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Diversity and Current Status of Grouper Fish, *Epinephelus* Bloch, 1793 in Indian Coastal Waters

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Abstract | The grouper fish, *Epinephelus* Bloch, 1793 represents an iconic genus of the family Serranidae and order Perciformes. They are highly-prized food fishes intended for subsistence, artisanal, recreational and commercial fisheries throughout their geographic range. Despite their economic importance, the status of grouper fishes has been increasingly imperiled through overfishing activities. The conservation efforts have also been constrained with this highly skewed *Epinephelus*. Hence, in order to save this esteemed resource, effective conservation and rehabilitation strategies need to be planned and implemented in the country. However, it requires the knowledge of the current status of grouper fish diversity which is not yet carried comprehensively. Hence this study was proposed to review the systematic study of the genus *Epinephelus* to fill the gaps in diversity studies of India. The study also documented the present IUCN status of the listed species of *Epinephelus* under different categories of conservation status.

Keywords | Conservation, Distribution, Diversity, *Epinephelus*, Groupers

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INTRODUCTION

India is one of the twelve megadiverse nations in the world and well known for its biodiversity richness (Serajuddin et al., 2018) with a distinctive biogeographic marine ecoregion (Spalding et al., 2007). The Indian coastline (7517 km) with different coastal ecosystems supports rich diverse resources having considerable economic importance. The marine diverse resources represent half of all extant vertebrates with an estimation of 2443 (75.6%) valid species (Gopi and Mishra, 2015). In recent decades, there has been a massive development of the fisheries sector in the Indian waters. The vessels now extend their trawling operations into deeper waters, catching more varieties of demersal fishes including groupers. Grouper landings have been continuously increasing during the last decade (2009-2018) with an average of 37970 tonnes and are shown in Figure 1. The highest landings of 53924 tonnes in 2017 and the lowest of 17606 tonnes were observed in 2009. In 2018 the landings have been accounted for about 51433 tonnes (CMFRI, 2019). However, species-specific landing data were not reported for the grouper species. Because of this low degree of resolution, 61% of grouper landings are reported as "groupers nei" in FAO (2016) database. Concurrent with the increase in landings and production of groupers, there may be a chance of overexploitation and some species on the threat of extinction.

Grouper fishes are cosmopolitan, occurring in tropical and subtropical areas (Heemstra and Randall, 1993). This highly diverse fish group plays a significant role in the coral reef ecosystem as regulators of the structure and composition of communities and forms an important link in the food chain (Rao, 2009). The groupers are top predators, sedentary and usually sluggish in movement, slow growing and long-lived (Heemstra and Randall, 1993). They have white, tender and tasty meat, and commands a high price in the market. Moreover, many species have been prioritized

as potential species for aquaculture (Noikotr et al., 2013; Pierre et al., 2008). Small grouper species are highly valued in the aquarium trade and remain as one of the valuable fishery resources along the coasts of India. These features attracted many enthusiastic researchers (Ottolenghi et al., 2004; Sadovy et al., 2013).

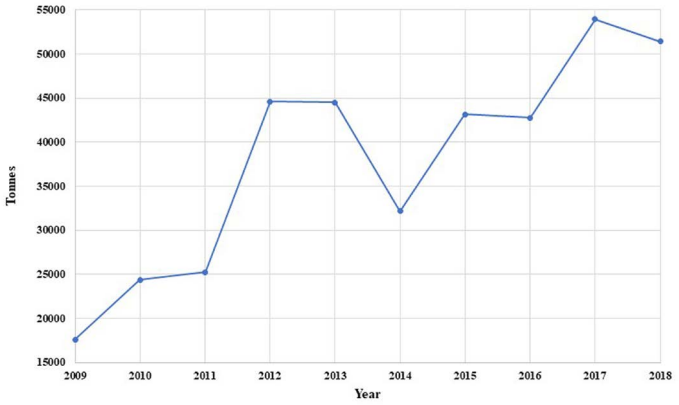

Figure 1: Trend of Grouper fish landings in India (2009-2018) (Source: CMFRI).

Over the past decade, a number of articles published on various aspects of *Epinephelus* species (Figure 2). In India, only 318 articles are published to an estimated 3386 articles worldwide. Thus, inspite of their commercial importance, the work done so far on *Epinephelus* species in India is scarce.

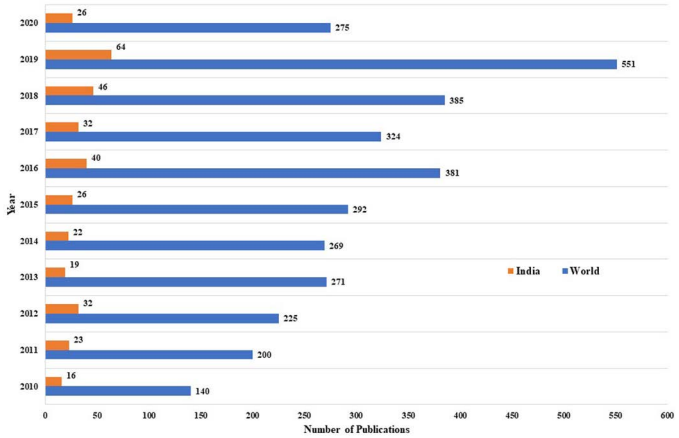

Figure 2: Number of articles published on *Epinephelus* in the last decade from India *vs.* world (Source: Science Direct, April 2020).

A perusal of the literature shows that these fishes are being subjected to intense fishing pressure for food, ornamental display and medicinal purposes globally (Sujatha et al., 2015; Vincent, 2006). The loss of groupers can have a serious effect on local ecosystems since these fishes play an important role in the structure of rocky bottom and coral reef communities (Sujatha et al., 2015). In spite of their commercial importance, the status of grouper fishes has been threatened by overexploitation. As a result, certain species of groupers have become a matter of serious concern. Hence, comprehensive information on the current status of grouper diversity is a prerequisite for efficient management and to formulate the steps to be taken to protect these fishes towards sustainable exploitation. Hence the present study was aimed to manifest the diversity and current status of *Epinephelus* in Indian coastal waters by reviewing the studies carried so far on the diversity and distribution of this fish. The Conservation status of *Epinephelus* species under different categories was also documented.

Diversity and Distribution of Groupers, *Epinephelus*

Grouper fishes of the Family Serranidae (Order: Perciformes; Class: Actinopterygii) are represented by 16 genera and 163 species with world-wide distribution. According to FishBase, around 54 species of the sub-family, Epinephelinae and 38 species of the genus, *Epinephelus* have been reported from the Indian waters (Froese and Pauly, 2019). Groupers inhabit a wide variety of habitats, mainly coral reefs, rocky areas, seagrass beds, and estuaries (Darwin et al., 2018; Rao, 2009). They exhibit a wide variety of reproductive and growth strategies (Morris et al., 2000). *Epinephelus* species are regularly landed by subsistence, artisanal, and commercial fisheries throughout their geographic range. A significant number of studies have been carried on the diversity of groupers, *Epinephelus* in various ecosystems of the Indian coastal waters and are presented in Table 1.

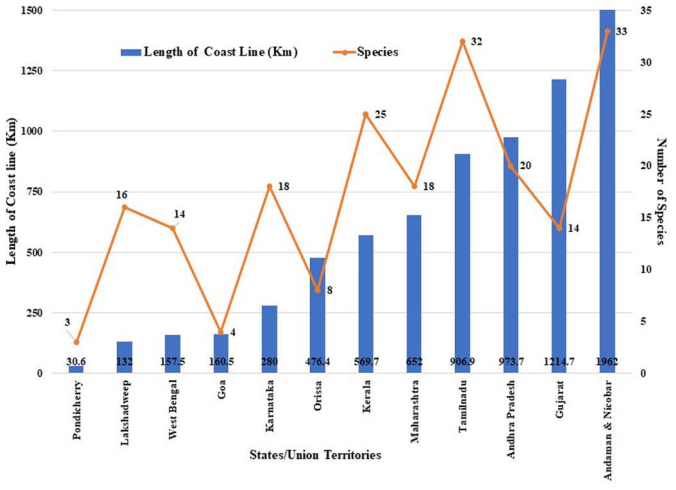

Figure 3: Species richness against the length of the coastline of all coastal states and union territories.

Data on the distribution of Indian groupers were collected from twelve coastal states and union territories of India (Figure 3) which revealed the presence of 47 species of *Epinephelus* in Indian waters (Table 2). The species richness against the length of the coast of all states and union territories is presented in Figure 3. The east coast represents 76.59% with 36 species, while the west coast

Table 1: Diversity studies on *Epinephelus* species in Indian coastal waters.

S. No.	State	Location	Reference
1	Gujarat	Location not mentioned	James et al., 1994
		Major coastal states of Gujarat	Barman et al., 2000
		Gulf of Kachchh	Subba Rao and Sastry, 2005
		Veraval	Joshi et al., 2018; Sen et al., 2019
2	Maharashtra	Location not mentioned	James et al., 1994
		Major fish landing centres of Maharashtra	Barman et al., 2012
		Sassoon Dock	Albert et al., 2017
		Mumbai Coast	Bhendekar et al., 2019
3	Goa	Grand Island	Sluka and Lazarus, 2010; Sluka, 2013
4	Karnataka	Natrani Island	Sluka and Lazarus, 2010; Sluka, 2013
		Major fish landing centres of Karnataka	Barman et al., 2013
		Mangalore, Karnataka	Mahesh et al., 2014
5	Kerala	Location not mentioned	James et al., 1994
		Ponnani estuary, Kerala	Bijukumar and Sushama, 2000
		Neendakara, Sakthikulangara, Munambam, Ponnani, Puthiyappa, and Azheekkal of Kerala	Biju and Deepthi, 2009
		Vizhinjam	Sluka and Lazarus, 2010
		Cochin	Gibinkumar et al., 2012; Anjali et al., 2019
		Vizhinjam	Sluka, 2013
		Location not mentioned	Bijukumar and Raghavan, 2015
		Mulloor, Vizhinjam, Kovalam, Thirumullavram of South Kerala	Baiju et al., 2016
6	Tamil Nadu	Parangipettai	Ramaiyan et al., 1987
		Location not mentioned	Ramesh et al., 2008
		Chennai metropolitan city limits (extending from Ennore in the north to Thiruvanmiyur in the south) Chennai	Krishnan et al., 2007
		Melakkal and Muttom	Sluka and Lazarus, 2010
		All coastal districts (10) Tamilnadu	Barman et al., 2011
		Mandapam and Keelakkarai	Roy and Gopalakrishnan, 2011
		Cuddalore and Parangipettai	Sambandamoorthy et al., 2015
		Nagapattinam	Ramu et al., 2015
		Wadge bank, Kanyakumari	Karuppasamy, 2016
		Pulicat	Govindan and Ravichandran, 2016
		Estuarine wetlands of Tamil Nadu	Mogalekar et al., 2017
		Cuddalore, Parangipettai, and Nallavadu	Jayaprabha et al., 2018
		Tuticorin, Southeast coast of India	Manojkumar et al., 2019
		Gulf of mannar	Varghese et al., 2011; Kumar et al., 2013; Joshi, 2016
		Thoothukudi Coast, Gulf of mannar	Jawahar et al., 2013
		Pamban, Gulf of mannar	Varghese and Joshi, 2017
		Keelakari, Gulf of mannar	Varghese et al., 2017
		Mandapam	Varghese and Gandhi 2019
		Thoothukudi	Anjali et al., 2019
7	Pondicherry	Pondicherry and Karaikal	Mishra and Krishnan, 2003
8	Andhra Pradesh	Major landing stations of Andhra Pradesh	Barman et al., 2004
		Visakhapatnam	Sujatha, 2004; Sreedhar et al., 2010; Deepti et al., 2014; Sujatha et al., 2015
9	Orissa	Odisha	Barman et al., 2007
		Chilaka	Mohanty et al., 2015

S. No.	State	Location	Reference
10	West Bengal	Digha	Yennawar et al., 2011; Yennawar et al., 2015, 2017
		Digha, Digha Mohana, Shankarpur, Petuaghat, Sagar, Fresergunge, Namkhana, Kakdwip and Diamond Harbour of West Bengal coast	Kar et al., 2017
		Digha Mohona	Ray and Mohapatra, 2020
11	Lakshadweep Islands	Lakshadweep	Chandrasekhara, 1991; Murty, 2001; Kumar et al., 2012
		Minicoy Island	Robert and Lazarus, 2006
12	Andaman and Nicobar Islands	Andaman and Nicobar	Pokapunt et al., 1993; Rajan, 2001, 2015; Rajan et al., 2013; Rao, 2009; Kirubasankar et al., 2013; Ramakrishna et al., 2010

represents 57.44% with 27 species. The Andaman and Nicobar islands represent 70.21% of grouper diversity with a maximum number of 33 species, followed by Tamil Nadu (68.08%) with 32 species, Kerala (53.19%) with 25 species, Andhra Pradesh (42.55%) with 20 species, Karnataka (38.29%) with 18 species, Maharashtra 38.29% with 18 species, Lakshadweep (34.04%) with 16 species, West Bengal (29.78%) 14 species, Gujarat (29.78%) with 14 species, Orissa (17.02%) with 8 species, Goa (8.51%) with 4 species and Puducherry (6.38%) with 3 species.

Regarding species distribution (Table 2), *E. coioides* was recorded as a dominant species in all coastal states except Puducherry. Similarly, *E. malabaricus* was identified as the second most widely distributed species in the coastal waters of 10 out of 12 states and union territories in India. Considering the distribution of species from the west coast, *E. coioides*, *E. diacanthus*, and *E. erythrurus* were abundant in all reported stations, while *E. areolatus, E. chlorostigma, E. fasciatus, E. fuscoguttatus, E. latifasciatus,* and *E. malabaricus* are dominant in all stations, except Goa. Along the east coast, *E. lanceolatus* and *E. malabaricus* were reported in all stations, while *E. bleekeri, E. coioides, E. latifasciatus* and *E. tauvina* were found in all stations except Puducherry. The distribution of some rare species was confined to particular regions of the east coast such as *E. corallicola* (Tamil Nadu), *E. fasciatomaculosus* (Tamil Nadu), *E. hata* (Andhra Pradesh), *E. magniscuttis* (Andhra Pradesh and West Bengal), *E. marginatus* (Andhra Pradesh), *E. melanostigma* (Tamil Nadu), *E. miliaris* (Tamil Nadu), *E. poecilonotus* (Tamil Nadu), *E. retouti* (Tamil Nadu), *E. rivulatus* (Tamil Nadu) and *E. sexfasciatus* (Tamil Nadu and West Bengal), whereas *E. bontoides* (Kerala), *E. chabaudi* (Karnataka and Kerala), *E. stoliczkae* (Maharastra and Karnataka) and *E. Tukula* (Goa and Maharastra) were restricted to the west coast of India. In addition to these mainland coastal water species, some species such as *E. amblycephalus, E. macrospilos* and *E. polystigma* are reported only from Andaman and Nicobar Islands, while *E. ongus* and *E. spilotoceps* were recorded from both Lakshadweep, and Andaman and Nicobar Islands of India.

It is evident that among the 47 *Epinephelus* species registered in India, 40 are commercial, while the remaining species are used for aquaria, game/sport fishery, subsistence fisheries and aquaculture (Table 2). In India, rearing of groupers in brackish water aquaculture is a relatively new development as a diversification option in pond and cage culture farms and is still in R and D phase. Certain behavioral characteristics with a high degree of territoriality and site specificity are making the groupers at risk and easy targets for fishermen (Heemstra and Randall, 1993; Morris et al., 2000; Sadovy et al., 2013). In this context, groupers are emerged as a particularly vulnerable group of fishes (Ranjan, 2015). The apparent vulnerability of the giant grouper, *E. lanceolatus* of Andaman and Nicobar Islands is protected under schedule I of the Wildlife (Protection) Act, 1972.

Regarding the conservation status as per the IUCN Red List of Threatened Species, out of 47 *Epinephelus* species reported from Indian coastal waters, 41 species (87.23%) are marked as Least Concern (LC) and 3 species (6.38%) each as Vulnerable (VU) and Data deficient (DD) (Table 2 and Figure 4).

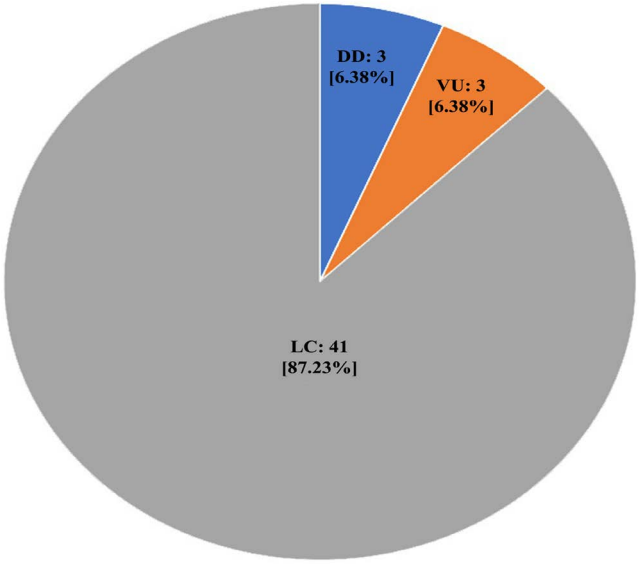

Figure 4: IUCN Status of *Epinephelus* species in Indian coastal waters.

Table 2: A comprehensive list and distribution status of extant Grouper (*Epinephelus* spp.) in Indian coastal waters.

S. No.	Species name	Common name	F	States/ Union Territories												IUCN status	Threat to humans	Use/Trade
				1	2	3	4	5	6	7	8	9	10	11	12			
1	*Epinephelus amblycephalus* (Bleeker, 1857)	Banded grouper													+	LC	Harmless	Minor commercial
2	*E. areolatus* (Forsskål, 1775)	Areolate grouper	+	+	+		+	+	+		+		+		+	LC	Harmless	Commercial, aquaculture
3	*E. bleekeri* (Vaillant, 1878)	Duskytail grouper	+		+		+	+	+		+	+	+	+	+	DD	Harmless	Minor commercial, aquaculture
4	*E. bontoides* (Bleeker, 1855)	Palemargin grouper						+								LC	Harmless	Of no interest
5	*E. chabaudi* (Castelnau, 1861)	Moustache grouper	+				+	+								LC	Harmless	commercial
6	*E. chlorostigma* (Valenciennes, 1828)	Brownspotted grouper	+	+	+		+	+	+		+				+	LC	Harmless	commercial
7	*E. coeruleopunctatus* (Bloch, 1790)	Whitespotted grouper	+		+			+	+		+		+	+	+	LC	Harmless	Minor commercial
8	*E. coioides* (Hamilton, 1822)	Orange-spotted grouper	+	+	+	+	+	+	+		+	+	+	+	+	LC	Harmless	Commercial, aquaculture
9	*E. corallicola* (Valenciennes, 1828)	Coral grouper	+						+					+	+	LC	Harmless	Subsistence fisheries
10	*E. diacanthus* (Valenciennes, 1828)	Spinycheek grouper	+	+	+	+	+	+	+		+	+				LC	Harmless	commercial
11	*E. epistictus* (Temminck and Schlegel, 1842)	Dotted grouper	+		+		+	+			+				+	LC	Harmless	Minor commercial
12	*E. erythrurus* (Valenciennes, 1828)	Cloudy grouper	+	+	+	+	+	+			+		+		+	LC	Harmless	Minor commercial
13	*E. fasciatomaculosus* (Peters, 1865)	Rock grouper							+							LC	Harmless	commercial
14	*E. fasciatus* (Forsskål, 1775)	Blacktip grouper	+	+	+		+	+	+				+	+	+	LC	Ciguatera poisoning	Commercial, gamefish,
15	*E. faveatus* (Valenciennes, 1828)	Barred-chest grouper	+				+	+	+						+	LC	Harmless	commercial
16	*E. flavocaeruleus* (Lacepède, 1802)	Blue-and-yellow grouper	+					+	+					+	+	LC	Harmless	Commercial, aquarium
17	*E. fuscoguttatus* (Forsskål, 1775)	Brown-marbled grouper	+	+	+		+	+	+					+	+	VU	Ciguatera poisoning	Minor commercial, gamefish,
18	*E. hata (=E.heniochus)* Fowler, 1904	Bridled grouper									+				+	LC	Harmless	commercial
19	*E. hexagonatus* (Forster, 1801)	Starspotted grouper	+					+	+		+			+	+	LC	Harmless	Minor commercial, gamefish
20	*E. lanceolatus* (Bloch, 1790)	Gaint grouper	+	+	+		+		+	+	+	+	+		+	DD	Traumatogenic	Commercial, aquaculture
21	*E. latifasciatus* (Temminck and Schlegel, 1842)	Striped grouper	+	+	+		+	+	+		+	+	+			LC	Harmless	commercial
22	*E. longispinis* (Kner, 1864)	Longspine grouper	+	+			+	+	+		+		+	+	+	LC	Harmless	commercial
23	*E. macrospilos* (Bleeker, 1855)	Snubnose grouper	+												+	LC	Harmless	Commercial
24	*E. maculatus* (Bloch, 1790)	Highfin grouper	+					+	+							LC	Ciguatera poisoning	Minor commercial, aquarium
25	*E. magniscuttis* Postel, Fourmanoir and Guézé, 1963	Speckled grouper									+		+			LC	Harmless	Commercial
26	*E. malabaricus* (Bloch and Schneider, 1801)	Malabar grouper	+	+	+		+	+	+	+	+	+	+		+	LC	Harmless	Highly commercial, aquaculture
27	*E. marginatus* (Lowe, 1834)	Dusky grouper	+								+					VU	Harmless	Highly Commercial, gamefish

S. No.	Species name	Common name	F	States/ Union Territories												IUCN status	Threat to humans	Use/Trade
				1	2	3	4	5	6	7	8	9	10	11	12			
28	*E. melanostigma* Schultz, 1953	One-blotch grouper	+						+					+	+	LC	Ciguatera poisoning	Subsistence fisheries
29	*E. merra* Bloch, 1793	Honeycomb grouper	+	+				+	+					+	+	LC	Ciguatera poisoning	Commercial, aquaculture,
30	*E. miliaris* (Valenciennes, 1830)	Netfin grouper							+						+	LC	Harmless	Minor Commercial
31	*E. morrhua* (Valenciennes, 1833)	Comet grouper	+		+			+	+		+	+		+		LC	Ciguatera poisoning	Minor commercial, gamefish
32	*E. multinotatus* (Peters, 1876)	White-blotched grouper	+													LC	Harmless	Commercial
33	*E. ongus* (summana) (Bloch, 1790)	White-streaked grouper	+											+	+	LC	Harmless	Minor commercial
34	*E. poecilonotus* (Temminck and Schlegel, 1842)	Dot-dash grouper	+						+							LC	Harmless	Subsistence fisheries
35	*E. polylepis* Randall and Heemstra, 1991	Smallscaled grouper	+	+	+		+									LC	Harmless	Commercial
36	*E. polyphekadion* (Bleeker, 1849)	Camouflage grouper	+						+					+	+	VU	Ciguatera poisoning	Commercial, aquaculture
37	*E. polystigma* (Bleeker, 1853)	White-dotted grouper													+	LC	Harmless	Subsistence fisheries
38	*E. quoyanus* (Valenciennes, 1830)	Longfin gouper	+						+						+	LC	Ciguatera poisoning	Commercial
39	*E. radiatus* (Day, 1868)	Oblique-banded grouper	+					+	+		+		+		+	LC	Harmless	Minor commercial
40	*E. retouti* Bleeker, 1868	Red-tipped grouper							+							LC	Harmless	Subsistence fisheries, gamefish
41	*E. rivulatus* (Valenciennes, 1830)	Halfmoon grouper	+						+							LC	Harmless	Minor commercial
42	*E. sexfasciatus* (Valenciennes, 1828)	Sixbar grouper							+				+		+	LC	Harmless	Commercial
43	*E. spilotoceps* Schultz, 1953	Foursaddle grouper	+											+	+	LC	Harmless	Commercial, gamefish
44	*E. stoliczkae* (Day, 1875)	Epaulet grouper	+		+		+									LC	Harmless	Minor commercial
45	*E. tauvina* (Forsskål, 1775)	Greasy grouper	+	+				+	+		+	+	+	+	+	DD	Ciguatera poisoning	Minor commercial, aquaculture
46	*E. tukula* (Morgans, 1959)	Potato grouper	+		+	+		+							+	LC	Harmless	Subsistence fisheries, gamefish
47	*E. undulosus* (Quoy and Gaimard, 1824)	Wavy-lined grouper	+		+		+	+	+	+	+				+	LC	Harmless	Minor commercial

*F: FishBase; 1: Gujarat; 2: Maharastra; 3: Goa; 4: Karnataka; 5: Kerala; 6: Tamil Nadu; 7: Puducherry; 8: Andhra Pradesh; 9: Orissa; 10: West Bengal; 11: Lakshadweep and 12: Andaman and Nicobar.

CONCLUSION AND RECOMMENDATIONS

The present study provides a complete checklist of *Epinephelus* species reported from Indian coastal waters. So far 47 species of *Epinephelus* have been reported. However, Fish Base (http://www.fishbase.org/) has shown only 38 species, including *E. multinotatus* which was not reported in Indian waters. Hence, the database of FishBase needs to be revised and updated to 47 species. Despite their importance for commercial fisheries, aquarium trade, aquaculture and coral reefs, these species are highly threatened by overexploitation, bycatch, and habitat loss due to degradation of coral reefs and the possible effects of climate change. These factors are also impacting the species biodiversity. To conserve these species, it is necessary to implement ecosystem-based management practices. Therefore, the following steps could be taken to improve the conservation of *Epinephelus* species along the coastal waters of India and elsewhere: (i) collection of landing station-wise data from commercial, bycatch, ornamental and recreational catches; (ii) genetic diversity studies to overcome taxonomic ambiguities (iii) identification of the nutrient profile and consideration of the minimum catch size to avoid depletion of the stock in future; (iv) integrated knowledge about the social, biophysical and ecological aspects of *Epinephelus* in a sustainable way; (v) increase efforts on education and conservation awareness in coastal tourism and communities; and, most importantly, (vi) creation of networks for marine reserves in priority conservation areas, protecting key species and habitats for their survival. This will not only pave the way for better protection of *Epinephelus* diversity but will also help maintain harmony in the marine community.

AUTHORS CONTRIBUTION

Both the authors contributed equally.

CONFLICT OF INTEREST

The authors have declared no conflict of interest.

REFERENCES

- Albert Idu KA, Akhilesh KV, Singh VV (2017). Report of potato grouper and Cloudy grouper in fishery landings at Mumbai. Mar. Fish. Inf. Sev. T E Ser., 231: 25-26.
- Anjali KM, Mandal A, Gunalan B, Ruban L, Anandajothi E, Thineshsanthar D, Manojkumar TG, Kandan S (2019). Identification of six grouper species under the genus *Epinephelus* (Bloch, 1793) from Indian waters using PCR-RFLP of cytochrome c oxidase I (COI) gene fragment. Food Control, 101: 39-44. https://doi.org/10.1016/j.foodcont.2019.02.024
- Baiju PT, Prabhakaran MP, Benno Pereira FG, Jayaprakas V (2016). Rocky reef-associated fish diversity of South Kerala coast, India. J. Aquat. Biol. Fish., 4: 31-44.
- Barman RP, Kar S, Mukherjee P (2004). Marine and estuarine fishes. In: State Fauna Series 5: Fauna of Andhra Pradesh (Part-2), Mammals and Marine and Estuarine Fishes. Publ. Dir., Zool. Surv. India, Kolkata. pp. 1-311.
- Barman RP, Mishra SS, Kar AS, Mukherjee P, Saren SC (2011). Fauna of Tamil Nadu. In: State Fauna Series, 17 (Part-2). Publ. Dir. Zool. Surv. India, Kolkata. pp. 1-418.
- Barman RP, Mishra SS, Kar AS, Mukherjee P, Saren SC (2012). In: Fauna of Maharashtra, State Fauna Series, 20 (Part-l). Publ. Dir. Zool. Surv. India, Kolkata. pp. 1-480.
- Barman RP, Mishra SS, Kar AS, Saren SC (2013). In: Fauna of Karnataka, State Fauna Series. Publ. Dir. Zool. Surv. India, Kolkata. 21: 1-595. https://doi.org/10.1007/978-3-642-38200-0_31
- Barman RP, Mishra SS, Kar S, Mukherjee P, Saren SC (2007). Marine and estuarine fish fauna of Orissa. Rec. Zool. Surv. India, Occ. Paper No. 260: 1-186.
- Barman RP, Mukherjee P, Kar S (2000). Marine and estuarine fishes. In: State Fauna Series No. 8, Fauna of Gujarat, Part 1. Publ. Dir. Zool. Surv. India, Kolkata. pp. 1-464.
- Bhendekar SN, Chellappan A, Sonavane AE, Mohanty P, Singh R, Shenoy L (2019). Geo-spatial distribution and faunal diversity in the trawling grounds off Mumbai coast, Maharashtra, India. Indian J. Mar. Sci., 48(9): 1435-1442.
- Bijukumar A, Deepthi GR (2009). Mean trophic index of fish fauna associated with trawl bycatch of Kerala, southwest coast of India. J. Mar. Biol. Assoc. India, 51(2): 145-154.
- Bijukumar A, Raghavan R (2015). A checklist of fishes of Kerala, India. J. Threat. Taxa. 7(13): 8036-8080. https://doi.org/10.11609/jott.2004.7.13.8036-8080
- Bijukumar A, Sushama S (2000). Ichthyofauna of Ponnani estuary, Kerala. J. Mar. Biol. Ass. India. 42(1-2): 182-189.
- Chandrasekhara Rao G (1991). Lakshadweep: General features. In: State Fauna Series No. 2, Fauna of Lakshadweep. Publ. Dir. Zool. Surv. India, Kolkata. pp. 1-144.
- CMFRI (2019). Annual report, 2018-19. Central Mar. Fish. Res. Inst. Kochi. pp. 320.
- Darwin Ch, Padmavathi P, Srinu G (2018). DNA divergence and genetic relatedness of *Epinephelus* species (Perciformes:Serranidae) of Indian waters inferred from *COI* sequence data. In: P. Vijaya Nirmala (ed.). Recent Trends Appl. Biol., (Adikavi Nannaya University, Rajamahendravaram, A.P., India). pp. 3-16.
- Deepti VA, Shrikanya KVL, Sujatha K (2014). Taxonomic studies and phylogenetic relationship of seven spotted groupers species of genus *Epinephelus* (Pisces: Serranidae) off Visakhapatnam, middle east coast of India. Indian J. Geo-Mar. Sci., 43(12): 2254-2268.
- FAO (Food and Agriculture Organization) (2016). The state of world fisheries and aquaculture-contributing to food security and nutrition for all. Rome. pp. 1-200.
- Froese R, Pauly D (2019). Fish Base. World Wide Web electronic publication. www.fishbase.org, version (12/2019).
- Gibinkumar TR, Sabu S, Pravin P, Boopendranath MR (2012). Bycatch characterization of shrimp trawl landings off southwest coast of India. Fish. Technol., 49: 132-140.
- Gopi KC, Mishra SS (2015). Diversity of marine fish of India. In: K. Venkataraman and C. Sivaperuman (eds). Marine Faunal Diversity in India. Taxonomy, Ecology and Conservation. Acad. Press, Elsevier Inc., USA. pp. 172-191. https://doi.

org/10.1016/B978-0-12-801948-1.00012-4
- Govindan S, Ravichandran R (2016). Fish fauna diversity and conservation status of Pulicat Lagoon in Tamil Nadu. Ann. Aquact. Res., 3(2): 1018.
- Heemstra PC, Randall JE (1993). Groupers of the world. In: FAO species catalogue. Groupers of the world (Family Serranidae, Subfamily Epinephelinae). An annotated and illustrated catalogue of the grouper, rockcod, hind, coral grouper and lyretail species known to date, (Rome: FAO Fisheries Synopsis). pp. 382.
- James PSBR, Lazarus S, Arumugam G (1994). Present status of 'major perch' fisheries in India. Bull. Cent. Mar. Fish. Res. Inst., 47: 1-9.
- Jawahar P, Brucelee G, Umamaheswari T (2013). Marine ornamental ichthyofauna of Thoothukudi coast, Gulf of Mannar, India. J. Bombay Nat. Hist. Soc., 110(2): 156-162.
- Jayaprabha N, Purusothaman S, Srinivasan M (2018). Biodiversity of coral reef associated fishes along southeast coast of India. Reg. Stud. Mar. Sci., 18: 97-105. https://doi.org/10.1016/j.rsma.2017.12.010
- Joshi A, Parmar EAR, Temkar GS, Desai AY, Bhatt AJ (2018). Ichthyofaunal Biodiversity of Kharakuva Fish Market, Veraval, Gujarat, India. Int. J. Bio-resource Stress Manage., 9(5): 596-605. https://doi.org/10.23910/IJBSM/2018.9.5.1902
- Joshi KK, Sreeram MP, Zacharia PU, Abdussamad EM, Varghese M, Habeeb Mohammed OM, Jayabalan K, Kanthan KP, Kannan K, Sreekumar KM, George G (2016). Check list of fishes of the Gulf of Mannar ecosystem, Tamil Nadu, India. J. Mar. Biol. Ass. India, 58(1): 34-54. https://doi.org/10.6024/jmbai.2016.58.1.1895-05
- Kar A, Raut SK, Bhattacharya M, Patra S, Das BK, Patra BC (2017). Marine fishes of West Bengal coast, India: Diversity and conservation preclusion. Reg. Stud. Mar. Sci., 1(16): 56-66. https://doi.org/10.1016/j.rsma.2017.08.009
- Karuppasamy K (2016). Biodiversity of fish species along Wadge Bank, South India. Thesis (M.F.Sc.), Fisheries Training and Research Centre, Parakkai, Tamil Nadu Fisheries University, Tamil Nadu. http://krishikosh.egranth.ac.in/handle/1/5810013496
- Kirubasankar R, Dam Roy S, George G, Sarma K, Krishnan P, Ramkumar S, Kaliyamoorthy M, Goutham Bharathi MP (2013). Fishery and exploitation of Malabar grouper, *Epinephelus malabaricus* (Bloch and Schneider 1801) from Andaman Islands. Asian Fish. Sci. 26: 167-75.
- Krishnan S, Mishra SS, Prabhakar D (2007). Fishes In: K. Venkataraman. Fauna of Chennai Coast, Marine Ecosystems Series, 1, Publ. Dir. Zool. Surv. India, Kolkata. pp. 1-294.
- Kumar JY, Geetha S, Sornaraj R (2013). Diversity and distribution of reef fishes in Gulf of Mannar islands, India. In: K. Venkataraman, Sivaperuman, C. Raghunathan (eds). Ecol. Conserv. Trop. Mar. Faunal Commun., Springer, Berlin, Heidelberg. pp. 297-310. https://doi.org/10.1007/978-3-642-38200-0_19
- Kumar TA, Vinoth R, Prakash S, Balasubramanian T (2012). Reef fishes of the Lakshadweep archipelago. Publ. Dir. Zool. Surv. India, Kolkata. pp. 1-180.
- Mahesh V, Benakappa S, Dineshbabu AP, Anjanayappa HN, Kumar Naik AS, Vijaykumar ME, Somasekara SR, Kumar J (2014). Finfish constituents of trawl low value by-catch off Mangalore. J. Exp. Zool. India. 17(2): 479-85.
- Manojkumar PP, Ranjith L, Karuppasamy K, Kanthan KP (2019). Fishery and population dynamics of *Epinephelus malabaricus* (Bloch and Schneider, 1801) off Tuticorin, southeast coast of India. J. Mar. Biol. Ass. India, 61(1): 26-30. https://doi.org/10.6024/jmbai.2019.61.1.2072-03
- Mishra SS, Krishnan S (2003). Marine Fishes of Pondichery and Karaikal. Rec. Zool. Surv. India Occ. Pap., 216: 1-52.
- Mogalekar HS, Canciyal J, Jawahar P, Patadiya DS, Sudhan C, Pavinkumar P, Santhoshkumar S, Subburaj A (2017). Estuarine fish diversity of Tamil Nadu, India. Indian J. Mar. Sci. 46(10): 1968-1985.
- Mohanty R, Mohapatra A, Mohanty S, Mishra S, Khan M, Pattnaik A (2015). Ichthyofaunal diversity of Chilika Lake, Odisha, India: An inventory, assessment of biodiversity status and comprehensive systematic checklist (1916-2014). Check List., 11(6): 1817. https://doi.org/10.15560/11.6.1817
- Morris AV, Roberts CM, Hawkins JP (2000). The threatened status of groupers (Epinephelinae). Biodivers. Conserv., 9(7): 919-942. https://doi.org/10.1023/A:1008996002822
- Murty VS (2001). Ornamental fish resources of Lakshadweep. Geol. Surv. Ind. Spl. Pub., 56: 103-111.
- Noikotr K, Chaveerach A, Pinthong K, Tanomtong A, Sudmoon R, Tanee T (2013). RAPD and barcode analyses of groupers of the genus *Epinephelus*. Genet. Mol. Res., 12(4): 5721-5732. https://doi.org/10.4238/2013.November.18.21
- Ottolenghi F, Silvestri C, Giordano P, Lovatelli A, New MB (2004). The Fattening of Eels, Groupers, Tunas and Yellowtails. Capture-based Aquaculture. Rome, FAO. 308. The fattening of eels, groupers, tunas and yellowtails. Captured-based aquaculture. Rome, FAO. pp. 308. https://doi.org/10.1002/aqc.840
- Pierre S, Gaillard S, Prévot-D'Alvise N, Aubert J, Rostaing-Capaillon O, Leung-Tack D, Grillasca JP (2008). Grouper aquaculture: Asian success and Mediterranean trials. Aquat. Conserv. Mar. Freshw. Ecosyst., 18(3): 297-308.
- Pokapunt W, Sirimontraporn P, Bussarawit S (1993). Serranid fishes (family Serranidae: subfamily Epinephelinae) from the Andaman Sea. Phuket mar. biol. Cent. Res. Bull., 12: 97-122.
- Rajan PT (2001). A field guide to Grouper and Snapper Fishes of Andaman and Nicobar Islands. Publ. Dir. Zool. Surv. India, Kolkata. pp. 1-103.
- Rajan PT (2015). New Record of Two Species of *Epinephelus* (Perciformes: Serranidae: Epinephelinae) from Andaman Islands, India. Rec. Zool. Surv. India.115(4): 321-323.
- Rajan PT, Sreeraj CR, Immanuel TI (2013). Fishes of Andaman and Nicobar Islands: A checklist. J. Andaman Sci. Assoc., 18(1): 47-87.
- Ramaiyan V, Purushothaman A, Natarajan R (1987). Check-list of estuarine and marine fishes of Parangipettai (Porto Novo) coastal waters. Matsya. 12: 1-19.
- Ramakrishna, Immanuel T, Sreeraj CR, Raghunathan C, Raghuraman R, Rajan PT, Yogesh Kumar 1S (2010). An account of additions to the Ichthyofauna of Andaman and Nicobar Islands. Rec. Zool. Surv. India, Occ. Paper. Publ. Dir. Zool. Surv. India, Kolkata. 326: 1-140.
- Ramesh R, Nammalwar P, Gowri VS (2008). Database on coastal information of Tamilnadu. Institute for Ocean Management, Anna University, Chennai. ENVIS, Dep. Environ. Gov. Tamilnadu, Chennai. pp. 133.
- Ramu S, Anandaraj T, Elaiyaraja C, Panneerselvam A (2015). Check list of marine fish from Nagapattinam coastal waters, south east coast of India. Int. J. Fish. Aquat. Stud., 2(6): 193-197.
- Rao DV (2009). Checklist of fishes of Andaman and Nicobar

Islands, Bay of Bengal. Environ. Ecol., 27(1A): 334-353.
- Ray D, Mohapatra A (2020). First report of ten grouper species (Serranidae: Epinephelinae) from the West Bengal coast, along the east coast of India. Indian J. Mar. Sci., 49(01): 108-117
- Robert DS, Lazarus S (2006). Groupers and Wrasses of Minicoy Island, Lakshadweep, India. Newsl. Groupers Wrasses Spec. Group. 9: 3-6.
- Roy TS, Gopalakrishnan A (2011). Identification of groupers based on pyloric caeca differentiation. J. Fish Biol., 79(5): 1334-1339. https://doi.org/10.1111/j.1095-8649.2011.03089.x
- Sadovy de Mitcheson Y, Craig MT, Bertoncini AA, Carpenter KE, Cheung WW, Choat JH, Cornish AS, Fennessy ST, Ferreira BP, Heemstra PC, Liu M (2013). Fishing groupers towards extinction: a global assessment of threats and extinction risks in a billion dollar fishery. Fish Fish. 14(2): 119-136. https://doi.org/10.1111/j.1467-2979.2011.00455.x
- Sambandamoorthy P, Nagamuthu J, Arumugam S, Perumal M (2015). Diversity and trophic level of ichthyofauna associated with the trawl bycatches of Cuddalore and Parangipettai, south-east coast of India. Mar. Biodivers. Rec., pp. 8. https://doi.org/10.1017/S1755267215000159
- Sen S, Dash G, Bharadiya SA (2019). First record of longspine grouper, *Epinephelus longispinis* (Kner, 1864) from Gujarat, North-West Coast of India. Thalassas: Int. J. Mar. Sci., 35(1): 287-289. https://doi.org/10.1007/s41208-019-0121-6
- Serajuddin M, Bano F, Awasthi M, Gupta P, Kumar G (2018). Marine Stock Enhancement in India: Current Status and Future Prospects. Marine Ecology-Biotic and Abiotic Interactions, Intech. Open, 1: 175-195. https://doi.org/10.5772/intechopen.75175
- Sluka RD (2013). Coastal marine fish biodiversity along the western coast of India. J. Threat. Taxa. 5(1): 3574-3579. https://doi.org/10.11609/JoTT.o3187.118
- Sluka RD, Lazarus S (2010). Grouper (Pisces: Serranidae) relative abundance and diversity on the west coast of India. Mar. Biodivers. Rec., pp. 3. https://doi.org/10.1017/S1755267210000606
- Spalding MD, Fox HE, Allen GR, Davidson N, Ferdaña ZA, Finlayson MA, Halpern BS, Jorge MA, Lombana AL, Lourie SA, Martin KD (2007). Marine ecoregions of the world: a bioregionalization of coastal and shelf areas. BioScience, 57(7): 573-583. https://doi.org/10.1641/B570707
- Sreedhar U, Prakash RR, Rajeswari G (2010). Present scenario of the coastal and deepwater trawl resources of southeast coast of India. In: B. Meenakumari, M.R. Boopendranath, L. Edwin, T.V. Sankar, N. Gopal and G. Ninan (eds), Proceedings of the coastal fishery resources of India: Conservation and sustainable utilisation. Soc. Fish. Technol., India, Cochin. pp. 1-13
- Subba Rao NV, Sastry DRK (2005). Fauna of marine national park, gulf of Kuchchh, Gujarat. Publ. Dir. Zool. Surv. India, Kolkata. pp. 1-79.
- Sujatha K (2004). Groupers off Visakhapatnam, North east coast of India. J. Mar. Biol. Ass. India. 46(1): 87-92.
- Sujatha K, Shrikanya KV, Iswarya Deepti VA (2015). Species diversity and some aspects of reproductive biology and life history of groupers (Pisces: Serranidae: Epinephelinae) off the central eastern coast of India. Mar. Biol. Res., 11(1): 18-33. https://doi.org/10.1080/17451000.2014.949271
- Varghese M, Gandhi A (2019). Diversity of reef associated fishes in hook and line fishery at Mandapam, Gulf of Mannar, south-east coast of India. Indian J. Fish. 66(2): 49-53. https://doi.org/10.21077/ijf.2019.66.2.82397-07
- Varghese M, Joshi KK (2017). Reef fish diversity of bottom set gillnet landings at Pamban, Tamil Nadu, India. Mar. Biol. Ass. India. 59(1): 14-18. https://doi.org/10.6024/jmbai.2017.59.1.1958-02
- Varghese M, Manisseri MK, Ramamoorthy N, Geetha PM, Thomas VJ, Gandhi A (2011). Coral reef fishes of Gulf of Mannar, SE of India. Fish. Chimes., 31(1): 38-40.
- Varghese M, Ranjith L, Joshi KK (2017). Diversity of reef fishes in trap fishery at Keelakarai, Gulf of Mannar, south-east coast of India. Indian J. Fish., 64(1): 23-30. https://doi.org/10.21077/ijf.2017.64.1.53263-04
- Vincent ACJ (2006). Live food and non-food fisheries on coral reefs, and their potential management. Conserv. Biol., 13: 183. https://doi.org/10.1017/CBO9780511804472.008
- Yennawar P, Mohapatra A, Ray D, Tudu P (2015). Ichthyofauna of Digha Coast, India. In: K. Venkataraman and C. Sivaperuman (eds), Marine faunal diversity in India: Taxonomy, ecology and conservation, Academic Press, USA. pp. 235. https://doi.org/10.1016/B978-0-12-801948-1.00015-X
- Yennawar P, Mohapatra A, Tudu PC (2017). An account of ichthyofauna of Digha coast, West Bengal. Rec. Zool. Surv. *India,* 117(1): 4-21. https://doi.org/10.26515/rzsi/v117/i1/2017/117289
- Yennawar P, Tudu P, Mohapatra A (2011). Occurrence of three red listed species of *Epinephelus* (Perciformes: Serranidae) on Digha coast, India. J. Threat. Taxa., 3(10): 2150-2152. https://doi.org/10.11609/JoTT.o2641.2150-2