

AqGRISI - A novel online framework for aquatic genetic resource information system to support national and global biological diversity commitments

Ajeay Kumar Pathak¹, Rajesh Dayal¹, Iliyas Rashid¹, Rejani Chandran¹, Poonam Jayant Singh¹, Reeta Chaturvedi¹, Rameshwar Pati¹, Ravi Kumar¹, Vindhya Mohindra¹, T. T. Ajith Kumar¹, Rajeev Kumar¹, Joykrushna Jena² and Kuldeep Kumar Lal^{1,3*}

¹ICAR-National Bureau of Fish Genetic Resources, Canal Ring Road, Dilkusha, Lucknow - 226 002, Uttar Pradesh, India

²Division of Fisheries Science, Krishi Anusandhan Bhawan - II, Indian Council of Agricultural Research, New Delhi - 110 012, India

³ICAR-Central Institute of Brackishwater Aquaculture, Chennai - 600 028, Tamil Nadu, India



*Correspondence e-mail:

Kuldeep.lal@icar.gov.in;
kuldeepklal@gmail.com

Keywords:

Aquatic Genetic Resource Information System,
Database, Fish, India

Received : 29.05.2024

Accepted : 17.03.2025

Abstract

This article presents the development of an online information system for aquatic genetic resources of India named, Aquatic Genetic Resource Information System of India (AqGRISI). The system is designed with integrated data and user management capabilities. The growing importance of online information systems in management of the biological diversity and agrobiodiversity has invited attention of the researchers to make such information publicly accessible through digital platforms. AqGRISI is developed as a concept framework and validated for use and is presently accessible at URL: <https://aqgrisi.nbfr.res.in/#/>. It is designed to manage compiled data from authenticated published sources, using a database management system and programming for online information presentation. It ensures accessibility through web technologies within the Windows operating environment. The system will provide comprehensive information of the fish species, from a single page, covering various aspects such as biology, distribution, taxonomy and type specimens. The database is integrated with information from in-house databases such as HRGFish, FMiR, FBIS, FishKaryome, and FishMicrosat along with patent information. Additionally, AqGRISI is linked to other nationally and internationally significant online resources and serves as a repository for fish accessions preserved in the National Fish Museum and Repository. It includes data on cell lines and facilitates the intake of information on the voucher specimens, cryopreserved sperm accessions and tagged fish species maintained at live germplasm resource centers of ICAR-National Bureau of Fish Genetic Resources. AqGRISI is enriched with dynamic digital maps featuring geospatially tagged type specimens with details on species occurrence. These type specimens are also linked to the National Museum of Natural History, Paris, France, allowing users to access images of holotype, syntype, paratypes and neotypes along with relevant taxonomic information. Among the available online resources on aquatic animals, AqGRISI envisages to serve as a centralised platform providing researchers, academicians, managers, planners and other stakeholders, with a single-point access to information on fish species. Currently the system is validated for information on finfish species; however, future expansions will enable customisation of this conceptual framework to include other components of aquatic biodiversity, such as shellfish, seaweeds and more. The concept framework also holds the possibility for usage by other countries especially in Asia, which share ancestral aquatic gene pools.

Introduction

Easy accessibility of data or information on genetic resources can catalyse policy frameworks for effective planning, management and sustainable utilisation of valuable genetic material. In this context, global initiatives are in place and

organisations, such as Commission on Genetic Resources for Food and Agriculture (CGRFA), is leading in preparation of the world's status on genetic resources and global plan of action for the commodities such as plant, animal, forest and aquatic biodiversity. The State of the World's Aquatic Genetic Resources for Food

and Agriculture (SOWGRA) (FAO, 2019) also points out the need for documenting knowledge on characteristics of aquatic genetic resources and makes it accessible through national and international databases. Additionally, the significance of the aquatic genetic resources, as documented in the first report prepared by Food and Agriculture Organisation (FAO), extends beyond resource-oriented conservation and management-based plans and practices. It also acts as a valuable resource for intellectual property rights (IPR) and trade-related issues, highlighting the need for sustainable utilisation and equitable benefit-sharing. The database integrated with programming and web technologies provide appropriate opportunities for construction of an online database for bio-resources, featured with information-oriented services to make information accessible to a wider range of communities through heterogeneous digital portals. Database technology, has also been widely used in plants and agriculture research to store information on different characteristics of the bio-resources such as morphological description (Villordon *et al.*, 2007), growth data (Psomas *et al.*, 2012), karyological data (Nagpure *et al.*, 2016) and gene information (Rashid *et al.*, 2017).

Indian subcontinent with its diverse agroclimatic conditions, supports a rich diversity of aquatic bio-resources encompassing a wide range of ecological habitats and fish fauna (Devi and Indra, 2012), which contributes to one of the most multispecies fisheries in the world (Ramanna-Pathak, 2015). It is noteworthy that India is known to represent about 8.9% of the known finfish species of the world (Baker *et al.*, 1993) occupying a position at the confluence of three biogeographic realms, viz., the Palaearctic, Afro-Tropical and Indo-Malayan. It is one of the few developing countries in the world to legislate comprehensive laws on biodiversity (BDA, 2023) within its national jurisdiction, which addresses access, utilisation and conservation of genetic resources, knowledge and Intellectual Property Rights (IPRs) across all the sectors of biological diversity in response to Convention on Biological Diversity (CBD). The law is implemented through an inclusive structure (BDA, 2023), where biodiversity management committees (BMC) are responsible for People's Biodiversity Register (PBRs) at grassroots level and linked to the National Executive Agency through State Biodiversity Boards (SBBs) and the apex body, National Biodiversity Authority (NBA). Therefore, it is unambiguous to understand that information systems on the genetic resources with precise and consistently updated knowledge will have significant support in fulfilling the national obligations to the international treaties under CBD (Jacob *et al.*, 2021). To support the biodiversity laws of India, NBA has designated nodal commodity-based repository under section 39 of the Biological Diversity Act 2002 and ICAR-NBFGFR with its National Museum and Repository is one of such designated repositories for the fish germplasm (<http://nbaindia.org/uploaded/pdf/notification/1%20designated%20repositories.pdf>).

The 2030 sustainable development (UN 2021) goals address the sustainability of genetic diversity of farmed animals and their wild relatives (SDG 2) and management of information and research capacity for the life below water (SDG 14). Similarly, global taxonomy initiative (GTI) under CBD, recognises the need for capacity building on taxonomy, documentation of diversity and repositories towards achieving targets of sustainable development goals and access benefit sharing. FAO (2018) recognising the need

of AqGR management at the country level, developed a minimum framework of essential criteria. The document classifies various aspects, such as genetic technologies, environment, infrastructure, capacity building as well as information and databases. This minimum framework recommends single, easily accessible database or information system on AqGR covering all the required elements. The state of world aquatic genetic resources (SOW) under the Commission of Genetic Resources, developed by FAO and released in 2019 is a milestone on the global status of aquaculture species (FAO, 2019). This documentation set up background for new planning processes under FAO for action such as Global plan of action (FAO, 2022) and action on blue transformation of Aquaculture (FAO, 2024). As a follow-up, a novel initiative, which was not existing earlier, was put in place viz. classification of farm types, leading to a global database on aquaculture species, AquaGRISI (FAO, 2025).

Globally, several databases on aquatic organisms are available (Grassle, 2000; Tedesco *et al.*, 2017; Froese and Pauly, 2024; Fricke *et al.*, 2025; WoRMS, 2025; MolluscaBase, 2025; Banki *et al.*, 2025). However, majority of them are associated with systematics, biology, distribution and museums information of the species. Efforts were made by a few workers to build the database on fish at the regional levels (Pathak *et al.*, 2016; 2019; Shao, 2019), but have limited information and are mostly localised. We examined the fish databases available at global and national scale, however, it was found that information on aquatic genetic resources of India is scattered and not enriched commensurate to the richness of diversity it possesses. The present database, AqGRISI is aimed to provide the information on aquatic genetic resources of India in totality, covering molecular genetics, distribution, specimen biology, conservation status and ecological attributes. Thus, considering the significance and benefits offered by the online information systems for overcoming and mitigating the issues and challenges in fisheries through conservation and management plans, the present paper discusses the development of a concept framework of an online information system for the aquatic genetic resources (AqGRISI), which is not only a point source of multiple information on a species but also deliver functional benefits of implementing repository functions for researchers. This novel concept aims for development of an online information system that links the conventional taxonomy information of the resources to the museum voucher accessions and supports the taxonomy research with ready availability of type specimen information linked to respective museums. The present framework establishes scope of enriching the multiple type of information related to genetics, genomics, biology, IPR, nutritional value, distribution, aquaculture, farmed types and also incorporates the details of accessions available in the repository.

The AqGRISI framework uses database, programming and web technologies to provide realistic information on aquatic genetic resources, by collating data from multiple sources and scrutinising the data for its authenticity and correctness by using the in-house expertise and literature. The present concept framework of this information system is validated with the information on finfish resources of India; however, it is expandable for other types of aquatic genetic resources and the framework can be used by other countries through fostering mutual collaborations.

Materials and methods

Information system development

Standard and environment

An Intel-based computer system of dual Xeon processor with 128 GB RAM and 2700 GB usable hard disk was configured with Windows 10, Internet Information Server 7.0, MS SQL 2012, ASP. Net MVC 5, JavaScript and HTML5 technologies. MS SQL 2012 relational database management system was used to develop the database structure, organising data, creating association between the physical tables and connections with web interfaces. ASP. Net MVC 5, JavaScript and HTML5 were used for developing the dashboards comprised of web interfaces integrated with windows components and tools for providing ease in working interactively with the databases.

Architecture

To avoid proprietary and facilitate openness in the system, the whole system was implemented as a Client/Server three tiers or triple layer architecture (Fig. 1). Such architecture improves usability, scalability and inter-operability. The thin-client approach was

implemented for accepting input and output display authenticated by the session functions. The system conforms to W3C and its relevant technologies.

Database development

The database is the core of an information system and should meet the requirements for the set objectives. It should be easy to maintain and extend as requirements change. The quality of the database structure may influence the whole system. The collated data was organised based on normal forms (Codd, 1971) and an entity-relationship model was developed, which was used to create the database structure using MS SQL 2012. The creation of database structure involved the physical design of the data tables for organising the data, association between tables as well as creating and managing connections. The intermediate tables were created by grouping entities with the option of partially loading domain entities with only the required data. To provide security to the database, Windows 10 to the MS SQL 2012 database server authentication was implemented. To avoid reconnection with the database, pooling was implemented. For consistent handling of exceptions, centralised exception management strategy with retry logic was adopted. The service agent objects working as an abstraction layer between the web interface and the remote service were added to provide a consistent interface regardless of the data

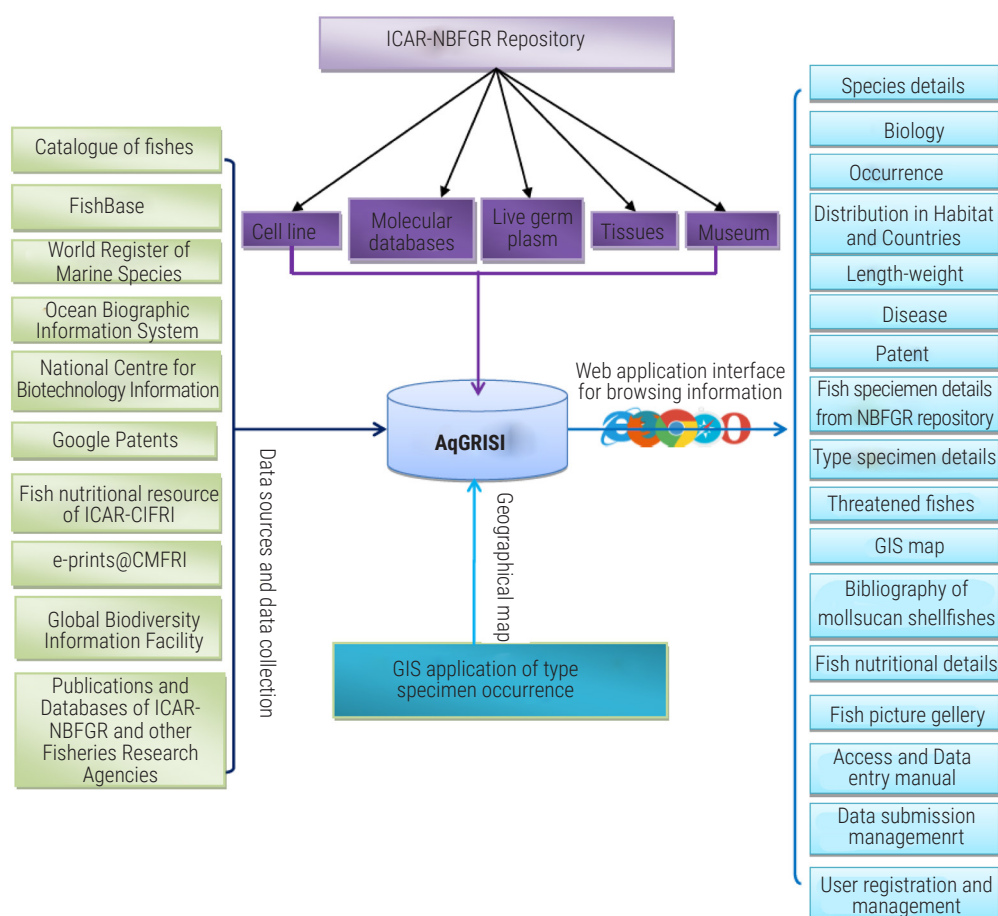


Fig. 1. Architecture of AqGRISI

format. Further, to handle data conflicts from the concurrent users, the connection-based transaction using optimistic data locking process was adopted and implemented.

Development of the web-based dashboards

For information delivery, interactive dashboard comprising of event driven web interfaces integrated with search, query and menu option tools were developed. These interfaces accept input from the user and output the information after querying from/searching in the database. To manage data and users, dashboards comprising of event driven web interfaces integrated with management components and tools were developed for registered users and database administrator.

Development of tools for retrieval, management and accession code generation

Query/search tools and hyper linking

To retrieve information from the database; keyword, specific and selective search options were designed and implemented in the homepage web interface of AqGRISI. The keyword search uses value of a single attribute, while specific and selective search uses values of two attributes. Beside search tools, functionalities to display the information using the hyperlinked and menu items were designed and incorporated in the dashboard.

User registration panel

A dashboard for user registration was developed. The registered users through login credentials are only allowed for data submission in AqGRISI using the data submission dashboard. The dashboard also includes option for new user registration.

Data submission dashboard

For data entry and updating the database by the registered users, a web-based data submission dashboard integrated with tools providing facility for editing, deleting, updating, viewing and submitting data was designed and adopted. This dashboard provides the capability to submit the data in the database by the registered users after its approval granted by the database administrator.

Data and user management dashboard

To manage and control data as well as users, a dashboard for the database administrator was developed. It is separate from main framework of AqGRISI to preserve the system security. The database administrator reserves the rights for control on the user and data.

Accession code generation for museum specimens

The museum or repository stored accessions have a variety of purpose, as reference specimens or genomic resources such as cell lines. These are made available to future researchers. The new

species or records described also need to be assigned as type specimen. Therefore, for precise storage and retrieval, an identifier code is the basic requirement. To provide unique accession code to the museum specimens, a program was developed in the Perl language and tested for 3240 AqGRISI records for any possible overlap. Thereafter, this program was used to generate the Museum accession codes for type collections, which were submitted by the discoverers.

Data collection and enrichment

The data were collected from five sources namely scientific literatures on national fisheries; reports available within ICAR-National Bureau of Fish Genetic Resources, India; fisheries databases on Internet; print and digital media such as published books/journals/ technical reports and off-line databases exclusively reporting information on Indian fish diversity. The parameters were decided based on the published information. For documenting data, structured digital data sheet using Microsoft Excel was prepared. The sheets duly filled with data were verified and entered in the database. Enrichment of the data will be a continuous process for updating of information.

Results

AqGRISI accessible at URL: <https://aqgrisi.nbfgri.res.in/#/> is an online information system featured with abilities of information delivery, data and user management (Fig. 2). It currently covers 3240 fish species native to fresh, brackish and marine ecosystems of India and provides information on 'Systematics', 'Synonyms', 'Common name', 'Local name', 'Biology', 'Length-weight', 'Type specimen', 'Disease', 'Habitat', 'Distribution', 'Conservation status', 'Patent' and 'Fish Nutrition'. This system also features in-house molecular databases like FishKaryome (Nagpure *et al.*, 2016), FisOmics (Pathak *et al.*, 2019) and HRGFish (Rashid *et al.*, 2017). Besides providing the information-oriented services, the system acts as a digital repository for fish accession types viz. live germplasm, tissue, cell line and museum specimens maintained at ICAR-NBFGRI. For increasing the content and scope, AqGRISI is also linked with other online resources of national and international importance viz. FishBase (<https://www.fishbase.in/search.php>), World Register of Marine Species (WoRMS) (<http://marinespecies.org/>), NUTRIFISHIN of ICAR-Central Inland Fisheries Research Institute (ICAR-CIFRI) (<http://cifri.res.in/nutrifishin/index.php>), Molluscan shellfish resources of India by ICAR-Central Marine Fisheries Research Institute (ICAR-CMFRI) (<http://eprints.cmfri.org.in/256/>), FAO (<http://www.fao.org/fishery/affris/species-profiles/>), National Center for Biotechnology Information (NCBI) (<https://www.ncbi.nlm.nih.gov>), Ocean Biographic Information System (OBIS) (<https://obis.org>), Google Patents (2019) and International Union for Conservation of Nature (IUCN) (<https://www.iucnredlist.org/>). Out of 3240 native fish species, the type specimens of 580 species are now linked to Museum national d'Histoire naturelle (MNHN) (<https://www.mnhn.fr/>), which provides pictures of holotypes, syntypes, paratypes and neotypes, with additional information. The integrated GIS maps supported with the occurrence information of specimens provides the ability to view the occurrence details of each type specimen in the different geographical context. The

homepage of AqGRISl (Fig. 2) briefly describes its content and shows three ways, viz. menu, hyperlinks and search/query window to browse the information from the database.

Content analysis of species and specimen records

Currently, AqGRISl holds 3240 native fish species belonging to 1043 genera, 256 families and 57 orders. AqGRISl reports disease information on 11 fish species in 54 records, type specimen information on 585 museum specimens. AqGRISl in its digital repository access through NRFC (NRFC 2019), holds 69 authenticated cell line records. Cell lines are an important research tools and are distributed for research under National Repository of Fish Cell lines (Murali *et al.*, 2023) and researchers can find all the details and procedure to access from NRFC, which is also accessible through AqGRISl. AqGRISl has provisioning for uploading patent

information on the species and for adding all the other kinds of accession details, which the repository might have in future such as voucher specimens, tagged live animals in live germplasm resource centers (NBFG, 2016). The envisioning of such features provides, AqGRISl, the flexibility and forward compatibility with the time to come.

Information on aquatic genetic resources

Three types of query/search options featured in AqGRISl provide the ability to retrieve and view the information (Fig. 3). These are keyword, specific and selective search. The keyword search facilitates to type in the value of an attribute. The specific search facilitates to select the type of information of interest from the first drop-down list box and then select the species from the second drop-down list box. Finally, the selective search facilitates to select an item listed under a category from the first drop-down list box and then select the species from the second drop-down list box.



Fig. 2. Homepage of AqGRISl

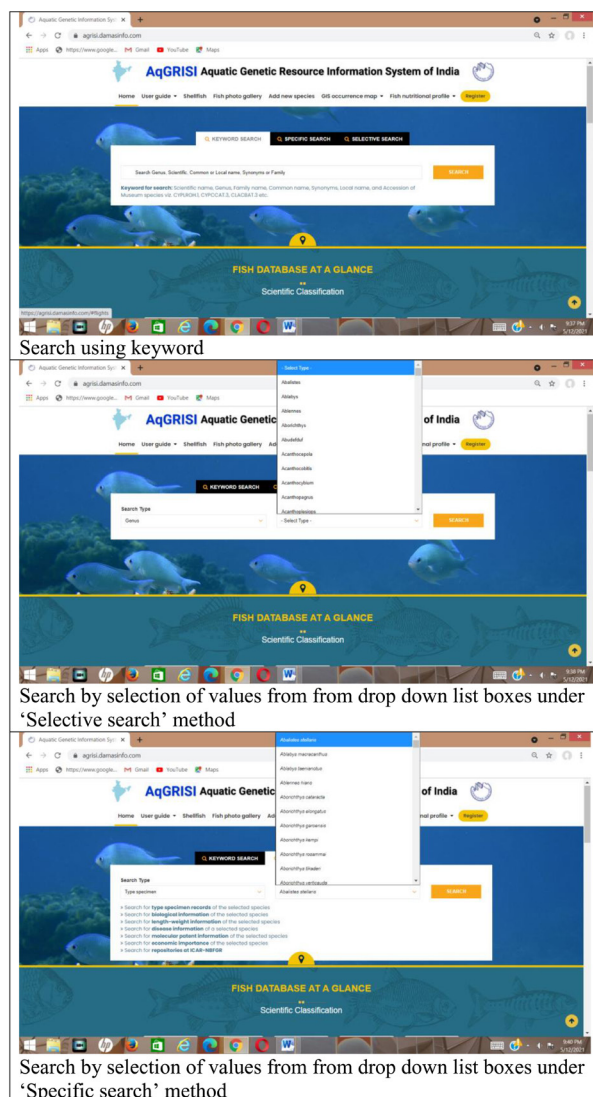


Fig. 3. Search tools in AqGRISl

Search by keyword

This search enables to view the information by type in value for 'Genus' or 'Scientific name' or 'Common name' or 'Synonyms' or 'Local name' or 'Family name' or 'accession code of museum species e.g., CYPLROH.1, CYPCCAT.3, CLACBAT.3 etc.' as a keyword (Fig. 3). For example, if a user types a keyword for Genus, the database fetches record of the species belonging to that genus and present the information with image of the species with details on 'Scientific name', 'Common name', 'Order' and 'Family'. Further, this page displays number of species and facilitates to view the species of another genus using a drop-down list box. The 'View details' option under 'Family' of each species on click opens a page that provides more details about the species by presenting information on 'Distribution', 'Type specimen', 'Habitat', 'Occurrence type', 'IUCN Red List status', 'Museum Specimen', 'Reported disease', 'ICAR-NBFGR Live Fish Germplasm Resource Centers', 'Nucleotide patent', 'Local name', 'Synonyms', 'Biology' and links to other online resources of international importance like FishBase, FAO, NCBI taxonomy, WoRMS and OBIS.

Selective search

This search type facilitates to view information of the species by selecting the type of information and species of interest (Fig. 3). This search type has two drop-down list boxes of which the first drop-down box includes 'Scientific name', 'Genus', 'Common name', 'Local name', 'Museum species', 'Family name', and 'Habitat'. After selection of an item of interest, the values in the next drop-down list box gets updated automatically and facilitates for selection of a species of interest. For example, if a user selects 'Museum species' from the first drop-down list box, the values in the next drop-down list box gets updated automatically and selection of a species of interest leads to display of the specimen records of the selected species in a page with details on 'Species code', 'Specimen accession code', 'Collection site' and 'Depositor'. The species name is hyperlinked to its species page and facilitates user to view more information on the species by presenting details as mentioned earlier in the 'Search by keyword' section.

Specific search

This search facilitates to select an item of interest listed under a category and then select the species of interest (Fig. 3). This type of search has two drop-down list boxes of which first drop-down list box has four categories viz. 'Specimen information', 'Species information', 'Information on accessions in repositories' and 'Species molecular information'. The 'Specimen information' category has length-weight and type specimen information items. The 'Species information' category covers items viz. 'biology', 'disease', 'economic importance' and 'molecular patents'. The 'Information on accessions in repositories' category covers items 'tissues accessions', 'cell lines', 'live germplasm', and 'museum specimens'. Finally, the 'Species molecular information' category is featured with in-house molecular databases viz. HRGFish, FishKaryome, FmIR, FishMicrosat and FBIS. After selection of an item of interest under a category of interest, the values in the adjacent drop-down box gets updated automatically that facilitates to select the species of interest. For example, if a user selects 'Length-weight' under the 'Specimen information' category from

the first drop-down list box, values in the next drop-down list box gets updated automatically, which facilitates to select the species of interest. The selection opens a page on the screen displaying the length-weight information on specimens of the selected species, hyperlinked to its species page and provides more information.

Information on aquatic genetic resources using hyperlinks

Listing of top ten families

The Home page of AqGRISI lists top ten families based on number of species belonging to the family. The number written above each family label in the homepage opens its page, which lists the species of that family in a page with images and provides details on 'scientific name', 'Common name', 'Family' and 'Order'. The 'View Details' option under 'Order' facilitates to view more details about that species as mentioned earlier in the 'Search by keyword' section. Additionally, this page has a drop-down list box that provides the user to view the species of other family with details therein.

Habitat-wise listing of species

The homepage of AqGRISI provides details on species belonging to each habitat type. Grossly three types of habitats have been categorised for Indian native fish fauna and the number written against the 'Species' label under each habitat type denotes number of species found in that habitat category. Each habitat type opens its respective habitat page and displays species image with information on 'Scientific name', 'Common name', 'Family' and 'Order'. The 'View Details' option under 'Order' facilitates the user to view more details about that species. Additionally, this page includes a list box to view the species of other habitats.

Species listing and information

To view list of all species covered in the database with details, a click on the number appearing above the 'Species' label in the home page opens a page where the user can know about the species with its image and details on 'Scientific name', 'Common name', 'Order' and 'Family'. The 'View Details' option under 'Family' facilitates to view more details about that species. All the species in this page have been organised alphabetically to provide ease in browsing the species.

Listing of species by genus, family and order

To view the species of a genus with details, the 'number' appearing above the 'Genus' label in the homepage and a click on it opens a page where user can view the species of a genus with image and details on 'Scientific name', 'Common name', 'Order' and 'Family'. This page has a drop-down list box which provide the ability to view the species of another genus with these details. Similarly, species with aforementioned information under each family can be viewed by clicking on the 'number' written above the 'Family' label and the 'number' written above the 'Order' label in the homepage.

Patent listing of species

AqGRISI also provisions to provide patent information on both native and non-native species. To view the patent information of the species, the 'number' appearing above the label 'Patent' in the homepage is to be clicked. This opens a page and presents the patent information on the species of interest. This page has drop-down list boxes that provide the ability for the user to view the patent information about the species of interest reported from other countries.

Disease information on species

AqGRISI also covers records of the known diseases caused by bacteria, viruses, fungi and parasites reported till now in the native fish species from Indian waters. To view disease information of the species, click on 'number' written above the label 'Disease' in the homepage. This opens a page that presents the details of disease reported in the species. The species name in this page is also linked to page that provides more details on that species. This page includes a drop-down list box that facilitates to view the disease details in the species caused by other pathogens.

Type specimen information

AqGRISI covers the type specimen records compiled from Catalog of Fishes (<https://www.calacademy.org/scientists/projects/eschmeyers-catalog-of-fishes>) and Global Biodiversity Information Facility (GBIF) (<https://www.gbif.org/en/>). The type specimen records of 580 species are only linked to MNHN that presents pictures of holotypes, syntypes, paratypes and neotypes, with description on type specimens of the species. To view the type specimen details of species, click on 'number' written above the 'Type specimen' label in the home page, which opens a page that presents details on 'Specimen type', 'Catalogue number', 'Locality', 'Longitude', 'Latitude', 'Reported year' and a 'Summary' compiled from Catalog of Fishes. This page includes two drop-down list boxes, one for family and another for species that enable the user to view the details about type specimen from the family of interest. The species name in this page is linked to its species page and provides more details about species as mentioned above in the 'Search by keyword' section.

Information on aquatic genetic resources of India using menu and menu items

The homepage of AqGRISI includes a menu bar that covers menu items and provides the user to work with menu items and its sub items (Fig. 2). The menu items 'Home', 'Shellfish', 'Fish photo gallery', 'Add new species', and 'Registration' have no sub-items while 'User guide', 'GIS Occurrence map' and 'Fish Nutritional profile' have sub-items. The 'Shellfish' is linked to the URL: <http://eprints.cmfri.org.in/256/> of ICAR-CMFRI and on click opens a page presenting the detail on bibliography and other information on molluscan shellfish resources of India. The 'Fish photo gallery', on click presents the coloured picture gallery of fishes. 'Add new species' enables the registered users for data submission and 'Registration' facilitates creation of registered users.

The 'User guide' has sub-items 'Data entry manual' and 'Database access manual', which opens up PDF documents on the screen. The former covers the steps for data submission on different aspects of Indian fishes by the registered user, while the later describes the steps of working with AqGRISI. The 'GIS Occurrence map' has two menu sub-items and selection of these sub-items presents GIS-based occurrence maps of type specimens compiled from Catalogue of Fishes and GBIF respectively. The 'Fish Nutritional profile' has sub items viz. 'Proximate composition', 'Amino acids', 'Fatty acids', 'Minerals', 'Vitamins' and 'Recommendation for Nutritionists/ Dieticians/ Physicians'. These sub-items are linked to the respective pages of NUTRIFISHIN website of ICAR-CIFRI.

Functional linkage to the museum accessions and other repositories

Like other databases/information system, AqGRISI is useful for taxonomic and genetic information and the resources available as its database links to other information available at specific portals. The information can be retrieved on cell lines records, tissue accession records, museum specimen records of fish species maintained in the National Fish Museum of ICAR-NBFGR and live germplasm specimen records of species maintained in ICAR-NBFGR Live Fish Germplasm Resource Centers. The 7119 type specimens of 580 species from Indian continent, available in Museum national d'Histoire naturelle (MNHN) (<https://www.mnhn.fr/>) are tagged and directly linked to aid in taxonomy studies. In future, such linkage can be established with other global and national musea, using such provisions. Additionally, the species have link to National Center for Biotechnology Information (NCBI) (<https://www.ncbi.nlm.nih.gov>) that aids in both taxonomic and genomic information. The accession records of the specimen in the above stated repositories are being updated regularly.

This program generates the accession code by using the first three characters of the family, the first character of the genus and first three characters from the species and then includes a numerical character using dot as separator character between the alphabet character set and the numerical character. This program automatically generates the unique accession code for the specimen when its details along with specimen name are entered by the user. For example, the accession code generated for the two specimens of *Labeo rohita* of Cyprinidae family will be CYPLROH.1 and CYPLROH.2. The museum specimen records of National Fish Museum and Repository, have unique accession code generated by the in-house developed program.

Data submission and user management

A data submission dashboard is accessible at URL: <https://aqgrisi.nbfgr.res.in/#/> by clicking on 'Add new species' menu item in the home page of AqGRISI. This data submission dashboard facilitates the registered users to feed and submit data in the database. The dashboard includes editing and viewing tools to edit and view the data entered by the user (Fig. 4). The submission of data by the user merely resides in the transaction database ready for screening by the experts. After evaluation, the validated records are approved by the database administrator for updating the master database. The records containing incomplete or incorrect information remains in

the transaction database and gets either deleted or sent back to the user with comments by the database administrator.

The database administrator has the rights to add, delete, edit, update and reject user as well as data entered by the registered users in order to keep the data and user both up to date. Fig. 4 shows the dashboard of database administrator who is also one of the registered users for data submission.

Discussion

Compared to terrestrial species, aquatic animals have received less priority in developing countries like India when it comes to generating comprehensive information on their biology, genetics, ecology, management, and conservation. Therefore, it is paramount to develop practical methods to document and monitor a wide range of aquatic species, while assessing the impacts of human interventions and management actions on the conservation of aquatic genetic resources. Over the years, aquatic genetic resources have always been an important concern for onward scientific research because of species extinction and decrease in wild populations. Moreover, enforcement of "Conservation of Biological Diversity" legislations for conservation, management and sustainable use of biological diversity of the planet earth, has motivated many countries to prepare the inventory of its biological resources and knowledge therein. It is quite evident that since the Precambrian era, species have always experienced evolutionary changes including extinction and, the acceleration in the rate of extinction is largely associated with human activities, which is not novel but of primary concern because of its devastating effects on diversity and populations (Myers, 1988; Thorne-Miller, 1999). The shift in water currents, temperature, river sedimentation, earthquakes and volcanoes are few major alarming threats for

aquatic environments that disrupt the biological systems. The effects can be extensive and far beyond expectations and could play a pivotal role in increasing the environmental degradation. Thus, policy reforms and improved management strategies are essential to halt and reverse the trends that have led to this situation (Pauly and Zeller, 2003). Recognising the impact of these challenges on biodiversity, worldwide research efforts are now focused on documenting and regularly updating information on the biology, genetics, ecology, management, and conservation of a wide range of aquatic animal species. According to a report published by the ICAR-NBFGR, a total of 227 Indian freshwater fishes were categorised as threatened based on the IUCN (2024) Red List Categories (<https://www.iucnredlist.org/>). Thus, periodic assessment and review of biodiversity is necessary to monitor the state of the biodiversity, which is effortlessly possible, if the biodiversity is recorded and updated over temporal and spatial scale. In the recent years, majority of the biodiversity projects are focusing on measuring and mapping the current state of biodiversity at different regional/country level, in terms of species occurrences, abundance at particular spot/ place/ area and making extrapolations, estimation, future projections and determining the trends by developing time-series data (Turnhout and Boonman-Berson, 2011). This could be possible due to increasing use of the database technology integrated with programming and web technologies in the natural biodiversity science, which have undoubtedly, eased in storing voluminous data and making the information of interest available by querying, searching and learning capabilities through heterogeneous digital networks. Preparing the database on aquatic genetic resources was one of the primary concerns of India to secure the intellectual property as well as sovereign right issues and formulating suitable plans, strategies and policies to safeguard the resources through sustainable management and conservation practices. AqGRISI developed in the present study is an internet-based information system backed

Fig. 4. Data submission dashboard for registered users

with the database that presents the information of fish germplasm resources of India. We believe, this could be advantageous for timely conservation and management of species in their habitat. Like other resources in the queue of the database/ information system on fishes available worldwide, AqGRISI is an additional resource providing the information on fish genetic resources of India. The comparison of AqGRISI with the existing database on fishes reveals that AqGRISI is better in content and also acts as a repository of type accessions. The database of AqGRISI is being updated regularly. It is a centralised source for viewing the information by the national and international agencies for formulation of policy/ management strategies. The development of a database for fish species available in Indian waters aligns with the objectives of the Biological Diversity Act, 2002; and its Amendment 2023 (BDA, 2023), which emphasises the documentation and accessibility of India's biological diversity, the sustainable use of its components, and the fair as well as equitable sharing of benefits derived from the biological resources, and traditional knowledge, along with related matters. A comprehensive analysis of the system indicates its potential usefulness for all fisheries stakeholders, especially for the decision-makers involved in planning, management, and conservation of aquatic genetic resources of India. The information system is designed to be simple and interactive for ease of use. However, it currently lacks efficient querying and search algorithms, which could be integrated to enhance system response time and optimise storage efficiency. Additionally, the absence of data analytics tools limits its capability for in-depth analysis. Future enhancements will include advanced analytics features to unravel hidden insights and explore distal and proximal relationships within the data.

AqGRISI is a centralised online resource for aquatic genetic resources of India, primarily documenting native fish species across three major habitat types viz., freshwater, brackish and marine water. The brackishwater category includes fishes from brackishwater habitats as well as those inhabiting fresh and brackishwater; brackish and marine water as well as those inhabiting all three habitat types (fresh, brackish and marine water). AqGRISI also serves as a digital repository for storing information on fish accessions maintained at ICAR-NBFGR, Lucknow. The integrated in-house script enables the generation of unique accession code for fish accessions, presently applicable for museum specimens. The linking of AqGRISI with online resources of external agencies assists users in validating and knowing more information about the species. AqGRISI featured with data and user management capabilities aims to provide the most recent and precise information. The GIS features included for type specimens provides the ability for viewing the information in different spatial context. In future, AqGRISI would be enhanced with advanced data analytics tools and scaled up to include additional parameters and a broader range of aquatic organisms. It is envisioned to become a key resource for supporting intellectual property rights (IPR) by safeguarding biological resources against misuse, in trade, ownership disputes and commercial exploitation.

Acknowledgments

Authors are thankful to the Director, ICAR-NBFGR, Lucknow for providing the facility to complete the work. The article is dedicated to Late Mrs. Reeta Chaturvedi, for her contribution in building NBFGR's IT capacity since inception and towards this database. She is one of the authors of this manuscript.

References

- Baker, J. P., Olem, H., Creager, C. S., Markus, M. D. and Parkhurst, B. R. 1993. Fish and fisheries management in lakes and reservoirs. EPA 841-R-93-002. Terrene Institute and US Environmental Protection Agency), *Fish. Aquat. Sci.*, 60: 182-192.
- BDA 2023. *Biological Diversity (Amendment) Act, 2023*. <https://moef.gov.in/moef/biological-diversity-amendment-act-2023/index.html>.
- Banki, O., Roskov, Y., Doring, M., Ower, G., Hernandez Robles, D. R., Plata Corredor, C. A., Stjernegaard Jeppesen, T., Orn, A., Pape, T., Hobern, D., Garnett, S., Little, H., DeWalt, R. E., Ma, K., Miller, J., Orrell, T., Aalbu, R., Abbott, J. and Adlard, R. 2025. *Catalogue of Life (Version 2025-03-14)*. Catalogue of Life, Amsterdam, Netherlands. <https://doi.org/10.48580/dgnz3>.
- Codd, E. F. 1971. Further normalization of the data base relational model. *IBM Research Report* RJ909.
- Devi, R. K. and Indra, T. J. 2012. *Check List of the native freshwater fishes of India*. <https://zsi.gov.in/uploads/documents/importantLinks/english/76.pdf>.
- FAO 2018. *Aquaculture Development 9. Development of aquatic genetic resources: A framework of essential criteria*. TG5 Suppl. 9. Rome. Licence: CC BY-NC-SA 3.0 IGO, Food and Agriculture Organisation of the United Nations, Rome. Italy, 88 p.
- FAO 2019. *The state of the world's aquatic genetic resources for food and agriculture*. FAO Commission on Genetic Resources for Food and Agriculture assessments. Food and Agriculture Organisation of the United Nations, Rome, Italy. 291 p. <https://doi.org/10.4060/CA5256EN>.
- FAO 2022. *Global plan of action for the conservation, sustainable use and development of aquatic genetic resources for food and agriculture*. Commission on Genetic Resources for Food and Agriculture. Food and Agriculture Organisation of the United Nations, Rome. Italy, 81 p. <https://doi.org/10.4060/cb9905en>.
- FAO 2024. *The state of world fisheries and aquaculture 2024 – Blue Transformation in action*. Food and Agriculture Organisation of the United Nations, Rome, Italy. <https://doi.org/10.4060/cd0683en>.
- FAO 2025. *Database of farmed types in aquaculture*. Database version 1-2025. Food and Agriculture Organisation of the United Nations, Rome. Italy. <https://www.fao.org/fishery/aquagris/home> (Accessed 18 March 2025).
- Fricke, R., Eschmeyer, W. N. and Van der Laan, R. 2025. *Eschmeyer's Catalog of Fishes: Genera, Species, References*. <http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp>. (Accessed 18 March 2025).
- Froese, R. and Pauly, D. 2024. *FishBase*. World Wide Web electronic publication. www.fishbase.org, version (10/2024). www.fishbase.org. Electronic version (Accessed 18 March 2025).
- Google Patents, 2019. <https://patents.google.com>.
- Grassle, J. F. 2000. The Ocean Biogeographic Information System (OBIS): An on-line, worldwide atlas for accessing, modeling and mapping marine biological data in a multidimensional geographic context. *Oceanography*, 13(3): 5-7.
- IUCN 2024. *The IUCN Red List of Threatened Species. Version 2024-2*. <https://www.iucnredlist.org> (Accessed 18 March 2025).
- Jacob, C. T., Yadava Y. S. and Lal, K. K. 2021. Review of the implementation of Aichi biodiversity targets with special reference to inland, coastal and marine fisheries sectors. *Asian Biotechnol. Dev. Rev.*, 23(2): 89-108.

- Murali S. K., Singh, V. K., Mishra, A. K., Kushwaha, B., Kumar, R., and Lal, K. K. 2023. Fish cell line: depositories, web resources and future applications. *Cytotechnology*, 76: 1-25. <https://doi.org/10.1007/s10616-023-00601-2>.
- MolluscaBase 2025. *MolluscaBase*. <https://www.molluscabase.org> <https://doi.org/10.14284/448> (Accessed 18 March 2025).
- Myers, N. 1988. Threatened biotas: «hot spots» in tropical forests. *Environmentalist*, 8(3):187-208.
- Nagpure, N. S., Pathak A. K., Pati, R., Rashid, I., Sharma, J., Singh, S. P., Singh, M., Sarkar, U. K., Kushwaha, B., Kumar, R. and Murali, S. 2016. Fish Karyome version 2.1: A chromosome database of fishes and other aquatic organisms. *Database*, 2016: 1-8.
- NBFGR 2016. *Guidelines for management of fish genetic resources in India*. ICAR-National Bureau of Fish Genetic Resources, Lucknow, India, 64+ xxiii p.
- NRFC 2019. *National Repository of Fish Cell Lines: Under National Museum of Fish Museum and Repository*, ICAR-National Bureau of Fish Genetic resources, Lucknow, India. <https://mail.nbfgr.res.in/nrfc/ourgroup.php> (Accessed 18 March 2025).
- Pathak, A. K., Singh, S. P., Dayal, R., Sarkar, U. K. and Chaturvedi, R. 2016. A regional information system on fishes from the Western Ghats, India: Its design, implementation and utility. *Indian J. Mar. Sci.*, 45(10): 1305-1309.
- Pathak, A. K., Rashid, I., Nagpure, N. S., Kumar, R., Pati, R., Singh, M., Murali, S., Kushwaha, B., Kumar, D. and Rai, A. 2019. FisOmics: A portal of fish genomic resources. *Genomics*, 111(6): 1923-1928. <https://doi.org/10.1016/j.ygeno.2019.01.003>.
- Pauly, D. and Zeller, D. 2003. The global fisheries crisis as a rationale for improving the FAO's database of fisheries statistics. *Fisheries Centre Research Reports*, 11(6): 1-9.
- Psomas, A. N., George-John, N., Haroutounian, S. A. and Skandamis, P. 2012. LabBase: Development and validation of an innovative food microbial growth responses database. *Computers and Electronics in Agriculture*, 85: 99-108.
- Ramanna-Pathak, A. 2015. Intellectual Property Rights access to genetic resources and Indian shrimp aquaculture: Evolving policy responses to globalization. *The Journal of World Intellectual Property*, 18(1-2): 41-64. <https://doi.org/10.1111/jwip.12030>.
- Rashid, I., Nagpure, N. S., Srivastava, P., Kumar, R., Pathak, A. K., Singh, M. and Kushwaha, B. 2017. HRGFish: A database of hypoxia responsive genes in fishes. *Sci. Rep.*, 7: 42346: <https://doi.org/10.1038/srep42346>.
- Shao, K. T. 2019. *The Fish Database of Taiwan*. <http://fishdb.sinica.edu.tw>.
- Tedesco, P. A., Beauchard, O., Bigorne, R., Blanchet, S., Buisson, L., Conti, L., Cornu, J. F., Dias, M. S., Grenouillet, G., Hugueny, B. and Jezequel, C. 2017. A global database on freshwater fish species occurrence in drainage basins. *Sci. Data*, 4: 170141.
- Thorne-Miller, B. 1999. *The living ocean: Understanding and protecting marine biodiversity*. Island Press, Washington DC, USA.
- Turnhout, E. and Boonman-Berson, S. 2011. Databases, scaling practices, and the globalization of biodiversity. *Ecology and Society*, 16(1): 35. [online] URL: <http://www.ecologyandsociety.org/vol16/iss1/art35/>.
- Villordon, A., Njuguna, W., Simon, G., Ndolo, P., and Labonte, D. 2007. Using Open-Source Software in developing a web-accessible database of sweetpotato germplasm collections in Kenya. *HortiTechnology*. 17(4): 567-570. <https://doi.org/10.21273/HORTTECH.17.4.567>.
- WoRMS 2025. *World Register of Marine Species*. <https://www.marinespecies.org> at VLIZ. <https://doi.org/10.14284/170>. (Accessed 18 March 2025).