Review Article

A Review on hidden Subterranean (Hypogean) Ichthyofaunal Resources of India along with IUCN status, Threats and its conservation strategies

ABSTRACT

Subterranean habitats are one of the most peculiar and mysterious ecosystems on earth, yet we still have very less information about their biodiversity.These animals often live in extremely nutrient-limited environments. Consequently, most of the subterranean fish species are relatively small in size to survive on limited food resources. We present here a systematic checklist along with IUCN conservation status and a comprehensive account of the diversity, distribution, threats and suggest conservation measures for the Indian subterranean fishes. A total of 18 species under 5 orders, 8 families and 7 genera are listed from the secondary data. According to the IUCN Red List status,nine subterranean fish fauna are listed under the Not Evaluated (50%) category, five Data Deficient (27.78%), two endangered (11.11%), and only one species come under the Critically Endangered (5.56%) and Least Concern category (5.56%). Several anthropogenic stressors including agriculture, overexploitation, deforestation, habitat disturbance, hydroelectrically plans, invasive species, human-fish conflicts, climate change, sand mining and un-ecofriendly tourism are threatening these underground fishes. Nevertheless, there have been only a few studies on subterranean fish fauna, partly because many subterranean occur in tropical regions, sometimes in caves of difficult access, where there are few local researchers. It is necessary to promote throughout society the importance and urgency of studying and conserving subterranean resources to preserve their ecosystem services.

Keywords: Cave; conservation; ecosystem management; IUCN; Subterranean fishes; Threats

INTRODUCTION

What is Subterranean?

The term “subterranean” is an adjective meaning something/somebody existing under the earth’s surface. These places include caves, wells, caverns, lava tubes and phreatic spaces.

Subterranean fauna refers to animal species that are adapted to live in an underground environment. Subterranean environments are characterized not only by continuous darkness but also by a reduced variability in the number of specific abiotic conditions such as moisture, temperature, and water chemistry, as well as by isolation and restriction in space (Fig 1). Manmade underground tunnels, namely concrete pipelines carrying domestic sewage, could also come under a type of subterranean habitat. In general, subterranean spaces are underexplored in terms of biodiversity monitoring. Conditions in subterranean ecosystems: absence of light (darkness), high air humidity, oligotrophic (low carbon and nutrient) conditions, stable temperatures and other limitations of easy access to these underground spaces, fear of unknown and uncertain things. There have been no efforts made in India to survey the known subterranean habitats. Furthermore, there is no dedicated research biospeleology (the science of cave/ hypogean organisms).

What are subterranean fishes?

Fishes, which live in the underground habitats are called subterranean fishes. These fishes also known as troglomorphic fish, troglobitic fish, stygobitic fish, phreatic fish and hypogean fish. Life in caves means life in perpetual darkness. Theses fishes have reduced or absence of eyes and hence depend on their sense of smell and vibrations to move through their surroundings and to find food and mate. Their colouration is also unique; some are pinkish red, some brown and even black. Many animals, which resemble strange organisms and don't even look like fishes but would rather resemble an earthworm or a baby snake, survive in the extreme conditions of subterranean habitats.

Major adaptations to subterranean fishes:

1. Quite small in size and attenuated body
2. Troglomorphic (living in the constant darkness of caves), pigmentation and eyes are useless
3. Surviving in a habitat with limited food.
4. The lateral line for sensing vibrations, and chemoreception (via smell and taste buds).
5. Loss of scales and swim bladder
6. Low metabolism (able to survive long periods of starvation)
7. Regressive characters (disappear or reduce over the course of metamorphosis or any character that is reduced during evolutionary change)

8. Progressive characters (develops more advanced characters over the course of metamorphosis)

Highlights:

- In 1436, the first subterranean cavefish *(Sinocyclocheilus grahami)*wasfirst discovered by Mao Lan at Alugu Cave in Yunnan Province, China.
- The Northern Cavefish *(Amblyopsis spelaea)* was the first cavefish described in scientific literature, discovered in 1842 from a cave in Kentucky.
- Cavefish occur on all continents, except Antarctica.
- *Horaglanis krishnai* is the first subterranean fish of India, described by AGK Menon in 1950s, while presenttime three species have been documented in the genus viz., *H. krishnai*, *H. alikunhi* (2004) and *H. abdulkamali* (2012).
- The smallest subterranean fish (max. size 2.6cm) of India is *Pangio bhujia*.
- In February 2019, the world's largest subterranean fish (400mm in standard length) was the Golden Mahseer, *Tor putitora*, which was discovered by Harries in Jaintia Hills, Meghalaya (NE India), India. This species is referred to as the biggest cavefish in the world.
- A second subterranean species of *Pangio* is described from an old dug-out well in Kerala, Southern India. The new species, *Pangio pathala* is unique within the genus in possessing the highest number (27) of caudal vertebrae (Remya *et al*. 2022).

Global overview: Diversity of Subterranean fish fauna

Subterranean fishes occur in all the continents except Antarctica (Browskey, R., 2018). China harbours the maximum number of species (91), followed by Brazil (44), USA (21), Mexico (18) and India (18) also shelter a good number of subterranean fish species.

Currently, all over the world, there are 293 species of cave and groundwater fishes, 53 species of interstitial fishes and 49 species with troglomorphic features from non-subterranean habitats (293+53+49= 395 species).

A total of 293 species belong to 11 orders, and 28 families represent subterranean ichthyofaunal diversity worldwide (Table: 1&2).

The most dominant order of subterranean fishes are Cypriniformes (136) followed by Siluriformes (89), Gobiiformes (19) and each family of Gymnotiformes, Cyprinodontiformes, Anabantiformes are contributing only one species (Fig.2).

The families Nemacheilidae (62 spp.), Cyprinidae (61 spp.), Tricomycteridae (33 spp.), Heptapteridae (24 spp.) and Amblyopsidae (16 spp.) comprise the most number of subterranean species (Fig.3). The most specious genera are *Sinocyclocheilus* (38), *Triplophysa* (28), *Trichomycterus* (21) and *Rhamdia* (14). Hence, these groups of freshwater fishes present a high potential for easy adaptation to subterranean life.

The genera which are restricted to subterranean habitats: The following Table 3 lists the genera of fishes which are only found in subterranean habitats, i.e they are hypogean-restricted (HR).

Diversity of Indian subterranean fish fauna:

India is the world's seventh-largest countryin terms of geographical area, but we have 18 distinctly subterranean fish species including *Pangio pathala* (eel loach species). A few authors have worked on the diversity of subterranean fishes from different parts of India because of less resources and gap of knowledge. Kerala houses a rich subterranean ichthyofauna compared to other states. Kerala is also referred to as the 'hotspot of Indian subterranean fishes. Of the 18 subterranean fish species known from the country till date, 10 are inhabitants of the dugout wells of Thrissur, Malappuram, Kottayam, Pathanamthitta, Kozhikode and Kannur districts in Kerala. Moreover, Meghalaya is not far behind in contributing to this unique subterranean fishes. The authors hope that the Indian subterranean fishes resist and survive until that aim is achieved.

A total of 18 species under 5 orders, 8 families and 7 genera are listed from the secondary data (Table 3). According to the IUCN red list status,nine subterranean species are included in the list of Not Evaluated (50%), Five Data Deficient (27.78%), 2 Endangered (11.11%), and only one species comes under the Critically Endangered (5.56%) and Least concern category (5.56%) (Fig. 4).

Threats to subterranean fishes

The major threats to these fishes are consequences of human activities related to agriculture, overexploitation, deforestation, habitat disturbance, pasture, hydroelectrical projects, introduction of invasive species, human-fish conflicts and climate change. These activities affect different subterranean aquatic habitats as well as fish fauna. In addition, Quarrying & mining for limestone and un-ecofriendly tourism can be extremely harmful to this particular unique underground ichthyofaunal diversity, since these can alter the physical characteristics of the habitats.

Conservation strategies for subterranean fishes

Groundwater depletion is a major global problem, but its influence on the often-mysterious subterranean biodiversity and its protection is undefined. In the Western Ghats biodiversity hotspot of India, poor governance of groundwater resources is threatening its evolutionarily distinct subterranean freshwater fauna, some taxa of which represent Gondwanan relics.

- Assessment of Threats and Biodiversity subterranean hotspots
- Regulatory Measures
- Local community actions
- Sustainable groundwater management
- Restoration/Mitigation Efforts
- GIS-based modelling ofsubterranean fishes or aquifers and predicting the spatial distribution of these fish species.
- Environmental DNA (eDNA) sampling for accessing the diversity of underground habitat.
- Ex-situ conservation
- Research

Environmental DNA can bring to the surface essential insights, such as the study of ecosystem assemblages and rare species detection, which are critical for the preservation of life below, as well as above, the ground.

Conclusion

The subterranean domain supports a diverse ecosystem of narrowly distributed species with special morphological and physiological characteristics, as well as an aphotic

habitat in both air and water-filled spaces beneath the surface. They range from modest subterranean habitats to deep caves or meso and macrofissures that may be filled by fresh, brackish, or marine waters as ecosystems. The influence of surface processes decreases as depth below ground increases, and environmental factors become much more stable (stable temperature, high humidity and permanent darkness). Various organizations and conferences that research biodiversity and associated conservation strategies help to identify areas of future research analyse current trends in aquatic biodiversity and even conduct specialized studies.

In India, information on biodiversity available on subterranean fish species is meager. Although, Indian subcontinent is harbour of thousands of caves, adequate efforts have never been made to carry out biospeleological surveys.

Finally, there is an urgent need to lay emphasis on research on caves and cave biodiversity of India and for increased education and awareness programs to improve the conservation needs and profile of the subterranean fishes and their habitat. Since information on the habitat and its ecology is lacking, students and teachers from local schools and colleges within the subterranean habitat can be employed for data collection, monitoring and eco-restoration activities. The funding agencies of the country should keep biospeleology in the list of the thrust areas of research. Fully dedicated research centres and facilities should be providfor biospeleological research.

Figure 1. A An illustration of the subterranean ecosystem (Gunther, 2011 and Sendra, 2020)

Figure 2. Order wise percentage contribution of subterranean fishes

Figure 3. Families wise percentage contribution of subterranean fishes

Figure 4. IUCN Red list categories of subterranean fishes with percentage contribution

Figure 5. Diversity of Indian subterranean fish fauna (PLATE-1)

Figure 6. Diversity of Indian subterranean fish fauna (PLATE-2)

Figure 7. Threats to subterranean fishes

Figure 8. eDNA is a powerful but underused biomonitoring tool in subterranean environments (Source: Sacco et al. 2022)

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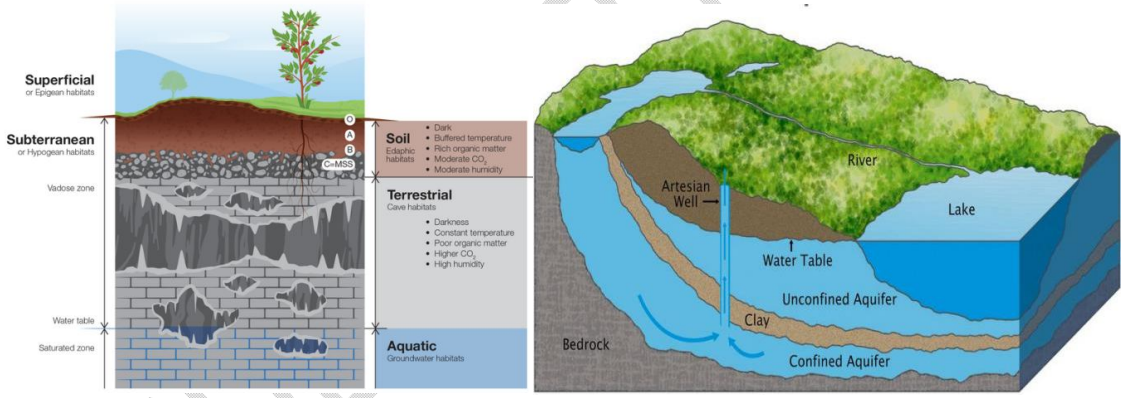

Figure 1. A An illustration of the subterranean ecosystem (Gunther, 2011 and Sendra, 2020)

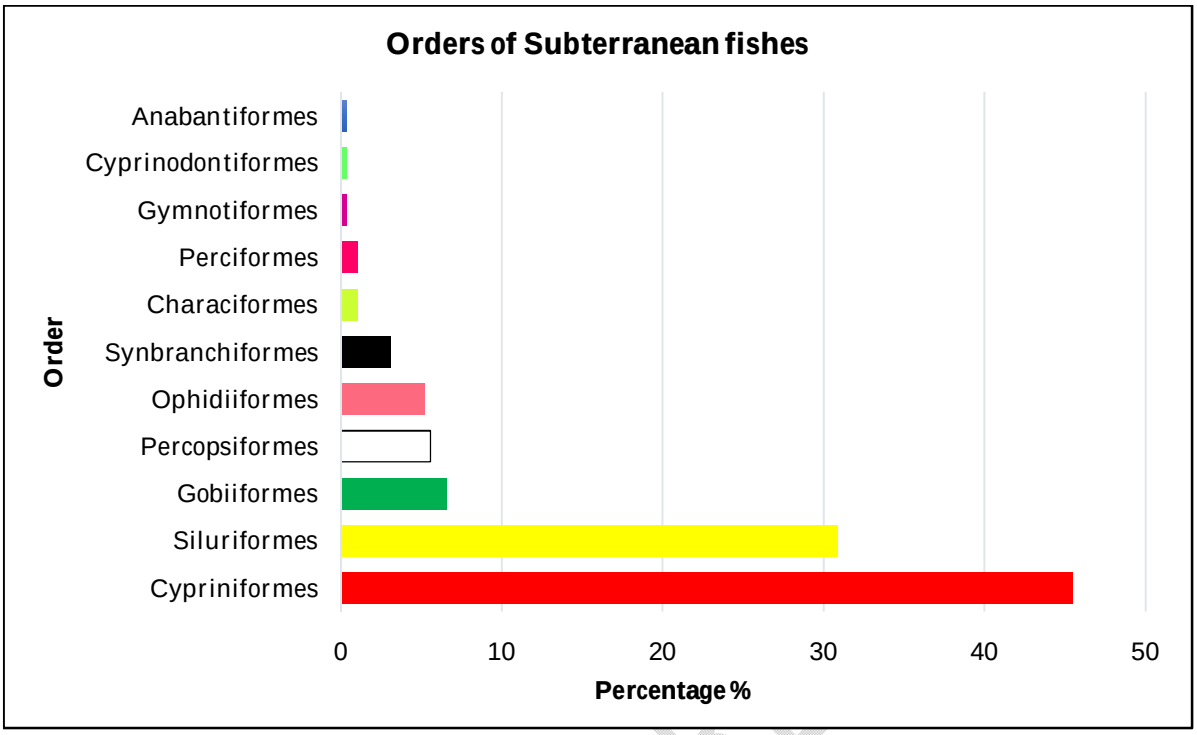

Figure 2. Order wise percentage contribution of subterranean fishes

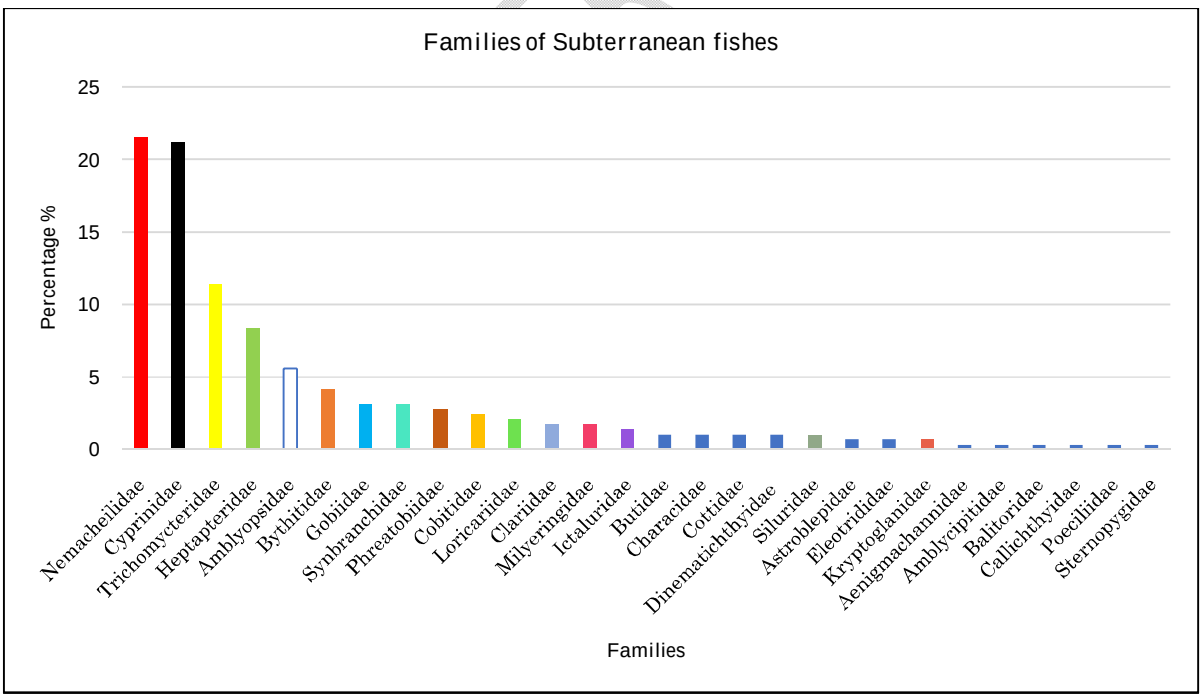

Figure 3. Families wise percentage contribution of subterranean fishes

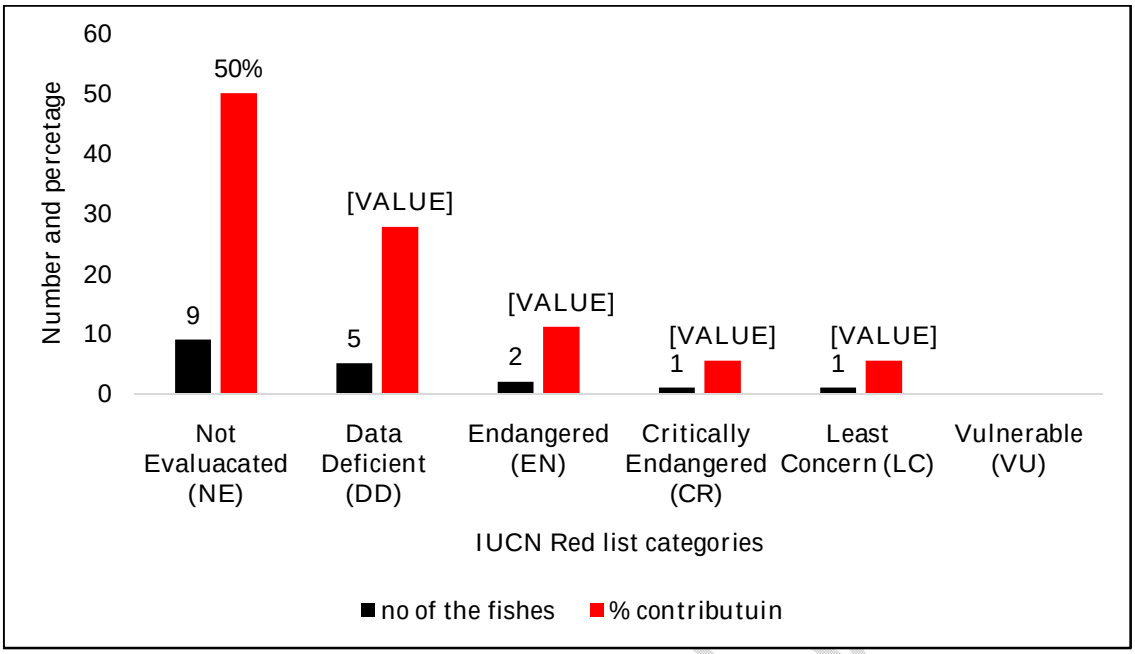

Figure 4. IUCN Red list categories of subterranean fishes with percentage contribution

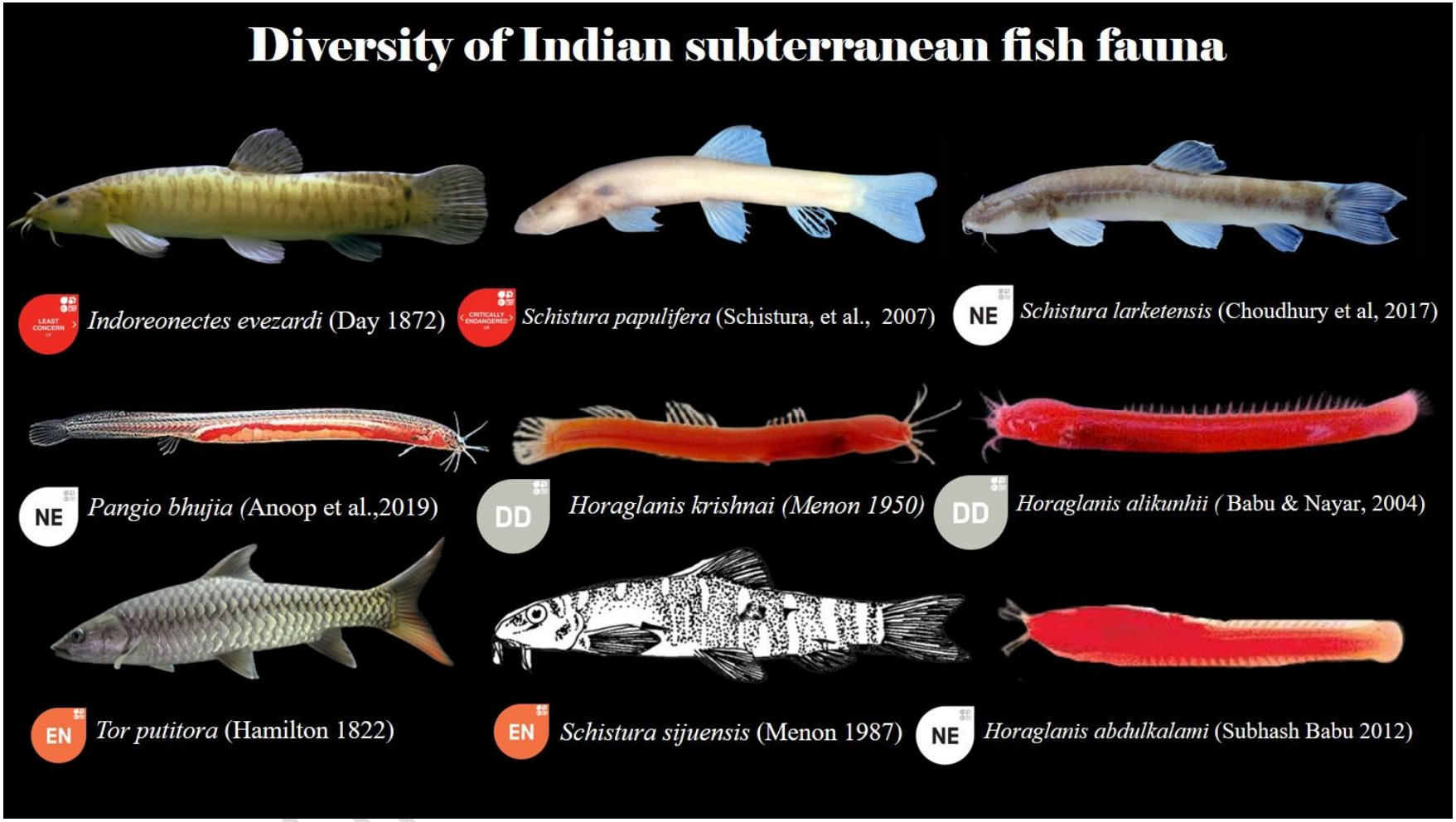

Figure 5. Diversity of Indian subterranean fish fauna (PLATE-1)

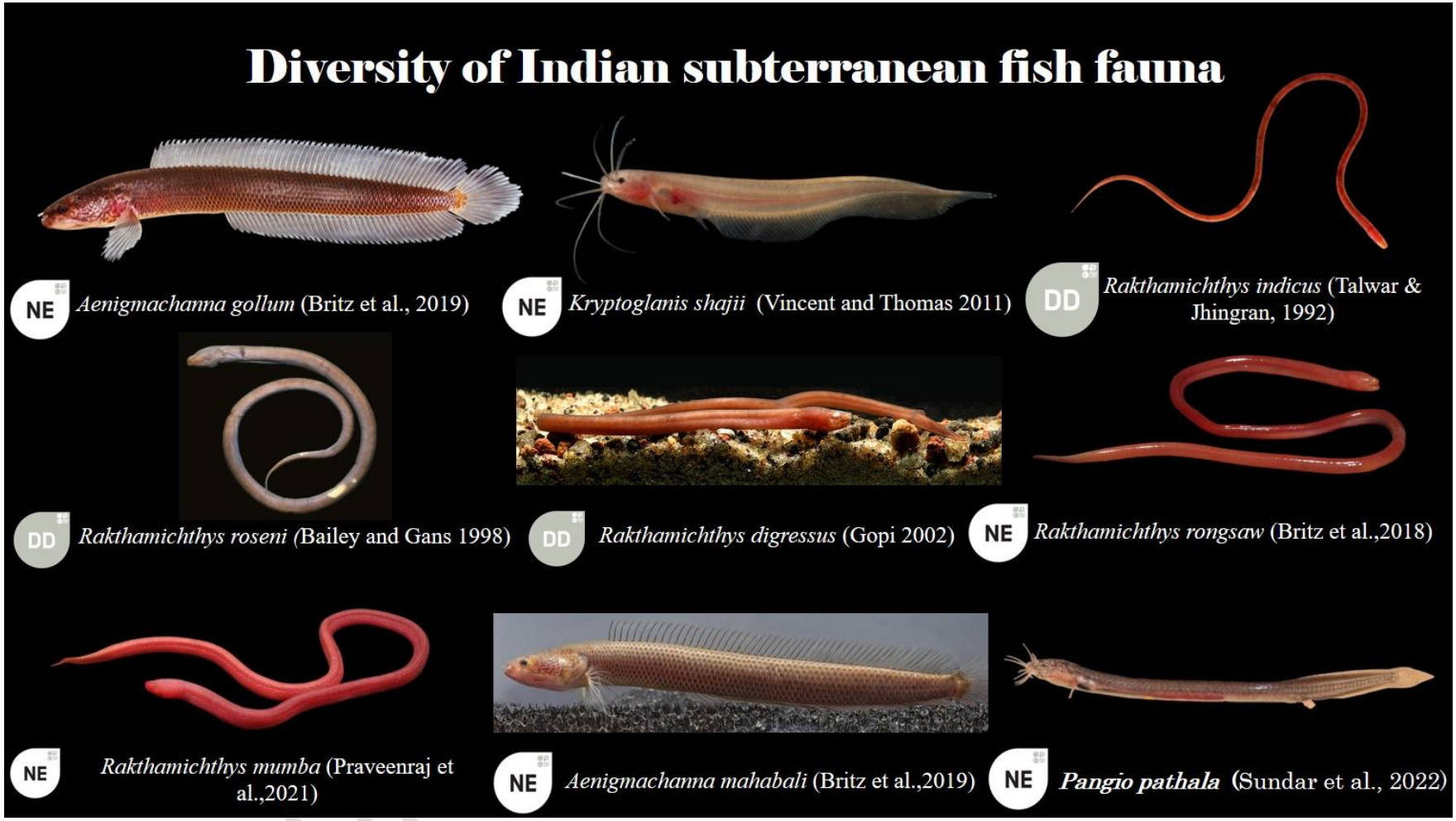

Figure 6. Diversity of Indian subterranean fish fauna (PLATE-2)

Figure 7. Threats to subterranean fishes

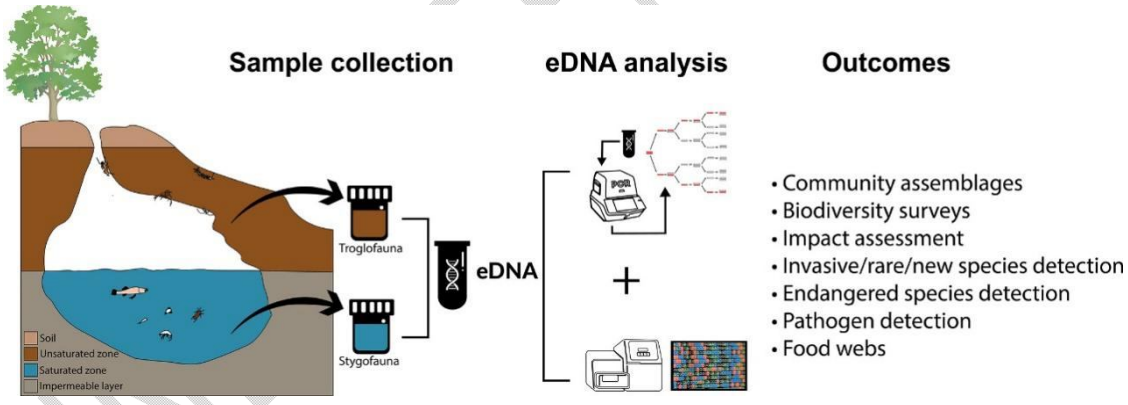

Figure 8. eDNA is a powerful but underused biomonitoring tool in subterranean environments (Source: Sacco et al. 2022)

Table 1. Order wise diversity of subterranean fish fauna

Order	**No. of spp.**
Cypriniformes	136
Siluriformes	89
Gobiiformes	19
Percopsiformes	16
Ophidiiformes	15
Synbranchiformes	9
Characiformes	3
Perciformes	3
Gymnotiformes	1
Cyprinodontiformes	1
Anabantiformes	1
Total	**293**

Table 2. Family wise diversity of subterranean fish fauna

Family	**No. of spp.**
Balitoridae	1
Cobitidae	8
Nemacheilidae	65
Cyprinidae	62
Characidae	3
Sternopygidae	1
Astroblepidae	2
Callichthyidae	1
Loricariidae	6
Trichomycteridae	33
Amblycipitidae	1
Clariidae	5
Heptapteridae	24
Ictaluridae	4
Kryptoglanidae	2
Phreatobiidae	8
Siluridae	3
Amblyopsidae	16
Bythitidae	12
Dinematichthyidae	3
Butidae	3
Eleotrididae	2
Gobiidae	9

Milyeringidae	5
Synbranchidae	9
Poeciliidae	1
Cottidae	3
Aenigmachannidae	1
Total	293

Table 3. Genera of subterranean fish fauna- hypogean-restricted (HR)

Genera	**Number of species**
Barbopsis	1
Caecieleotris	1
Caecobarbus	1
Caecocypris	1
Caecogobius	1
Cryptotora	1
Draconectes	1
Longanalus	1
Pseudosinocyclocheilus	1
Satan	1
Speolabeo	1

Speonectes	1
Speoplatyrhinus	1
Stygichthys	1
Troglichthys	1
Troglocobitis	1
Troglocyclocheilus	1
Trogloglanis	1
Typhlias	1
Typhlobarbus	1
Uegitglanis	1
Amblyopsis	2
Eidinemacheilus	2
Horaglanis	3
Kryptoglanis	2
Lucifuga	7
Milyeringa	2
Phreatobius	4
Prietella	2
Protocobitis	3

Troglonectes	7
Typhleotris	3
Typhlichthys	12
33 genera hypogean-restricted	42 species in HR genera (18% of all genera)

(Source:https://cavefishes.org.uk/)

Table 4. Checklist of subterranean fishes of India along with IUCN status

Sl. No.	Scientific name	Common name	Order	Family	Distribution	IUCN status	CITES/ CMS
1.	*Indoreonectes evezardi* (Day 1872)		Cypriniformes	Nemacheilidae	Western Ghats & Satpura range and Bastar District, Madhya Pradesh. Karnataka, Maharashtra.	LC	NE
2.	*Schistura sijuensis* (Menon 1987)		Cypriniformes	Nemacheilidae	Siju Cave and Garo Hills, Meghalaya	EN	NE
3.	*Schistura papulifera* (Kottelat et al, 2007)		Cypriniformes	Nemacheilidae	Krem Synrang Pamiang system, Jaintia Hills, Meghalaya	CR	NE
4.	*Schistura larketensis* (Choudhury et al, 2017)		Cypriniformes	Nemacheilidae	East Jaintia Hills District, Meghalaya	NE	NE
5.	*Pangio bhujia* (Anoop et al. 2019)		Cypriniformes	Cobitiidae	Cherinjal, Kozhikode District, Kerala	NE	NE
6.	*Tor putitora* (Hamilton, 1822)	Golden Mahseer, Putitor mahseer	Cypriniformes	Cyprinidae	Jaintia Hills, Meghalaya	EN	NE

7.	*Horaglanis krishnai* (Menon 1950)	Cave Catfish, Indian blind catfish	Siluriformes	Clariidae	Kottayam, Kerala	DC	NE
8.	*Horaglanis alikunhii* (Babu and Nayar 2004)	Alikunhii's Blind Catfish	Siluriformes	Clariidae	Parappukara village, Thrissur District, Kerala	DC	NE
9.	*Horaglanis abdulkalami* (Babu 2012)		Siluriformes	Clariidae	Thrissur District, Kerala	NE	NE
10.	*Aenigmachanna gollum* (Britz et al, 2019)	Gollum snakehead	Anabantiformes	Aenigmachannidae	Malappuram, Kerala	NE	NE
11.	*Kryptoglanis shajii* (Vincent and Thomas 2011)		Siluriformes	Krytoglaniidae	Western Ghats in Kerala& Thrissur District, Kerala	NE	NE
12.	*Rakthamichthys indicus* (Talwar and Jhingran 1992)	Malabar swamp eel	Synbranchiformes	Synbranchidae	Kottayam, Kerala State	DC	NE

13.	*Rakthamichthys roseni* (Bailey and Gans 1998)		Synbranchiformes	Synbranchidae	Periyam village, northern Kerala State	DC	NE
14.	*Rakthamichthys digressus* (Gopi 2002)		Synbranchiformes	Synbranchidae	Kuthiravattom, a suburb of Calicut, Kerala	DC	NE
15.	*Rakthamichthys rongsaw* (Britz et al, 2018)		Synbranchiformes	Synbranchidae	Nongriat Village, Sohra, Khasi Hills, Meghalaya	NE	NE
16.	*Rakthamichthys mumba* (Praveenraj et al, 2021)	Mumbai blind eel	Synbranchiformes	Synbranchidae	Mumbai City, Maharashtra	NE	NE
17.	*Aenigmachanna mahabali* (Britz et al, 2019)	Gollum snakehead, Dragon snakeheads	Anabantiformes	Aenigmachannidae	Oorakam, Malappuram, Kerala	NE	NE
18.	*Pangio pathala* (Sundar et al, 2022)		Cypriniformes	Cobitidae	Old dug-out well in Kerala, Southern India	NE	NE