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UPFBase—A freshwater fish diversity database of Uttar Pradesh, India

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ABSTRACT

Worldwide, global databases on fishes lack fish diversity information at regional scale of a country, which has fascinated many fishery workers to know the regional scale fish diversity. Databases are essential part of the biodiversity science and have been used widely in the biological research. The present study discusses development, services and utility of the database application (UPFBase) providing information on the freshwater fish biodiversity of Uttar Pradesh. To develop UPFBase, data on the fish biodiversity of this region was compiled from different sources that include primary data generated from different projects and secondary data from published literatures. The collected data were screened and then digitized. Microsoft ACCESS relational database and Visual Basic language technologies were used for designing and implementing the standalone database application with the data management capability. Presently, UPFBase provides taxonomy, synonyms, local name, common name, morphology, biology, distribution, habitat, economic importance, conservation status and other fishery information on 129 fishes belonging to 11 orders and 27 families. UPFBase is user friendly and provides ease in working through search, query and action command button tools. It can easily be deployed on the mobile storages devices like CD-ROM, Pen drive, PCMCIA etc and can be installed on any Windows based Intel x86 machines. This version of UPFBase was built for countries, where computational hardware and software resources are in scare and it is expected that it might play imperious role in knowing and managing the indigenous fish diversity for decision making and posterity.

Keywords: Database, Fish diversity, Freshwater, India, UPFBase, Uttar Pradesh

Worldwide, global databases on fishes lack fishery information at the regional scale of a country, which has fascinated many fisheries workers to develop database at the regional scale of interest. In India, fish diversity database on major geographic scale are almost lacking except biodiversity hotspots.

Uttar Pradesh (UP) is the most populated state and blessed with vast potential of aquatic bioresources that exhibit rich genetic and vivid freshwater fishdiversity. UP contributes nearly 14.68% of Indian fish biodiversity and offers considerable scope for inland fisheries development and aquaculture (Lakra 2010). Biodiversity is the core issue of the 21st century (Wilson 2000, Kumar and Khanna 2006) and loss of biodiversity is one of the world's most pressing crises. The estimated current species extinction rate is between 1,000 and 10,000 times higher than it would naturally be (Bowker 2005). India contributes 60–70% of the world's biological resources and is one among 12 biodiversity countries and 25 hotspots of the richest and highly endangered eco regions of the world (Mayers *et al.* 2000). Fishes are one of the important elements in the economy of many nations being the stable item in the diet of many people for nutritional security (Talwar and Jhingran 1991). Therefore, apart from their economic importance, among all the vertebrate groups, fishes form the highest species diversity. Over years, demand of water in Uttar Pradesh state is increasing due to which many bio resources are experiencing serious threats to both aquatic biodiversity and ecosystem stability. Therefore, research is being pursued globally to develop systematic conservation planning to protect freshwater biodiversity (Margulesand Pressey 2000, Saunders *et al.* 2002, Nel *et al.* 2009) and various methods, strategies and priorities have been proposed (Cowx and Welcomme 1998, Sarkar *et al.* 2008). During the last few decades, a number of fishes are disappearing and the fish biodiversity of the state is declining at alarming rate. There are many studies on different accounts of fish fauna from UP but hardly any effort has been made to this date to digitise and provide the up to date information for managing the fish and fishery resources in this state. Collecting, harnessing and documenting information on the fish genetic resources to present the species biodiversity is a herculean task as data are scattered and confined to many old and new publications. With the advent of database concept since 1960, the database technologies have eased in arranging, updating and analyzing the collected data. Database

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technology has been widely used in plants and agriculture research to store information such as morphological description (Villordon 2007), growth data (Psomas *et al.* 2012), karyological data (Nagpure *et al.* 2016), gene information (Huala 2001) etc. To address the fish biodiversity problems of any state, it is essential to have the information and databases play much imperative role to store and manage the biodiversity related information. Thus, in the present study, an effort was made to develop the database application known as UPFBase to present the freshwater fish biodiversity of Uttar Pradesh.

MATERIALS AND METHODS

Data collection: For developing any database, the first activity is to look for the data for which the database is to be developed. To accomplish this task, data for fish on taxonomy, synonyms, local name, common name, morphology, biology, distribution, habitat, economic importance, conservation status and other fishery information was collected using primary (Primary sources include data generated from the exploration studies carried out under the different research projects) and secondary sources (published sources include books, journals, on and off line databases) both, screened and the compiled data was documented on the standard digital datasheet designed using Microsoft Excel. Table 1 presents list of sources used in data collection of these parameters. The content of the digital datasheets was revised again by the fisheries experts of the groups to make the data ready for database development. A diagrammatical sketch on the methodology followed for database development has been depicted in Fig. 1.

Development of entity relationship model: To define the conceptual view of the UPFBase, the entity-relationship model (E-R) first proposed by Peter Pin-Shan Chen of Massachusetts Institute of Technology (MIT) in the year 1970 was used to graphically represent the logical relationship of entities before formulating the design of the database.

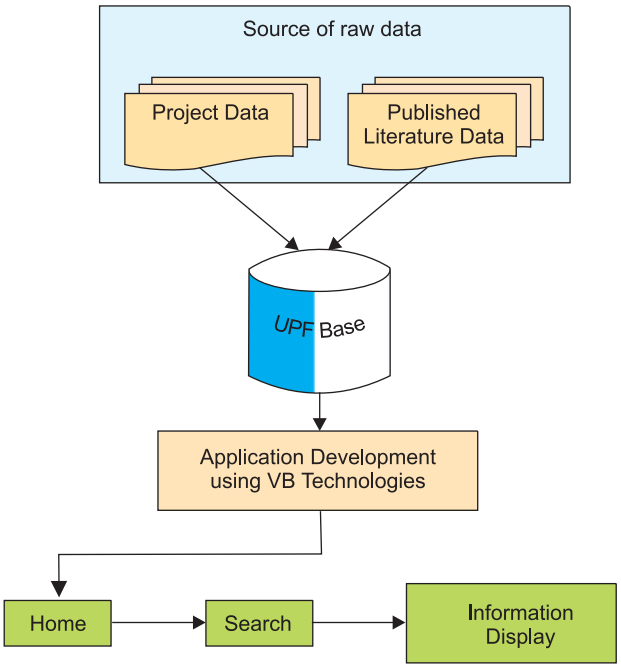

Fig. 1. Methodology followed for developing the database application (UPFBase).

Design of the database: Microsoft ACCESS relational database management system was used to design the database using the E-R model. UPFBase database contains 9 Tables. The association between the tables was done using the super, primary and foreign keys. The association defines the relationship and the entities in the database that are one-to-one, one-to-many and many-to-one relationship. The tables include single-value, multi value and composite attribute types. Degree 2 and 3 types of relationship were created between the entities to design the database.

Design of the data entry interface: To populate data in UPFBase by avoiding the direct access, a data entry form connected with UPFBase using Visual Basic technology was designed. Data format, validation rules and other checks

Table 1. List of sources used in data collection for preparing the database

Projects referred for data collection	Funding agency
Studies on selected endangered fish species using ecosystem scaling and the habitat fingerprinting approach for tributaries of river Ganga	Council of Science and Technology, Uttar Pradesh, India
Germplasm exploration, assessment and documentation of the freshwater fish diversity of Uttar Pradesh, India	Uttar Pradesh State Biodiversity Board, Lucknow, India
Assessment of fish biodiversity and habitat in the selected stretch of the river Ganga (Varanasi and Allahabad, Uttar Pradesh, India) and development of conservation model using GIS tools	ICAR-National Bureau of Fish Genetic Resources, Lucknow, Uttar Pradesh, India
Evaluation of wildlife protected areas for their potential to serve as aquatic sanctuaries for endangered species	ICAR-National Bureau of Fish Genetic Resources, Lucknow, Uttar Pradesh, India
Investigation of fish germplasm resources of the selected waterbodies for conservation and management of freshwater sanctuary	ICAR-National Bureau of Fish Genetic Resources, Lucknow, Uttar Pradesh, India
Evaluation and assessment of freshwater fish diversity of the river Ganges basin for conservation and management	ICAR-National Bureau of Fish Genetic Resources, Lucknow, Uttar Pradesh, India

were applied in the data entry controls for correct entry of the data in UPFBase.

Design of application interface for database: To work with UPFBase, an application interface logically connected with this database using Visual Basic technology was designed that includes query, search and action command buttons to retrieve, view and generate the report on the information presented about the fish species of interest.

Testing and implementation: Based on the requirements discussed within the organisation and with other fisheries experts, the test scenarios and test cases were prepared parallel to the design of the database application. The test scenarios are the bullet point that guide to drill down things further and are always used before the test cases. Once the test case writing was over, it was shared with the development team to give them an idea of the testing scope and they have to make sure that development which happened was satisfying the written test cases. All the test cases were reviewed by the different angles like requirement coverage, spelling grammar, test case writing standards, backward compatibility, platform compatibility, test data references, types of targeted testing (manual functional, performance, platform compatibility, usability, security, multi-tenancy) etc. Thus, in the testing phase the test started after developing the entire requirement. The important tasks performed during this phase were exploratory testing and execution of written test cases, logging defects/ bugs, resolving defects/bugs on priority, taking of new code on the environment on which testing is happening, marking and verification of defects/ bugs. After successful testing, the computer program along with databases was converted into a package for successful deployment and working.

Available literature on freshwater fishes of Uttar Pradesh: Scattered publication of many studies on fish fauna of UP are available with reference to systematic, bio-geographical, biology of commercially important fishes and aquatic ecological aspects (Sarkar *et al.* 2015). Motwani and David (1957) reported 95 fish species from the river Son. Srivastava *et al.* (1965) reported 55 species from the river Ken of Banda district, UP. Eighty seven were reported species from the eastern part of the UP (Srivastava 1968). Earlier, fish fauna from this part of UP were reported by Day (1878), Hora (1922, 1949) and Swarup (1967). The fish fauna of Faizabad which is an adjoining district and one of the districts in the eastern belt of UP reported 52 species belonging to 36 genera, 19 families and 7 orders (Hussian and Tilak 1984). In the Ganga river system of UP, Menon (1974) listed 141 species while studying environmental impact on fisheries of Ganga River system. Natarajan (1989) recorded 45 commercial important fishes from the important landing centers situated on the bank of the river Ganga. Subsequently, the fish diversity in UP and Bihar both were studied and Srivastava (1988) reported occurrence of 111 fish species from these regions. Reports are also on disappearance of few fishes from this region (Singh *et al.* 1994). Joshi (1994) gave an account on fish fauna of the Kali River. In the upper Ganga from Rishikesh to Kanpur, 83 fish species were documented and it was suggested to develop protected areas for long term conservation (Rao 2001). The fish diversity in the plains of UP were studied and 129 fish species were reported from this region (Khan 2000). Again, the Payne *et al.* (2004) reported 30 fish species in Allahabad stretches of the River Ganga. The fish fauna in the Sharda Sagar (district Pilibhit) and Rihand reservoir (district Sonebhadra) were studied by Motwani and Saigal (1974) and Anon (1981) and they reported 61 and 41 fish species respectively from these reservoirs. Later, Sarkar *et al.* (2007) studied the fish fauna in the lake of Samaspur Bird Sanctuary, UP and reported a total of 46 species belonging to 7 orders, 19 families and 33 genera. Concomitantly, from the river Gerua in the Katerniaghat Wildlife Sanctuary (KWS) located in the Behariach district, 87 species belonging to 22 families and 52 genera were reported (Sarkar *et al.* 2008). A recent study by Sarkar *et al.* (2010) reported 56 species belonging to 42 genera, 20 families and 7 orders from the river Gomti and 92 fish species belonging to 58 genera and 24 families from the river Ganga in UP (Sarkar *et al.* 2011). Length-weight relationship of fourteen Indian freshwater fishes from the rivers Betwa and Gomti were recorded (Sani *et al.* 2010) and 62 fish species were recorded from the Ganga basin, India (Lakra *et al.* 2010). Subsequently, the ichthyofaunal diversity in Faizabad district of UP was investigated and 62 fish species belonging to 41 genera, 20 families and 9 orders from the rivers, lakes, irrigation canals and ponds were reported (Kumar *et al.* 2013). At Lucknow in the river Gomti, 83 fish species belonging to 58 genera, 21 families and 8 orders were identified (Verma *et al.* 2015). Fish fauna pertaining to hilly area of the state were also studied by numerous workers, but mention may be made of a few such as Hora (1937), Hora and Mukherjee (1936), Menon (1949, 1974), Pant (1970), Singh *et al.* (1983) and Singh (1990). In the river Ramganga Shivaliks of western Himalaya, a total 43 species were recorded (Atkore *et al.* 2011). To envisage the fish diversity from hilly area to plains and in the lower portion, the study was conducted across all the stretches (upper, middle and lower stretches) of the river Ganga in which UP state came in the middle zone covering Haridwar, Narora, Kanpur and Varanasi cities and the study provided 143 freshwater fish species belonging to 11 orders, 72 genera and 32 families, which is about 20% of freshwater fish of the total fishes reported in India (Sarkar *et al*. 2012). This study added three more species in the checklist of freshwater fishes of the Ganges basin in India reported by Srestha (1990), Krishnamurti *et al*. (1991), Payne *et al*. (2004), Pathak and Tyagi (2010), Sarkar *et al*. (2012). Earlier to this, the river Gomti at Sitapur, Lucknow, Haidergarh, Sultanpur and Jaunpur districts of Uttar Pradesh was assessed for fish diversity and 56 fish species belonging to 20 families and 42 genera were reported (Sarkar *et al.* 2010). 63 fish species belonging to 20 families and 45 genera were reported from the river Betwa, which is a tropical river in the Ganga basin at Hamirpur, UP and the study depicted that the reported species contributes about

56.75% of total fish diversity (Sarkar *et al*. 2010) reported from UP (Srivastva 1988). Earlier to that, Joshi *et al.* (2009) reported occurrence of 61 fish species belonging to 45 genera, 20 families and 7 orders from this river. The presence of 21 fish species from the site of Lakhimpurkheri in the river Ghaghra was again recorded (Joshi *et al.* 2009). Now it is evident that many prior studies on the fish community structures are lacking accounts on trophic indices and such studies are limited to few tropical rivers of the West Bengal (Das *et al*. 2007). Adequate information on drainage wise fish biodiversity pattern and their current status in UP is lacking much. Recent study in the tributaries of the Ganges basins and other tropical rivers of India revealed that threatened species in the drainage basins are facing various anthropogenic disturbances (Sarkar *et al.* 2013) and in the near future their low abundance could reach to extinction (Sarkar *et al.* 2009, Lakra *et al.* 2011). On November 9 2000, the 27th state of India named as Uttaranchal was carved out from UP, and in January 2007, this new state changed its name to Uttarakhand, meaning "northern region,". Thereafter, UP remained only with warm water fish diversity leaving the cold water fish diversity especially occurring in the snow fed and cold desert regions. The coldwater fisheries harbour 258 species belonging to 21 families and 76 genera. Out of these, the maximum of 255 species are recorded from North-East Himalaya, 203 from the west and central Himalaya and 91 from the Deccan plateau (Singh and Akhtar 2015). As the river Ganga also passes through UP, the occurrences of fishes of genera like *Garra, Nemacheilus*, *Labeo, Barilius* are also reported from this river and its tributaries in this region.

RESULTS AND DISCUSSION

UPFBase covers taxonomy, synonyms, local name, common name, morphology, biology, distribution, habitat, economic importance, conservation status and other fishery information of 129 fishes belonging to 11 orders, 27 families and 81 genera. UPFBase application is ease in operation and can be made functional by installing the package from any mobile storage device like CD-ROM, Pen drive and PCMCIA on any Intel x86 machine with 512 MB of RAM, 250GB hard drive and 1024×768 resolution monitor under Windows XP/NT/2000 or later operating system. The installation loads the application along with the database in the 'Program' folder under Windows by creating a separate folder. The installation of the application also creates a shortcut icon on the desktop of the screen that can be used to invoke the application without navigating to the application in 'Program' folder. Fig. 2 shows screenshot of the application after application is started by the user using mouse click on the shortcut icon created on the desktop of the screen.

Species selection by querying: The 'START' action command button (Fig. 2) provides the ability for user to query about the fish species of interest and retrieve the related information from the database. When the user clicks on the 'START' command action button, a query window

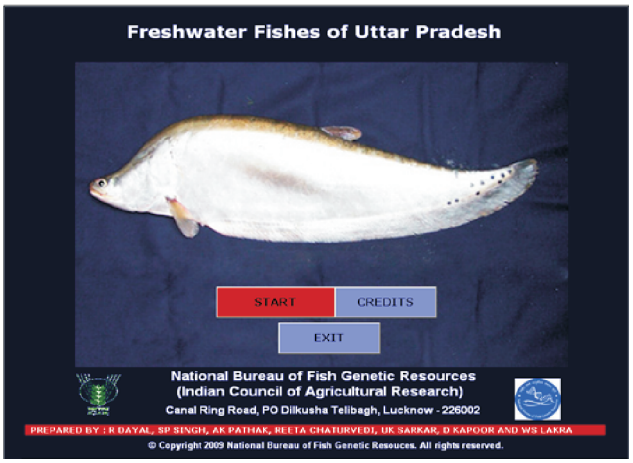

Fig. 2. Main screen of the database application.

with drop down list box, radio buttons and action command buttons pops up on the main screen (Fig. 3) that enables user to select the fish species of interest either by scientific name by using the drop down list box provided against to 'Scientific Name' or by selecting genus and species name separately using drop down list boxes against to 'Genus and Species' or by selecting family and species name separately using drop down list boxes against to 'Family and Species'. After selection, the user has to click on the 'OK' action command button to execute the query. The 'Close' action command button closes the 'Search by species' application window.

Information retrieval: After selecting the species of interest, the application fetches data on different parameters of the fish species from the database and presents the information in a form included with text boxes, action command buttons and image box. Suppose the user selects '*Amblypharyngodon mola*' species and clicks on OK action command button (Fig. 3), the details about the fish species are presented in a form as shown in Fig. 4. The action command buttons provided at the bottom of the form present additional information on the fish species. The 'Local name' action command button provides the ability for viewing local name in different languages of the displayed fish species; 'Taxonomy' action command button provides the ability for viewing taxonomy information of the displayed fish species; 'Synonyms' action command button provides the ability for viewing synonyms of the displayed fish species; 'Distribution' action command button provides the ability for viewing distribution in India and abroad of the displayed fish species. In addition to these action command buttons, the 'Report' action command button generates the print view of the displayed form along with information on local name, taxonomy, synonyms and distribution which can be printed by selecting the printing device to get the hard copy of the information on the fish species. The 'Photoprint' action command button presents the print view of the fish picture, which can be printed by the selecting the printing device to get the hard copy of the fish picture. The 'BACK' action command button provides the ability

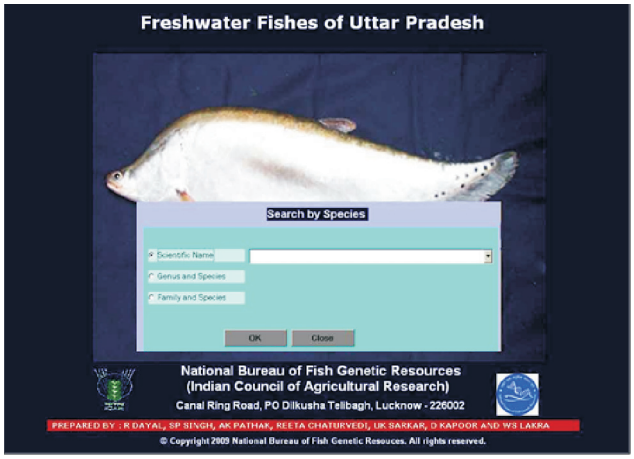

Fig. 3. A query screen for the user to select fish species of interest.

for user to move back to earlier screen of the application (Fig. 3) by closing the form application window (Fig. 4).

UPFBase database application on the freshwater fishes of UP is first of its kind. The regional databases on fisheries is lacking much in the developing countries like India, which is essential to know the indigenous faunal diversity and manage the fish biodiversity of the region in their niche for posterity. In India, studies on diversity of the freshwater fishes in the major river basins were primarily focused on the catch data of the major taxonomic groups at spatial scale (Vishwanath *et al.* 1998). Hardly any effect in the past was made to document all the taxonomic groups and present the fish biodiversity in holistic way at the regional scale. To protect the fish biodiversity of any state or region, it is imperative that the state or region should have record on occurrence of the fish species with relevant details and that should be easy to store, manage and update. Such historical records of occurrences would be beneficial in knowing the distributional range of fish species. The application of database technology has eased in storing, updating and managing the voluminous data and provides an amicable solution. Observing the significance of the regional scale fish biodiversity for conservation and management, two databases on the fish biodiversity for Western Ghats and

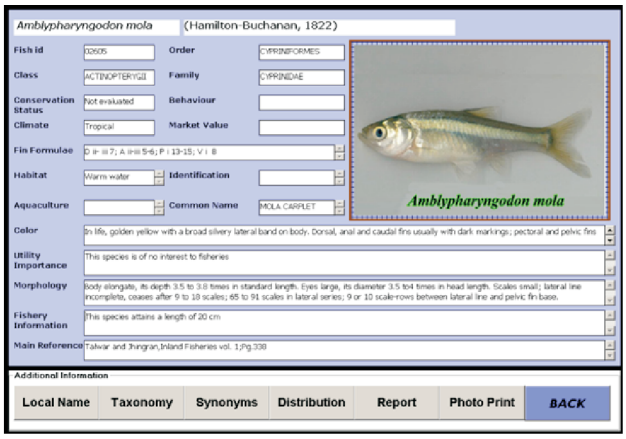

Fig. 4. Form displaying the information about selected fish species.

Northeast regions of India are already in place (Pathak *et al.* 2014, Pathak *et al.* 2016). In continuation, efforts were made to publish databases on certain fish groups like catfishes (Pathak *et al.* 2013), marine ornamental and shell fishes of India (Pathak *et al.* 2011). The application of database technology was further applied in developing different fish genomic databases (Nagpure *et al.* 2012, Nagpure *et al.* 2015, Nagpure *et al.* 2016, Rashid *et al.* 2017).

The present database on the freshwater fishes of UP is an application of the database technology that provides the ability for user to view taxonomy, synonyms, local name, common name, morphology, biology, distribution, habitat, economic importance, conservation status and other fishery information of 129 fishes belonging to 11 orders, 28 families and 81 genera using integrated search, query and action command button tools. The database can be an imperative resource for knowing the freshwater fishes of this state and studying in depth not only in terms of observation, identification and classification but also to record their physical, chemical and genetic properties in order to help the ecosystem to lead a sustainable fishery in the state. The Government of Uttar Pradesh has declared endangered *Chitala chitala* as a State Fish for implementing plan and strategies towards its conservation. Worldwide, global databases on fish do not have mechanism to know about fish reported from the different regions of India like Western Ghats, Northeast region, Peninsular region, Central India and different states of India as their interest at the lowest geographical scale is limited to the country. The recent data available in the database of ICAR-National Bureau of Fish Genetic Resources, Lucknow, India (NBFGR) reports 3,535 finfishes of which 3,035 are native and 500 are exotic fishes from India representing 46 orders, 252 families and 1,018 genera. Out of 3,035 native fishes, 1,016 are fresh, 113 are brackish and 1,906 are marine water species (ICAR-NBFGR, Annual Report 2016–17). On the contrary, FishBase (2017) (Froese and Pauly 2017) reported 974 freshwater fishes from India. Thus, based on the data available with NBFGR, presently the western ghats contributes ~37.3%, northeast ~41.5% and UP ~12.6% freshwater diversity of the nation's freshwater diversity. The social and economic development of any region depends on the sustainable management of its natural resources. To protect biodiversity, ecosystems and wildlife, the sustainable development goal 14 "Life under water" describes "Fisheries contribute significantly to global food security, livelihoods and the economy. Therefore, there is a need to manage fishing sustainably as overfishing can damage fish habitat and weaken functioning of the ecosystem. This leads to the infringement in the biodiversity with negative repercussions for sustainable social and economic development. In order to achieve the healthy balance, it is essential to know about the fish residing in the waterbodies of that region. The database technology with its query and data management capability is a milestone for documenting and storing the large amount of bio-

resource information in an organized and systematic manner. Now a days the database technology is being used in every sphere of life proving itself as a valuable technology for creating repository resource in a well-defined and organized form. The database application on the freshwater fish diversity of UP is another feather in the cap of regional fish diversity databases of India that can be acted as a sustainable fisheries management tool for resource managers and exchange of germplasm resources by providing the access and benefit to the cliental of this region.

The assessment by ICAR-National Bureau of Fish Genetic Resources (NBFGR), Lucknow revealed the occurrence of 123 fish species from UP and the utilization pattern of these species reported about 33% as ornamental; nearly 57% as potential food and 10% as potential sport fishes[3]. Based on the IUCN categories, the CAMP Workshop (Molurand Walker 1998) for freshwater fishes identified certain fish species, which have attained the threatened/ endangered status. According to the recent conservation assessment of NBFGR, a total of 20 freshwater fishes were categorized as threatened of which 9 under endangered and 11 under vulnerable category (Lakra *et al.* 2010).

UPFBase presently covers 129 fishes belonging to 11 orders, 28 families and 81 genera and through integrated search, query and action command button tools, it provides taxonomy, synonyms, local name, common name, fish image, morphology, biology, distribution, habitat, economic importance, conservation status and other fishery information. Besides viewing information, the database provides facility for generating reports and getting the printed information using printing device. The database has been made user friendly and includes the curated and updated information about the freshwater fish diversity of UP. Thus, this digital documentation of freshwater fish diversity of UP can be used as an important resource for the researchers, academicians and policy makers, biodiversity managers and additionally providing the access and benefit to the different stakeholders. Further, it might be well informed resource for sustaining and protecting inland fisheries of this state for enhancement strategies and posterity.

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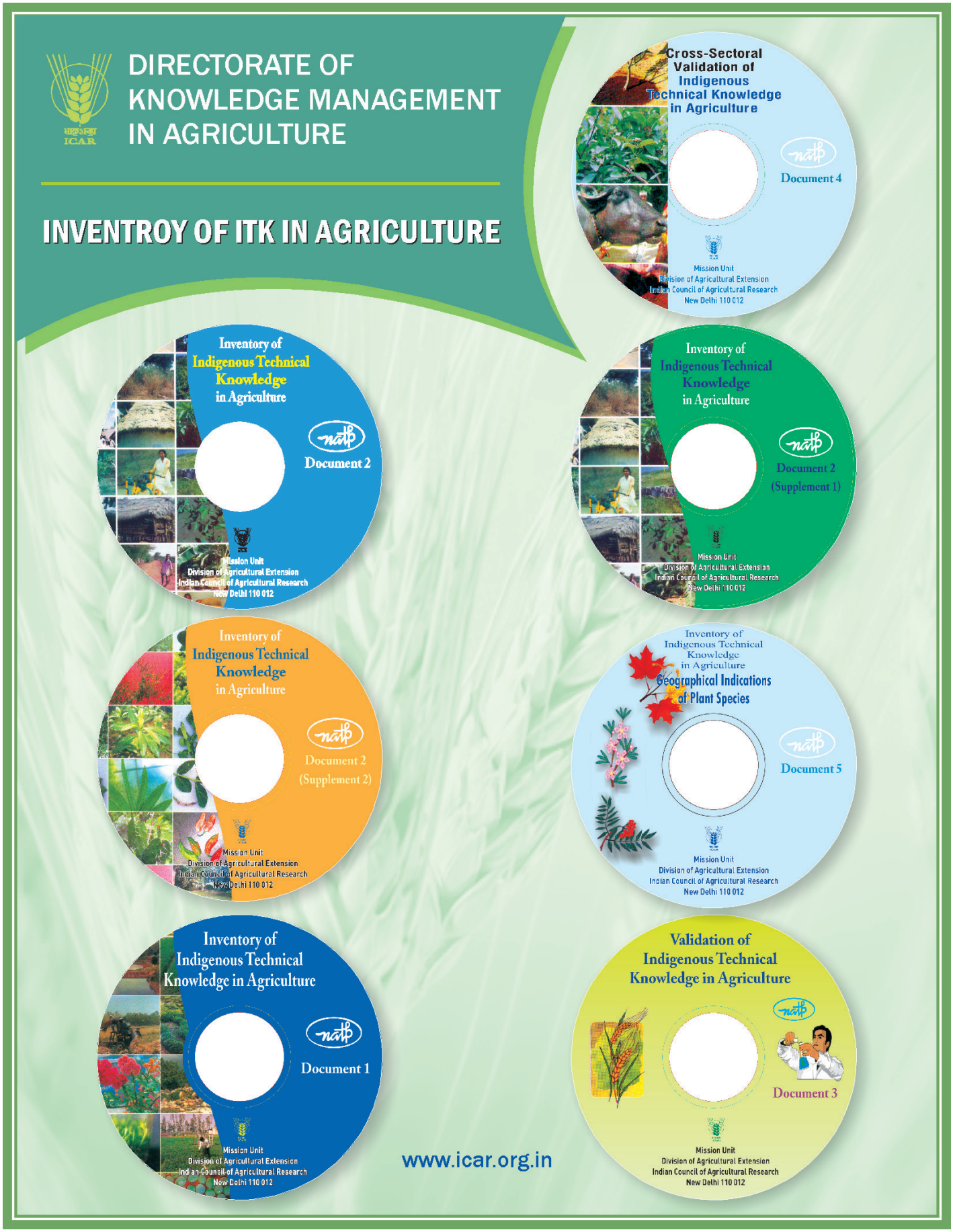
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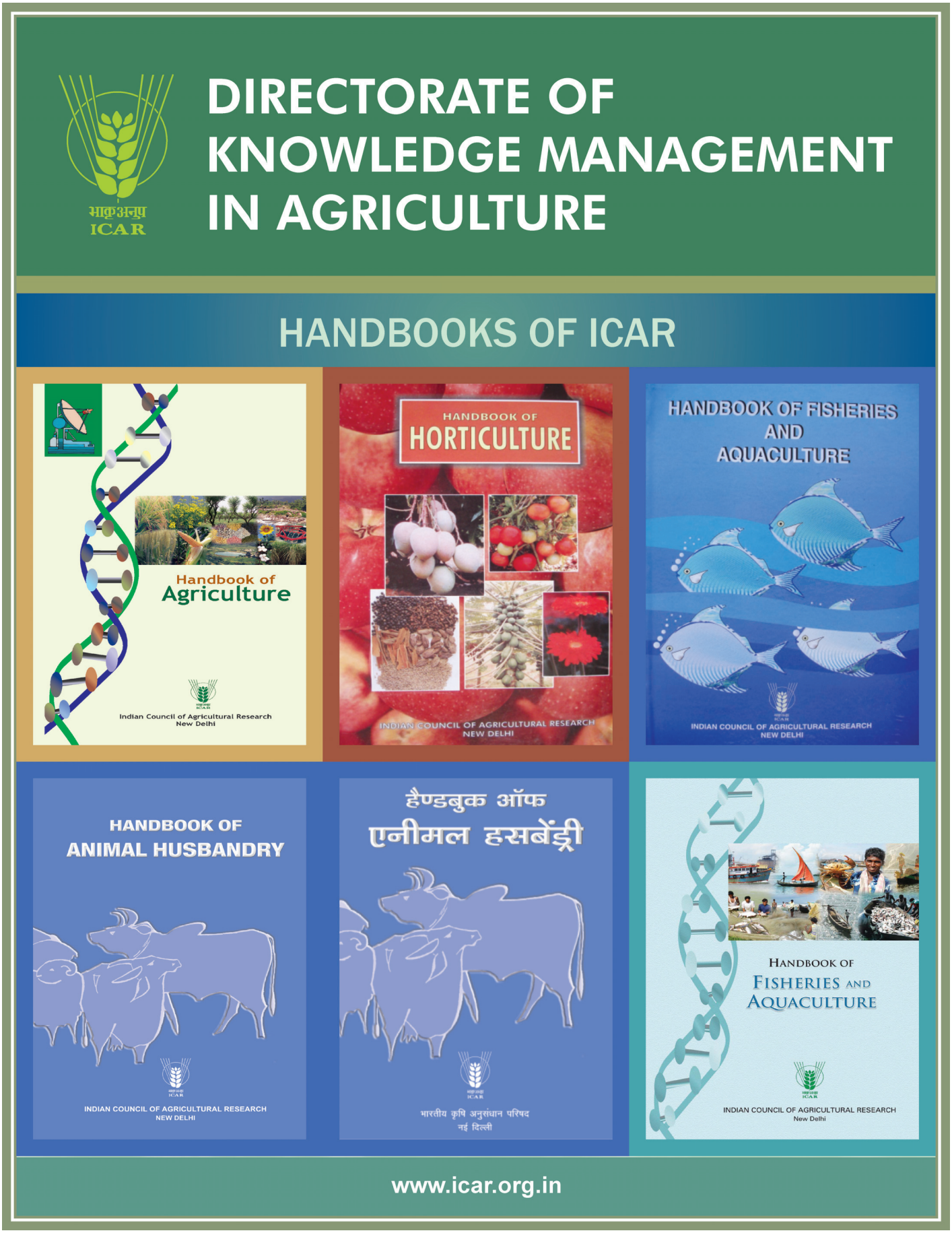
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