

The Freshwater Biodiversity Information System (FBIS) fish data: a georeferenced dataset of freshwater fishes occurring in South Africa

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ABSTRACT

Freshwater fishes are recognised as South Africa's most threatened species group. Reliable, long-term data on fish occurrence records are critical for effectively managing and conserving these species. A comprehensive freshwater fish dataset was compiled and uploaded to the Freshwater Biodiversity Information System (FBIS, freshwaterbiodiversity.org), comprising all available records of formally described freshwater fish species occurring in South Africa. An 18-month historic-data collation effort resulted in the accrual of 35 955 new records of freshwater fish from South Africa spanning 194 years (1828–2022), that have since been uploaded to the Global Biodiversity Information Facility (GBIF). Together with pre-existing GBIF records (24 861), a total of 60 837 freshwater fish records are thus now available for South Africa. The data show a marked decline in the number of native fish occurrence records over the last decade. Conversely, the number of occurrences for non-native fishes increased over the past three decades. A data breakdown is provided for each of South Africa's nine provinces including total number of records, and the numbers of native, non-native, endemic and threatened species. These data provide a much-needed update of the known status and distribution of freshwater fishes in the country.

INTRODUCTION

Freshwater fishes are regarded as South Africa's most threatened species group (Skowno *et al.*, 2019). The country is home to 106 native freshwater fish taxa (Chakona

et al., 2022), of which almost 50% are endemic (Skowno *et al.*, 2019). However, like in many other parts of the world, the habitats that support freshwater fishes within South Africa face numerous anthropogenic pressures that threaten not only the survival of these species (two-thirds of the endemic species are threatened with extinction; Skowno *et al.*, 2019), but also the integrity of freshwater ecosystems as a whole (Dudgeon *et al.*, 2006; Darwall *et al.*, 2009; Geist, 2011).

Access to reliable, long-term freshwater fish data sets is critical for conserving these species and the aquatic ecosystems that they inhabit (Dallas *et al.*, 2022). Despite a well-established freshwater fish research infrastructure and rich history of fish sampling in South Africa, to date there has been limited sharing of knowledge or data on a national level (Kajee *et al.*, 2023). Until recently, an operational information system for accessing freshwater fish data has not existed. However, in 2020 a new online database called the Freshwater Biodiversity Information System (FBIS, <https://freshwaterbiodiversity.org>) was launched to improve access to freshwater biodiversity data in South Africa (Dallas *et al.*, 2022).

This paper describes how the FBIS was used to collate South Africa's largest freshwater fish species occurrence dataset to date - a process that enabled the upload of over 35,000 new fish occurrence records to the Global Biodiversity Information Facility (GBIF).

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Key words: Freshwater fish; South Africa; GBIF; occurrence data; FBIS.

Citation: Kajee M, Dallas HF, Swanepoel A, Griffiths CL, Shelton JM. The Freshwater Biodiversity Information System (FBIS) fish data: a georeferenced dataset of freshwater fishes occurring in South Africa. *J. Limnol.* 2023;82:2133.

Edited by: Diego Fontaneto, *National Research Council, Water Research Institute (CNR-IRSA), Verbania Pallanza, Italy.*

Received: 10 March 2023.

Accepted: 16 March 2023.

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J. Limnol., 2023; 82(s1):2133
DOI: 10.4081/jlimnol.2023.2133

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METHODS

Study area

The geographic scope of this project was restricted to

the boundaries of the Republic of South Africa, but also included the Kingdom of Eswatini (formerly Swaziland) and the Kingdom of Lesotho (for convenience purposes, this study area is hereafter referred to as ‘South Africa’). Data collection was limited to rivers, dams and freshwater lakes within South Africa. Importantly, estuarine and marine systems were excluded.

Bounding box coordinates: 34°50'59.55"S and 22°6'21.6"S Latitude; 16°20'51.56"E and 33°0'10.55"E Longitude (WGS84).

Study species

Coverage includes all freshwater fish species known to occur in the wild (species held in captivity were excluded) within South Africa. For the purpose of this chapter, only formally described species and sub-species recognised using the GBIF taxonomic backbone were included. Species in the process of being described, or those belonging to groups currently under taxonomic review (such as new taxa identified within the genera *Enteromius*, *Galaxias* and *Sandelia*) were omitted completely from the data collection and analyses of this study, pending resolution of their taxonomic status.

Freshwater fish species are defined as species that spend all, or a critical part, of their lives in either freshwater or brackish environments (Skelton, 2001; Arthington *et al.*, 2016). For the purpose of this study, only primary freshwater fish (fishes living in inland waters, with little or no tolerance of saltwater), secondary freshwater fish (fishes relatively tolerant of salt water, but normally living in inland waters) and diadromous/catadromous fish (fishes that, in the course of their life cycle, regularly migrate between inland waters and the sea, or vice versa) species were included. Importantly, both marine peripheral and sporadic marine species were omitted entirely from both the data collection and analysis (see Skelton (2001) for ecological-tolerance category definitions).

Based on these criteria, a freshwater fish species list was compiled using the South African Institute of Aquatic Biodiversity’s (SAIAB) database and the RHP (River Health Programme) (2015) Rivers Database (Dallas *et al.*, 2007), the freshwater fish field guide by Skelton (2001), as well as subsequent scientific papers, including Skelton (2002), Skelton (2016), Ellender and Weyl (2014) and Weyl *et al.* (2020). This list was then used to guide the data collection process.

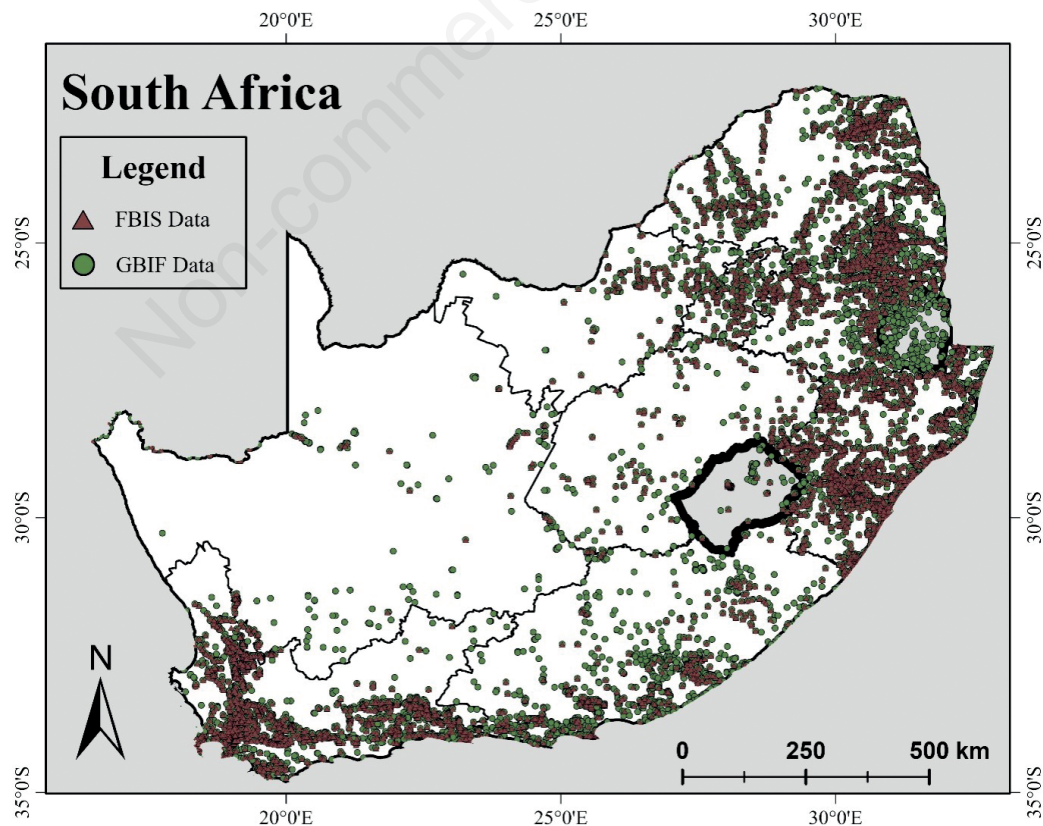


Fig. 1. Map of the Republic of South Africa, including the Kingdom of Eswatini (formerly Swaziland) and the Kingdom of Lesotho, the whole area hereafter referred to as ‘South Africa’.

Data collection

Fish species occurrence records were gathered from multiple sources between November 2018 and May 2020, with the aim of collating all known, accessible records of freshwater fish occurrences in South Africa. Specific details pertaining to the scope of the data set, as well as the collection and analyses of the data, are provided in the sections below. All data were initially uploaded onto the FBIS database (Dallas *et al.*, 2022; freshwaterbiodiversity.org) and then all non-GBIF data were uploaded to the GBIF (<https://gbif.org>) in March 2023.

Published data

A thorough literature search for geo-referenced, time-stamped occurrence records was undertaken for each species included on the fish species list using Google Scholar. To ensure that relevant papers were identified, the following search term combination was used for all native freshwater fishes: “*Genus species*” and “*South Africa*” (where “*Genus species*” represents the scientific name of each taxon). A different search term was used for non-native species, to further refine the search. The following search term was used: “*Genus species*” and “*South Africa*” and “*study*” OR “*survey*” OR “*sample*” OR “*site*” and “*map*” OR “*coordinate*” OR “*coordinates*” OR “*latitude*” OR “*longitude*” OR “*GPS*” (where “*Genus species*” represents the scientific name of each taxon). Relevant articles were identified based on their titles, abstracts, methods and results sections. Only the first 500 search results returned by Google Scholar were assessed for relevancy, due to time constraints. This number was

selected based on an initial trial phase, which determined that after 500 search results, Google Scholar mostly outputted irrelevant, obscure articles.

Articles (including peer-reviewed publications, theses and published reports) were deemed to be relevant if information from the title, abstract or methods section indicated that the article contained occurrence data for the specific freshwater fish taxon in South Africa. If an article was deemed to be relevant, the article was catalogued in a Microsoft Excel (365 ProPlus) spreadsheet and the PDF version of the article was downloaded. Data from each relevant article were extracted once all species searches were complete.

Databases

Occurrence data for freshwater fishes in South Africa were also collected from 15 national databases curated within FBIS, and from one international database (GBIF), which included the South African Institute for Aquatic Biodiversity (SAIAB) database (Tab. 1).

Unpublished data

Several freshwater fish experts and conservation organisations from across the country were identified and contacted to request any additional unpublished data that may exist in analog form, or on private hardware (Tab. S1). Additionally, several presentations were delivered at conferences, workshops and meetings to appeal for data. In October 2019, the FBIS database was launched online and opened for the upload of additional data by approved, registered users. These data, validated by experts, were

Tab. 1. List of databases accessed to search for freshwater fish occurrence records in South Africa.

#	Name of database
1	Global Biodiversity Information Facility (GBIF)*
2	South African National Parks Fish Database
3	Limpopo Department of Environmental Affairs Fish Database
4	Rivers Database 2015
5	Mpumalanga Tourism and Parks Agency Fish Database
6	Cape Nature State of Biodiversity Database
7	Clean Stream Biological Services Fish Database
8	Inkomati-Usuthu Catchment Management Agency Database
9	Nepid Fish Database
10	Ecotone Freshwater Consultants Database
11	Ecosun Database
12	Department of Water and Sanitation Regional Fish Database
13	Gauteng Department of Agriculture and Rural Development Database
14	Freshwater Research Centre Monitoring Database
15	The Biodiversity Company SASS and Fish Database

*The Global Biodiversity Information Facility’s (GBIF) database: these data included all data uploaded to GBIF by South African and International research institutions like SAIAB, as well as citizen science data from iNaturalist that were classified by GBIF as “Research Grade” data.

downloaded on 22 September 2022, and incorporated into the final dataset.

Data extraction

Each article that was deemed to be relevant during the literature search was inspected for GPS coordinates. In cases where GPS coordinates were not provided, the paper was temporarily archived and catalogued, and an email was sent to the listed corresponding author asking whether these were available and if so, requesting a copy. Where site-specific coordinates were provided, these were converted to decimal degrees and entered into the dataset. In addition to the taxon name, sampling date and GPS coordinates, biological information on species origin ('native' or 'non-native'), ecological tolerance ('primary freshwater'; 'secondary freshwater'; or 'diadromous'), endemism ('widespread'; 'subregional endemic'; 'national endemic'; 'regional endemic level 1'; 'regional endemic level 2'; 'micro-endemic 1'; 'micro-endemic 2'; Dallas *et al.*, 2022), and conservation status (IUCN Red List categories: 'Not Evaluated'; 'Data Deficient'; 'Least Concern'; 'Near Threatened'; 'Vulnerable'; 'Endangered'; 'Critically Endangered') were collected. In this paper, 'threatened species' refers to those falling within the categories Vulnerable, Endangered and Critically Endangered. Companion data including collector details, physico-chemical data, habitat, sampling method and abundance measures were also documented for each record, where available. See Supplementary Tab. S2 for details of the full list of parameters included during data extraction. All collected data were standardised and uploaded onto the FBIS platform.

Data analysis

The total number of species occurrence records were calculated for each native and non-native freshwater fish species in South Africa. The total number of fish species occurrence records in South Africa per year were calculated for native species, non-native species and all species combined. These calculations were then done separately for each of South Africa's nine provinces. The total number of records, and total number of species falling within the following categories were also calculated for each province: each origin category; each endemism category and each IUCN conservation status category. Distribution and abundance patterns were assessed and visualised in R Software (Version 3.5.0; R Core Team, Vienna, Austria).

RESULTS

Dataset description

Object name: Darwin Core Archive: The Freshwater Biodiversity Information System (FBIS) Fish Data

Character encoding: UTF-8

Format name: Darwin Core Archive format

Format version: 1.2

Distribution: https://ipt.sanbi.org.za/iptfrc/archive.do?r=fbis_fish_data

GBIF UUID: <https://www.gbif.org/dataset/3ea542dc-885d-4c8a-91a3-64d0a5d78301>

Permanent link: <https://doi.org/10.15468/gmk6hg>

Date of creation: 28 February 2023

Date of last revision: 14 March 2023

Publication date of data: 14 March 2023

Language: English

Metadata language: English

Date of metadata creation: 28 February 2023

Metadata managers: Mohammed Kajee (kjxmoh007@myuct.ac.za), Helen Dallas (helen@frcsa.org.za), Jeremy Shelton (jeremy@frcsa.org.za)

Licences of use: Access to and use of the data and metadata is free to any user under a Creative Commons Attribution (CC-BY) 4.0 License. When using data from this dataset, the authors would appreciate if data users cite the following: i) this data paper, ii) the GBIF dataset, and iii) the original dataset.

GBIF dataset citation: Freshwater Biodiversity Information System (FBIS) Fish Data. Version 1.6. Freshwater Research Centre <https://doi.org/10.15468/gmk6hg>

Original dataset citation: Freshwater Biodiversity Information System (FBIS), 2022. Downloaded from <https://freshwaterbiodiversity.org> on <current date>.

Project management details

Project title: The Freshwater Biodiversity Information System (FBIS)

Database managers: Mohammed Kajee, Helen Dallas, Jeremy Shelton

IT managers: Tim Sutton, Dimas Tri Cuptura; Kartoza Open-Source Geospatial Solutions

Funding: The FBIS project is led by the Freshwater Research Centre (FRC) in partnership Kartoza Open-Source Geospatial Solutions and the South African National Biodiversity Institute (SANBI). The project is funded by the JRS Biodiversity Foundation and the South African National Biodiversity Institute (SANBI).

Summary statistics

The Freshwater Biodiversity Information System (FBIS) Fish Data dataset contains 60,837 freshwater fish records in South Africa. Of this, 24 861 were publicly available on GBIF with 35 955 records being sourced from other databases, published theses and reports, peer-reviewed scientific articles, and unpublished data held by expert freshwater scientists in South Africa. The dataset spans 194 years (1828-2022), with the vast majority

(89%) of records being collected between 1975 and present (Fig. 2).

Taxonomic coverage

The dataset includes records for 134 species (129 species with georeferenced coordinates), belonging to 51 genera and 22 families. Of the 129 species with records in South Africa, 105 (81%) are native, with 24 (19%) being non-native (Tab. 2). The top five most data-rich species were *Ore-*

ochromis mossambicus (n=3674); *Clarias gariepinus* (n=2783); *Pseudocrenilabrus philander* (n=2542); *Enteromius trimaculatus* (n=2447); and *Labeobarbus marequensis* (n=2376). In total, 20 species had more than 1000 records each, while 62 species had between 100-999 records. Many species were notably data-scarce; 51 species having less than 100 records and 12 species less than 10 records.

Taxon specialists: Paul Skelton, Albert Chakona, Olaf Weyl, Dean Impson, Dewidine Van der Colff

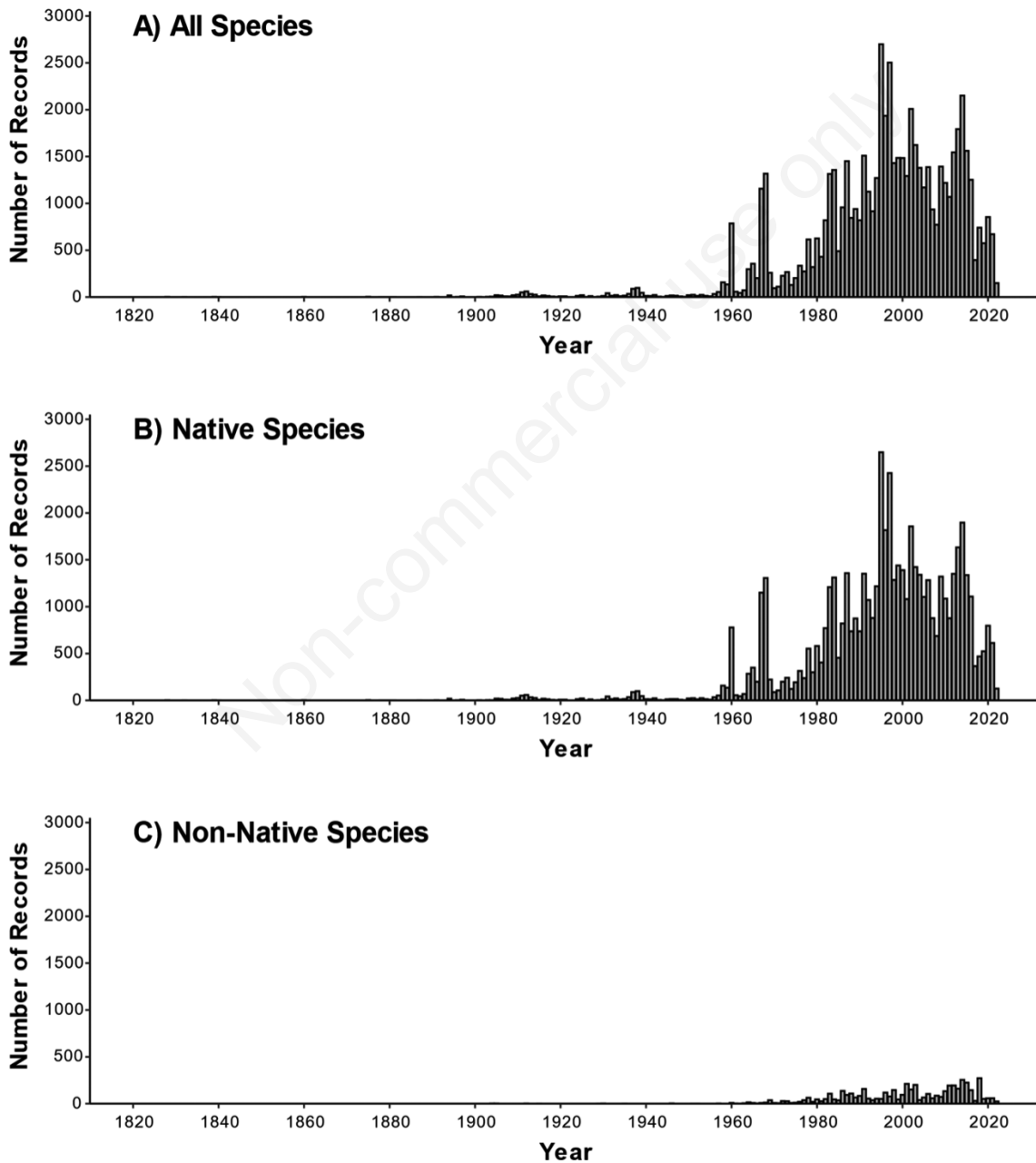


Fig. 2. Number of occurrence records of freshwater fish species occurring in South Africa for each year between 1860 and 2020 for all species combined (A; n=60,837), for native species only (B; n=56,096) and for non-native species only (C; n=4741).

South African freshwater fish records

Tab. 2. Alphabetical list of 134 freshwater fish species occurring in South Africa and the number of records found for each species. Non-native species are indicated with an asterisk (*). Species with zero records are highlighted in grey.

Scientific name	Number of records	Scientific name	Number of records	Scientific name	Number of records
<i>Ambassis natalensis</i>	72	<i>Enteromius paludinosus</i>	1715	<i>Opsaridium peringueyi</i>	474
<i>Amphilius natalensis</i>	444	<i>Enteromius radiatus</i>	402	<i>Oreochromis andersonii*</i>	0
<i>Amphilius uranoscopus</i>	1006	<i>Enteromius toppini</i>	590	<i>Oreochromis aureus*</i>	15
<i>Anguilla bengalensis</i>	26	<i>Enteromius treurenensis</i>	28	<i>Oreochromis mossambicus</i>	3674
<i>Anguilla bicolor</i>	9	<i>Enteromius trimaculatus</i>	2447	<i>Oreochromis niloticus*</i>	80
<i>Anguilla marmorata</i>	195	<i>Enteromius unitaeniatus</i>	873	<i>Oreochromis placidus</i>	4
<i>Anguilla mossambica</i>	1088	<i>Enteromius viviparus</i>	1779	<i>Pangasius sanitwongsei*</i>	3
<i>Austroglanis barnardi</i>	100	<i>Galaxias zebratus</i>	1250	<i>Perca fluviatilis*</i>	4
<i>Austroglanis gilli</i>	330	<i>Gambusia affinis*</i>	203	<i>Petrocephalus wesselsi</i>	214
<i>Austroglanis sclateri</i>	140	<i>Hydrocynus vittatus</i>	367	<i>Poecilia reticulata*</i>	103
<i>Brycinus imberi</i>	346	<i>Hypophthalmichthys molitrix*</i>	14	<i>Protopterus annectens</i>	0
<i>Brycinus lateralis</i>	72	<i>Kneria auriculata</i>	8	<i>Pseudobarbus afer</i>	554
<i>Carassius auratus*</i>	31	<i>Labeo capensis</i>	416	<i>Pseudobarbus asper</i>	379
<i>Chetia brevis</i>	27	<i>Labeo congoro</i>	215	<i>Pseudobarbus burchelli</i>	655
<i>Chetia flaviventris</i>	123	<i>Labeo cylindricus</i>	1292	<i>Pseudobarbus burgi</i>	215
<i>Chiloglanis anoterus</i>	571	<i>Labeo molybdinus</i>	1771	<i>Pseudobarbus calidus</i>	359
<i>Chiloglanis bifurcus</i>	84	<i>Labeo rosae</i>	619	<i>Pseudobarbus capensis</i>	97
<i>Chiloglanis emarginatus</i>	120	<i>Labeo rubromaculatus</i>	227	<i>Pseudobarbus erubescens</i>	149
<i>Chiloglanis paratus</i>	957	<i>Labeo ruddi</i>	252	<i>Pseudobarbus hospes</i>	76
<i>Chiloglanis pretoriae</i>	1540	<i>Labeo seeberi</i>	278	<i>Pseudobarbus phlegethon</i>	229
<i>Chiloglanis swierstrai</i>	458	<i>Labeo umbratus</i>	575	<i>Pseudobarbus quathlambae</i>	153
<i>Clarias gariepinus</i>	2783	<i>Labeobarbus aeneus</i>	608	<i>Pseudobarbus senticeps</i>	17
<i>Clarias ngamensis</i>	9	<i>Labeobarbus kimberleyensis</i>	202	<i>Pseudobarbus serra</i>	605
<i>Clarias theodora</i>	98	<i>Labeobarbus marequensis</i>	2376	<i>Pseudobarbus skeltoni</i>	38
<i>Coptodon rendalli</i>	1152	<i>Labeobarbus natalensis</i>	1081	<i>Pseudobarbus swartzi</i>	10
<i>Coptodon zilli*</i>	14	<i>Labeobarbus nelspruitensis</i>	121	<i>Pseudobarbus tenuis</i>	428
<i>Ctenopharyngodon idella*</i>	35	<i>Labeobarbus polylepis</i>	360	<i>Pseudobarbus trevelyani</i>	89
<i>Ctenopoma multispine</i>	28	<i>Labeobarbus seeberi</i>	316	<i>Pseudobarbus verloreini</i>	39
<i>Cyprinus carpio*</i>	642	<i>Lacustricola katangae</i>	126	<i>Pseudocrenilabrus philander</i>	2542
<i>Engraulicypris brevianalis</i>	833	<i>Lacustricola myaposae</i>	129	<i>Pterygoplichthys disjunctivus*</i>	16
<i>Engraulicypris gariepinus</i>	66	<i>Lepomis macrochirus*</i>	411	<i>Salmo salar*</i>	0
<i>Enteromius afrohamiltoni</i>	336	<i>Marcusenius caudisquamatus</i>	9	<i>Salmo trutta*</i>	71
<i>Enteromius amatolicus</i>	37	<i>Marcusenius krameri</i>	17	<i>Salvelinus fontinalis*</i>	2
<i>Enteromius annectens</i>	431	<i>Marcusenius pongolensis</i>	51	<i>Sandelia bainsii</i>	155
<i>Enteromius anoplus</i>	2096	<i>Megalops cyprinoides</i>	71	<i>Sandelia capensis</i>	1685
<i>Enteromius argenteus</i>	426	<i>Micralestes acutidens</i>	1105	<i>Schilbe intermedius</i>	461
<i>Enteromius bifrenatus</i>	244	<i>Microctenopoma intermedium</i>	6	<i>Serranochromis jallae</i>	0
<i>Enteromius brevipinnis</i>	152	<i>Micropanchax johnstoni</i>	89	<i>Serranochromis meridianus</i>	72
<i>Enteromius eutaenia</i>	658	<i>Micropterus dolomieu*</i>	657	<i>Serranochromis robustus*</i>	2
<i>Enteromius gurneyi</i>	170	<i>Micropterus floridanus*</i>	62	<i>Synodontis zambezensis</i>	228
<i>Enteromius lineomaculatus</i>	126	<i>Micropterus punctulatus*</i>	369	<i>Tilapia sparrmanii</i>	2290
<i>Enteromius mattozi</i>	81	<i>Micropterus salmoides*</i>	1362	<i>Tinca tinca*</i>	8
<i>Enteromius motebensis</i>	126	<i>Nothobranchius orthonotus</i>	48	<i>Xiphophorus helleri*</i>	45
<i>Enteromius neefi</i>	475	<i>Nothobranchius pienaari</i>	0	<i>Xiphophorus maculatus*</i>	8
<i>Enteromius pallidus</i>	351	<i>Oncorhynchus mykiss*</i>	584	Total	60837

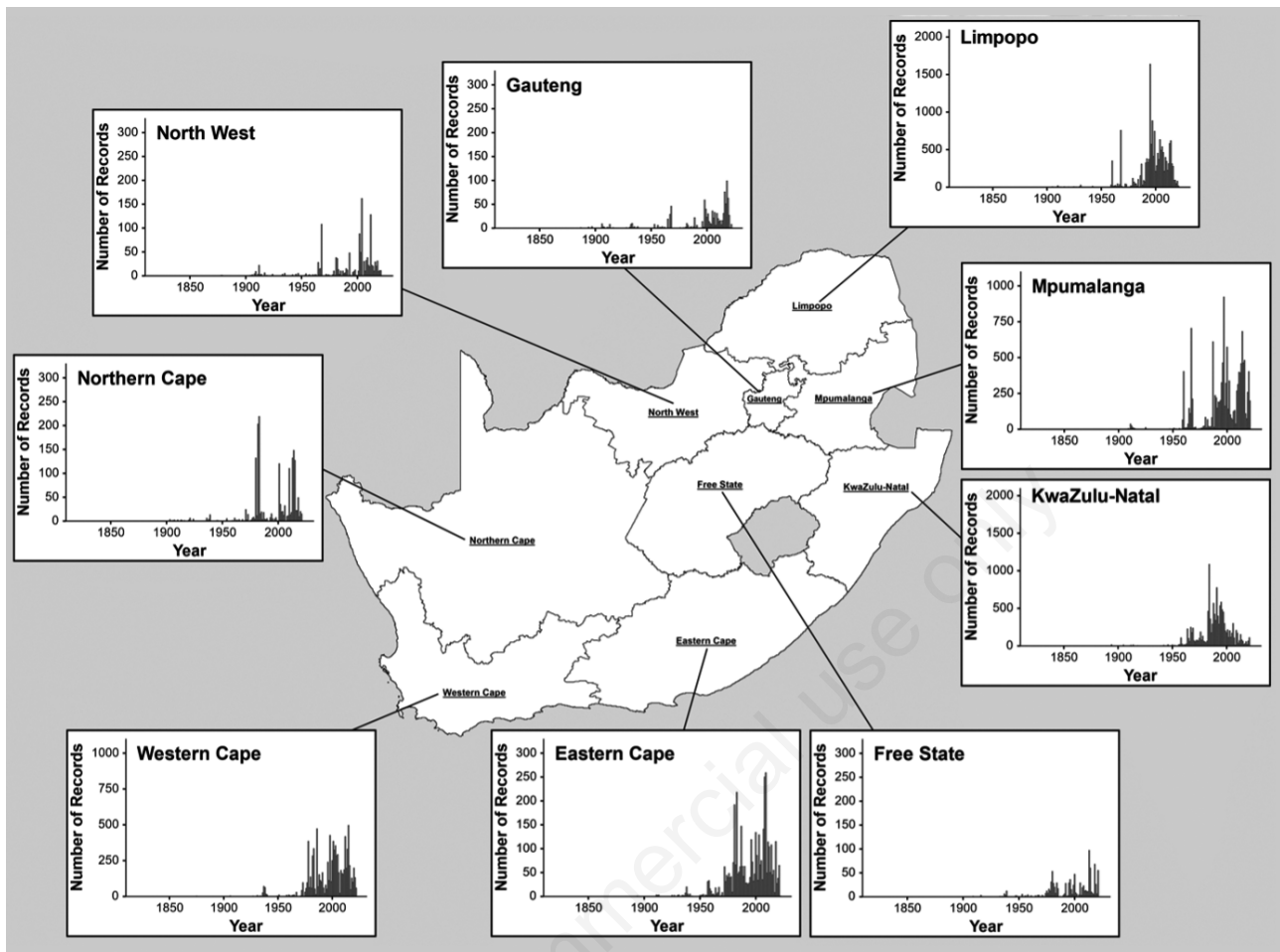


Fig. 3. Number of occurrence records of freshwater fish species recorded per year in each of South Africa's nine provinces from 1828–2022.

Quality control for taxonomic data: Nomenclature validation and cleaning were based on formally described species and sub-species recognised using the GBIF taxonomic backbone.

Geographic coverage

A breakdown of freshwater fish occurrence records is provided for all nine of South Africa's provinces. The province with the greatest number of records was Limpopo ($n=15,332$), followed by KwaZulu-Natal ($n=12,615$), Mpumalanga ($n=12,300$) and the Western Cape ($n=9236$) (Figs. 3 and 4). The provinces with the least number of records were the Free State ($n = 964$) and Gauteng ($n=989$). Non-native species occurred in all nine provinces. KwaZulu-Natal had the greatest number of non-native species (20 species), followed by the West-

ern Cape (16) and the Eastern Cape (14). These three provinces also had the largest number of threatened species (KZN=9; WC=16; EC=11). Endemic species were found in all nine provinces, with the Western Cape (22 species) having the highest number of endemic species (Fig. 4).

Data availability

The dataset in its entirety is freely available and can be downloaded from the FBIS (<https://freshwaterbiodiversity.org>). This includes 126 columns of data per record, which incorporates additional information on, *inter alia*, taxonomy, conservation status, ecological tolerance, and endemism. The occurrence records that were not previously available on GBIF were uploaded to GBIF in March 2023 (<https://doi.org/10.15468/gmk6hg>).

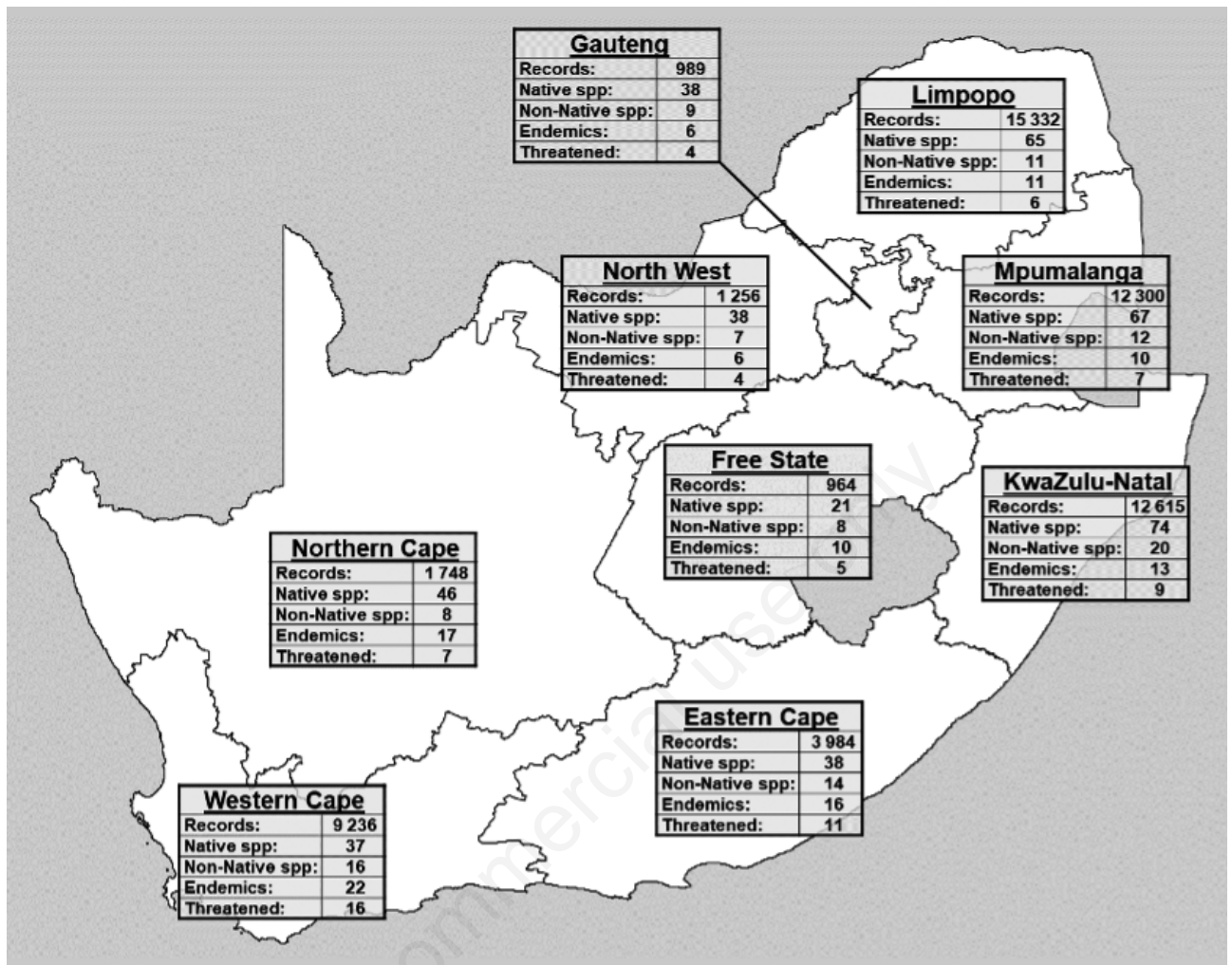


Fig. 4. Total number of freshwater fish occurrence records, and the number of native, non-native, endemic and threatened species recorded in each of South Africa's nine provinces.

ACKNOWLEDGEMENTS

We would like to thank the FRC staff and interns for their support in developing the FBIS database. We would also like to express our gratitude to the team at Kartoza for all of their hard work and support with the technical development and implementation of the FBIS platform. We are especially grateful to Fhatani Ranwashe for his assistance with setting up our IPT and assistance with uploading this database to GBIF. We also thank Paul Skelton, Albert Chakona, Olaf Weyl, Dean Impson, and Dewidine Van der Colff for their advice and taxonomic input throughout the database development process. Lastly, we thank Karla Alujević for her help with data cleaning and summary statistic coding in R. Funding for the development of the FBIS was provided by the JRS

Biodiversity Foundation (Grants 60606 and 60919) and SANBI. This work is also supported in part by the National Research Foundation (NRF) of South Africa (Grant Number: MND2000621534710–UID: 133692) and the NRF-SAIAB DST/ NRF Research Chair in Inland Fisheries and Freshwater Ecology (UID 110507). Student funding, in the form of an MSc bursary, was also provided by the Freshwater Biodiversity Unit of SANBI and the University of Cape Town.

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