Original Article

Journal of Aridland Agriculture 2015, 1: 43-54
http://scienceflora.org/journals/index.php/jaa/
doi: 10.19071/jaa.2015.v1.2669

Fish species richness and habitat quality mapping with geographical information system across Cauvery River in Tamil Nadu, India

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Received: 11.12.2015
Accepted: 31.12.2015
Published: 31.12.2015

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ABSTRACT

Geographical information system (GIS) is associated as an essential tool and as a part of natural resource management activities worldwide. Though GIS is receiving special attention in the field of hydrology, and the aquaculture management, their deployment for spatial decision support in this domain continues to be very slow. This situation is owing to a variety of constraints together with an absence of appreciation of the technology, restricted understanding of GIS principles and associated methodology, and inadequate structure commitment to confirm continuity of these spatial decision support tools. This paper addresses these constraints and includes the use of basic GIS techniques. Fish and water samples were collected and analyzed from seven sites along the Cauvery river basin, Tamil Nadu, India, and the results were incorporated into GIS platform. The section on GIS terminology addresses the two fundamental types of GIS (mapping and interpretative analysis) and discusses the aspects related to the visualization of outcomes. Spatial distribution maps were prepared for the above-analyzed parameters. Inverse distance weighting tool have been applied to express the results obtained from the study area.

KEY WORDS: Cauvery river, fish distribution, geographical information system, mapping, physico-chemical parameters

INTRODUCTION

The World's lakes, rivers, and ponds are probably the earth's most important freshwater resource with 2.5-3% available at present (Pimentel *et al.*, 2004). India is endowed with a large network of rivers, canals, tanks, ponds, reservoirs, and backwaters, which harbor a rich diversity of fishes contributing to 11% of the total fish species of the world (Shaji and Laladhas, 2013). Freshwater source from rivers and dams are used for irrigation, power generation, and generally for human consumption. Increasing human activities on lands, streams, and rivers changed the hydrological and ecological processes (Li *et al.*, 2001). Aquatic communities are largely adapted to unmodified habitats, and when the habitats are altered, the capability to support native aquatic community also gets altered (Eng *et al.*, 2013). In India, the traditional approach to wildlife conservation has been focused on the "charismatic" large vertebrates and their habitats (Redford *et al.*, 2011). This has involved the creation of sanctuaries or national parks for their protection. Since the Western Ghats contains many threatened and endemic species of fishes, there is an urgent need to consider their conservation (Raghavan *et al.*, 2015). Many of these species are under tremendous stress due to habitat changes and other human-induced impacts. There has no systematic effort to assess the status of such fishes, their distribution, and ecological requirements other than baseline inventory. However, such information is not sufficient enough to prepare specific conservation strategies. Sound management of aquatic resources needs an understanding the conditions of habitats, the extent of changes in habitats and the factors influencing the changes.

Fishes are important in river systems as they can serve as indicators of overall aquatic ecosystem health (Rapport, 1995; Li *et al.*, 2010) and also as a main source of food. Threats to fishes that can render species vulnerable or endangered can arise in several different ways, but not all of them are man-made habitat alteration, pollution, and over exploration (Ramirez-Llodra *et al.*, 2011). Cauvery basin is the source of water for an extensive irrigation system for five districts (Namakkal, Karur, Thanjavur, Tiruchirappalli, and Nagapattinam), which produces over 40% of the food crops and hydroelectric power in Tamil Nadu, India (Begum and Harikrishna, 2008; Begum *et al.*, 2009).

Global positioning system (GPS) is a space-based satellite navigation system that provides location and time information in all weather condition, anywhere on or near the earth, where there is an unobstructed line of sight or more GPS satellites (Bevis *et al.*, 1992; Mandl, 1997). GPS recover contains a computer that triangulates its own position by getting bearings from at least 3 satellites use between 24 and 32 medium earth orbit satellites that transmit microwave signals (Celik, 2015; Kadiyala *et al.*, 2015). Those satellites are under current use to positionize deforestation, river pollution, substratum habitat structure, fish faunal diversity, and interpolation (Machado, 2011). Herein, we have used geographical information systems (GIS) and remote sensing data for extracting the river drainage pattern, and fish diversity pattern.

GIS applications have not been limited to the geographic field but also been introduced in many other domains (Abler, 1993; Batty, 2002; Townsend and Walsh, 1996; Sancar, 2010; Goodchild and Haining, 2004; Anemone *et al.*, 2011; Murthy *et al.*, 2015). However, certain special applications require GIS software provided with high-performance capabilities for certain operations, including storage, retrieval, and processing of geospatial data. These requirements, in a conventional GIS, have increasingly led to bottlenecks in computational efficiency (Huang *et al.*, 2011; Diniz and Telles, 2006). The areas of basins studied mainly using GIS and Remote Sensing techniques in similar studies are of the range of a few hundred to a little over thousands sq.km, whereas the study area considered here is 81,155 km^2. Traditional techniques for determining channel width, depth, and cross-section area are time-consuming and may not be truly representative of the spatial variability within a watershed (Thirukumaran and Ramkumar, 2015; Jaganathan *et al.*, 2015; Venkatesan *et al.*, 2015).

In this study, fish and water samples were collected and analyzed, and the results were incorporated into GIS platform. Spatial distribution maps were prepared for all the analyzed parameters. Inverse distance weighting (IDW) tool was applied to express the results obtained from the study area. IDW is a very user-friendly tool which expresses the highest and lowest spotted study area according to the analyzed data input given. The IDW tools were mainly used with unknown value point fixed with concentrations level.

MATERIALS AND METHODS

Study Area

The Cauvery river rises from the Western Ghats in the Kodagu district of Karnataka, and the details of the area study were shown in Figures 1 and 2, Table 1. The Cauvery basin extends over States of Tamil Nadu, Karnataka, Kerala, and Union Territory of Puducherry draining an area of 81,155 km^2. Which is nearly 2.7% of the total geographical area of the country with a maximum length and width of about 560 km and 245 km. It lies between 75°27′ to 79°54′ E and 10°9′ to 13°30′ N.

Fish Collection and Identification

Fishes were collected using a cast net and dragnet from the stream and river (Figure 2). Care was taken not to damage the species while collecting the fishes. A total of 10 specimens (Figure 3) from each species were collected, and fishes were photographed before preservation. Further, the sampled fishes were preserved in 10% formalin for further taxonomic studies. The habitat characters were noted to know whether the color pattern of the fish is influencing by its habitat character. The specimens were tagged, and the reference numbers were given for further specimen identification. These identification parameters of the fish species was confirmed using (Talwar and Jhingran, 1991; Jayaram, 1999) and Fish Base (www.fishbase.org).

Habitat structure, Substratum analyses, and Stream fish Communities are estimated according to (Gorman and Karr, 1978; Armantrout, 1990; Manimekalan, 1998; Arunachalam, 2000). Along with, the habitat riparian zone, bank vegetation, land use, agricultural practices, and forestry operations have been taken into account for study area characterization.

Physico-chemical Analysis of the Water Quality at Sampling Sites

Water samples were collected from all the seven sampling stations during post-monsoon (June-July), in 2012-2013 at the depth of 10 cm. Water quality analyses such as pH, conductivity, turbidity, total dissolved solids (TDS),

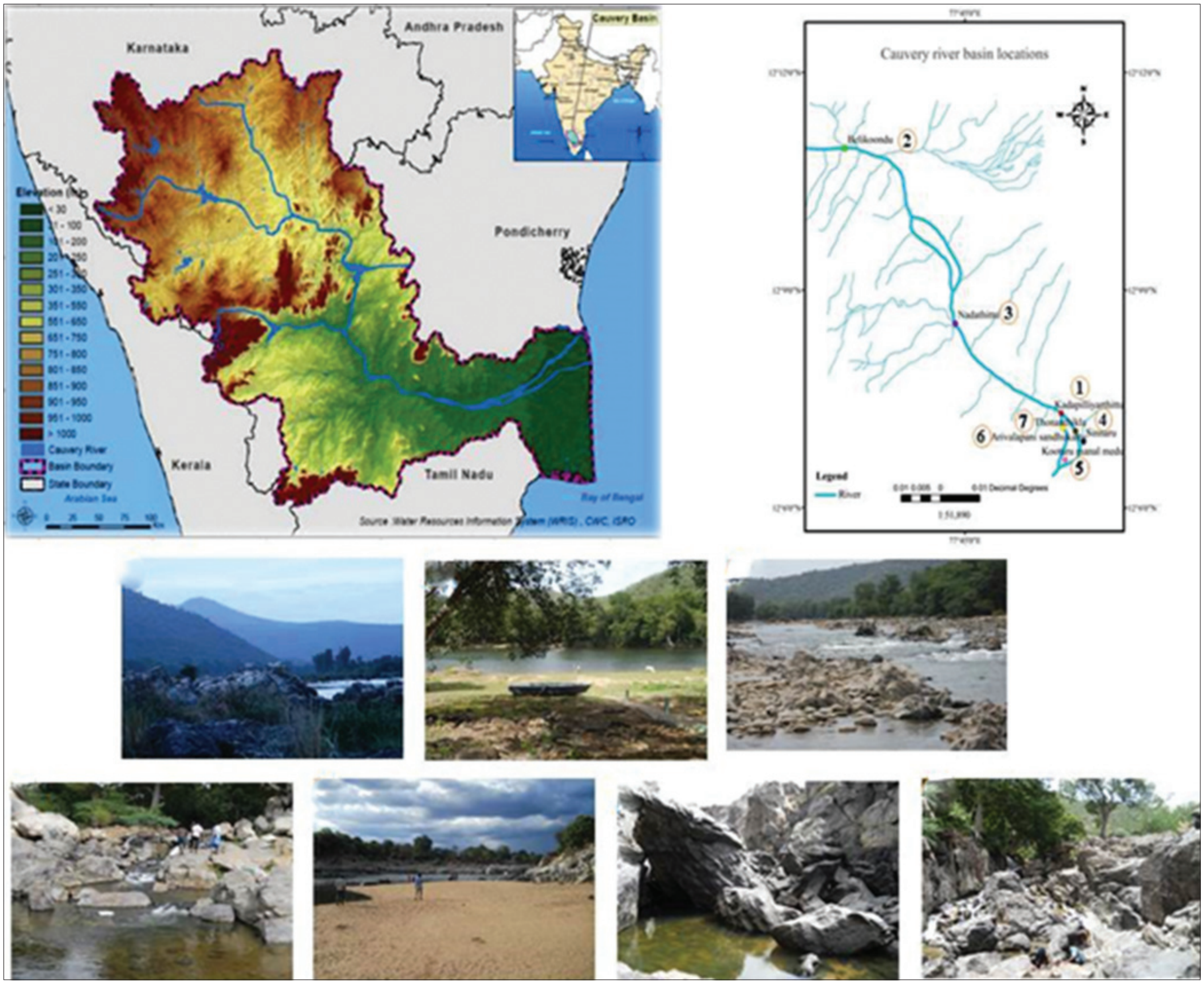

Figure 1: The geographical locations and the shoreline of sampling sites

Table 1: Geographical details of the sampling site

Name of collection site	Geographical location				Shoreline		
	Longitude	Latitude	Altitude	Pool cause	Riparian cover	Human impacts/pollution	Recreation
Kadapilliyarthittu (site 1)	77°46′28.3″ E	12°07′18.2″ N	310 (m)	Lateral scour	Medium level plantations	Anthropogenic activity, dynamite fishing	To promote tourism, work in progress
Belikoondu (site 2)	77°43′12.6″ E	12°11′02.1″ N	267 (m)	Trench	Medium level plantations	Dynamite fishing	No tourist site
Nadathittu (site 3)	77°44′49.0″ E	12°08′32.0″ N	262 (m)	Trench	Medium level plantations	Dynamite fishing	No tourist site
Sinnaru (site 4)	77°46′48.5″ E	12°06′54.8″ N	225 (m)	Trench	Medium level of plantations	No anthropogenic activity	No tourist site
Kootarumanalmedu (site 5)	12°06′41.3″ N	77°46′29.5″ E	303 (m)	Lateral scour	Low level plantations	Dynamite fishing and anthropogenic activity	Tourism destination
Arivalapanisandhukattu (site 6)	12°07′06.2″ N	77°46′29.2″ E	338 (m)	Falls	Low level plantations	Dynamite fishing and anthropogenic activity	No tourist site
Thonanthikla (site 7)	12°07′02.4″ N	77°46′36.7″ E	341 (m)	Falls	Very low level plantations	No anthropogenic activity	No tourist site

resistivity, salinity, dissolved oxygen (DO), and water temperature were done as per the regulations of APHA 1995, respectively. Field analysis of the samples was done using portable water analyzer (X tech, Nagman Instruments Electronics, India) (Gurumurthy and Tripti, 2015; Thomas *et al*., 2015; Anushiya and Ramachandran, 2015).

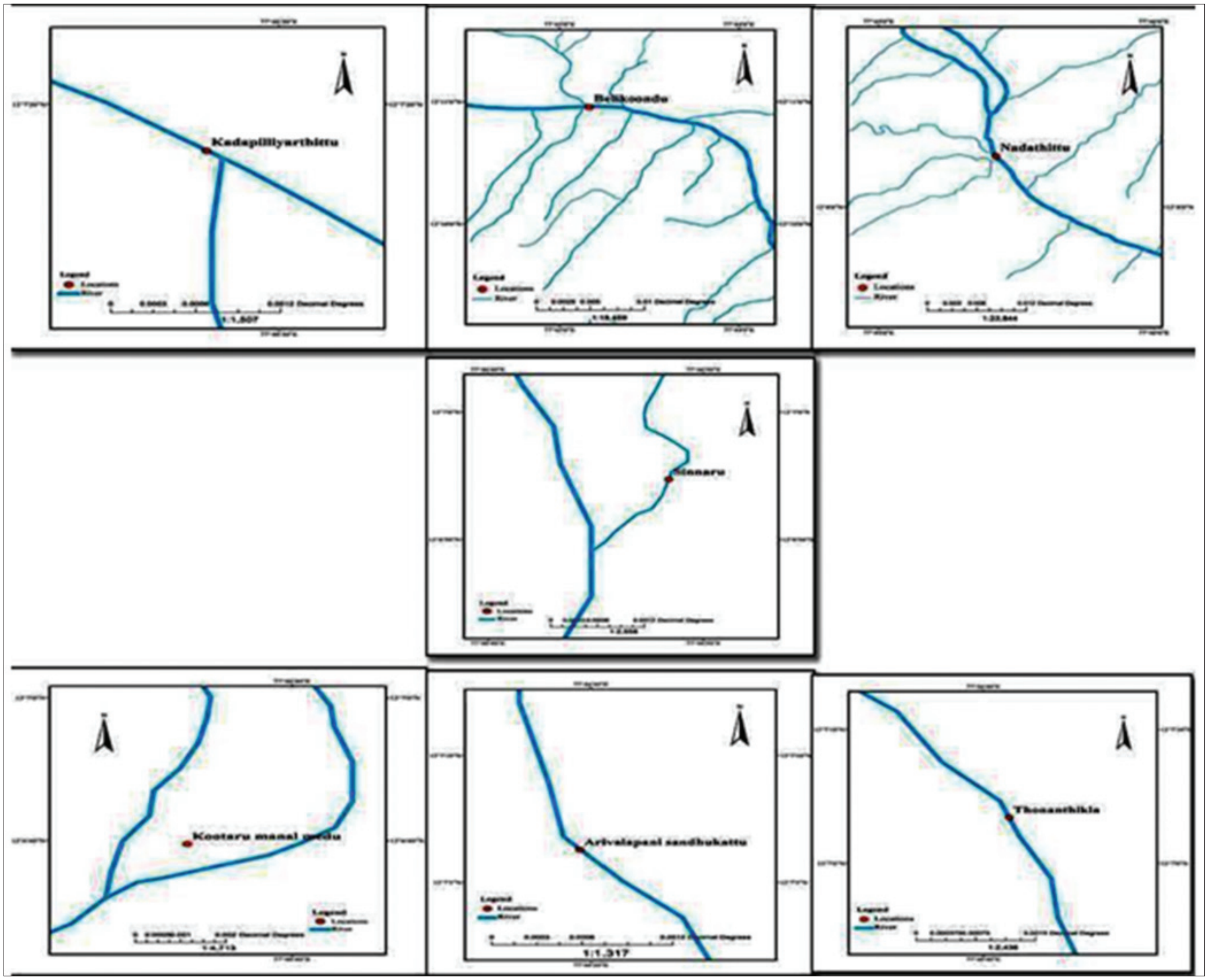

Figure 2: The representative map showing the typical study area

Application of GIS-based Models

Interpretative analysis

To quantify species diversity, for the purposes of comparison, a number of indices have been followed. To measure the species diversity (H) the most widely used Shannon index (Shannon and Weaver, 1949), Evenness index (E) (Pielou, 1975), and Dominance index (D) (Simpson, 1949) were used. Similarity coefficients of the fish community were calculated by using the widely used Jaccard index (Southwood, 1978). The above statistical analyses were performed using SPSS software.

Mapping analysis

The study area has been identified geographically, and the respective toposheet has been taken for digitization using the Arc GIS 9.3 version software. The water quality parameter, habitat characters, and fish diversity are cartographically displayed and the present status of the sampling sites has been characterized using IDW tool in Arc GIS 9.3 version software.

Data processing and analysis

Further, the data from different appropriate sources are coded and recorded into a database system. For the accuracy of the data recorded at every source of the survey, correspondence between elementary data sheets and the original coding sheets were considered; accuracy and quality of the data were inspected up, edited, and coded at the field level.

RESULTS AND DISCUSSION

Sampling Site Selection

The study area has been selected based on the previous work done on the species distribution record. The geographical locations and the shoreline date were shown

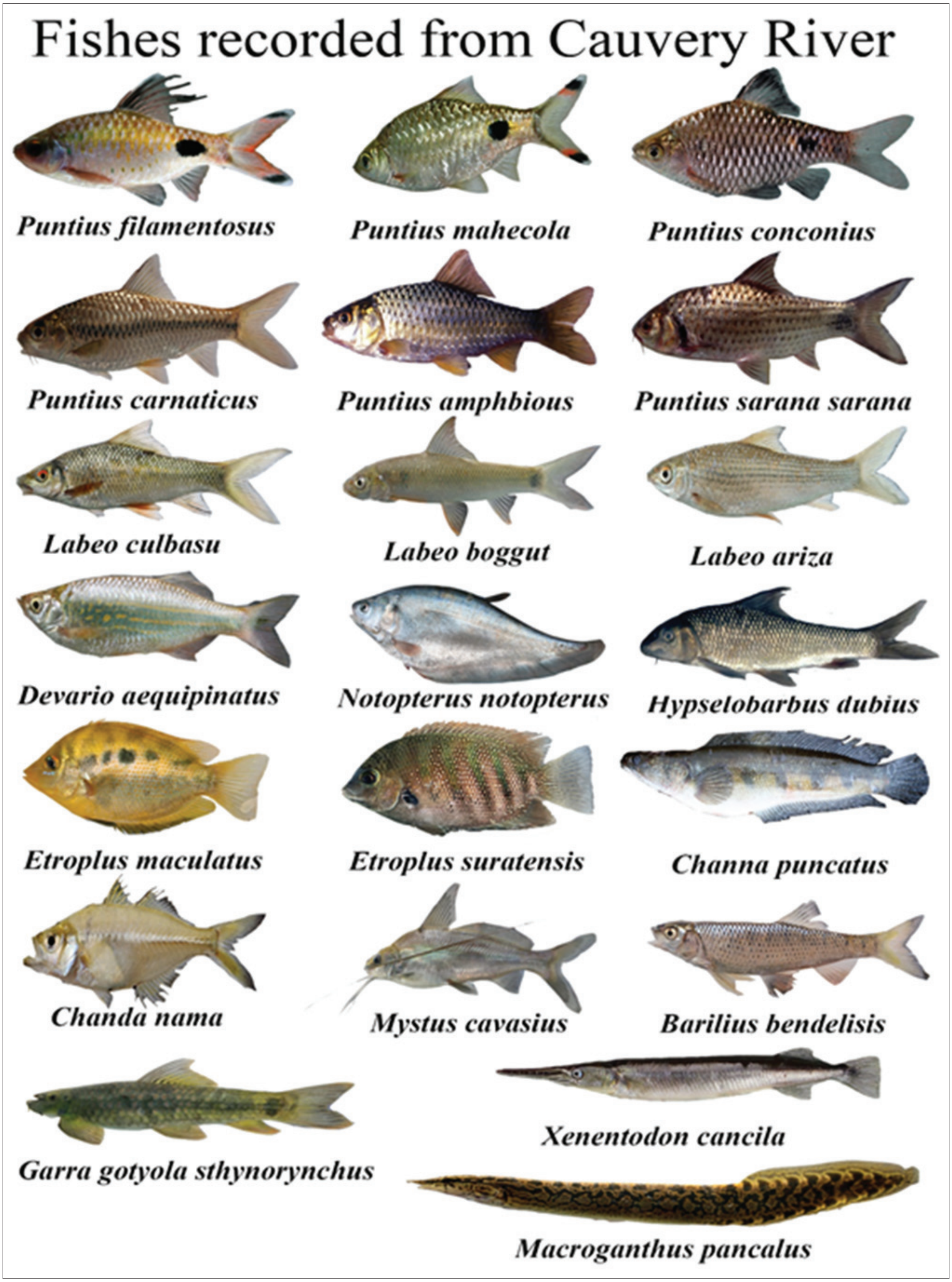

Figure 3: Various available fish diversity from Cauvery river and its representative images

in Table 1. The sampling sites were shown in Fig. 1, Kadapilliyarthittu (site 1), Belikoondu (site 2), Nadathittu (site 3), Sinnaru (site 4), Kootarumanalmedu (site 5), Arivalapanisandhukattu (site 6), and Thonanthikla (site 7).

Fish Species Density, Abundance, and Distribution

A total of 37 species were recorded from seven sampling sites during the present study in Cauvery river (Table 2 and Figure 3). Maximum species richness (S-21) was recorded with high diversity value in site 4 (H-0.95) and site 3 (H-0.92), and the minimum (S-4) species was recorded at site 5 (H-0.75). Species abundance was recorded high in site 3 (77), site 4 (75) and the least was recorded for site 2 (16) and site 5 (16). High Evenness value was noted in site 4 (E-1.26), site 3 (E-1.19) and the lowest was noted in site 5 (E-0.45). Maximum Dominance (D-0.408) was noted in site 5,

Table 2: Fish species density, abundance and distribution in in Cauvery river systems

Species	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Notopterus notopterus	0	0	0	0	3	0	0
Catla catla	0	0	0	0	0	0	0
Cirrhinus mirgala	0	0	0	0	0	0	0
Cirrhinus cirrhosus	0	0	0	6	0	0	2
Hypselobarbus dubius	0	1	3	3	0	0	0
Labeo boggut	0	0	0	0	0	0	1
Labeo kontius	0	0	0	0	0	0	2
Labeo ariza	1	0	0	1	0	0	2
Labeo calbasu	0	1	1	0	0	0	0
Puntius mahecola	4	3	3	0	0	0	0
Puntius conconius	10	1	3	4	0	0	0
Puntius carnaticus	4	0	9	5	0	0	2
Puntius filamentosus	0	0	5	2	0	0	5
Puntius sarana sarana	0	0	0	6	0	0	0
Puntius amphbious	0	0	0	2	0	0	0
Schematorynchus nuckta	0	0	0	3	0	0	0
Tor kudhree	0	0	2	3	0	0	4
Tor malabaricus	0	0	2	4	0	0	3
Salmostoma acinaces	0	0	4	0	10	0	0
Barilius bendelisis	2	0	3	3	0	2	0
Devario aequipinnatus	0	0	10	2	0	7	3
Rasbora danconius	0	0	2	7	0	0	5
Garra mullya	2	0	3	4	0	4	11
Garra gotyola stenorynchus	0	2	4	0	0	0	0
Lepidocephalus thermalis	0	0	7	0	0	0	0
Mystus cavasius	0	0	1	3	0	0	0
Mystus puncatus	0	0	0	1	0	0	2
Wallagu attu	0	0	0	0	0	0	0
Hyporhamphus limbatus	0	0	2	0	0	2	1
Xenetodon cancilia	0	0	2	2	0	3	2
Chanda nama	0	0	0	7	0	0	0
Etroplus suratensis	10	8	1	0	1	0	0
Etroplus maculatus	4	0	10	0	2	0	0
Glossogobius guiris	0	0	0	5	0	0	0
Channa punctatus	0	0	0	0	0	0	0
Macroganthus pancalus	0	0	0	2	0	0	0
Mastacembelus armatus	0	0	0	0	0	0	1

and lowest (D-0.09) was noted in site 7. The total fish species present in Grand Anicut Cauvery accounts to 24 species belonging to 18 genera and 13 families, out of 24 species 10 are cultivated and seven are ornamental fish species. Around 20% of the cultivated species and 75% of the ornamental fishes belong to the family Cyprinidae. Among several fish species recorded, the only *Garra gotyla stenorhynchus* is reordered as one of the endangered species in Grand Anicut Cauvery, which is locally consumed (Murthy *et al.*, 2015).

Physico-chemical Parameters

The water quality parameters have been entered in the Arc GIS database, and IDW tool has used the values were interpreted in the map format as discussed below. The negative log of the activity of the hydrogen ion (pH) in all the seven sampling sites was shown in Table 3 and Plate 1a. The pH is an important factor that determines the suitability of water for various purposes, including toxicity to animals and plants. In this study, sampling sites 1, 2, 3, 5, and 6 holds a measly pH of 9.1-9.6. The pH was found faintly alkaline; this may be the anthropogenic activity posing a decrease in pH range. The Sampling site 6 has lower pH 8.5, followed by sampling site 7 with pH 8.9. As per Indian standards, pH 6.5-8.5 is the desirable limit for river water. From the results, it was observed that the sampling site 4 and 7 had alkaline pH, and it is importable. In many sampling stations, pH was recorded above 8.5 exceeding the WHO permissible limit (6.5-8.5) (Narmada *et al.*, 2015).

Electrical conductivity (EC) of all the sampling sites were expressed in the table and in GIS map is shown in Table 3 and Plate 1b. The present study indicates the presence of significant amounts (soluble salts) of anions and cations in each sampling site. The EC was found to be minimum about 312 µmhos/cm at site 7 and maximum of 391 µmhos/cm at site 1. On observations, the other sampling sites 2, 3, 4, 5, and 6, the EC was found to be 355, 389, 321, 355, 355 µmhos/cm, respectively. This indicates that more number of ions might be present in the river basin (Dhanakumar *et al.*, 2015).

The TDS present in all the sampling sites and it is predicted GIS mapping was shown in Table 3 and Plate 1c. TDS is a measure of the solid materials dissolved in the river water. This includes salts, some organic materials, and a wide range of other materials from nutrients to toxic materials. In this study, TDS ranged from a minimum of 25 mg/L at site 1 to a maximum of 100 mg/L in site 7 during monsoon; and the minimum of 249 mg/L at site 7,

Table 3: Physio-chemical parameters of seven sampling sites

Location	pH	Conductivity (mS)	TDS (ppm)	Resistivity (KΩ)	DO (mg/L)	Salinity (ppt)	Water temperature (°C)
Kadapilliyarthittu	9.6	391	263	2.58	0.72	0.18	30.5
Belikoondu	9.1	355	265	2.59	0.33	0.11	31.3
Nadathittu	9.4	389	263	2.63	0.63	0.17	32.7
Sinnaru	9.2	385	259	2.52	0.11	0.21	30.2
Kootarumanalmedu	9.1	355	265	2.59	0.33	0.11	31.3
Arivalapanisandhukattu	8.5	321	269	2.55	0.43	0.16	31.5
Thonanthikla	8.9	312	249	2.65	0.55	0.19	30.4

TDS: Total dissolved solids, DO: Dissolved oxygen

to a maximum of 263 mg/L at sampling site 1 and 2. However, during post monsoon session the TDS ranged between 269 mg/L at site 6 and 259 mg/L at site 4. It is to be noted that the permissible limit of TDS is 200 mg/L and is important for all freshwater and marine organisms.

To assess the river water conditions, the survey for electrical resistivity was taken in all the sampling sites, and the values were shown in Table 3 and Plate 1d. Electrical resistivity also known as resistivity, specific electrical resistance, or volume resistivity, is an intrinsic property that quantifies how strongly a given material opposes the flow of electric current. The minimum resistivity value was recorded (2.52 KΩ) in the sampling site 4 and maximum resistivity value (2.65 KΩ) was recorded in the sampling site 7. The resistivity value for all other sampling sites 1, 2, 3, 5, and 6 are notably 2.58, 2.59, 2.63, 2.59, and 2.55 KΩ, respectively (Jayakumar *et al.*, 2015).

DO in samples was found in the range of 0.11-0.21 mg/L (Table 3). The average value of DO in river water ranged from 4.2 mg/l to 3.5 mg/L, which is acceptable when compared to the tolerance limit of 3 mg/L or higher as prescribed by the ISI: 2296-(1982) for Inland surface water subject to pollution (Balagurunathan and Shanmugasundaram, 2015). The lowest DO (3.43 mg/L) recorded at sampling site 6 is due to organic-rich domestic waste let into the river by the tourists and the highest DO 5.55 mg/L was recorded at sampling site 7. The DO that observed to be low and high in other sampling sites may due to eutrophication and increase in the bacterial population, which results in a high-BOD which intern reduces the DO. The increase in DO indicates the favorable condition for respiration and other physiological process for aquatic organisms.

The salinity of the samples was as high as 0.21 mg/L at site 4, and the lowest was around 0.11 mg/L at site 2-5. As the sampling sites have a low salinity value the water is suitable for drinking and other purposes. Salinity is an ecological factor which considerably influences the types of organisms that live in a water body. The GIS mapping and the table of interpretation were shown in Table 3 and Plate 1e.

Temperature plays an important role in water system. Change in temperature was observed in water due to biotic and abiotic reactions, and water temperature changes were according to change in atmosphere. The water temperature increased in accordance with an increase in atmospheric temperature. In this study, water temperature ranged between 30.2°C, at site 4 and 32.7°C, at site 3 (Table 3 and Plate 1f). This low- and high-temperature difference could be due to the vegetation around the river banks (Murthy *et al.*, 2015).

Elevation and Fish Distributions

The high Altitude was noted in site 7 as 341 m and lowest altitude was noted in site 4 as 225 m as shown in Table 4 and Plate 2a. The altitude also plays a key role in the quality of water where the high altitude streams and according to a survey of physic-chemical parameters the river is rich in nutrients with fertile habitat for fish survival (Aprile and Darwich, 2013). The high abundance was 77 was noted at site 3 and lowest 16 in site 2 and 5. The species abundance was high at a lower altitude (Table 4 and Plate 2b). The maximum fish richness (S = 21) was recorded in site 4 and the minimum value was in site 5 (S = 4). The species richness was high with increasing stream order (Table 4 and Plate 2c). The high value of diversity was noted in sampling site 4 as 0.959 (H) and lowest value was noted in site 5 (H = 0.751) (Table 4 and Plate 2d). The maximum evenness value (E = 1.268) was recorded in site 4 and the minimum value was in site 5 (E = 0.452) (Table 4 and Plate 2e). The high value of dominance was noted in site 5 (D = 0.408) and the lowest value was noted in site 4 (D = 0.047) (Table 4 and Plate 2f). The high value of Stream width was noted in site 2 (m = 80) and lowest value was noted in site 7 (m = 25) (Table 4 and Plate 2g) and the maximum value of stream depth of 5.33 (m) was recorded in site 3 and minimum value was at sampling site (4 0.66 m) (Table 4 and Plate 2h).

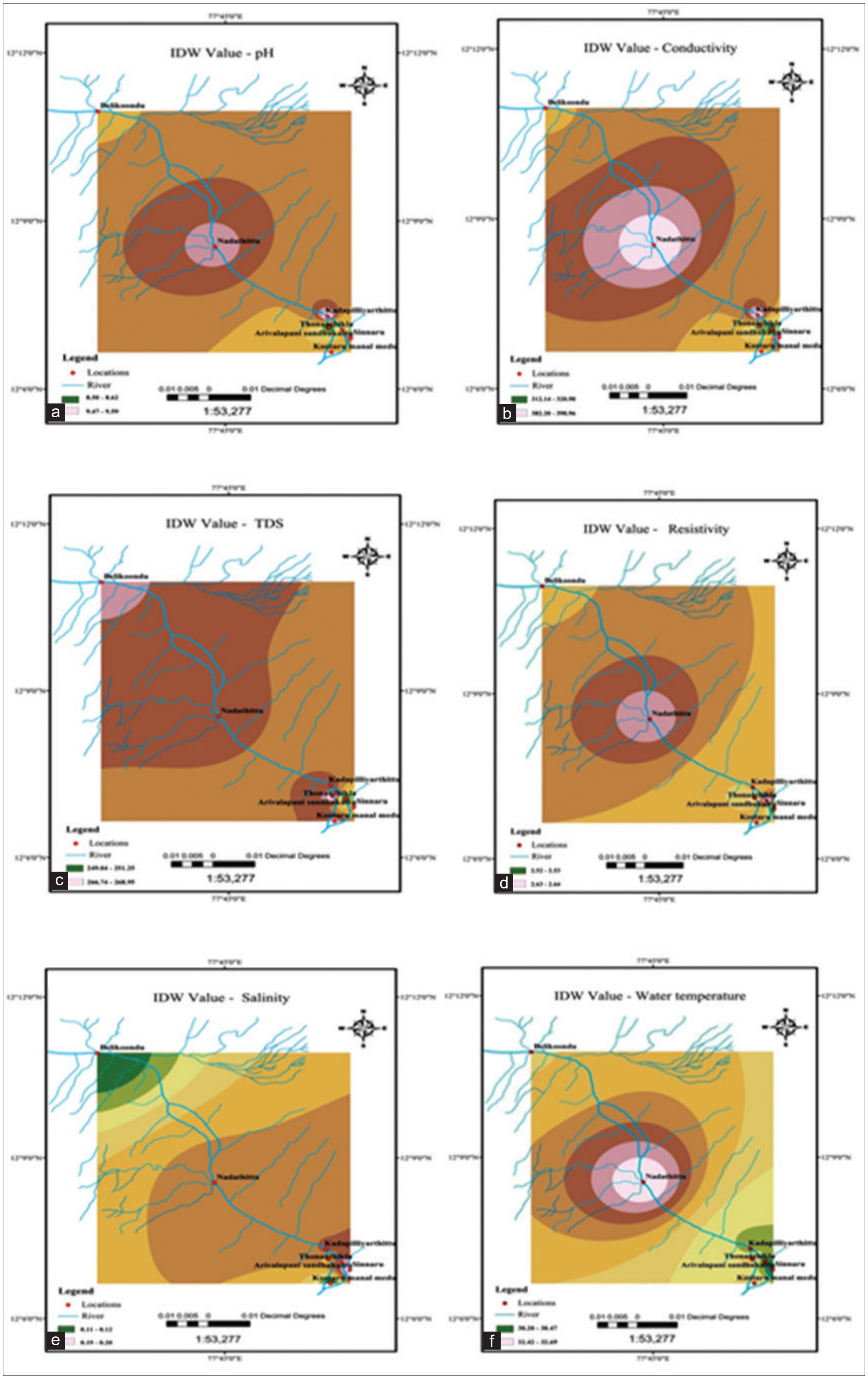

Plate 1: Various physico-chemical parameters of the study area

Fish Distribution and Substratum Type in Cauvery River

The fish distribution pattern and the substratum type of all the sampling sites were presented in Table 5 and Plate 3. The distribution analyses indicate that *Etroplus suratensis* was the dominantly distributed species in the sampling sites 1, 2, and 3 and its substratum being muddy with medium flowing water with high depth. In contrast to this, the sparsely distributed species was found to be *Labeo calbasu* in site 2 and 3 and *Labeo ariza* in site 4 with its substratum being the submerged rocks. However, the other sites have reported variation in the distribution pattern of the fishes. This clearly indicates that there is a higher degree of correlation between the distribution pattern and the substratum type. Hence, the GIS tool helps us to assess the magnitude of correlation between the substratum type and fish distribution which can be further utilized for management strategies.

CONCLUSION

The present study documents the fish species diversity, habitat quality assessment of Cauvery river basin. The fish species and its habitat characters were acquired from all the sampling sites. The study area was found to be flourished with flora and fauna. The water quality

Table 4: Species diversity from seven sampling locations

Locations	Abundance	Richness (S)	Diversity (H)	Evenness (E)	Dominance (D)	Stream width (m)	Stream depth (m)
Kadapilliyarthittu	37	8	0.886	0.8	0.165	75	1.5
Belikoondu	16	6	0.804	0.625	0.267	80	2
Nadathittu	77	20	0.921	1.198	0.065	70	6
Sinnaru	75	21	0.959	1.268	0.047	55	0.5
Kootarumanalmedu	16	4	0.751	0.452	0.408	70	2
Arivalapanisandhukattu	18	5	0.925	0.646	0.209	30	1.5
Thonanthikla	46	15	0.909	1.069	0.09	25	1

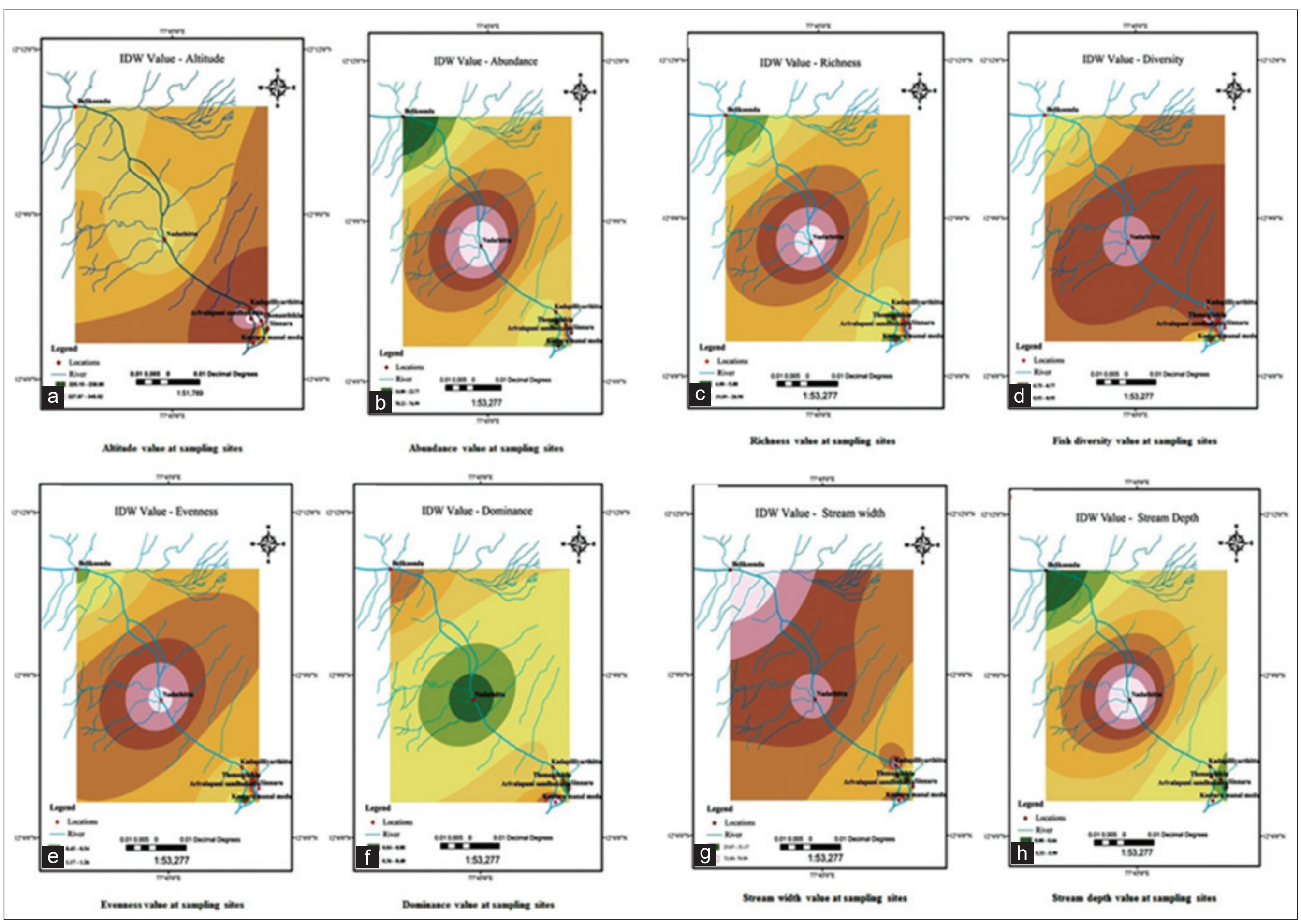

Plate 2: The various fish species density, abundance and distribution in Cauvery river systems

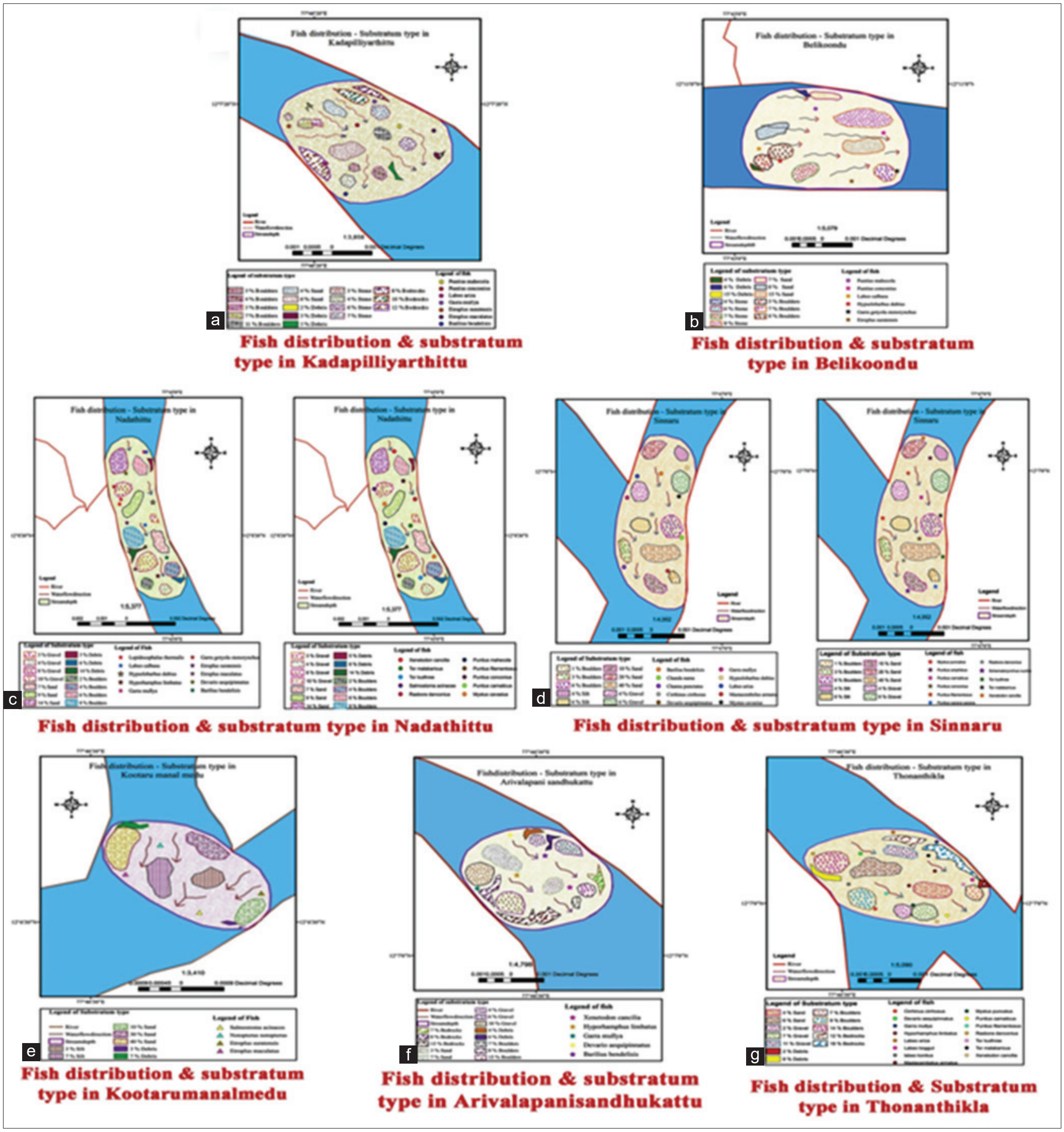

Plate 3: The various fish species distribution and substratum type in Cauvery river

analyses reveal that it meets the Indian drinking water standards and suits for the survival of fishes and other aquatic organisms. The habitat assessment of the study area says that there are four habitat types (pool, riffle, run, and glide) with six substratum type (Fine sand, debris, Silt, Bedrocks, Gravel, Rubbles, and boulders). The shoreline was also found to be sandy border rigid with rocks. This makes up a good habitat for the aquatic organisms. Moreover, the substratum and the vegetation cater them as a good food resource. Moreover, the river habitat is utilized by the humans for introducing the particular type of fish community for their usage as a source of protein food. Hence, through this study, it is being realized that GIS can be utilized to its full potential as a spatial decision support tool for hydrology and the aquaculture management.

ACKNOWLEDGMENT

The authors gratefully acknowledge facilities provided by the Department of Environmental Science, Bharathiar University and UGC New Delhi for sanctioning Major Research Project grant.

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