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Issues on the inclusion of *Puntius denisonii* (Day), a freshwater ornamental fish of global value, as Schedule-I species under the Wild Life (Protection) Amendment Act, 2021 of India

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Puntius denisonii is popularly known as Miss Kerala in India or Denison barb or Red line torpedo barb in the global ornamental fish trade. The species is endemic to fast-flowing rivers and streams of the Western Ghats of India. The species was not very popular earlier in aquatic trade but has been in great demand in global aquarium trade since it was exhibited at AQARAMA 1997 in Singapore and ranked third under the new species category. The export of the species from India started in 1996–1997, which increased progressively and constituted about 60%–65% of a total of 1.44 million US\$ worth of ornamental fish exported from India in 2007–2008. Thereafter, it started declining and presently became negligible. It was attributed to depleting stocks of *P. denisonii* in rivers and streams of Western Ghats. The species was recommended to be listed as endangered on the IUCN red list in a CAMP workshop held at NBFGR, Lucknow, India in September 1997, owing to habitat degradation and the declining number of mature individuals in the wild. It was categorized as Vulnerable in 2009 and Endangered in 2015 under the IUCN red list. The Department of Fisheries, Government of Kerala has restricted the collection of smaller size fish from natural water bodies since 2008 to revive wild stocks. The Ministry of Environment, Forest and Climate Change, Government of India has now proposed to include *P. denisonii* along with two other freshwater fish species, *Semiplotus semiplotus* (Assamese kingfish) and *Osteobrama belangeri* (Manipur osteobrama), as Schedule-I species under the Wild Life (Protection) Amendment Act, 2021 of India. The species listed under this Schedule are prohibited to be hunted throughout the country. The captive breeding technology of *P. denisonii* has already been developed in the country more than a decade back, and fish is being produced commercially at several farms presently including hatcheries of the Kerala Government. The species is also being cultured and produced on a commercial scale by many ornamental fish farmers of Indonesia and supplied to the global ornamental fish trade at cheaper rates, and more color strains. The major factors that are responsible

for the depletion of the stocks of *P. denisonii* and the overall fish biodiversity of Western Ghat regions are discussed in detail. The conflicts and repercussions that will arise because of the inclusion of Denison Barb or any other freshwater fish as Schedule-I species under the Wild Life (Protection) Amendment Act, 2021 of India are also discussed.

KEYWORDS

Puntius denisoni, *Sahyadria denisonii*, Denison barb, redline torpedo barb, Western Ghats, fish biodiversity, monsoon flood plains fishery, Freshwater aquatic biodiversity reserves

Introduction

A senior contributing editor of *AMAZONAS* magazine, Red Talbot, published an article on the 28 June 2013 issue of the magazine titled “India’s underground fish trade” (Talbot, 2013). The article begins with a statement that activists have been advocating a complete ban on marine aquarium fish collection, and regularly attack the marine aquarium trade, but the same level of debate does not occur among freshwater aquarists. The writing of Red Talbot was based on the article “Uncovering an obscure trade: Threatened freshwater fishes, and aquarium pet markets” published in the journal *Biological Conservation* (Vol. 164, Year 2013), authored and lead by Rajeev Raghavan, a fisheries science researcher and conservation biologist from India. Both these articles emphasized that India’s freshwater aquarium trade is having a detrimental impact on endangered, highly endemic fishes frequently harvested, and exported for aquarium usage. The species in question was *Puntius denisonii* (Day, 1865) a freshwater ornamental fish, endemic to the Western Ghats (WGs) of India. The article of Red Talbot not only initiated a debate among freshwater aquarists as he desired, but also, after 8 years, resulted in the listing of *P. denisonii* as Schedule-I species under the Wild Life (Protection) Amendment Act, 2021 proposed for implementation by the Ministry of Environment, Forest, and Climate Change (MOEF & CC), Government of India (GOI), vide Bill number 159. The Bill (Bill No. 159, 2021) seeks to increase the species protected under the law, and implement the Convention on International Trade in Endangered Species (CITES) of wild fauna and flora. CITES is an international agreement between governments of member countries to ensure that international trade in specimens of wild animals and plants does not threaten the survival of the species. Any fauna once listed under Schedule-I is prohibited to be hunted throughout the country except under threat to human life or in case of a disease that is beyond recovery, and a person is liable to the harshest penalties for violation of the law. The action of MOEF & CC has raised many questions that need to be answered and analyzed.

- i. Did it require such a stringent measure on the part of MOEF & CC, GOI to conserve wild stock of *P. denisonii*?
- ii. Why was only *P. denisonii* included as Schedule-I species, and no other native freshwater ornamental fish species exported from India that are categorized threatened and included in the IUCN red list?
- iii. Is it the aquarium trade that is responsible for the depletion of wild stock of *P. denisonii*, and many other endemic freshwater ornamental fish species of WGs?
- iv. If it was not the aquarium trade, then what were the factors for the depletion of wild stocks of *P. denisonii*, and other endemic fish species?

There is a need to review, if it is justified or unjustified. However, it will require the readers to know the physiography of WGs of India, and its fish biodiversity, as well as the importance of *P. denisonii*, and other endemic species in the domestic and global aquarium trade. The major contributing factors that are causing the depletion of fish biodiversity in the WGs are also elaborated and discussed.

Western Ghats: World heritage site

The WGs of India is a UNESCO world heritage site. The WGs cover an area of about 129,037 km² stretching to a length of 1,490 km along the western coast of India from Tapi Valley in the north (about 21°16' N) to Kanyakumari in the south (8°19' N), traversing through six coastal states of the country, viz., Gujarat, Maharashtra, Goa, Kerala, Karnataka, and Tamil Nadu (Gadgil, 2011). The WGs along with its geographical extension in the wet zone of Sri Lanka is known as one of the eighth “hottest hot spots” of biodiversity in the world (Myers et al., 2000), second only to the Eastern Himalaya, and one among the four biodiversity hotspots in India. The WGs covers about 5% of the total land of India, and harbors nearly 4,000 species of flowering plants, which are about

27% of the country's total plant species, about 645 species of evergreen trees including 56% endemic to the Ghats, and 850–1,000 species of the bryophytes including 682 species of mosses with 28% endemism. A total of about 350 (20% endemic) species of ants, 330 (11% endemic) species of butterflies, 174 (40% endemic) species of donates (dragonflies and damselflies), and 269 (76% endemic) species of molluscs (land snails) have been described from this region. The range is home to 120 species of mammals, 225 species of reptiles, 220 (78% endemic) species of amphibians, and 508 species of birds, which include many endemic to WGs. This diversity has been in continuous decline over the last century and more especially in recent decades, with many biological communities and types being almost eliminated due to the ever-increasing human activities and climate change (Gadgil, 2011). A large number of streams that originate from the WGs flow eastward and drain to the east coast in the Bay of Bengal through the Godavari, Cauveri, Krishna, Thamiraparani, and Tungabhadra rivers but a few streams/ivers, viz., Periyar, Bharathappuzha, Pamba, Netravati, Sharavathi, Kali, Mandovi, and Zuari, flow westwards and drain to the west coast in the Arabian Sea. All the west-flowing rivers are fast-moving due to a steeper gradient compared to east-flowing rivers (Gadgil, 2011).

Fish diversity of Western Ghats

The southern and central division of WGs, which includes rivers and streams of Kerala, has been identified as one of the few sites in the world showing exceptional biodiversity and a high degree of endemism with respect to freshwater fishes (Kottelat and Whitten, 1996). Shaji et al. (2000) have comprehensively documented the freshwater fish diversity of WGs and listed 287 fishes, of which 192 (67%) were endemic and 18 were exotic. The list included 106 fish species that were of ornamental importance. Dahanukar et al. (2004) reported the presence of a total of 288 species of fish belonging to 12 orders, 41 families, and 109 genera, of which 118 species were endemic and 51 were unique to WGs. The status of 105 of 288 species was not known due to data deficiency, but among the remaining 183 species, 58 species were categorized as Lower Risk (LR), 41 as Vulnerable (VU), 54 as Endangered (EN), and 24 as Critically Endangered (CR), while the remaining 6 species were exotic. It suggests that at least 41% of fish fauna is threatened by being either VU, EN, or CR. The most species-rich families were the Cyprinids (72 species), hill stream loaches (34 species; including stone loaches, now regarded as a separate family), Bagrid catfishes (19 species), and Sisorid catfishes (12 species).

The number of species was reported to be 290 by Dahanukar et al. (2011) with the addition of two new species, i.e., *Mystus seengtee* and *Channa diplogramma*. It included 189 endemic species with 12 species as CR, 54 as EN, and 31 as VU. The number of species was reported to increase to 320 in a new study by Dahanukar and Raghavan (2013) belonging to 11 orders, 35 families, and 112 genera including some secondary freshwater species that can also

live in brackish water and marine habitats. The list includes 212 endemic species, of which 47% were categorized as threatened or nearly threatened category. Thereafter, a few more new species have been reported from WGs in the recent past that includes *Pethia longicauda* (Katwate et al., 2014), *Pethia sanjaymooluri* (Katwate et al., 2016), *Channa pseudomarulius* (Britz et al., 2017), *Aenigmachanna gollum* (Britz et al., 2019a), *Channa rara* (Britz et al., 2019b), and *Waikhomia hira* (Katwate et al., 2020). Many of the endemic species of WGs are popular in the global aquarium trade. It mainly includes melon barb, several species of *Dawkinsia* barbs, zebra loach, *Horabagrus* catfish, dwarf pufferfish, and dwarf Malabar pufferfish, and most importantly *P. denisonii* presently known as *Sahyadria denisonii* (Raghavan et al., 2013a). There is a higher fish richness in the southern part of the WGs than in the northern and the highest in the Chalakudy River alone with 98 species (Raghavan et al., 2008). The other rivers with high species numbers include the Periyar, Bharatapuzha, Pamba, and Chaliyar, as well as upstream tributaries of the Kaveri, Pambar, Bhavani, and Krishna rivers (Shaji et al., 2000; Shaji and Easa, 2001; Kurup and Radhakrishnan, 2006a, and Kurup and Radhakrishnan, 2006b; Arunkumar and Manimekelan, 2018). Mercy and Malika (2010) reported that out of the 300 odd species of freshwater fishes of the WGs, 155 species have ornamental value.

Red Line Torpedo Barb: *Puntius denisonii*

The *P. denisonii* (Day, 1865) named after Sir William Denison, popularly known as Red line torpedo barb (RLTB), is a very popular freshwater ornamental fish in the global aquarium trade. It is called so owing to its torpedo-shaped body, and a deep red-colored line running from the tip of the mouth to the middle of the body. It belongs to the order *Cyprinidae* and the family *Barbinae*. RLTBs are represented by two distinct species, *denisonii* and *chalakkudiensis* (Pethiyagoda et al., 2012), which are quite different from other similar barbs, and are now placed under a different genus *Sahyadria* based on osteology and molecular characteristics (Raghavan et al., 2013a). However, in the present communication, it has been referred to as *P. denisonii* only because of its popularity.

The *P. denisonii* inhabits fast-flowing rivers and streams of WGs. It is a benthopelagic species that is gregarious, and shoals are known to occur in rocky pools with thick overhanging vegetation along the banks (Radhakrishnan and Kurup, 2005). They thrive in a sub-tropical climate in water with a pH of 6.8–7.8, a water hardness of 5–25 dGH, and a temperature of 65 to 79°F (18 to 26°C). Denison's barb is an omnivore and feeds on insects, worms, small crustaceans, organic debris, formulated flakes, pellets, and other processed feeds. The average size of the fish is 9–11 cm (3.5–4.3 inches) with a maximum length of 15 cm, and an age range of 5–8 years. A young fish attains sexual maturity at 12 months of age and a total length of 7.8 ± 2.2 cm (Mercy et al., 2015). The breeding technology of the fish has been

developed in the country (Mercy et al., 2013 and Mercy et al., 2015) and presently about 1.00 lakh fish are being produced annually at the fish farm of the Department of Fisheries, Kerala and two to three private ornamental fish farms (personal communication of the second author with hatchery owners).

Distribution of *P. denisonii* in WGs rivers

P. denisonii is endemic to the fast-flowing hill streams and rivers of the southern region of WGs specifically in the state of Kerala, and sparsely in Karnataka as a fragmented population (Biju et al., 2000; Shaji and Easa, 2001; Mercy et al., 2002; Kurup and Radhakrishnan, 2006b; Prasad et al., 2008, and Raghavan et al., 2010). Talwar and Jhingran (1991) reported the presence of *P. denisonii* in the rivers of Alaram (a tributary of Vallapatnam), Chalakudy, Chaliyar, Kallada, and Kallar (Table 1). It was later reported in Chandragiri, Periyar, Vallapatnam (Biju et al., 2000), Pampa (Shaji and Easa, 2001), Achenovil (Shaji and Easa, 2001), Bharatapuzha (Mercy et al., 2002), Manimala (Thomas, 2010), Karingode (Kurup and Radhakrishna, 2006b), and Anjarkandy (Mercy and Malika, 2010).

The presence of *P. denisonii* has been reported in 15 out of the 44 rivers flowing through the state of Kerala, and originating in WGs (Table 2). The Kallar River is not counted separately as it is a

tributary of the Pampa or Pamba River. All these rivers are west-flowing except for the Bhavani River that originates in the Nilgiri hills of Tamil Nādu. Thampy et al. (2021) have reported the presence of *P. denisonii* in the Wayanad part of the Kabini river. It is the first incidence of the presence of this fish in any east-flowing river. The rivers of WGs are small in terms of length and width, with low water discharge, and are entirely monsoon fed, which either completely dry out during summer or shrink into a small rivulet. These rivers are more prone to environmental effects as they are small and also lack a delta (Latha and Vasudevan, 2016). A fast flow owing to hilly terrain, high elevation, meandering curves, and large riparian zones are important characteristics of all these rivers. All of these rivers originate 1,000 m above sea level except for Achenovil, Anjarkandy, and Manimala. A few of these rivers, viz., Bharthapuzha, Chaliyar, Pampa, Periyar, and Vallapatnam, are fed by several tributaries, while others have either one or none. Several dams have been constructed on a few of these rivers for irrigation, electricity generation, or drinking water purposes.

Export of ornamental fishes from India and the importance of *P. denisonii* in the global aquarium trade

The export of freshwater ornamental fish from India is reported to begin in the year 1969, and the first consignment

TABLE 1 The rivers of the Western Ghats, India, with the presence of *P. denisonii*.

S. No.	Name of River	Distribution Range						References
		1991 ¹	2008 ²	2009 ³	2010 ⁴	2015 ⁵	2015 ⁶	
1.	Acheneovil		x	x	–	x	x	Shaji and Easa, 2001; Kurup et al., 2004
2.	Anjarkandy		–	–	x	x	x	Mercy and Malika, 2010
3.	Bhavani		–	–	x	x	x	Mercy and Malika, 2010
4.	Bharthapuzha		x	x	x	x	x	Kurup and Radhakrishnan, 2006b
5.	Chalakudy	x	x	x	x	x	x	Shaji et al., 2000; Kurup et al., 2004
6.	Chaliyar	x	x	x	–	x	x	Shaji et al., 2000; Shaji and Easa, 2001
7.	Chandragiri		x	x	x	x	x	Biju et al., 2000; Kurup and Radhakrishnan, 2006b
8.	Kallada	x	–	–	–	–	–	–
9.	Kallar*	x	x	x	–	x	–	Shaji et al., 2000
10.	Karingode		–	–	x	x	x	Kurup and Radhakrishnan, 2006b
11.	Kuppam		–	–	x	x	x	Mercy and Malika, 2010
12.	Kuttiyadi		–	–	x	x	x	Kurup et al., 2004; Mercy and Malika, 2010
13.	Manimala						x	Thomas, 2010
14.	Pampa		x	x	x	x	x	Shaji and Easa, 2001; Thomas, 2010
15.	Periyar		x	x	–	x	x	Biju et al., 2000; Thomas, 2010
16.	Vallapatnam		x	x	x	x	x	Biju et al., 2000; Mercy and Malika, 2010
Total		4	9	9	10	14	15	

¹Talwar and Jhingran, 1991; ²Kurup and Radhakrishnan, 2008; ³Raghavan et al., 2009; ⁴Mercy and Malika, 2010; ⁵Mercy et al., 2015; ⁶Suhair and Kumar, 2015. *A tributary of Pampa River.

TABLE 2 Physiographic characteristics of the Western Ghats Rivers known for the presence of *P. denisonii* during the period 1991 to 2022.

S. No.	Name of River*	Origin	Elevation (m)	Total Length (km)	Navigational Length (km)	Flow Direction	Mouth	Number of Dams on the River
1.	Acheneovil (1)	Devermala ^A	700	128.0	32.0	West	Pampa River	Nil
2.	Anjarakandy (0)	Kannoth ^A	600	48.0	27.2	West	Arabian Sea	Nil
3.	Bhavani (0)	NilgiriHills ^B	>2,000	215.0	–	East	Cauvery	2
4.	Bharthapuzha (5)	Annamalai Hills ^A	1,964	209.0	40.0	West	Lakshadweep	12
5.	Chalakudy (1)	Annamalai Hills ^B	1,250	145.5	16.0	West	Arabian sea	13
6.	Chaliyar (8)	Ilambalaari ^A	2,066	169.0	68.4	West	Lakshadweep	9
7.	Chandragiri (1)	Chettiamachal ^A	1,350	105.0	12.8	West	Arabian Sea	Nil
8.	Kallada (0)	AmbanadHills ^A	1,524	121.0	40.0	West	Arabian Sea	1
9.	Kallar#	Chemunjimotta ^A	1,860	–	–	West	Pampa River	–
10.	Kariangode (1)	Coorg Hills ^C	1,520	64.0	24.0	West	Arabian Sea	1
11.	Kuppam (1)	Padinkad ^A	1,630	82.0	24.0	West	Lakshadweep	Nil
12.	Kuttiyadi (0)	Narikiotta ^A	1,320	74.0	9.6	West	Arabian Sea	1

*Number of tributaries in parathesis, #Tributary of Pampa River; A Kerala, BTamil Nadu, CKarnatakaSource:https://puzhakal0.tripod.com/river.html (Accessed on 27.04.2022)

was valued at Rs. 16.40 lakhs only (Sekharan and Ramachandran, 2006). However, the contribution of India to the global export of ornamental fishes remains very low (Figure 1). It was only 1.558 million US\$, i.e., Rs. 10.884 crores (MPEDA), out of the global export of 322 million US\$, i.e., 0.48% of the total world export during 2019–2020 (Trend Economy, 2020).

India is known in the global aquarium trade for the wild-caught indigenous fishes mainly from rivers, streams of northeast states, and WGs, which constitute about 85%–90% of total ornamental fish export (Silas et al., 2011; Jayalal and Ramachandran, 2013). It initially included several species of *Channa*, *Botia*, *Puntius*, *Barilius*, *Garra*, *Glyptothorax*, *Horabagrus*, *Schistura*, etc. (Silas et al., 2011). *P. denisonii* was not known in the international market before it was first

collected and exported to Germany in 1996 (Raghavan et al., 2007). Subsequently, it was exhibited at “AQUARAMA 1997 Singapore”, an international exhibition on ornamental fishes, under the “New Species Category”, and won the third prize (Anon, 2006). Thereafter, it soon became a popular aquarium fish among international aquarium hobbyists owing to its vibrant red color marking along the lateral line in the anterior half and its torpedo-shaped body. It constituted about 60%–65% of the total live ornamental fish exported from India during 2007–2008, which was valued at 1.44 million US\$ (Mittal, 2009). About 1.5 lakh individual fishes were exported by the Kerala Aquatic Ventures Private Limited in 2010–2011 (Raghavan et al., 2012) while over 3.00 lakh RLTBs were reported to be exported from India during the period 2005–2012 to seven countries (Raghavan et al., 2013b). These numbers could be much higher

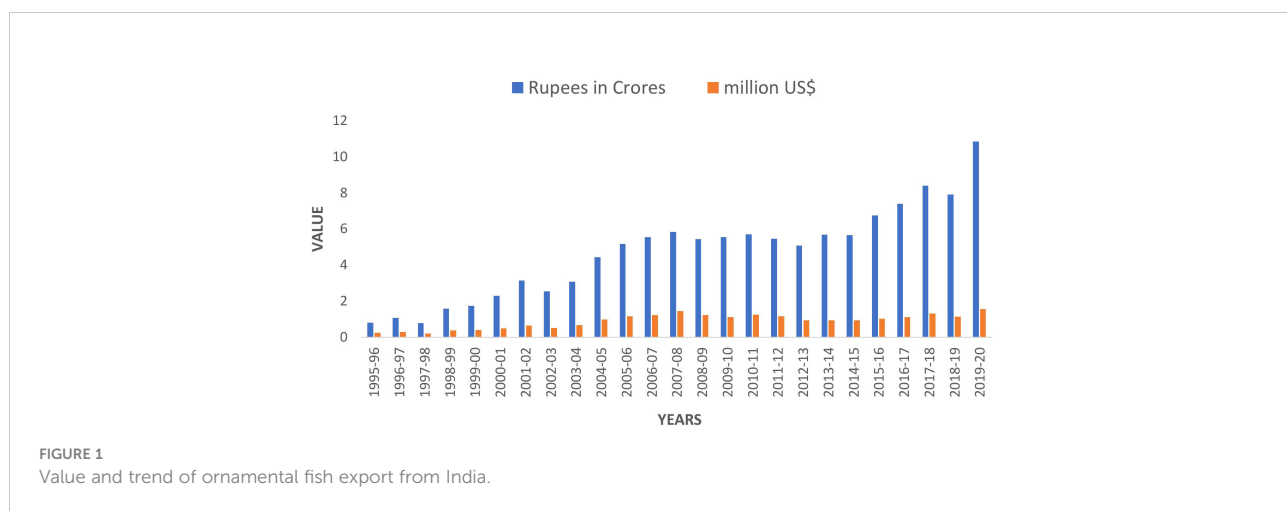


FIGURE 1 Value and trend of ornamental fish export from India.

as other fish that were exported under the generic label “Live ornamental fish” possibly included RLTBs (Raghavan et al., 2013b). It was also estimated that about 5,000 *P. denisonii* were being collected and exported from Kerala on a weekly basis, which may include 1000–1750 females (Raghavan et al., 2012).

The total value of ornamental fish exported from India started to decline from 2007–2008 onwards (Figure 1), and the same trend continued up to 2014–2015 (0.933 million US\$; Rs. 5.66 crores). It was possibly because the share of *P. denisonii* reduced from export consignments of India as the Kerala fisheries department imposed a restriction on its collection from the wild during 2008. It was the same period when captive-bred *P. denisonii* from other countries was available for the global aquarium trade (Mittal, 2009). The export value started to increase from 2014–2015 onwards, and achieved the highest value in 2019–2020 (1.55 million US\$; Rs. 10.84 crores), and expected to be more than double during 2021–2022, and further higher during 2022–2023 (personal communication of the first author with some exporters). It is because of the increasing demand for pond-reared Koi carps and livebearers from India in United Arab Emirates. The major share of native species from India is presently composed of *Botia lohachata* (Botia loach), *Botia striata* (Zebra loach), *Waikhomia sahyadriensis* (Maharaja barb), *Channa aurantimaculata* (Spotted snakehead), *Channa barca* (Barca snakehead), *Channa bleheri* (Rainbow snakehead), *Etroplus canarensis* (Canara pearl spot), *Tor putitora* (Golden Mahaser), *Hemibagarus kudremukhensis* (Nilgiri mystus), and a few more.

Inclusion of *P. denisonii* in the IUCN red list

The workshop on “Conservation Assessment and Management Plan (CAMP)” held at the National Bureau of Fish Genetics Resources (NBFGGR), Lucknow, India in September 1997 recommended the inclusion of *P. denisonii* under the endangered category. A total of 329 freshwater fish species from Indian waters were assessed in the workshop, of which 47 were categorized as critically endangered, and 98 as endangered. The RLTB, *P. denisonii*, was one of the endangered categories (Molur and Walker, 1998). It was recorded to be present only at four locations in the WGs section of Kerala, viz., Cheenkannipuzha, Mundayapuzha (Mundayapuzha river), Achankovil, and Chaliyar, with a distribution range of <5,000 km². Both Cheenkannipuzha and Mundayapuzha are tributaries of the river Vallapatnam, i.e., one of the 41 west-flowing rivers of WGs in Kerala. The other parameters that supported the categorization of *P. denisonii* as endangered were loss of habitat due to poisoning, pollution, and local trade as well as unavailability of captive breeding technology. The fish was

categorized as VU in 2009 and EN in 2015 under the IUCN red list (Ali et al., 2015).

Is aquarium trade responsible for the depletion of *P. denisonii* wild stock?

The aquarium trade has been held responsible for the depletion of wild stock of *P. denisonii* or many more indigenous fishes of the northeast and WGs of India (Dahanukar et al., 2004; Kurup et al., 2004; Sekharan and Ramachandran, 2006; Raghavan et al., 2007; Daniels, 2011; Dahanukar and Raghavan, 2013; Jayalal and Ramachandran, 2013; Raghavan et al., 2013b), which have been included in the IUCN red list. These indigenous fishes were not in much demand in the domestic aquarium trade until very recently, but the demand increased with the growing interest among hobbyists for planted and biotope aquarium setups. Presently, few species of the barbs, viz., *Puntius filamentosus*, *P. denisonii*, and *P. ticto*, and a few hill stream loaches, i.e., *B. striata* (Zebra loach), *Botia dario* (Bengal loach), etc., are in demand in the domestic aquarium trade but the numbers are very few (personal observation of the first author). The native fish are mainly collected for export purposes only. Are these collected in such a large number that it will lead to their stock depletion or habitat destruction and will eventually become endangered or critically endangered? The answer is “NO”. The number of fish that are collected and exported (Raghavan et al., 2012 and Raghavan et al., 2013b) is insignificant to the number and quantity of fish harvested for food purposes (Mohite and Samant, 2013; Shaji and Laladhas, 2013). The natural stocks of many of the fish species, including both edible and ornamental, have depleted due to various reasons that remain undescribed while blaming the aquarium trade. The major contributing factors are as follows:

Distribution and stock assessment

The information on the distribution of *P. denisonii* and its population in rivers and streams of WGs is possibly incomplete even at present. The fish was introduced to the global aquarium trade in 1997 (Anon, 2006) while it was reported to be endangered in the CAMP workshop held at NBFGGR Lucknow (India) during September 1997 (Molur and Walker, 1998). It was known to be present only in three rivers, i.e., Achankovil, Chaliyar, and Vallapatnam (Cheenkannipuzha, and Mundayapuzha) at that time. It was only after the year 2000 that the presence of the fish was reported in other rivers of the WGs, which increased to a total of 15 rivers in 2015 (Table 2). It is evident that the presence of fish in more rivers of WGs was

known only after it was introduced to the export trade. However, it was also possible that the stock of the fish has already depleted in those rivers also before its presence was reported. The increasing export demand would have definitely resulted in an increased collection of “Live Fish” from these rivers. However, it should also be noted that presently there is not much demand for wild-collected *P. denisonii* from India in the global aquarium trade as fish breeders in other countries are breeding the fish in captivity (Mittal, 2009) with more varieties of new strains that have a higher demand in the global trade. There is a need for studies to find out if the reduced collection of “Live fish” has resulted in the revival of stocks in rivers of WGs.

There are only a few studies on the stock assessment of *P. denisonii* in the rivers of WGs (Kurup and Harikrishnan, 2008; Raghavan et al., 2008; Mercy and Malika, 2010; Dahanukar et al., 2011). Kurup and Harikrishnan (2008) studied the population characteristics and stock assessment of *P. denisonii* from different locations of Kanjirpuzha River, which is a major tributary of the Bharathapuzha River on a bi-monthly basis during the period 2001–2003. The growth parameters, total mortality, natural mortality, and MSY were calculated based on the catch data. The potential yield, current annual yield, and MSY of *P. denisonii* were estimated to be 1.52, 1.036, and 0.94 tons, respectively. It was concluded that the population of *P. denisonii* is not under threat from overfishing, and the Kanjirampuzha River supports a sustainable population.

Mercy and Malika (2010) conducted a survey of 11 rivers of WGs, viz., Chandragiri, Kariangode, Kuppam, Valapattanam, Anjarkandipuzha, Kuttiyadi, Chaliyar, Chalakudy, Bharathapuzha, Bhavani, and Pamba, for the period 2003–2007. It was concluded that *P. denisonii* was not endangered, and the stocks were not depleted in nature except in the Chalakudy River, though the collection of the fish has increased considerably from earlier studies. In a further study from October 2008 to December 2009, the total biomass was estimated to be only 33% of the virgin stock in the Valapattanam and Karingode rivers. The reasons for stock depletion were stated to be habitat degradation due to unethical practices of fishing like the use of dynamites, copper sulfate, and other poisons that are employed for harvesting food fishes but it ultimately affects non-target groups like ornamental fishes.

Obstruction to the rhythmic flow of rivers

The natural flow of streams and rivers is essential in determining the biodiversity richness of riverine flora and fauna. A number of species and their life cycle are known to have evolved following the rhythmic flow of the rivers (Dynesius and Nilsson, 1994). The natural and rhythmic flow of many rivers around the world has been obstructed due to the construction of a large number of multipurpose dams (Dudgeon, 2000; Pringle

et al., 2000; Nilsson et al., 2005) including those of WGs. The construction of dams converts a river into chains of reservoirs with no flow in between the reservoirs. The Periyar river in between Parambikulam, Sholayar, Mullaperiyar, and Idukki dams does not flow for long before it is joined by the next tributary or recharged from the catchment area (Latha and Vasudevan, 2016). Studies indicate that the flow diversion, alteration, and reduction due to dams have a significant impact on the riverine ecosystem, its microhabitats, and flora and fauna in several ways (Bartens et al., 2008). There are 80 dams in the rivers of Kerala along the length of WGs, of which 43 are large dams. The WG dams and Small Hydro Projects (SHP) account for about 80% of India’s hydropower generation (Jumani et al., 2018). These dams and SHPs have significantly altered the physiochemical characteristics, blocked sedimentation and nutrient transport, obstructed fish migration, and encouraged invasions of alien fish species by disrupting the longitudinal, lateral, and vertical connectivity of rivers (Dudgeon, 2000; Rosenberg et al., 2000).

The fishery of *Tenualosa ilisha*, an anadromous Indian shad, collapsed in the river Cauvery above the Mettur Dam, Tamil Nadu as the fish from Cauvery-Coleroon system could not ascend the river Cauvery for breeding. The construction of three lower barrages, i.e., the Upper Anicut, the Grand Anicut, and the Lower Anicut, partly restricted the upstream migration of *T. ilisha*, but it was reported to have completely disappeared from the upstream stretches after the commissioning of Mettur Dam (Sugunan, 1995).

The fish community responses to streamflow alterations and habitat modification by small SHPs in Netravati River of WGs were studied by Jumani et al. (2018). The fish assemblages were surveyed in two dammed tributaries and one undammed tributary of the river at different locations including upstream and downstream. It was found that the undammed river had high species richness, diversity, and endemism compared to the two dammed rivers. The percentage of adults and juveniles of rheophilic species (*Tor khudree*) was higher in the undammed river while dammed rivers were dominated by eurytopic species *Devario malabaricus*. The rivers of south India are known for the presence of rheophilic species (Sudasinghe et al., 2021).

Loss of riparian zone and vegetation

The riparian zone is the transition zone between the terrestrial and aquatic habitat, and the vegetation in this zone is known as riparian vegetation. The vegetation in the riparian zone is highly influenced by the quantum and flow of water in the river channel. The altitude, climatic conditions, and soil characteristics determine the nature of plant communities (Nair, 1994) while the physical and the geomorphological features of the watershed are also influenced by riparian vegetation, which characterizes the riparian forest dynamics (Naiman et al., 1998).

A reduced or increased flow of river may severely influence the abundance, and reduction in the population rate of the specific species in the riparian vegetation (Tabacchi et al., 1996; Braatne et al., 2008). The riparian canopy regulates water temperature in the streams/ rivers by shadowing them, which, in turn, plays an important role in the distribution of fish communities (Marsh-Matthews and Matthews, 2000). It also controls stream sediments, and nutrient dynamics by supplying organic matter via litter fall, while their root systems stabilize the bank and filter lateral sediment and nutrient inputs (Naiman and Decamps, 1997). The submerged leaves' surfaces are sites of primary and secondary production by microalgae, bacteria, and planktonic microorganisms (Dosskey et al., 2010). A mapping of a stretch of the Chalakudy River showed that 60 km of riparian vegetation has submerged due to the construction of six dams and dried up along 28.8-km stream/river banks due to the complete diversion of waters downstream to dams (Hyder, 2003; Hyder and Devika, 2020). It has resulted in the destruction of about 2.66 km² of riparian forests, which is equivalent to 80% of the presently remaining riparian vegetation in the Chalakudy River. Although no direct studies have been conducted on the effect of the loss of riparian vegetation on the depletion of *P. denisonii*, it could be one of the important factors of fish biodiversity depletion in WGs (Hyder, 2003; Mohite and Samant, 2013; Jumani et al., 2018).

Sand mining in WG rivers

The river beds are characterized by sediments, i.e., loose sand, clay, silt, and other soil particles that settle at the bottom. These sediment beds largely affect the water quality and biological productivity of a river or stream by controlling light penetration and influencing ecological functioning (Owens et al., 2005). These sediments are breeding and grazing ground for many freshwaters and estuarine fishes; therefore, any change in the quality and quantity of sediments influences fisheries both upstream and downstream (Brown et al., 1998; Harvey and Lisle, 1998; Paukert et al., 2008; Freedman et al., 2013; Mingist and Gebremedhin, 2016). The sand mining from rivers around the world including WGs rivers has resulted in irreversible losses (Koehnken and Rintoul 2018). It causes channel instability both up- and downstream, disrupting existing equilibrium and erosion of banks due to incision. Aquatic ecology including the presence of riparian vegetation is significantly dependent on the sand deposits in the river bed as sand deposits help maintain a high water table in rivers. The local fish populations were found to be affected in the Arno-Garno and Ribo rivers in Ethiopia due to sand mining that destroyed spawning grounds, interfered with migratory routes, and caused large-scale fish kills (Mingist and Gebremedhin, 2016). The replacement of riffles with pools and decreased flow velocity due to sand mining were found to replace lotic species with lentic and invasive species

(Brown et al., 1998; Harvey and Lisle, 1998; Paukert et al., 2008; Freedman et al., 2013).

Wyźga et al. (2009) studied the impact of sand mining and channelization on the fish communities of the Czarny Dunajec River in the Polish Carpathians. The diversity and abundance of fish species were significantly higher in multi-channelled unmanaged rivers without any sand mining practices than in single channels with incised cross-sections due to mining. Freedman et al. (2013) observed that the spawning of brood-hider and substratum chooser fish species was more adversely impacted than nest or open substratum spawners due to sand mining. Heavy siltation of streams due to deforestation and sand mining, which modify the stream beds, directly affects several endemic species as it degrades their breeding substrates (Dahanukar et al., 2011). Hill stream loaches of the families *Balitoridae*, *Cobitidae*, *Nemacheilidae*, and several species of cyprinids including the critically endangered *Neolissochilus wynaadensis* and *Tor remadevii* are particularly vulnerable to siltation.

Sand mining is a very common practice in almost all the rivers and streams of WGs despite restrictions by the government through the enactment of the Kerala River Bank Protection and Sand Removal Regulation Act 2001 (Hyder, 2003). The sand beds of the Bharatapuzha River are replaced by grasses and sedges due to the ever-increasing sand mining over the last three decades (Latha and Vasudevan, 2016). It was estimated that about 2.856×10^6 tons of sand is extracted from the Bharatapuzha river annually. It is almost 54.92 times more than the annual replenishment of 0.052×10^6 tons. The river bed is deepened by more than 20 ft in many places. The river bed remains exposed for most of the time during the year, and the river fails to flow full even during the monsoon. The sand deposits are reported to be completely lost from the Chalakudy River bed. About 0.92×10^6 tons of sand was extracted from the river annually, which is 76.66 times more than the annual replenishment of 0.012×10^6 tons. The river bed has been lowered by an average of 6–8 m in many places (Latha and Vasudevan, 2016). The river bed of the Pamba River has been lowered to about 1.23 m during 1985–2000 (8 cm/year). This is attributed to the heavy extent of sand mining upstream as well as downstream. About 0.84×10^6 tons of sand is annually extracted from the Pamba River bed, which is 30 times the annual replenishment rate of 0.028×10^6 tons (Latha and Vasudevan, 2016).

Pollution of Western Ghats rivers

The ever-increasing urbanization, industrialization, agricultural activities, etc. have been a cause of water pollution around the globe, and adversely affected fish diversity and production (Shelford, 1918; Jones, 1964; Bukola et al., 2015; Silva et al., 2016; Malik et al., 2020). The completely pristine

water of WGs rivers is also being constantly polluted by the discharge of several large industries built in the catchment area of the river banks. The discharge from the Gwalior rayons factory by Grasim industries in Mavoor located in the Chaliyar catchment was reported to result in heavy fish mortality and dislocation of Nereid worms in the Chaliyar River flowing between Elamaram and Pallikkadavu near Calicut in a study during 1979 by the Central Marine Fisheries Research Institute (Latha and Vasudevan, 2016). Industrial pollution was observed to pose a serious threat to the riverine ecosystem in the lower reaches of Periyar about 15 km upstream from the backwaters of Cochin. About 250 small and big industries engaged in the production of fertilizers and pesticides, petroleum refining, heavy metal processing, radioactive mineral processing, rubber processing, tallow extraction, battery manufacturing, mercury production, acid manufacturing, and pigment and latex production are concentrated between Angamaly and Cochin along the river bank. The industries of the Edayar-Eloor area consume about 190,000 m³ of water per day and discharge 75% of the same wastewater along with a variety of pollutants. Greenpeace India describes the lower Periyar as a “Global Toxic Hotspot”, with alarming levels of hazardous chemicals such as ammonia, DDT, trivalent chromium, cyanide, endosulfan, and BHC (Latha and Vasudevan, 2016).

Land-use changes

The land uses have changed many folds in the catchment area of WGs rivers due to the ever-increasing population, urbanization, industrialization, and livelihood earning activities. There has been an upsurge in construction in the lower catchment region of the Pamba River owing to sand mining and a large-scale livelihood shift from agriculture. As a result, the Vembanad backwaters that receive drainage from the Pamba River have shrunk by almost 12,000 ha, and biodiversity is depleted. The Varaalchal wetland in Koyipram Panchayat of Pathanamthitta district of Kerala, once a rich fish resource, and an extensive paddy cultivable wetland of about 500 acres, has become a mere stagnant area of weeds and sewage due to various commercial exploitation activities (Latha and Vasudevan, 2016). The Aranmula wetlands where paddy was grown traditionally has become waterlogged due to a check dam across the Valiyathodu stream, which was a natural flood escape route between the Pamba and Aranmula wetlands. The paddy cultivation had reduced by 50% in the year 2000. A large part of the forest area in the Periyar River basin has been cleared for various developmental activities. Land use and land cover study of the Bharathapuzha River basin conducted using imageries from 1973 to 2005 revealed that there was 31% depletion in the natural vegetation cover and 8.7% depletion in wetland

agriculture area. The urban spread in the basin had increased by 32% (Latha and Vasudevan, 2016).

A large area in Vazhachal Forest Division (Chalakydy) has been converted into forest plantations for timber as part of the forest department policy. The Plantation Corporation of Kerala has converted large tracts of the riparian forest into oil palm and rubber plantations. Deforestation in the upper catchments had an impact on river flow that causes many of the streams to dry up in the summer months. Good riparian vegetation has become rare in the lower zones of Chalakydy due to high disturbance caused by anthropogenic activities.

The paddy fields during flooding are highly suitable grounds for the breeding of many species of fish (Shaji and Laladhas, 2013). The total extent of paddy fields in the Kerala state was 880,000 ha in 1970–1971, and rice accounted for the highest share (32%) of the total cropped area in the state (Athira and Kumar, 2016). It reduced to 560,000 ha in 1990–1991 and 230,000 in 2007–2008 (Thomas, 2011). The total area of paddy fields in the state was only 202,907 in 2018–2019. The loss of forest in the WGs has been so rapid that out of the original 182,500 km² of primary vegetation, only 12,450 km², i.e., 6.8%, is available (Myers et al., 2000; Gunawardene et al., 2007). All these changes in land-use patterns have been responsible for habitat destruction and fish biodiversity depletion.

Invasion by alien fish species

A species could be alien to a new habitat if introduced not only from a distant geographical location but also from a different habitat in the same region. The invasion of alien species has been a major cause of depletion of endemic fish species all around the globe (Canonic et al., 2005; Burrill, 2014; Erarto and Getahun, 2020) including in India (Joshi et al., 2014; Joshi et al., 2021), which has reduced fish production as well as aquatic biodiversity. The rivers and reservoirs of WGs are no exception to this (Sugunan, 1995; Radhakrishnan et al., 2012; Biju Kumar et al., 2015; Thampy et al., 2021). The invasion of alien species has not only adversely affected minor or marginal fisheries but even major commercial fisheries. The catches of *Cirrhinus cirrhosa* were found to be severely declined in Bhavanisagar, Stanley, and other reservoirs of Tamil Nādu after the introduction of *C. mrigala*, another Indian Major Carp native to the Gangetic River systems of India (Sugunan, 1995). The Mozambique tilapia *Oreochromis mossambicus* has been the most successful among all the alien fishes. At least 24 reservoirs in Tamil Nadu have tilapia either as the major component of fish catch or represent a dominant fishery. It outnumbers other fishes by 90 to 10 in the Amaravathy reservoir. The Mahseers, once a dominating fishery composed of *Tor*, *T. putitora*, and *Acrossocheilus hexagonolepis*, have also become threatened in many reservoirs of Tamil Nadu (Sugunan, 1995).

Radhakrishnan et al. (2012) conducted an extensive survey covering 465 locations of 25 river systems in WGs from 2000 to 2004. A total of 32 alien species belonging to seven orders and 10 families, mainly *Cyprinidae* (14), *Poeciliidae* (4), and *Channidae* (3), were recorded. The freshwater garfish *Xenentodon cancella*, snakehead murrel *Channa striata*, and Mozambique tilapia *Oreochromis mossambicus* were found to dominate other species in many rivers and locations including pools, runs, riffles, and reservoirs. All the above-mentioned three species are omnivores and known to feed on eggs and young ones of other fish species.

Fish-eating habits of locals

Fish is an integral part of the diet of a Keralite family (Kerala being an 85% fish-eating population; Shyam et al., 2015; Shyam, 2020); one meal features fish every day (Gulati, 1984). The fish consumption in the state of Kerala is 19.41 kg/head, which is the second highest in the country after Tripura with 29.29 kg/head. The all-India average is 9.00 kg/head only (Anon, 2020). A recent study by Shyam (2020) revealed that the monthly mean consumption of fish in three districts of Kerala, i.e., Thiruvanthapuram, Kochi, and Kozhikode, was 9.26 kg per household, which included 6.00 kg of low-value fish. The total fishermen population in the state is 10.44 lakhs (Inland: 23%; Marine: 67%), which is 2.92% of the total population of the state. Fishing is the full-time activity of 152,708 fishermen in inland regions (Anon, 2020). The fishermen population per district in Kerala is 74,597, which was the fourth highest in the country behind Bihar (158,615), West Bengal (140,707), and Andhra Pradesh (115,129). Hence, fishing is a very common activity for rural people inhabiting near the river banks. The fishing activity for many of the locals in rivers of WGs was earlier limited to family consumption only but gradually it also became a source of livelihood, which increased pressure on the fishing (Mohite and Samant, 2013). The conservation of fish biodiversity or selective fishing is never the concern of these local fishing populations probably due to a lack of awareness. Eating dry fish is very popular in many regions of India. The largest dry fish market in Asia is situated at Jagiroad in the Marigaon district of Assam. Several tons of dry fish, both freshwater and marine, are sold here every day. The freshwater fishes that are dried mainly include small-size fishes.

Un-eco-friendly fishing practices

The gill net, cast net, and drag net are few of the common fishing methods in rivers and reservoirs of WGs that are widely used. Each method has its advantages and disadvantages, which are possibly known to all concerned, but few of the other fishing practices employed in rivers of WGs that are serious threats to

fish biodiversity as well as fish production are discussed here. It includes Monsoon Floodplain Fishery (MFF), electric fishing, and the use of dynamites.

The MFF or Oothapiduthamis, is the traditional practice of fishing at the onset of the southwest monsoon when freshwater fishes migrate to paddy fields from adjoining rivers and canals for egg-laying. These upward migrating brood fishes are collected by using diverse types of traditional fishing gears (Nathoodu, Adichil, Chaattom, Ottal, Koodu, Kuthuvalla, etc.) by fisherfolks and even non-conventional fishermen. Oothapidutham is celebrated as a festival throughout the state of Kerala. Shaji and Laladhas (2013) observed that a total of 1,159 kg of fish was harvested within 6 days from the 489-ha paddy wetland system of Kuzhur-Annmandu Panchayats in Thrissur districts of Kerala. The fishes that were caught included *Anabas testudineus*, *Anguilla bicolor*, *Channa striata*, *Amblypharyngodon melettinus*, *Horabagrus brachysoma*, *Xenentodon cancella*, *Wallago attu*, *Puntius parrah*, *P. mahecola*, *P. filamentosus*, *Babodes subnasutus*, *Ompok bimaculatus*, *Nandus*, and *Macroganthurus guentheri*. All the fishes except the species *Anguilla bicolor* were berried. A few of the important rivers in Thrissur district are Bharatapuzha, Chalakudy, and Chaliyar. The total area under paddy cultivation in the state was 202,907 ha during 2018–2019 as per the Department of Economics and Statistics, Government of Kerala.

The use of dynamites, which is also termed “Fish bombing”, has become a serious problem around the globe (Agnew et al., 2009; FAO & UNEP, 2010; Braulik et al., 2015) including India in both marine and freshwater fishing. It is a fishing practice of using explosives to stun or kill schools of fish for easy collection. It is both an illegal and unethical way of fish collection brought about by the increasing greed of fishermen. Fish bombing kills not only the target fish but also all other unwanted aquatic organisms within the surroundings and destroys the habitat (Saila et al., 1993; Guard and Masaiganah, 1997; McManus et al., 1997; Riegl and Luke, 1999). The use of dynamite fishing has been a common practice in rivers and reservoirs of WGs (Lalmohan and Rama Devi, 2000; Hyder, 2003; Thampy et al., 2021). Hyder (2003) reported counting 37 blasts of dynamite for fishing purposes during 3–4 h walk from Athirapally to Thumboormuzhi in 2001 while surveying riparian vegetation along the middle and lower zones of the Chalakudy River.

Climate change

Global warming and many human-induced activities result in climate change worldwide. India has also experienced a significant increase in temperature except for the Indo-Gangetic plains in the last 60 years, and the country’s average temperature is expected to rise by 4.4°C at the end of the year 2100 (Nanditha et al., 2020). The summer monsoon rainfall (June to September) over India has also declined by around 6%

from 1951 to 2015, with notable decreases over the Indo-Gangetic Plains and the WGs (Kulkarni et al., 2020). The effect of climate change is further pronounced in WGs due to localized changes in the region. The forest cover in WGs has reduced by 2.49% between 2001 and 2016. It has resulted in reduced water retention capacity of the catchment, the conversion of several perennial streams to seasonal streams, and climate change. The mean temperature increased from 30.9°C in 2001 to 31.9°C in 2016. All these changes in the climate alter the ecology and, consequently, the biodiversity and hydrologic regime of a region. It affects the sustenance of water that leads to the loss of native biodiversity and the invasion of new species (Ramachandra et al., 2013; Kulkarni et al., 2020). Temperature plays an important role in the growth and development of aquatic animals (Ngoan, 2018; Maulu et al., 2021). A slight change in temperature has a profound effect on the reproduction of fishes by altering the maturation period, breeding season, hatching, and larval development (Pankhurst and Munday, 2011). Extreme climatic events increase the susceptibility of freshwater fishes to infections and disease outbreaks (Lopez et al., 2010). The changing climate was found to accelerate fish diversity in the Kabini river, which experienced a severe shortage of water during the summers of 2017–2019 and massive floods during the monsoons of 2018–2019. The post-flood months of 2018 and 2019 resulted in widespread mortality of fishes at several locations in the Kabini catchment due to bacterial disease outbreaks (Thampy et al., 2021).

Conservation status of fish biodiversity of Western Ghats

The fish biodiversity and the conservation status of fishes of WGs have been studied and reviewed by a number of researchers in the last two decades (Table 3).

The total number of fish species was found to increase due to both the discovery of new endemic species and the increasing presence of alien species in the WGs. However, the endemism, as well as the conservation status reported by different researchers,

was observed to be highly varying (Table 3). The reason for these variations is beyond the scope of the present article but needs to be examined. Presently, the issue of concern is to specify that several species of fish from WGs, which include many species of ornamental importance, have been categorized as CR, EN, and VU at different stages, but *P. denisonii* has been treated indiscriminately and recommended for listing as a Schedule-I species according to Wild Life (Protection) Amendment Act, 2021.

Indiscriminate treatment of *P. denisonii*

P. denisonii is victimized by its popularity: “popularity” that is probably less in the global aquarium trade and more among scientific communities. Daniels (2011) in his paper “Miss Kerala in Peril” has stated that the species that stayed dormant for 130 years was rediscovered as soon as live specimens and photographs came to light during the 1990s and thereafter it was exhibited in AQUARAMA 1997 at Singapore and ranked third under a new category. “Miss Kerala” became a beauty pageant not only in the aquarium but a common subject of discussion on many national and international scientific platforms with a series of publications in reputed scientific journals with a high impact factor. We encountered more than 100 publications on *P. denisonii*, very few on biology and culture but many on the threatened status of fish biodiversity of WGs due to the collection of the fish for the aquarium trade. The major factors that have resulted in the depletion of not only *P. denisonii* but also many other species from both biodiversity hot spots of India (WGs and East-Himalayan regions) that challenged the biodiversity were not discussed. It was truly stated that the “Damsel was in distress” and the “Aquarium trade in India was obscure”, but the damsel was victimized by its fame. Daniels (2011) stated that the species has been unscrupulously caught and traded. It may be appropriate to mention that it was unscrupulously debated and discussed too by scientific communities within the country, which gained the attention of a few researchers outside the country.

TABLE 3 Conservation status of endemic fishes of Western Ghats at different periods.

S. No.	Number of Species										References
	Total	Endemic	Assessed	CR	EN	VU	DD	NT	LC	##	
1.	287	192	98	24	37	13	14	8	2	–	Shaji et al., 2000
2.	290	189	290	12	54	31	26	6	161	–	Dahanukar et al., 2011
3.	320	212	193	9	36	21	17	4	106	–	Dhanukar and Raghavan, 2013
4.	379*	151	307	12	53	36	18	12	171	5	Dayal et al., 2014

*Inclusive of brackish water and marine species. CR, Critically endangered; EN, Endangered; VU, Vulnerable; DD, Data deficient; NT, Near threatened; LC, Least concern. ##Others: Low vulnerability: 1, Low-risk conservation dependent: 1, Rare: 1, and Indeterminate: 2.

Conflicts and repercussions

It was the first time that small-size freshwater fishes like *P. denisonii*, *Semiplotus semiplotus*, and *Osteobrama belangeri* were recommended for listing as Schedule-I of the Wild Life Protection Act of India. *O. belangeri* was found to be present in the state of Manipur but is presently extinct while *S. semiplotus* is distributed in the rivers of Assam and *P. denisonii* is found in many rivers of WGs although stocks may be depleted. Both these fish are caught and consumed by local fishermen as food. There is no fishing method available to exclude these fishes selectively from the catch while fishing in any of the water bodies. The fishing activities and fisheries resources in water bodies of a state are managed by the respective state fisheries departments while any animals protected under Wild Life Protection Act, 1972 are under the control of the local forest department. The state fisheries department will be issuing the license or permission for fishing in these water bodies while the forest department will be arresting the fishermen for fishing as they will be unable to exclude prohibited species from the catch. Fishing in all these water bodies will become a punishable offense for thousands of fishermen and local people collecting fish either for livelihood or food purposes. The implementation of the act may lead to conflicts between different implementing agencies and the local fishermen. It is also expected to face opposition from local fishermen and villagers once they understand the seriousness of the issue. However, it is also doubtful if the concerned agencies could do the same in the field once it is enforced. The Department of Fisheries, Government of Kerala has imposed a ban since 2008 on the collection of *P. denisonii* smaller than 9–10". The fish has been part of the export consignment even after that but there was no any recorded evidence if any person was caught (as informed by the second author).

Conclusion

The faunal and floral biodiversity is continuously depleting in many parts of the world mainly due to human-induced activities. A number of international agencies and the governments of respective countries are enforcing several laws (de Klemm and Shine, 1993; UNEP, 2018; Singh and Dukariya, 2021) to protect and conserve the rich biodiversity resources both terrestrial and aquatic. These laws have been highly rewarding in many cases (Vaughan, 2021) but failed to bring desired results with instances of strong opposition by local communities (Muhumuza and Balkwill, 2013). The failures were on account of improper evaluation of merits, demerits, effectiveness, and consequences of the particular law enforcement by the implementing agencies.

The Wild Life Protection Act 1972 of the Government of India and subsequent amendments (1982, 1986, 1991, 1993, 2002, 2006, and 2013) before the year 2021 provided protection to only whale shark (*Rhincodon typus*), eight species of shark and rays, all the species of sea horses and giant grouper (*Epinephelus lanceolatus*) among fishes. All these fish species are of very large size with a total body length range of 100–1,700 cm (excluding seahorses) and found in sea only except for Gangetic shark (*Glyphis gangeticus*), Ganges sting ray (*Himantura fluviatilis*), and green sawfish (*Pristis zijsron*), which are of migratory nature and found in specific freshwater river systems. The large size of these fishes requires a specific type of crafts and gears for fishing and also helps in easy exclusion from the catch if caught accidentally through traditional fishing methods.

Bill no. 159 proposed by MOEF & CC, Government of India as Wild Life (Protection) Amendment Act, 2021 recommended the first-time inclusion of three freshwater species, viz., *O. belangeri* (maximum length: 38 cm), *S. semiplotus* (maximum length: 60 cm), and *P. denisonii* (maximum length: 15 cm), endemic to rivers of Manipur, Assam, and WGs, respectively, as Schedule-I species. The wild stocks of all the three species have significantly reduced and are included in the red list of the IUCN as NT, VU, and EN, which warrant the implementation of measures to rebuild the stocks. If IUCN threatened status of wild stock of any fish species was the criteria for listing as Schedule-I species than the exclusion of so many other NT, EN and VU species (Table 3) appear unjustified. Most importantly, all these fishes are caught by local communities and fishermen as food fishes along with other freshwater fishes during the fishing activity. There are no fishing methods to exclude these fishes from the catch.

Bill no. 159 was subsequently reviewed by a Standing Committee on Science and Technology. The committee has revised the list of protected fish species (Report No. 365, 2022). The new list excludes *O. belangeri*, *S. semiplotus*, and *P. denisonii*, but recommended to include nine species, viz., golden mahseer (*Tor putitora*), Haragi (*Hypselobarbus pulchellus*), Bowany barb (*Barbodes bovanicus*), hump-backed mahseer (*Tor remadeviae*), loach (*Mesonoemachelium herrei*), loach (*Schistura papulifera*), catfish (*Glyptothorax kudremukhensis*), catfish (*Glyptothorax kashmirensis*), and Nilgiri mystus (*Hemibagrus punctatus*), under Schedule-I and seven species, viz., snakehead (*C. aurantimaculata*), rainbow snakehead (*C. bleheri*), Barca snakehead (*C. barca*), Canara pearl spot (*E. canarensis*), Maharaja barb (*W. sahyadriensis*), Zebra loach (*B. striata*), and Ocellated pufferfish (*Leodon cutcutia*), under Schedule-II. *C. aurantimaculata* and *C. barca* are indicated as DD in the IUCN list and *L. cutcutia* is LC while all the above 16 species are mentioned as "Not evaluated" under CITES (FishBase, 2022). All these fishes are again caught by local people and fishermen as food and few species to some extent are caught for aquarium trade and mainly export. The exclusion of *P. denisonii*, *S. semiplotus*, and *O. belangeri* was possibly based

on the recommendation of Sanjy Molur, Executive Director, Zoo Outreach Organisation, Coimbatore, India (Report No. 365-Vol.II, Page no. 97; 2022), suggesting the exclusion of these fishes from Schedule-I as *P. denisonii* and *S. semiplotus* are netted with other food fishes, consumed by locals, and impossible to fish individually while *O. belangeri* has already become extinct from India. Molur and associates (Raghavan et al., 2013b) have been advocating restriction on fishing of *P. denisonii* and blaming aquarium trade for the depletion of the wild stock.

It is not important which fish species are excluded or granted protection under Wild Life Protection Act, 1972. The issue is on the inclusion of freshwater fish species that are widely distributed and caught by local people and fishermen as food, which cannot be excluded from netting even if desired. The local communities and fishermen will be catching the fish for self-consumption or for livelihood with the permission issued by the Department of Fisheries while the officials of the Department of Forest will be punishing and arresting them for violation of the law.

The imposing selective restriction on catching of threatened fishes specifically of freshwater origin with small to medium size and wide distribution may not be an effective strategy of endemic biodiversity conservation but through appropriate conservation measures (Arthington et al., 2016). The marking of “Freshwater Aquatic Biodiversity Reserves” could be one effective biodiversity conservation measure. These reserves will be much similar to Marine Protected Areas (MPA) established for the conservation of marine resources (Saravanan et al., 2011) or Fish Conservation Zones (FCZs) for freshwater fishes (Loury, 2020). The marking of FCZs proved to be highly successful in Cambodia, Lao PDR, Myanmar, Thailand, and Vietnam. The fishery of mahseer (*Tor* spp. and *Neolissochilus strachery*) in the Nago River of Thailand, Probarbus fishes (*Probarbus jullieni* and *P. labeamajor*), Irrawaddy dolphin (*Orcaella brevirostris*), and Mekong giant catfish (*Pangasiandon gigas*) in Mekong River, Lao PDR has been successfully improved through FCZs.

The “Freshwater Aquatic Biodiversity Reserves (FABRs)” will be small selective sections in multiple numbers of a large river both upstream and downstream. It will be a reserved zone with no commercial activity of any type, i.e., fishing, wood cutting, agriculture, and sand mining. Additionally, there will be a simultaneous effort to restore the habitat as per the specific requirement of the species to develop enormous breeding and

feeding grounds for endemic aquatic species. It could be the construction of riffles and pools, the restoration of riparian vegetation, reviving the flow of water, etc. on select WGs rivers in the case of *P. denisonii* and other fishes with similar breeding and feeding habits. The marking of FABR will be an integrated approach of resource conservation and management through habitat restoration. The community participation (Adrianto et al., 2005) could be the key element of FABR in all stages from selection to management of sites as in case of FCZs.

A biodiversity conservation approach that will enhance the food availability and livelihood opportunities for local communities will be more effective than imposing complete restriction on resource utilization. There is continuous export of *P. denisonii* from India (Raghavan et al., 2013b), although the Government of Kerala has imposed a restriction on fish collection since 2008. Governments need to properly evaluate and frame a balanced policy to safeguard biodiversity as well as the socio-economic interest of local communities.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work, and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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