral fin spines: The total number primary pectoral fin spines.

Dorsal fin rays: This follows the unbranched rays and is counted as the number of separate, evenly placed, articulating bases rather than counting the last two as a single ray.

Anal fin rays: This follows the unbranched rays and is counted as the number of separate, evenly placed, articulating bases rather than counting the last two as a single ray.

Pelvic fin rays: This includes all rays medial to the principal unbranched pelvic ray. The count was usually taken on the left side unless the fin was damaged or abnormally developed.

Pectoral fin rays: This includes all rays medial to the principal unbranched pectoral ray.

Number of caudal fin rays: The total no of rays in the caudal fin in both upper lobe and lower lobe.

Lateral line transverse upper: Count of the scale from Insertion of the dorsal fin to the lateral line.

Lateral line transverse lower: Count of the scale from lateral line to insertion of the pelvic fin.

Circumpeduncular scales: It is taken at the region of the least depth of the caudal peduncle.

Circumferential scales: It is counted through the last full scale rows anterior to the dorsal and pelvic fins.

Predorsal scale: The scales counted from origin of dorsal fin to the snout.

Lateral line scales: It include only those anterior to the caudal fin base extending to and including the first to touch the cleithrum.

2.5 RESULTS AND DISCUSSION

In the present study the *Tor* species were collected from the tributaries of Chalakudy, Chaliyar, Periyar, Kabni, Bhavani, Kallada and Cauveri river systems. Other than *Tor khudree, T. malabaricus* and *T. mussullah* species like *T. tor, T. putitora, T. kulkarnii* and *T. remadevii* were also considered for the validity of the study.

1. ***Tor khudree*** (Sykes)

Synonymy of the Species

Barbus khudree, Sykes, 1839, *Trans. Zool. Soc. Lond.*, 2: 357 (type-locality: Mulla Mutha river *nr.* Poona, Maharashtra); Hora, 1948, *J. Bombay nat. Hist. Soc.*, 49(1): 25 (Redescription).

Barbus neilli, Day, 1869, *Proc. Zool. Soc. Lond.*: 581 (type-locality: Madras Presidency); Day, 1878, *Fishes of India*: 569, pl.140, fig. 4; Day, 1889. *Fauna Br. India*, Fishes, 1: 314.

Barbus malabaricus, Jerdon Day, 1878, *Fishes of India*: 569, pl. 138, fig. 6; Day, 1889, *Fauna Br. India*, Fishes, 1: 314; Hora, 1943, *J. Bombay nat. Hist. Soc.*, 44(2): 166 (Status discussed).

Barbus (*Tor*) *khudree*, Hora, 1943, *J. Bombay nat. Hist. Soc.*, 44(1): 6.

Tor mosal mahanadicus, David, 1953, *J. zool. Soc. India*, 5(2): 245 (type-locality: Mahanadi river at Hirakhud, Orissa).

Tor khudree longispinnis, (Gunther) Sen and Jayaram, 1982, *Rec. zool. Surv. India Occ. Paper*, (39): 13.

Tor khudree, Tilak and Sharma, 1982, *Game fishes of India and Angling*: 46, fig. 6

Fin formula: D iv 9; A ii 7; P i 14; V i 8.

Body elongate, streamlined, head length almost equal to depth of the body; indistinct small tubercles on the lateral side of the body in male; head length is 31.37% percent of standard length; pointed snout, its length contained 34.6% of head. Nostrils nearer to eye than to tip of snout. Eye is in the anterior half of head, its size highly variable with size of fish, its diameter is 22.5% of head. Dorsal fin almost in the middle of body. Predorsal scale 9-10. Circumpeduncular scales 10 rows.

2. *Tor malabaricus* (Jerdon)

Fin formula: D iii 9; A ii 5; P i 15; V i 8.

Barbus malabaricus, Jerdon, 1848, *Mad. J. Lit. Sci.* 15: 302-346.

Barbus (Tor) khudree malabaricus, Mac Donald, 1944, *J. Bombay nat. Hist. Soc.*, 44(3): 52-57.

Tor malabaricus, Molur and Walker, 1998, *CAMP Report.* 156p.

Bodies elongate its depth equal to length of head at dorsal origin. Eyes rather small, visible from underside of head. Mouth terminal, moderate; lips fleshy, the lower lip produced into a median lobe of varying length. Head length around 30% of standard length. Snout not so prolonged as in the case of *Tor khudree.* Its length around 38% in head length. Scales large; lateral line with 21 to 24 (usually 22) scales; lateral transverse scale rows $3_{1/2}/2_{1/2}$.

3. *Tor mussullah* (Sykes)

Fin formula D iv 9; A iii 5; P i 15; V i 8.

Barbus mussullah, Sykes, 1838, Proc. Zool. Soc. Lond.: 159. (type-locality: Ghod river at Sirur *nr.* Poona); Hora, 1942, *J. Bombay nat. Hist. Soc.*, 43(2): 163 (status discussed).

Barbus (*Tor*) *mussullah,* Hora, 1943, *J. Bombay nat. Hist. Soc.*, 44(1): 5.

Tor mussullah, Tilak and Sharma, 1982, *Game Fishes of India and Angling*: 53, fig.12.

Hypselobarbus mussullah, Menon, 1992, *J. Bombay nat. Hist. Soc*., 89 (2): 210 (considered as synonym of *T. Khudree*).

Tor mussullah, Jayaram, 1997, *J. Bombay nat. Hist. Soc*., 94: 48-55.

Body fairly deep, its depth 3.1 to 3.4 times in standard length. Head relatively small, its length about 4 times in standard length and much less than body depth. Eyes small, not visible from underside of head. Scales large; lateral line with 26 – 27 scales; lateral transverse scale-rows $4_{1/2}/3_{1/2}$.

4. *Tor putitora* (Ham. – Buch.)

Cyprinus putitora, Hamilton- Buchanan, 1822, *Fishes of Ganges*:303.338 (type locality: Eastern parts of Bengal).

Barbus tor, Day (*nec* Hamilton- Buchanan) (*partim*), 1878, *Fishes of India*: 564, pl.136, fig. 5: Day (*partim*), 1889, *Fauna Br. India, Fishes*, 1:307.

Barbus (tor) putitora, Hora, 1939, *Bombay nat. Hist. Soc*., 41 (2): 277,fig.2 and pl.

Tor putitora, Tilak and Sharma, 1982, *Game fish. India Angl.,* 39, figs.4, 5 and 6.

Fin formula: D iv 8; A ii 5; P i 16-17; V i 8.

An oblong, somewhat compressed, streamlined Mahseer; head broadly pointed anteriorly; length of head greater than the body depth. Back reddish sap green in colour; below the lateral line the body is orange fading in to silvery white on the belly; paired fins yellowish. Lips fleshy, lower lip with a median lobe with varying length; in specimens from fast flowing highly rocky streams it is longer, smaller with ordinary lips (not hypertrophied) in specimen living in slow moving sandy and pebbly habitats. Head length is 28.15 percent of standard length; snout length is 33.68 percent of head length. 23-28 scales on the lateral line. Lateral transverse scale rows $2_{1/2} - 4_{1/2}$. Dorsal fin almost in middle of body with upper margin concave. Pectoral fin 65.61percent of headlength.

5. *Tor tor* (Ham. – Buch.)

Fin formula: D iv 8; A iii 5; P i 14-17; V i 8.

Cyprinus tor, Hamilton-Buchanan, 1822, *Fishes of Ganges*: 305, 388 (type-locality: Mahananda river, West Bengal).

Barbus tor, Day (*partim*), 1878, *Fishes of India*: 564; Day, (*partim*), 1889, *Fauna Br. India,* Fishes, 1: 307, fig. 104.

Barbus (*Tor*) *tor,* Hora, 1940, *J. Bombay nat. Hist. Soc.*, 41(3): 518, text-fig. and pls. 1, 2 and 3.

Tor tor, ***Sen*** and Jayaram, 1982 , *Rec. Zool. Surv. India, Occ. Paper* No. 39, pp.2-4, figs 1-2.

A more stoutly built Mahseer than the putitor, with the ventral profile more prominently arched than the dorsal. Head shorter than the length of the body. Dorsal surface greyish green and below the body olive green. Fins deep orange. Head 25.81 percent of standard length. Snout pointed, its length 36.92 percent of head length. 22-28 scales on the lateral line. Lateral transverse scale rows 4 $_{1/2}$ -4 $_{1/2}$/2 $_{1/2}$-3 $_{1/2.}$ Dorsal fin almost in the middle of body with its upper margin concave.

6. *Tor remadevii* (Kurup and Radhakrishnan)

Fin formula: D.IV, 10; P.I, 15; V.I, 8; A.I, 5; C.19; L.1. 27-29.

*Tor remadevii***,** Kurup and Radhakrishnan, 2010, *J. Bombay nat. Hist. Soc.*, 107: 227-230.

An elongate species with the dorsal fin equal to depth of the body and with a strong osseous spine, head straight, snout pointed and with a terminal or slightly upturned mouth, lips fleshy and the mentum small (fleshy in younger specimens), head length more than body depth, a deep hump at the occipit, lateral line scales 27-29. Lateral transverse scale-rows 4 $_{1/2}$/2 $_{1/2}$-3. Head length 32.45% of standard length. Elongated snout and its length 33.34% of head length.

Body colour greenish to metallic silvery along back and fins reddish with blackish patches. Dorsal profile has a moderate to prominent hump after the head region, before the insertion of dorsal fin.

7. *Tor kulkarnii* (Menon)

Fin formula: D.IV, 9; P.I, 14-16; V.I, 8; A.III, 5; C.19; L.1. 24-26.

Tor kulkarnii, Menon, 1992, *J. Bombay nat. Hist. Soc.*, 89: 222.

Body elongate and compressed, compression more towards tail; a short head considerably shorter than the depth of the body. Upper profile convex before dorsal fin, slightly concave behind it, ventral profile gently arched. Mouth moderate and terminal. Lips fleshy. Head sharpish, oval, flatish above; its length considerably shorter than depth of body; it contained 24.08% standard length. Snout pointed, its length 34.25 percent of head length. Nostrils nearer to eye than to tip of snout. Dorsal fin almost in the middle of body with its upper margin concave. Lateral line with 24 to 26 scales; lateral transverse scale rows 3 $_{1/2}$/2 $_{1/2.}$ *Tor kulkarnii* is a dwarf cognate of *T. khudree*. The small head and the deeper body distinguish this from all other forms from all other species of *Tor.*

Since, there is no comprehensive key available for identification of *Tor* species, the present study made an attempt to prepare a taxonomic key for the *Tor* including all the species so far described. .

2.5.1 Key to the *Tor* species

1a. Length of head considerably greater than body depth...**2**

1b. Length of head considerably shorter or more or less equal to body depth………………………………………………………………..……….4

2a. Dorsal fin inserted midway between tip of snout and caudal fin base... **3**

2b. Dorsal fin inserted slightly near to the tip of caudal fin base than tip of snout…………………………….. ***Tor malabaricus***

3a. A characteristic hump over occiput, head and snout straight, mouth slightly upturned, body bluish dark with fins red orange… ***Tor remadevii***

3b. No hump over occiput, Head and snout normal, mouth slightly subterminal, colour silvery with the fins yellowish....................***Tor putitora***

4a. Length of head equal to depth of body (rarely shorter)…………………………………………………………………....***5***

4b. Length of head shorter than depth of body……………………….…………..……**7**

5a. A fan-shaped rounded structure behind upper lip present……… ……………………………………………………………….. ***Tor progenius***

5b. No such fan-shaped structure behind upper lip **6**

6a. Eye diameter 3.2-4.2 in head length, L.l. scales 23-26……………….***T. mosal***

6b. Eye diameter 5.5-7 in head length, L.l. scales 25-27………………***T. khudree***

7a. A characteristic hump over occiput……………………………....***T.mussullah***

7b. No such characteristic hump over occiput…………………………..………**8**

8a. Dorsal spine weak, articulated; 3 to 3.5 rows of scales between dorsal fin base and lateral line.. ***Tor neilli***

8b. Dorsal spine strong; 2.5 to 3.5 rows of scales between dorsal fin base and lateral line... **9**

9a. Length of head about 4 times in S.L, 6-9 scales before dorsal fin…… ***T. tor***

9b. Length of head more than 4 times in S.L., 10-11 scales before dorsal fin………………………………………………………………. ***T. kulkarnii***

Table 2.1. Descriptive statistics of the transformed morphometric variables of *Tor* species

Morphometric charecters	*Tor khudree* (n= 25)		*Tor malabaricus* (n=25)		*Tor mussullah* (n= 10)	
	Mean±SD	**Range**	**Mean±SD**	**Range**	**Mean±SD**	**Range**
BD	26.72±1.31	24.22- 27.80	23.24±3.45	17.3- 28.79	30.80±1.24	28.44-32.22
PFL	19.26±0.81	17.92-20.36	19.08±1.89	14.88- 21.50	20.29±0.65	19.16-20.98
PFL	17.45±1.12	15.47-18.90	17.25±1.70	13.65- 20.98	18.84±0.98	17.23--19.93
DFL	23.19±1.05	22.01-25.63	23.28±1.87	18.80- 27.76	25.68±0.87	24.64-26.88
AFL	17.38±1.28	14.72-18.89	17.23±1.82	12.12- 20.24	18.57±0.89	17.53-19.87
PrePL	27.75±1.51	25.26-30.36	27.33±2.32	19.44- 29.70	28.14±2.50	25.07-31.87
PrePelL	52.47±2.08	48.50-56.03	48.80±3.94	40.26- 55.98	51.11±2.09	48.14-53.48
PreAL	82.05±9.95	71.07-97.04	70.21±5.78	61.66- 78.86	74.92±1.65	72.51-76.93
PreDL	50.95±2.30	47.55-55.22	47.74±4.93	40.74- 55.25	51.83±0.90	50.81-52.99
PoDL	43.00±8.36	32.72-53.40	32.83±4.50	25.77- 41.65	36.85±1.33	35.16-38.61
HL	27.01±.081	23.92-28.36	26.92.08±1.89	24.88- 29.5	22.29±0.65	19.16-24.98
PASL	23.56±5.23	15.94-29.38	20.45±2.99	14.51- 26.23	31.20±2.37	27.59-34.46
HD	68.03±7.06	55.52-76.55	61.21±8.22	48.44-73.15	56.08±2.15	52.71-59.10
HW	51.55±7.37	35.77-60.47	50.33±4.72	42.80- 59.21	79.69±4.45	75.10-87.77
SnL	37.91±8.46	28.05-50.27	31.99±4.00	26.82-39.45	47.92±2.34	45.68-52.38
UJL	28.40±2.35	24.95-31.91	30.85±4.97	19.58-36.85	40.11±4.59	33.82-47.26
RBL	18.73±4.65	12.14-26.87	17.76±2.96	12.98-24.66	28.18±1.11	25.85-9.51
MBL	24.16±4.61	14.44-30.94	22.13±2.63	17.18-25.65	33.01±6.70	22.30-41.74
GWM	21.58±3.43	15.67-27.51	22.01±2.73	17.53-27.66	25.38±2.74	22.89-31.08
ED	20.17±2.34	15.29-22.62	19.19±3.55	12.74-24.20	22.31±3.21	19.01-27.80
IOW	29.87±5.46	23.64-39.64	30.19±3.95	21.54-34.99	38.84±5.48	30.38-45.38

Table 2.2. Descriptive statistics of the transformed morphometric variables of *Tor* species

Morphometric characters	*Tor tor* (n= 3)			*Tor putitora* (n=3)			*Tor remadevii* (n= 3)			*Tor kulkarnii* (n=3)		
	Mean±SD	**Range**		**Mean±SD**	**Range**		**Mean±SD**	**Range**		**Mean±SD**	**Range**	
BD	29.03±1.46	28.00	30.07	26.447±0.0	22.409	31.48	28.99±0.30	28.77	29.34	29.99±1.24	28.67	31.12
PFL	21.60±1.42	20.59	22.60	20.042±0.5	19.655	20.428	19.33±0.51	18.78	19.78	6.42±0.84	5.70	7.34
PFL	18.45±1.31	17.53	19.37	17.047±0.5	16.658	17.436	17.78±0.46	17.28	18.19	5.80±0.14	5.70	5.96
DFL	26.51±0.96	25.83	27.19	24.530±0.1	24.403	24.658	28.68±0.56	28.03	29.00	14.32±0.83	13.47	15.14
AFL	8.42±0.55	8.03	8.81	13.375±0.2	13.171	13.579	18.49±0.17	18.30	18.62	7.74±0.08	7.66	7.80
PrePL	29.56±2.87	27.53	31.59	33.305±0.6	32.881	33.728	28.81±1.15	27.53	29.77	22.10±0.50	21.53	22.48
PrePelL	55.27±4.74	51.92	58.62	54.217±0.4	53.880	54.555	50.68±0.23	50.41	50.84	52.1±0.10	49.1	54.20
PreAL	83.01±0.70	82.52	83.51	77.123±0.6	76.682	77.564	80.67±1.20	79.45	81.84	16.09±1.60	14.51	17.70
PreDL	40.38±5.82	36.26	44.49	57.800±0.9	57.135	58.465	51.56±1.16	50.23	52.28	52.75±5.61	48.80	59.17
PoDL	38.54±1.73	37.32	39.76	54.335±0.8	53.717	54.954	33.02±0.02	33.01	33.05	44.70±3.08	41.15	46.63
HL	26.60±40.7	22.76	28.44	33.62±0.5	29.20	34.041	32.02±0.86	31.00	33.02	25.93±10	24.05	28..64
PASL	26.89±3.38	24.50	29.28	18.807±3.2	16.484	21.130	22.70±0.70	21.94	23.33	28.00±0.00	26.20	29.10
HD	72.97±0.03	72.95	72.99	58.974±0.0	58.973	58.974	63.01±1.77	61.09	64.56	80.81±4.26	76.00	84.09
HW	56.71±0.34	56.47	56.95	48.974±0.0	48.962	48.985	46.37±0.22	46.12	46.53	73.18±1.60	72.00	75.00
SnL	23.17±1.40	22.18	24.16	33.018±0.0	32.988	33.048	38.27±0.56	37.71	38.83	24.06±2.96	22.00	27.45
UJL	30.82±0.25	30.64	30.99	25.630±3.0	23.484	27.776	39.45±0.52	39.05	40.04	23.10±0.20	22.20	24.10
RBL	21.26±0.39	20.99	21.54	17.785±2.7	15.873	19.698	18.76±0.08	18.70	18.85	14.44±1.09	13.64	15.69
MBL	23.30±1.13	22.49	24.10	20.401±2.7	18.478	22.324	25.42±0.77	24.96	26.30	19.26±0.96	18.18	20.00
GWM	20.94±0.47	20.61	21.27	15.566±3.4	13.146	17.986	24.98±0.46	24.59	25.49	26.91±0.79	26.00	27.45
ED	30.95±0.34	30.70	31.19	17.947±0.0	17.908	17.986	20.90±0.92	20.24	21.94	21.05±0.91	20.00	21.59
IOW	92.84±1.03	92.11	93.57	27.825±0.2	27.676	27.975	29.480.03	29.45	29.51	41.62±0.62	40.91	42.00

Table 2.3. Descriptive statistics of the meristic variables of *Tor* species

Morphometric characters	*Tor khudree* (n= 25)			*Tor malabaricus* (n=25)			*Tor mussullah* (n=10)		
	Mean±SD	Range		Mean±SD	Range		Mean±SD	Range	
DFUBR	4.00±0.00	4.00	4.00	4.00±4.00	4.00	4.00	4.00±0.0	4.00	4.00
AFUBR	2.20±0.42	2.00	3.00	2.07±0.33	2.00	3.00	3.00±0.0	3.00	3.00
PelFUBR	1.00±0.00	1.00	1.00	1.00±0.00	1.00	1.00	1.00±0.0	1.00	1.00
PecFUBR	1.00±0.00	1.00	1.00	1.00±0.00	1.00	1.00	1.00±0.0	1.00	1.00
DFBR	9.00±0.00	9.00	9.00	9.00±0.00	9.00	9.00	9.00±0.0	9.00	9.00
AFBR	5.00±0.00	5.00	5.00	5.00±0.00	5.00	5.00	5.00±0.0	5.00	5.00
PelFBR	7.70±0.48	7.00	8.00	7.20±0.39	7.00	8.00	8.00±0.0	8.00	8.00
CFR	20.30±2.16	19.00	24.00	21.40±1.18	19.00	22.00	19.50±2.8	18.00	24.00
PecFR	13.80±0.42	13.00	14.00	13.93±0.56	12.00	14.00	15.00±0.0	15.00	15.00
LLTU	4.50±0.00	4.50	4.50	3.77±0.49	3.50	4.50	4.50±0.0	4.50	4.50
LLTL	2.50±0.00	2.50	2.50	2.50±0.00	2.50	2.50	3.25±0.5	2.50	3.50
CPS	11.30±0.48	11.00	12.00	10.33±0.80	10.00	12.00	11.00±0.0	11.00	11.00
CFS	16.60±0.97	16.00	18.00	17.60±0.79	16.00	18.00	16.00±0.0	16.00	16.00
PDS	8.10±0.32	8.00	9.00	7.27±0.62	7.00	9.00	6.50±0.9	6.00	8.00
LLS	25.70±0.67	25.00	27.00	23.80±1.41	24.00	26.00	23.63±0.5	23.00	24.00
Coloration	Dark grey colour on the dorsal side. Below lateral line milky white. Pectoral, pelvic and anal fins dark orange colour. Twinges of yellow and orange in dorsal and caudal fin. Dark grey body with dark brown fin also observed. Some specimen with silvery white belly.			Body dark brown in above the lateral line. Creamy white below the lateral line. Colour varies based on the habitat. Pelvic and pectoral fin light orange colour. Anal fin dark orange with brown. Yellowish reflections on the dorsal and caudal fins. Dark brown body on dorsal side with color less fins (very light yellow and reddish edges) also noted in some locations.			Dark with bronzy reflections above the lateral line. Below the lateral line silvery grey. Belly reddish creamy. Base of the scales bluish grey. Pectoral, pelvic and anal fins are dark orange. Reddish grey caudal and dorsal fins.		

Table 2.4. Descriptive statistics of the meristic variables of *Tor* species

Morphometric characters	*Tor tor* (n= 3)			*Tor putitora* (n=3)			*Tor remadevii* (n= 3)			*Tor kulkarnii* (n=3)		
	Mean±SD	Range		Mean±SD	Range		Mean±SD	Range		Mean±SD	Range	
DFUBR	4.00±0	4.00	4.00	4.00±0	4.00	4.00	4.00±0.0	4.00	4.00	4.00±0	4.00	4.00
AFUBR	3.00±0	3.00	3.00	3.00±0	3.00	3.00	1.00±0.0	1.00	1.00	3.00±0	3.00	3.00
PelFUBR	1.00±0	1.00	1.00	1.00±0	1.00	1.00	1.00±0.0	1.00	1.00	1.00±0	1.00	1.00
PecFUBR	1.00±0	1.00	1.00	1.00±0	1.00	1.00	1.00±0.0	1.00	1.00	1.00±0	1.00	1.00
DFBR	9.00±0	9.00	9.00	9.50±0.5	9.00	10.00	10.00±0.0	10.00	10.00	9.00±0	9.00	9.00
AFBR	5.00±0	5.00	5.00	5.00±0	5.00	5.00	5.00±0.0	5.00	5.00	5.00±0	5.00	5.00
PelFBR	7.67±0.58	7.00	8.00	8.00±0	8.00	8.00	8.00±0.0	8.00	8.00	7.67±0.58	7.00	8.00
CFR	19.00±0	19.00	19.00	19.00±0	19.00	19.00	19.00±0.0	19.00	19.00	19.00±0	19.00	19.00
PecFR	14.67±1.00	14.00	16.00	15.50±1.5	14.00	17.00	15.00±0.0	15.00	15.00	15.00±1.00	14.00	16.00
LLTU	3.50±0	4.50	4.50	4.50±0	4.50	4.50	4.50±0.0	4.50	4.50	4.50±0	4.50	4.50
LLTL	2.50±0.58	2.50	3.50	2.50±0	2.50	2.50	2.67±0.3	2.50	3.00	2.83±0.58	2.50	3.50
CPS	9.00±0	9.00	9.00	11.50±0.5	11.00	12.00	14.00±0.0	14.00	14.00	9.00±0	9.00	9.00
CFS	17.00±0	17.00	17.00	14.00±0	14.00	14.00	20.00±0.0	20.00	20.00	17.00±0	17.00	17.00
PDS	10.00±0	10.00	10.00	10.50±0.5	10.00	11.00	10.00±0.0	10.00	10.00	10.00±0	10.00	10.00
LLS	25.00±1	24.00	26.00	25.50±2.5	23.00	28.00	28.00±1.2	27.00	29.00	25.00±1	24.00	26.00
Coloration	Dorsal surface greyish green and below the body olive green. Fins deep orange.			Dorsal surface reddish to sap green. Body below lateral line light orange to silvery white. Fins peacock – green.			Dorsal side greenish to metallic black with sides silvery and on ventral side white.			Sides above lateral line and back are dark, the sides below lateral line creamy yellowish white and silver bluish grey below on the belly. Head dark olive, yellowish white below. Fins bluish grey.		

The morphometric characters of the *Tor* species were analysed (Table 2.1 and 2.2). The results of multivariate analysis using morphometric and meristic variables of *Tor* species were grouped in to five classes (Table 2.5). The first class contain 3 species; *T. khudree*, *T. remadevii* and *T. mussullah. Tor malabaricus* collected from all the four river systems is grouped in separate cluster. The class 1 species showed more similarity with *Tor malabaricus* and more distance with *Tor kulkarnii. T. kulkarnii, T. tor* and *T. putitora* each one is grouped as distinct separate cluster it show they are distinct separate species. It is clear that the variation within the species is 31.27% and between the species is 68.73%. Individuals of *T. mussullah*, *T. malabaricus*, *Tor tor, Tor putitora* and *Tor kulkarnii* were grouped in to different separate cluster (Figure 2.2). There is no overlapping of characters between the species. The individuals of *T. khudree* from Periyar river system came close to *T.remadevii,* whereas *Tor tor, Tor putitora* and *Tor kulkarnii* species were clustered faraway from *T. khudree.* This differentiation suggests that there are some common characters existing between *T. khudree* and *T.remadevii*. Since *T.remadevii* shows more similarity with *T. khudree* than other *Tor* species, it may be a sister species of *T. khudree.* Furher molecular study may help to distinguish the exact relationship between *T. khudree* and *T.remadevii.*

There are clear intraspecific variation is observed within the individuals of *Tor khudree*. The *Tor khudree* collected from Chaliyar, Kabini and Kallada river systems are grouped in to the same cluster in dendrogram (Figure 2.2). But the *Tor khudree* individuals collected from Bhavani and Chalakudy rivers formed a separate cluster and grouped away from the first cluster of *Tor khudree*. The similarity between the species of Chaliyar and Kabini rivers clearly explain the importance of the geographical proximity of these two rivers. The differences in physico-chemical characteristics of the water bodies and the isolated geographical location of the rivers Kallada, Chaliyar, Chalakudy and Bhavani may also explain the morphological variation in *Tor khudree.* Poulet *et al.* (2005), Swain *et al.* (2005) and Gould (1966) were also supporting the above statement that the morphometric differences within a species are generally linked with reproductive or geographical isolation due to the interactive effects of environment, selection and genetics on individual ontogenies. This indicates the importance of the analysis of genetic structure for the identification of species.

A number of influential factors have been identified to explain the environmental effects on the morphometric characteristics (Swain *et al.,* 2005). Haas *et al*. (2010) found that the physical characteristics of habitats drive changes in the morphological attributes of native fish populations. According to Lindsey (1988) the environmental component in morphologic characters is determined during the early larval stages when variation in temperature, salinity, oxygen and pH or food availability can modify the trait. Each morphologic character has a genetic basis but the environment may modify the expression of that particular character (Zelditch *et al.,* 1992).

Table 2.5. Distances between the central objects

	1 ***T. mussullah*** ***T.khudree*** ***T. remadevii***	**2** ***T. malabaricus***	**3** ***T. kulkarnii***	**4** ***T. putitora***	**5** ***T. tor***
1 ***T. mussullah*** ***T.khudree*** ***T. remadevii***	0				
2 ***T. malabaricus***	127.810	0			
3 ***T. kulkarnii***	297.552	172.386	0		
4 ***T. putitora***	169.691	149.026	130.669	0	
5 ***T.tor***	212.457	87.987	88.609	49.188	0

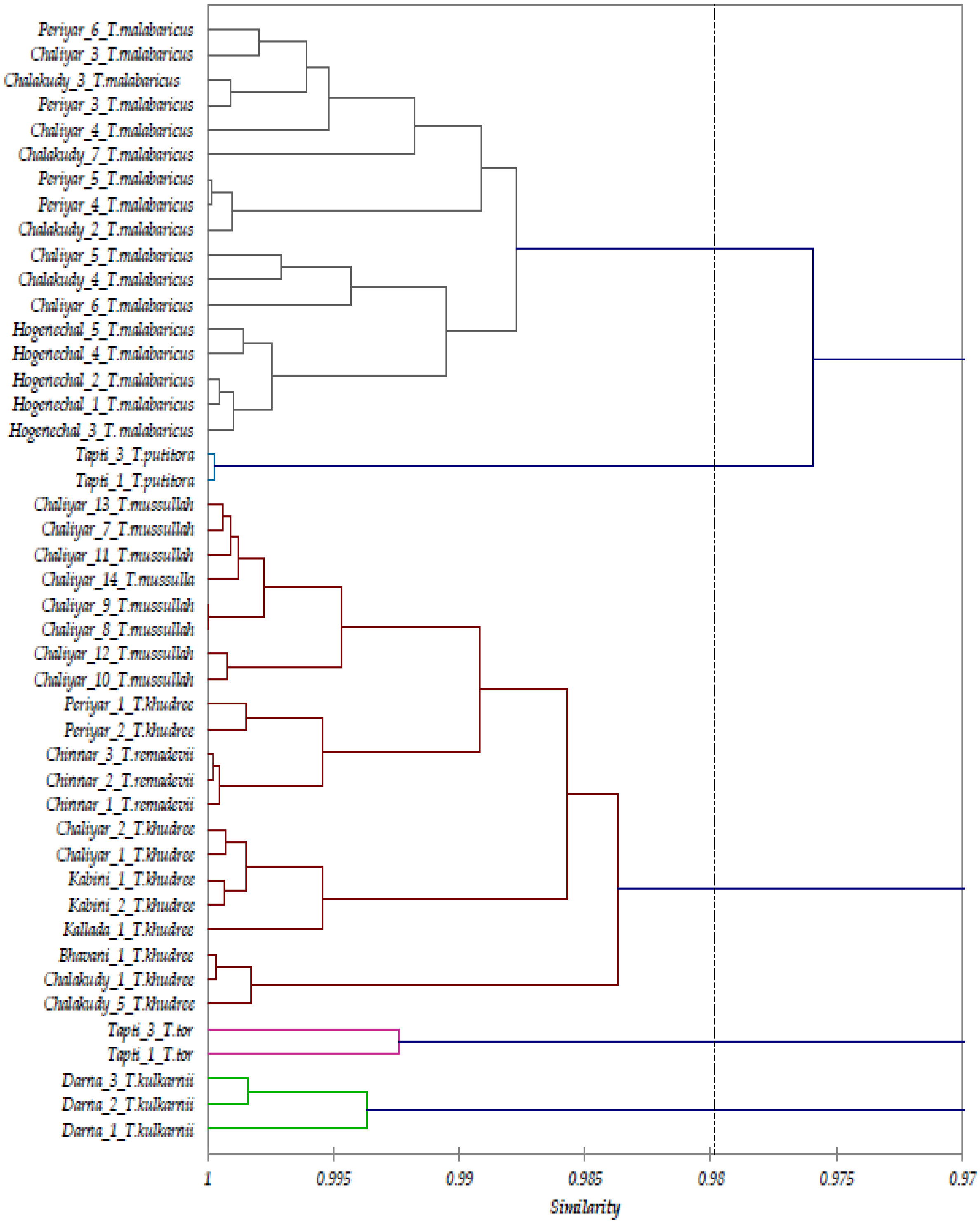

Figure 2.2. The dendrogram showing the similarity between the species

The external appearance and the color patterns observed in the specimens of *Tor* species from various geographical locations were differed. The individuals of *T. khudree* and *T. malabaricus* collected from different river systems showed varying color patterns. *T. khudree* from Chaliyar and Chalakudy as well as *T. malabaricus* from Chaliyar and Periyar river systems exhibit a differential body shape and color pattern (Figure 2.3A-D). It is observed that a characteristic bone is present on the ventral part of head in *T. malabaricus* collected from Chaliyar, Chalakudy and Periyar rivers; no earlier reports are available about this morphological character of *Tor malabaricus* (Silas *et al.,* 2005 and Jerdon, 1948). *Tor mussullah* collected from the two locations, Cherupuzha and Manjeeri, of the Chaliyar river system also exhibit difference in color pattern (Figure 2.4 E and F). Based on the present study it is possible to say that the color variation is not a criterion for the identification of *Tor* species. The color will change depending on the environmental factors. *Tor sp.* specimen collected from Bhavani river has showed a differential appearance in morphology (Figure 2.4 G). This species is grouped with the *Tor khudree* species from Chalakudy and formed a separate cluster in the dendrogram (Figure 2.2). More studies are needed to confirm the identity of these specimens.

In the present study, it is difficult to point out which of the several biotic and abiotic factors contributed to the variation in *Tor* species. Many reports are available to prove that the body shape in fishes can be modified by the temperature (Martin, 1949; Beacham, 1990), quantity of food (Currens *et al.,* 1989) and type of food or feeding mode (Meyer, 1987, 1990; Witte *et al.,* 1990; Wimberger, 1991, 1992; Wainwright *et al.,* 1991; Day *et al.,* 1994; Robinson and Wilson, 1996; Pakkasmaa, 2001; Proulx and Magnan, 2004). Imre *et al.* (2002) indicated that the morphological variation in the caudal area in brook charr (*Salvelinus fontinalis*) from microhabitats differing in water velocity and a deeper caudal peduncle is observed in fishes from turbulent waters.

Figure 2.3. A-D *Tor* species from different river systems

E *T. mussullah* from Chaliyar river (Manjeeri)

F *T. mussullah* from Chaliyar river (Cherupuzha)

G *Tor species* from Bhavani river

Figure 2.4. E-G *Tor* species from different river systems

There are many well documented studies on species identification and analysis of stock structure in fishes using morphological traits which also supports the present study. The studies of Fernandez and Devraj (1989) in *Coilia dussumieri* and *Harpondon nehereus* along the Northeast coast of India; Serajuddin (2004) in spiny eel, *M. armatus* from Kalinadi, a tributary of Ganga river; Saini *et al.* (2008) in giant river catfish, *Mystus seenghala*; Sajina *et al.* (2011) in the populations of *M. cordyla* (horse mackerel); Cakmak and Alp (2010) in *Mastacembelus mastacembelus*; Rahmani (2009) in *Chalcalburnus chalcoides*; Janhunen *et al.* (2009) in Arctic charr, *S. alpines;* Tzeng (2004) in the spotted Mackerel (*Scomber australasicus*) of Taiwan; Turan *et al.* (2004) in *Engraulis encrasicolus;* Bektas and Belduz (2009) in *T. trachurus* of Turkey; Murta (2000) in *Trachurus trachurus*; and Chen *et al.* (1989) in *Mugil cephalus* are some of the classical examples.

The correlation coefficient of variation shows comparatively lower ranging from 4.89% to 9.38%. In fishes, the coefficients of variation within populations are usually far greater than 10% (Carvalho, 1994). The lower coefficient of variation indicates minimal or very low intra-population variation. Similar results were obtained by Mamuris *et al*. (1998) in the seven populations of red mullet (*Mullus barbatus*) and by Quilang *et al*. (2007) in four populations of Silver perch (*Leiopotherapon plumbeus*).

The principal component analysis shows the morphometric characters like head length (HL), body depth (BD), standard length (SL), total length (TL), head width (HW), dorsal fin length (DFL), pre dorsal length (PreDL), post dorsal length (PoDL), Lateral Line scale (LLS), pre pelvic length (PrePelL) and pre anal length (PreAL) were with higher factor loadings (Figure 2.5). In the meristic characters, less variation is seen between the populations of same species. Meristic characters are commonly determined during early development and are independent of individual size. The present results also supports Sarkar *et al.* (2009)

and the stock identification of fish from twelve different geographical locations using morphometric and meristic methods proved that morphometric characters like body structure, pectoral fins and mouth shape were differed from most of the population, but meristic characters was not much varied from each other. Cakmak and Alp (2010) also reported significant morphometric differences among the populations of Mesopotamian Spiny Eel, *Mastacembelus mastacembelus*, while the meristic traits did not differ in three populations.

As mentioned earlier *Tor malabaricus* specimen were able to collect from Chaliyar, Chalakudy and Periyar river systems. Only *Tor khudree* was reported and *Tor malabaricus* was not reported by the earlier workers from the Periyar river (Arun, 1998; Radhakrishnan and Kurup, 2010). Based on the informations given by the tribals, there are three types of *Tor* species available in the river. Specimens collected from Hogeneckal also showed similarity with *Tor malabaricus* and existed as a separate group in the same cluster. This leads to the suspicion in the presence of *Tor malabaricus* in Hogeneckal and also needs further studies for species confirmation. A species may undergo micro-evolutionary processes and differentiate into genetically distinct sub-populations in the course of time (Carvalho and Hauser, 1994; Moritz, 1994 and Begg *et al*. (1999). If we are not able to recognize such distinct species or populations, it will lead to the loss of genetic diversity and other ecological consequences.

The existence of *T. mussullah* and the validity of *T. malabaricus* are some major ambiguities related to genus *Tor*. Both species had a taxonomic confusion with *T. khudree.* The presence of *T. khudree* and *T. mussullah* were recorded from Chaliyar river (Manimekalan, 2000; Easa and Shaji, 2003; Easa and Basha, 1995). Baby *et al*. (2010) could not identify the *T. khudree* from river Chaliyar and they mentioned that the *T. khudree* recorded by Easa and Basha (1995) could be *T. malabaricus* but not *T. khudree.* The present study also supports the presence of *T. khudree* and *T. mussullah* in Chaliyar.

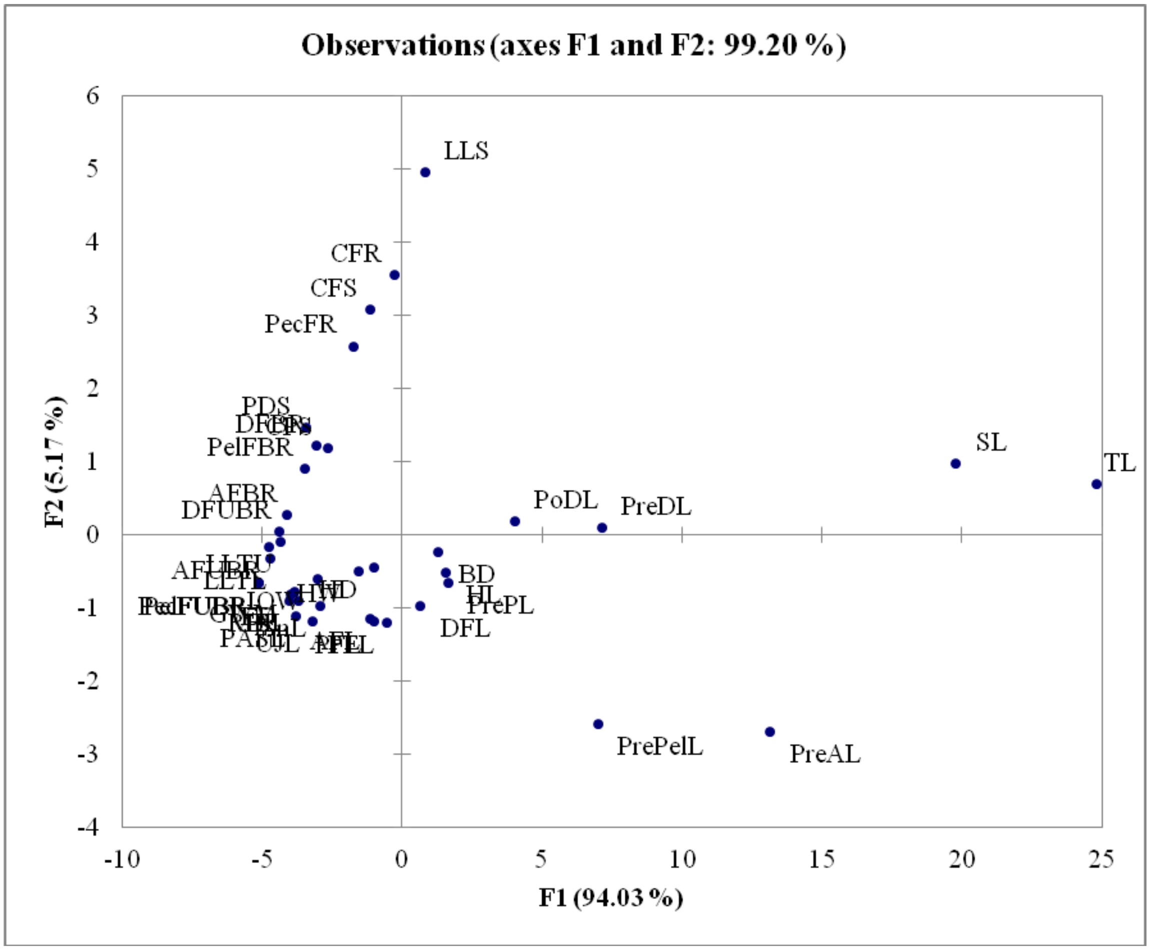

Figure 2.5. Scatter plot diagram resulting from the principal component analysis

The taxonomy of *T. malabaricus* is extremely confusing because of the morphological variation they exhibit. In 1848 Jerdon described this species and Day reported this species from Courtallam (Tamil Nadu) and the generic name of the species was added to *Tor* Gray by Smith (1945).The species was considered as a synonym of *T. khudree* by Hora (1943) and Menon (1992). Mac Donald (1944), Silas (1949), Kulkarni (1978), Indra (1993) and Sen and Jayaram (1982) treated this species as a sub species of *Tor khudree* (*Tor khudree malabaricus*). The Conservation Management Assessment Plan workshop (Molur and Walker, 1998) separated *T. malabaricus* as a distinct species. Silas *et al.* (2005) confirmed the validity of *T. malabaricus* as a separate species using RAPD technique. According to

Arunachalam (IUCN, 2013) all the *T. khudree* recorded from Kerala, Karnataka and Tamil Nadu are *T. malabaricus*, except for three populations in Chalakudy, Cauvery and Krishna basins.

According to Menon (1992) the humpbacked *Tor* from peninsula so far named as *T. mussullah* is not *T. mussullah* and it is considered the same as *T. khudree* and referred this species to under the genus *Hypselobarbus*. Comparative cytogenetic studies of *T. khudree* and *T. mussullah* using conventional staining and NOR banding differentiated these two species (Kushwaha *et al.,* 2001). The present study separated three groups of *Tor* and also indicated the existence of three species of *Tor*- *T. khudree, T. mussullah* and *T. malabaricus* in Southern Western Ghats.

2.6 CONCLUSION

Tor species from Southern Western Ghats have a confusing taxonomy and exhibit a clear morphological variation. Both *Tor khudree* and *Tor malabaricus* were showed an intraspecific variation based on the geographical location. The samples from geographically proximal or neighboring localities are more similar genetically than samples from more geographically distant localities. The multivariate analysis of the morphometric characters has proved the existence of three different groups of *Tor* species in Southern Western Ghats. Further studies have to be performed to define the exact identity of each species and their inter-relationship.