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Srivastava et al - Mapping Indian inland fish diversity using historical occurrence data (447-464)

Mapping Indian inland fish diversity using historical occurrence data in FishBase

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Abstract

Fish museums across the world are a repository of historical data on fish abundance and occurrence. These occurrence points when mapped provide a picture of present-day and earlier fish distribution. The accuracy of the map will depend on how exhaustive the museum collection is for the area, and also on the museums' collection practices (comprehensive-ness and survey design). FishBase 2000, a structured database on finfishes developed by the World Fish Centre, Malaysia (formerly known

as ICLARM-The World Fish Centre), contains more than 3500 data sets on the occurrence point of over 300 inland fishes of India. The occurrence information in the FishBase that covers a wide temporal range (1816 to 1998) has been compiled from seven museums external to India. Due to heterogeneity in source and period, most of the location names were not standardized and there was a need to relate these with the names in use presently. To identify all the names, a methodology was developed to assign the co-ordinates to all the occurrence points using different geo-registered base maps, old maps of India and information compiled from websites using a specific search strategy. With the mapping of all the occurrence points, it was possible to list the fish species found within individual broad political and geographical regions of India using Arc View 3.1 software. Different ecological areas were identified from different parts of India to compare the regions based on fish species composition and to see the effectiveness of the database at fine and coarse scales. The database was also compared with some other reports to assess its accuracy. The present study has indicated that it would be possible to extrapolate the museum occurrence data compiled in FishBase into distribution, provided occurrence points could be validated and enriched by additional data sets. However, lack of base maps and habitat information for the fish concerned were the limiting factors.

Key words

database, distribution, FishBase, mapping, museum, species.

1. Introduction

There has been drastic decline in the number of fish species, particularly the freshwater fishes, which are 10 times more likely to be threatened than their marine and brackish water counterparts (Froese and Torres, 1999). Creating a fish germplasm conservation program requires knowledge of the species status (threatened and endangered) and their distribution. Mapping the fish collections and estimating potential distribution is important to conservation efforts. Preparation requires sufficient data on the occurrence of the fish species, because the species' abundance and distribution tend to be linked with the number of sites they occupy (Gaston *et al.*, 2000). Once the occurrence data are mapped, fish distribution can be extrapolated using watershed and elevation data to give a spatial distribution for a species. This would allow development of hypotheses about the relationship between a particular fish species distribution and different physiographic features.

One approach of detecting the decline in species numbers and distribution focuses on estimating the change (in terms of presence and absence) of species based on comparison between the historical data lying in museums across the world and the data obtained from current surveys and literature (Shaffer *et al.*, 1998). Collectively museums across the world hold a huge repository of information. Edwards *et al.*, (2000) suggested that about 3 billion (i.e. 3 X 10^9) specimens of all organisms are held in different natural history collections. For fish, the estimated number of specimens is over 10 million (3.8 million specimens in North American Museums, 7-8 million in European museums and an unknown amount of information in Australian and South African museums) (Poss and Collette, 1995; Kottelat *et al.*, 1993).

Several workers have attempted the coarse scale mapping of the fish distribution information (in terms of presence/absence and abundance) using secondary data sources like natural history collections and literature (Solow, 1993; Burgman *et al.*, 1995; McCarthy, 1998; Shaffer *et al.*, 1998; Heino, 2001; Unmack, 2001). The simplest way to map fish species' distribution from these data sets will be to draw a line around the outermost occurrence points. However, since these data sets are collected opportunistically, without any well-defined sampling design, extrapolation of such information must be supported with correlates (such as habitat and other climatic conditions) with the species' distribution.

Such conventional modelling methods for these data sets have many limitations, so it will be important to test and develop intelligence-based models (neural networks and decision trees), which utilize the habitat and climatic information for improving the algorithms. The first attempt in this regard was done by Nix (1986), using bio-climatic modelling for the distribution and abundance of snakes, with the assumption that species' abundance is determined by climatic limits. However, in the case of fish, the historical events of geologic change and evolution must also be considered.

Geographical information systems (GIS) allow one to assess the influence of physiological and climatic characteristics on fish distribution. This information will provide managers with the tools to evaluate the importance of particular parameters on the distribution of fish. So there is an urgent need to develop a system having a geo-referenced database of fish and fish habitats. This method was evaluated using India as a case study. India has diverse aquatic flora and fauna, with about 2118 species of finfish reported; this includes 1360 marine, 238 brackish water, and 520 freshwater fish (Kapoor *et al.*, 2002).

The fish occurrence data for India were taken from FishBase(2002), which was compiled from different museums located across the world (Table 1). These data were mapped spatially based on the occurrence information provided with each specimen. For this, at first the series of base maps for India was prepared on different attributes, which directly and indirectly affect fish distribution. All the maps were geo-referenced with each other and were transformed to a common coordinate system (geographic) and datum (Indian); this allowed the overlaying of one map over another.

Table 1. List of museums having occurrence records.

	Museum	Locatio
1.	National Museum of Natural History	Washington, DC, USA
2.	California Academy of Sciences	San Francisco, California, USA
3.	Natural History Museum	London, UK
4.	Naturhistoriska Riksmuseet	Stockholm, Sweden
5.	Muséum National d'Histoire Naturelle	Paris, France
6.	Kobenhavns Universitet Zoologisk Museum	Copenhagen, Denmark
7.	Universität Hamburg, Zoologisches Institut und Museum	Hamburg, Germany

Because the database was compiled from information existing in museums, which is collected opportunistically without any well-designed sampling, such databases must be compared with some recently compiled reports and database. To meet this requirement, the database was compared with different reports like “Conservation Assessment and Management Plan (CAMP) report for the freshwater fish of India” (CAMP, 1998) and some reports on the fish diversity of different regions of India such as Western Ghat and the North-eastern region of India (Ponniah and Gopalakrishnan, 2000; Ponniah and Sarkar, 2000).

2. Materials and methods

2.1 Base maps used for the study

Different base maps as given below (2.1.1, 2.1.2, and 2.1.3) were used collectively to assign the coordinates to the fish occurrence information given in the FishBase.

2.1.1 Political map of India

To identify different locations of fish occurrence, the "Administrative Boundary Database of India (ABDB)" prepared by the Survey of India was used (ABDB, 1990).

2.1.2 Drainage Basin and Stream network map

The stream network and drainage basin map of India was downloaded from the U.S. Geological Survey (USGS) web site (USGS Hydro1K documentation, 2002). The Hydro1K is a geographic database on the stream network derived from GTOPO30, a global digital elevation model (DEM) with a horizontal grid spacing of approximately 1 km. The drainage basins are derived using the vector streamlines along with the flow direction layer. The map was further clipped to show the drainage basin of India and was then geo-registered. The different rivers were labelled using the Rivers map of India available at 1: 5 000 000 scales from the Survey of India.

2.1.3 Ecoregions

To identify the different major ecoregions of India, the ecoregions map (designed for terrestrial organisms) prepared for the whole world was utilized (Olson *et al*., 2001).

2.2 Fish occurrence data obtained from FishBase

For arranging the fish occurrence data, information was extracted from FishBase, a web-based database that covers over 25 000 species of fish known to science (FishBase, 2002). In total, FishBase contains over 630 000 records for 19 000 species. However, for the inland region of India, there were only 326 occurrence records on 127 species with coordinates and over 3 000 occurrence records on 337 species that were without coordinates. Effort was made to assign coordinates to all the occurrence data based on different base maps prepared for India. Since the information is mainly collected from museums, many location names were old and the same place is often reported under different names

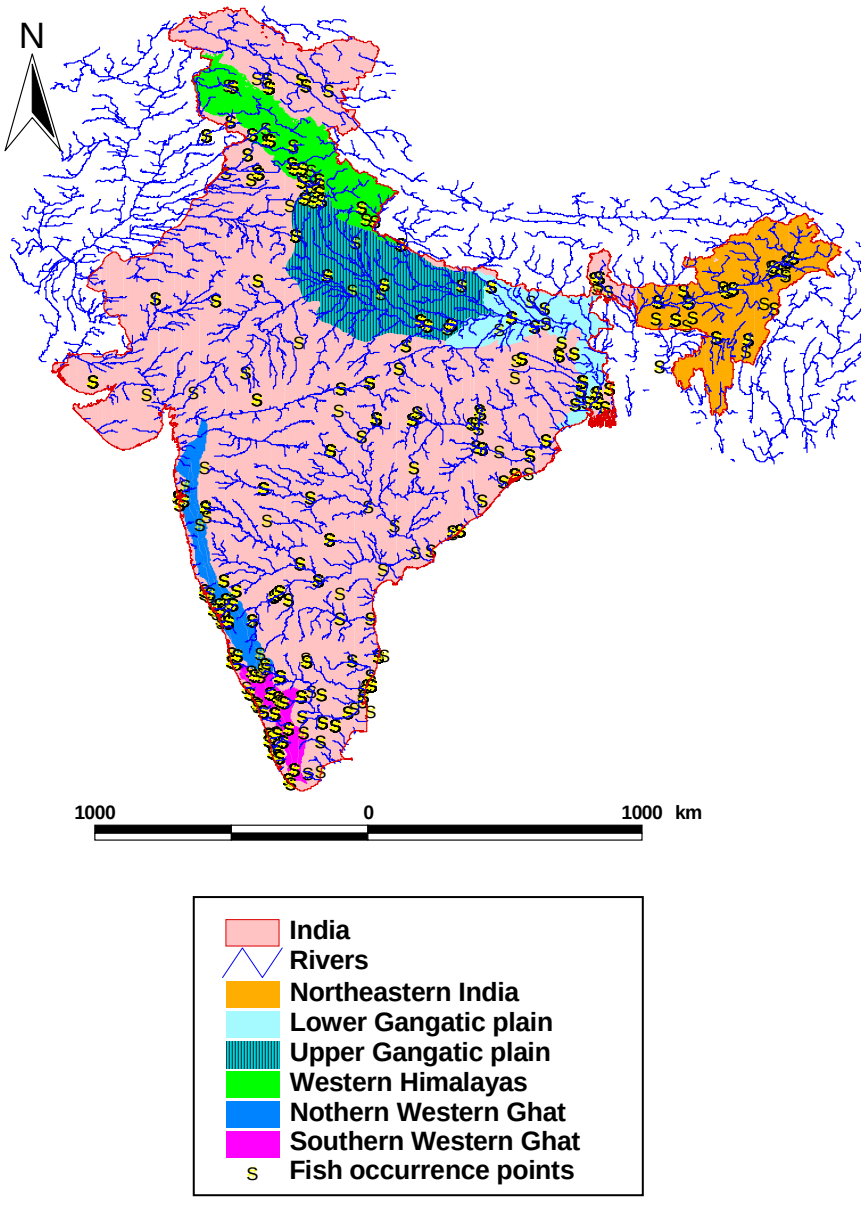
(synonyms like Kozhikode and Calicut), and spellings (e.g. Pune, Poonah and Poona; similarly Guwahati was spelled as Gauhati, Gouhati and Gowhatty). The occurrence information (i.e. new/old name of the place) was reported in one or two of the following types: district, city/town, village, region (hill ranges, coast, river basin etc.), and name of the water body Since the information was given usually in a combination of two or more location names (like Ganga River at Calcutta) it was easier to confirm the location. To locate each occurrence point on map the following sources were also utilized in addition to the sources mentioned in section 2.1:

- old map of India available on Internet (Maps of India, 2000);
- map of Indian districts with village-level information available on Internet (Maps of India, 2000);
- the global gazetteer web site having information on location of 2 880 532 of the world's cities and towns. (Global Gazetteer, 2001);
- the Hill Ranges and River map of India (Hill Ranges and River, 1990); and
- other hill ranges, rivers, forest, and tourist's maps of India available on Internet utilized using the Google search engine.

At first, all the occurrence data were arranged according to state, and each location name was searched for the above-mentioned sources. When more than one location name was given, the location was confirmed by searching for it from different sources of information (digital maps, internet sites etc.). For some data, when the distance and directions were given from a certain place, the occurrence point was located using the distance measurement module of the GIS software. After ascertaining the location of each point, the coordinates were assigned. For some generalized information indicated by state name or by the name of broad regions (up to state level), the centeroid of the region was determined using GIS software and coordinates were assigned accordingly. Finally, the coordinates were assigned to 2927 locations out of 3216 occurrence records; however, the coordinates were not assigned to other data as they were too generalized (the information was given as 'whole of India' or 'whole north India'). The analysis allowed 3253 occurrence records to be plotted with coordinates for India. All these coordinates were transformed into geographic locations with a database attached to it on a digital GIS map (Map 1).

2.3 Spatial and statistical analyses

To study fish distribution in the different zones of India, certain zones were identified and polygons of these regions were added to the map. These regions were: the Western Himalayas, the Gangatic plain, the



Map 1. Map showing the different identified regions along with the occurrence points and the drainage of India.

Western Ghat, and the Northeastern region. To study the effectiveness of the database at a smaller scale, the Gangatic plain was divided into the upper and lower Gangatic plain and the Western Ghat was divided into the northern and southern Western Ghat. The hierarchical cluster analysis of the species found in different geographic regions was carried out using the SPSS Ver. 10.0 software (Figure 1).

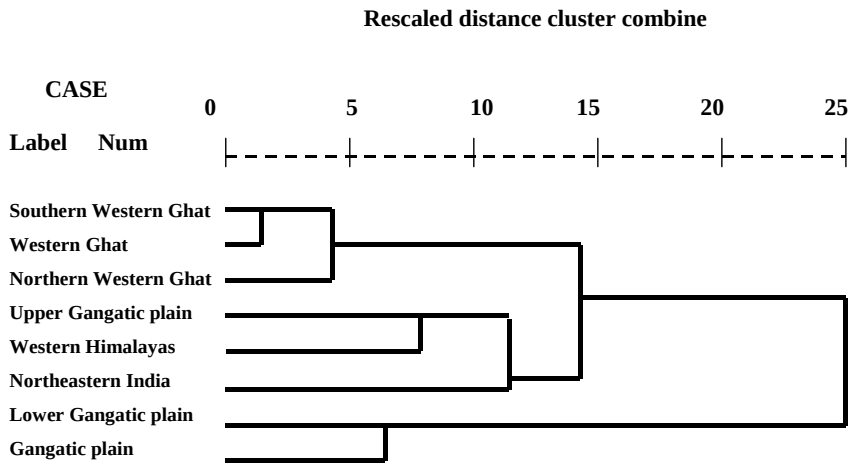


Figure 1. The clustering of different geographic regions of India based on the fish species' occurrence.

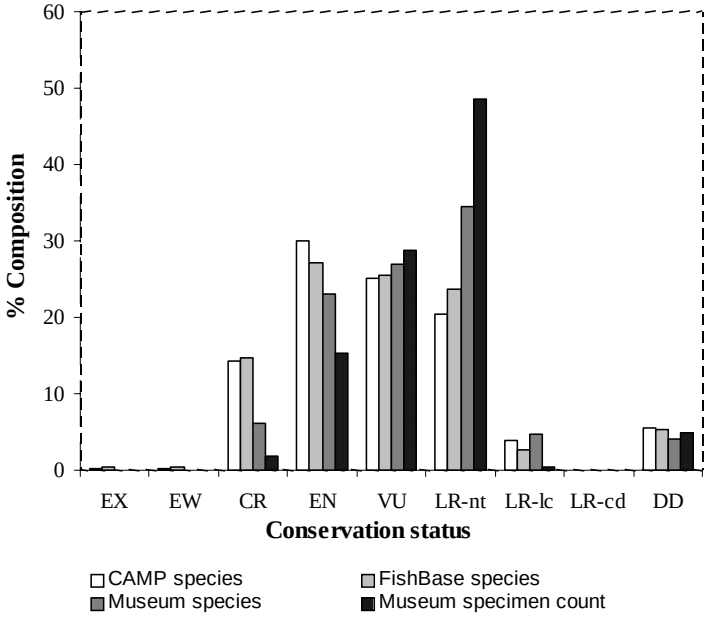
The elevation range for different fish species was calculated using the GTOPO 30 digital elevation model. The mean of cells falling within 50 km of the occurrence point was calculated using the ArcInfo software and was tabulated for all the occurrence points. The elevation range, watershed, and final distribution maps were prepared using the Spatial Analyst module of the ArcView software.

2.4 Other data sets

Conservation Assessment and Management Plan (CAMP) report for the freshwater fish of India (CAMP, 1998) was based on expert consultation involving fishery and taxonomic experts from different parts of India. Based on information compiled by NBFGR, the conservation status of 224 fish species were assessed based on IUCN criteria (IUCN, 2001).

The reports on the fish diversity of different regions of India, such as the Western Ghat and the Northeastern region of India (Ponniah and Gopalakrishnan, 2000; Ponniah and Sarkar, 2000) were produced in workshops organized by NBFGR in which fishery and taxonomic experts from these regions examined and evaluated the information compiled from studies carried out in these regions.

To analyze the relative coverage of freshwater fish species of different conservation status, the total number of species in the following sources was compared: FishBase, species records of museums from which FishBase had incorporated the data, and the species covered in the CAMP workshop (Figure 2). Further, the total number of specimen for each species held in different museum was also compared (Museum count - Figure 2).



EX : Extinct
EW : Extinct in the Wild
CR : Critically Endangered
EN : Endangered
VU : Vulnerable
LR-nt : Lower Risk - near threatened
LR-lc : Lower Risk - least concern
LR-CD : Lower Risk - conservation dependent
DD : Date Deficient

Figure 2. Composition of fish species of different conservation status in different databases.

3. Results and discussion

3.1 Fish diversity map

The 3253 occurrence points provided sufficient information on the distribution of Indian fish after mapping and it was possible to identify the diversity of fish according to eco-region, river basin and political boundary at a coarse scale. The fish biodiversity for each region was compared and is presented in Table 2. The data covered a wide temporal range (1816 to 1998), but no temporal analyses were performed, as the number of occurrence points for each species was limited. Among the identified region, the lower Gangatic plain exhibited the maximum number of the fish species; this is mostly attributed to high stream order of the river Ganga and the presence of estuarine conditions. The Western Ghat region showed the maximum number of fish species per unit area.

Table 2. Summary of information extracted from the maps and the occurrence database.

	Upper Gangatic plain	Lower Gangatic plain	Gangatic plain	Northern Western Ghat	Southern Western Ghat	Western Ghat	North-eastern region	Western Himalayas	India
Number of family	22	31	31	18	20	23	28	20	40
Number of species	90	127	146	66	73	107	134	77	337
Native species	86	122	138	38	37	57	123	70	231
Endemic species	4	4	7	28	34	48	11	6	99
Introduced species	-	1	1	-	2	2	-	1	7
Number of occurrence points	229	402	631	13	183	296	389	205	3 253
Species (1000 km^2)	330.8	978.6	363.3	866	1 703.4	898.7	516.7	461.8	102.5
Family (1000 km^2)	80.9	238.9	77.1	236.2	466.7	193.1	107.9	119.9	12.2
Number of segments	181	128	310	35	21	57	157	81	-
Gradient mean (std. dev.)	0.000 8 (0.0018)	0.00068 (0.00123)	0.00077 (0.0016)	0.0014 (0.002)	0.0021 (0.0025)	0.0017 (0.002)	0.005 (0.0086)	0.013 (0.29)	-
Stream order mean (std. dev.)	2.2 (1.4)	2.2 (1.4)	2.2 (1.4)	1.31 (0.62)	1.18 (0.40)	1.3 (0.55)	2.04 (1.44)	1.60 (0.78)	-

The different eco-regions identified were clustered on the basis of the occurrence of different fish species; the result of analysis indicates (Figure 1) that the fish species composition of the upper Gangatic plain, Western Himalayas and North-eastern region form one group while the Western Ghat and the Lower Gangatic plain formed another group. The Lower Gangatic fish were different from those of the other regions mainly due to the presence of estuarine fish.

Further, to check the accuracy of the map, the fish composition information of the database was compared with different recently compiled reports. Very few compilations of fish species data at regional and national level exist. In most cases, the boundaries of the region are not well defined and different taxonomic classifications are followed. In the present study the museum database was compared with: (i) Conservation Assessment and Management Plan (CAMP) report, in which, out of 587 freshwater fish species of India, 327 fish were assessed for their conservation status (CAMP, 1998); and (ii) some compilations made by National Bureau of Fish Genetic Resources, Lucknow, India for the Western Ghat region (Ponniah and Gopalakrishnan, 2000) and the North-eastern region of India (Ponniah and Sarkar, 2000) on the fish diversity.

The FishBase database, which contains information on 622 freshwater fish of India and follows Eschmeyer's nomenclature (Eschmeyer, 1998), was compared with the CAMP report, which contains information on conservation status of 327 freshwater fish of India and follows Nelson's nomenclature (Nelson, 1994). Only 224 species were common in both the data sets. The mismatch of species in the two data sets was due to different taxonomic nomenclatures followed by the two data sets. This provided conservation status information on 148 fish species (with 1576 occurrence points) of the museum data set.

When the proportion of the different conservation status of species from FishBase was compared with species in the CAMP report, it was found to be similar. However, when the museum database was compared in the similar way, the proportion of critically endangered and endangered species was significantly lower and the proportion of species at lower risk was higher (Museum - Figure 2 and Table 3). This was further magnified when the proportion of the number of the occurrence points was taken into account (Museum count - Figure 2 and Table 3). This indicates that the number of threatened and endangered species is likely to be less in the database built from museum collections. In other words, a lower number of occurrence records from museums may indicate a critical conservation status of a fish. Several studies have indicated that the species declining in abundance often also tend to show a decline in the number of sites they occupy (Winters and Wheeler, 1985; Swain and Sinclair, 1994; Gaston *et al.*, 2000) and hence would be less likely to be represented in the museum collections.

Reference to the number of species for different regions varied in the literature: for the Western Ghat region, the number varied between 102 (Sehgal, 1999) and 287 (Shaji *et al.*, 2000). One possible reason for such variation might be lack of proper maps defining the boundaries of

the region, and often wider areas are included. As an example for the Western Ghat region, which does not have estuarine condition, brackish water species were included (Shaji *et al.*, 2000). The occurrence point mapped using the FishBase data indicated 107 fish species against the 287 species reported in the Western Ghat by Shaji *et al.,* (2000), and only two introduced species of the region were reported in FishBase out of 17 reported in the recent studies. For the Northeastern region of India, 134 fish species were reported; for the same region, Sen (2000) reported 267 fish species and Ghosh and Lipton (1982) reported only 172 species, while Kar (2003) reported 133 fish species in Barak River system in the same region. Therefore, when using the museum data, the information for a relatively smaller region like the Western Ghat resulted in fewer total species (almost one-third of the total fish species). This indicates the correspondence of FishBase data based with museum records was higher at the coarse scale. To make the museum data more effective at the finer level, the occurrence information needs to be enriched with the additional data sets and extrapolated to determine distribution data for each species.

Table 3. Chi-square test with respect to the CAMP species data.

	Number of fish	Chi-square value	d.f.	p value
FishBase species	224	1.31	7	0.988
Museum species	148	17.2	7	0.016
Museum count	1 576	60.8	7	0.000
CAMP species	327	-	-	-

3.2 Extrapolation of occurrence to distribution

The number of occurrence points for over 300 freshwater fish varied from 1 to 79, and for most of the species the number of occurrence points was fewer than 10 for the whole of India (Figure 3). As expected, it was easier to predict the distribution for the species with a higher number of occurrence points.

One way of extending an analysis of past and current distribution is to extrapolate the occurrence data to other areas, based on different climatic and physiographic parameters. In areas with a similar climate, elevation and hydrological conditions are likely to contain similar aquatic species composition unless they are subjected to some anthropogenic influence (dams, pollution etc.). The occurrence information for the fish *Tor khudree* (Sykes 1839) was extrapolated (Map 2) using two parameters – the elevation range, and the watershed of the occurrence. The elevation ranges of different species were extracted using the Arc Info software; the mean of minimum and maximum elevation points in the 50 km circular area around the each occurrence point was calculated (assuming that the fish will move at least within this area) and listed for some of the important fish species (Table 4). For extrapolating the occurrence points to the distribution, at first the occurrence points were overlaid over the watershed map and watershed of occurrence was selected. Thereafter the elevation range of the species was extracted using the Spatial Analyst module of the Arc View software. The two maps, watershed of occurrence, and the elevation range were combined to determine the distribution of the fish.

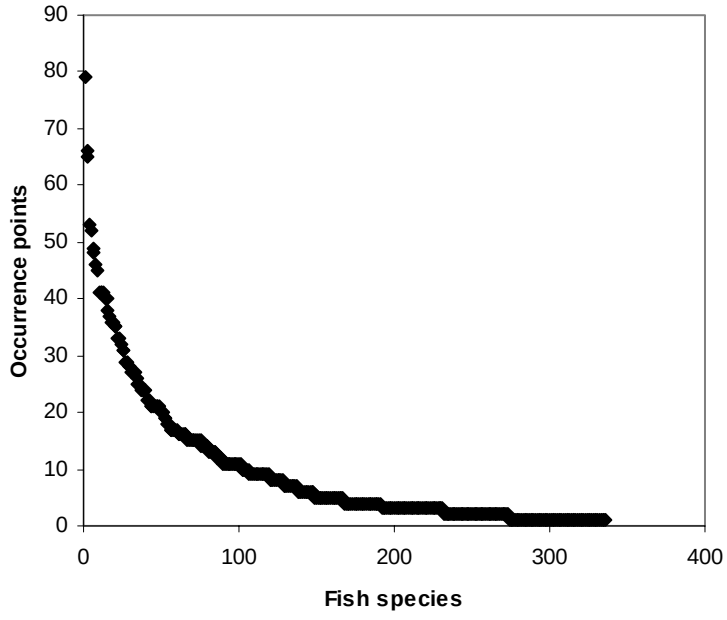


Figure 3. Graph showing the number of occurrence points for different fish species from museum data in FishBase.

The accuracy of the prepared map can be further enhanced by the addition of several other parameters like temperature range, riparian vegetation, and anthropogenic stress. However, the availability of base maps and habitat information for different fish species was the main limiting factor.

Table 4. Occurrence details from derived FishBase of some of the important fish species of India.

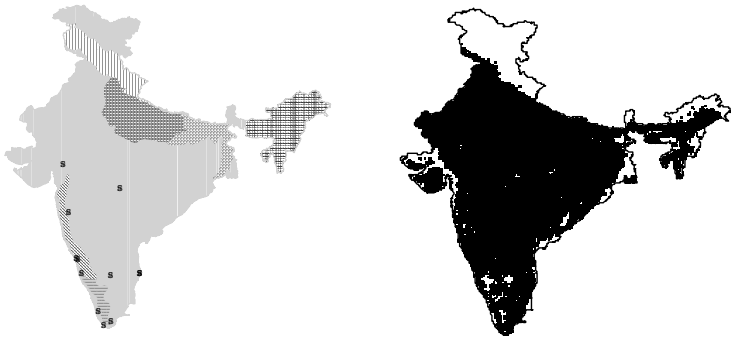
	Fish Species	Family	Counts	Elevation range (m)
1	Tor tor *(Hamilton, 1822)*	Cyprinidae	17	257-1446
2	*Tor khudree* (Sykes 1839)	Cyprinidae	12	31-856
3	*Tor putitora* (Hamilton, 1822)	Cyprinidae	15	442-2475
4	*Notopterus notopterus* (Pallas, 1769)	Notopteridae	33	9-1011
5	Labeo rohita *(Hamilton, 1822)*	Cyprinidae	21	7-298
6	*Heteropneustes fossilis* (Bloch, 1794)	Heteropneustidae	40	9-469
7	Catla catla *(Hamilton, 1822)*	Cyprinidae	13	9-407
8	*Clarias batrachus* (Linnaeus, 1758)	Clariidae	17	9-1011

4. Conclusion

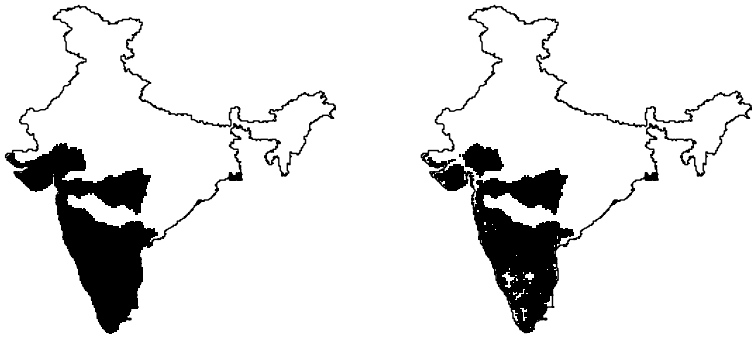
The occurrence map prepared from the occurrence points in the FishBase gave a good idea of the fish diversity for any region of India (political or geographical boundary); the fish diversity list can be prepared immediately at a coarse level. However, the use of such a map to extract information at the micro-level may be misleading. When the database was compared with some recently compiled reports, it was seen that the endangered species are more likely to be omitted from such a database, which are compiled from historical museum records, in comparison to the less threatened species. The information on the exotic species was not covered properly in such a database.

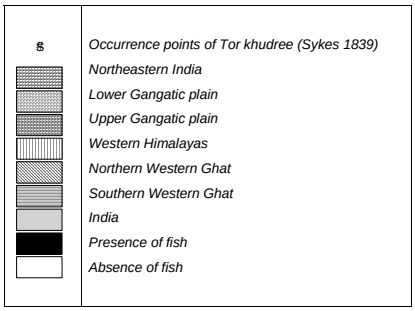
It is important to check each step of prediction with other data sets based on different scientific studies conducted at micro-level. Key components that will enhance the accuracy will be the availability of the data on habitat requirements of different fish species and the base map of the habitat-related parameters. With the application of intelligence-based modelling (such as neural networks, genetic algorithms and decision trees), it will be possible to extrapolate the occurrence information to distribution.

(a) (b)



(c) (d)





Map 2. The steps in extrapolation of Tor khudree (Sykes 1839) distribution. (a) T. khudree (Sykes 1839) occurrence point; (b) the elevation range for the fish; (c) the watershed in which the fish occur; (d) the combination of elevation and the watershed of occurrence.

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