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Using Natural History Collections to Determine the Relative Changes in Diversity and Distribution of Freshwater Molluscs in KwaZulu-Natal, South Africa

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ABSTRACT

Research using natural history collections to track anthropogenic activities has recently been on the rise. Natural history collections have been utilised beyond their traditional taxonomic and systematic roles, generating data that shape present and future research. We evaluated the value of natural history collections in answering questions about the changes in the occurrence of freshwater mollusc species in KwaZulu-Natal, South Africa, over the past 124 years. The historical records were sourced from four natural history collections databases in South Africa. Specimen records were curated and validated against two independent online platforms. The number of shells and diversity among collections were compared, and trends in the database were analysed. We recorded a significant decline in the number of specimens collected between 1897 and 1960, and after 1980 and 2021, respectively. The majority of freshwater mollusc specimens that were collected belonged to *Bulinus tropicus* (Krauss, 1848) (307 records), followed by *Pseudosuccinea columella* (Say, 1817) (270 records) and *Radix natalensis* (Krauss, 1848) (268 records), while 34% of specimens collected received one observation each. Three species database records exhibited positive observation trends, while two species showed negative database record trends. We also found that potentially declining species database records accounted for 52% of the total freshwater molluscs in KwaZulu-Natal. The broad-scale compositional shift of endemic species and the greater prevalence of invasive species may be exacerbated by inadequate sampling and a lack of long-term monitoring programs at selected sites. We argue that random sampling and donations are insufficient to sustain the growth of these collections. National programs, such as the River Eco-Status Monitoring Programme (REMP) and Freshwater Biodiversity Information System (FBIS), have the opportunity to identify and include new key biodiversity sites for biomonitoring of biodiversity. Thus, an increase in financial and skills investment is advocated to monitor biodiversity and the emergence of future diseases.

1 | Introduction

Historically, natural history collections were made for entertainment, where collecting efforts were intimately linked to private cabinets of “curiosities”, exhibiting the status of the wealthy members of society while allowing viewers to see

artefacts and biota from distant places (Lintz 1991; Hooper-Greenhill 1992; Lane 1996; Hilton et al. 2021). Thereafter, during the Renaissance, the efforts to preserve natural history collections were to “teaching our youth to appreciate the wonderful works of the Creator” (Alexander 1979). Later, this education function evolved into a view of nature as an open book,

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where field surveys contributed to building natural history collections (Lane 1996; Hilton et al. 2021). It was only in the 19th century that collections were used to advance ecological studies (Farrington 1915; Farber 1982; Lane 1996; Holmes et al. 2016; Watanabe 2019; Hilton et al. 2021; Li et al. 2023). These collections and their associated data provide a foundation for present and future research addressing national and global relevance issues. Each unique specimen record contains information regarding the name of the organism and the collector(s), as well as the date and place of collection, when applicable. These attributes could make specimen records valuable for studying ecological changes over time (Shochat et al. 2006; Ward et al. 2015; Li et al. 2023; Alofs et al. 2025).

Using natural history collections to address faunal change over time is challenging; however, because of the different, often specialised collecting reasons driven by the interests of museum researchers and their institutions (Ward 2012; De Siracusa et al. 2020). As a result, certain taxa are omitted during collecting trips instead of collecting all species present, and new localities are preferred instead of sampling the same localities over time (Ward 2012; De Siracusa et al. 2020). Freshwater ecosystems and their associated riparian habitats are among the most biologically diverse on Earth and have inestimable economic, health, cultural, scientific, and educational values (Wantzen et al. 2016; Albert et al. 2021; Vári et al. 2022), and the impact of human activities on lakes, rivers, streams, wetlands, and groundwater has accelerated changes in freshwater ecosystems over time (Böhm et al. 2020; Lopes-Lima et al. 2021).

These activities significantly reduce biodiversity and deprive present and future generations of access to resources (Wantzen et al. 2016; Rodell et al. 2018; Vári et al. 2022). Globally, freshwater biodiversity is declining in major river basins (Turak et al. 2017; Böhm et al. 2020; Lopes-Lima et al. 2021; Ziganira and Downs 2025). As a whole, South Africa is not exempt from this trend; the rivers of KwaZulu-Natal are being impacted by various anthropogenic activities that threaten their sustainability (Agboola et al. 2020; Evans et al. 2022; Burnett et al. 2025), the leading causes of natural land cover loss and the ultimate decline in environmental functionality and connectivity in KwaZulu-Natal (Alexander et al. 2021).

While the importance of natural history collections for research is generally appreciated (Shultz et al. 2021), the use of a freshwater mollusc collection to analyse changes in diversity and distribution in South Africa, particularly in KwaZulu-Natal, is lacking. We hypothesised that there would be differences in both space and time, as well as in the number of records provided by natural history collections and online records. To reconstruct long-term changes in freshwater mollusc communities in KwaZulu-Natal, we compiled a database of records from the Albany Museum in Makhanda (AMM), East London Museum in East London (ELM), KwaZulu-Natal Museum in Pietermaritzburg (KZNM), and the National Freshwater Snail Collection (NFSC) of South Africa in Potchefstroom, and validated the results by comparison with online data repositories Freshwater Biodiversity Information System (FBIS) and the Global Biodiversity Information Facility (GBIF) relative trends.

2 | Methods

2.1 | Database Preparation

Our data were drawn from the Mollusca collection of the KwaZulu-Natal Museum (KZNM) in Pietermaritzburg, KwaZulu-Natal, South Africa. This collection is relatively old, and consists predominantly of dry shells, with the oldest dated 1897. This collection is ranked among the top 15 largest in the world, and the largest in both Africa and the Indian Ocean rim (Kilburn and Herbert 1994; Ziganira 2018; Cole 2021). We also relied on previously digitised and geocoded collection records of the National Freshwater Snail Collection (NFSC), South Africa, housed at North-West University in Potchefstroom, East London Museum in East London, Eastern Cape Province (ELM), and Albany Museum in Makhanda, Eastern Cape Province (AMM), from their KwaZulu-Natal collections. Despite several emails to Iziko South Africa Museum in Cape Town (SAMC), our data requests to include their freshwater mollusc data in our study were not responded to.

2.2 | Study Location and Species

The province of KwaZulu-Natal is situated in the coastal region of eastern South Africa between latitudes 27° and 31°. Bounded by the Drakensberg escarpment to the west and the Indian Ocean to the east, the ecological conditions at the northern and southern boundaries are similar to those in neighbouring Mozambique and the Eastern Cape Province, respectively (Brown 1967). There are ca. 69 species of freshwater Mollusca inhabiting KwaZulu-Natal (Brown 1967, 1994). For our study, we selected freshwater mollusc species whose historical distribution overlapped with the present extent of KwaZulu-Natal using QGIS version 3.8.15 (Figure 1). Desirable candidate species records needed to have a taxon's full name (Genus and species), locality description, collection date, and geographical location coordinates. We filtered records based on the presence or absence of collection dates and coordinates and used these for further analyses.

2.3 | Data Curation

We filtered our database records of freshwater Mollusca belonging to KwaZulu-Natal out of the four natural history collections. Although our database included multiple sources of specimen acquisition, we focused on taxa for which specimens were identified to species level (Ewers-Saucedo et al. 2021; Li et al. 2023). This way, we minimised the problem of misidentifications. The database was refined and organised in Microsoft Excel version 2013. To validate taxon identification, we relied on the dedication of data providers because digitised specimens required data entry from physical specimens and checked species identification if validation suggested discrepancies (Ewers-Saucedo et al. 2021). We attempted to provide geographic location coordinates for each record that lacked these coordinates but had a locality description. Records without geographical location coordinates were geocoded using the GEOLocate Web Application tool (<https://www.geo-locate.org/>; Ziganira 2018). The NFSC data were geocoded using the Natural Science Collections

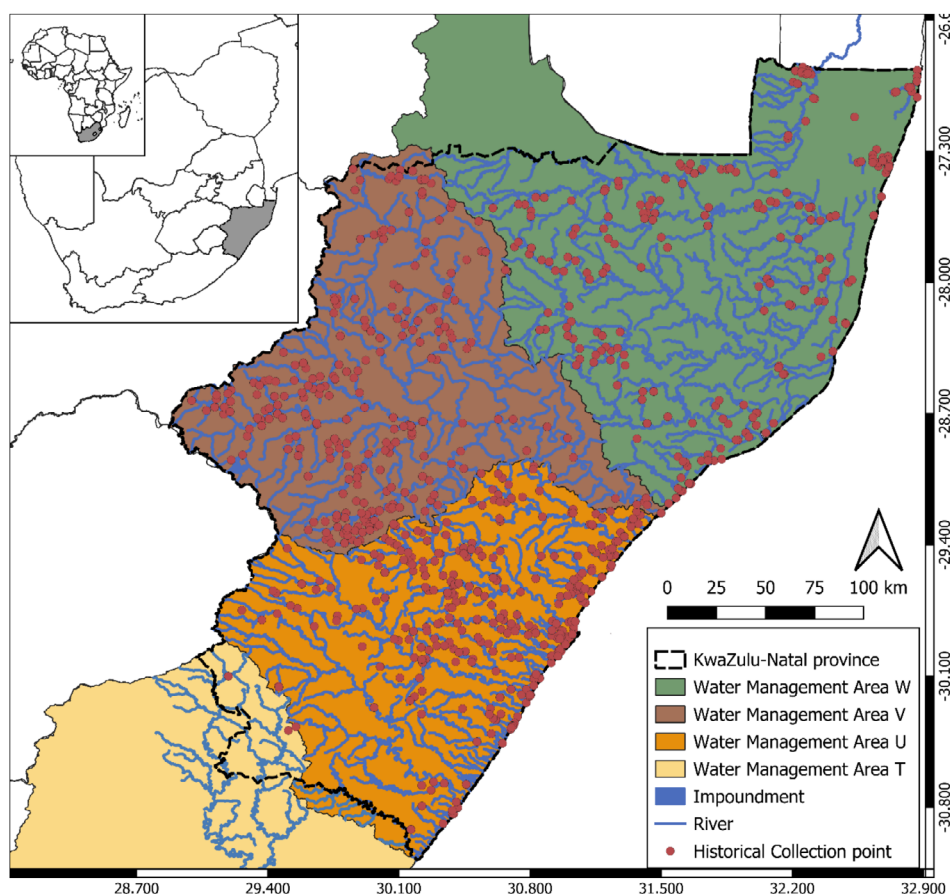


FIGURE 1 | Map of KwaZulu-Natal, South Africa, showing the spatial distribution of the investigated collection records.

Facility (NSCF) Georeferencer tool and standardised protocols from the Georeferencer tool (Engelbrecht 2021). Molluscs with no locality information or ambiguous distribution description were excluded. Several natural history records had outdated taxon names. We validated species names for all records using the 'MolluscaBase' (<https://www.molluscabase.org/>) to avoid discrepancies during data analyses.

2.4 | Temporal and Spatial Analyses

We refined the data by excluding specimens that lacked a collection date or locality information. This limited our study to specimens collected between 1897 and 2021. For temporal analyses, we used the collection date for each specimen to rank records obtained each year between 1897 and 2021, examining the trends in specimen record collection over time. To better understand long-term collection trends, we calculated the total number of records based on a 10-year interval, as annual fluctuations can be challenging to interpret (Li et al. 2023). This allowed us to determine the number of species recorded sequentially through time (Muratov 2010; Table 1) between 1897 and 2021.

For spatial analyses, all records, regardless of whether they had geographical location coordinates, were used, regardless of the collection year. Map layers were created in QGIS (version 3.8.15) from selected records with geographical location coordinates. We explored the spatio-temporal trends of records by examining specimen distribution and density across 10-year periods,

1897–1906, 1907–1916, 1917–1926, 1927–1936, 1937–1946, 1947–1956, 1957–1966, 1967–1976, 1977–1986, 1987–1996, 1997–2006, 2007–2016, 2017–2021 (Table 1).

2.5 | Database Validation

To validate our data, we compared the species record numbers and distribution in our collection database with the species list in the Freshwater Biodiversity Information System (FBIS) for KwaZulu-Natal (FBIS 2022). The FBIS is a powerful, open-access platform for hosting, sharing, and analysing freshwater biodiversity data for South Africa (Dallas and Shelton 2024). These data records are harvested from the Global Biodiversity Information Facility (GBIF), peer-reviewed scientific papers, published reports, university theses, and unpublished reports (Dallas and Shelton 2024). Also, for all species records present in both the investigated database and the FBIS, we compared the number of species records between 1897 and 2021 over 10-year intervals.

2.6 | Records of Potentially Declining Species

A potentially declining species' database records approach allowed us to compare the distribution and frequency of each species' database records between historical and present dates (Table S1). Each species' database record was compared against the 10-year interval to simplify collection periods. Potentially

TABLE 1 | Total number of collection and preservation records of freshwater mollusc species and families in the Albany Museum (AMM), East London Museum (ELM), KwaZulu-Natal Museum (KZNM), and the National Freshwater Snail Collection (NFSC), South Africa, collected between 1897 and 2021. In total, 1884 database records were collected from 16 families and 69 species. Number refers to the number of specimens.

Family	Taxa	1897– 1906	1907– 1916	1917– 1926	1927– 1936	1937– 1946	1947– 1956	1957– 1966	1967– 1976	1977– 1986	1987– 1996	1997– 2006	2007– 2016	2017– 2021	Total	%
Planorbidae	<i>Afrogyrorbis natalensis</i>	1		6				13	14	1					35	1.86
Viviparidae	<i>Bellamya capillata</i>	1		2					3	1	1	3	2		13	0.69
Planorbidae	<i>Biomphalaria pfeifferi</i>	2	1	5				23	50	5	2	1			89	4.72
Mytilidae	<i>Brachidontes virgiliae</i>						1	1	3	1	3		1		10	0.53
Bulinidae	<i>Bulinus africanus</i>				2			15	1	1	1	2			22	1.17
Bulinidae	<i>Bulinus forskalii</i>	2	2	4				7	142	4	2	14			177	9.39
Bulinidae	<i>Bulinus globosus</i>	2						3	1	1	1	4			12	0.64
Bulinidae	<i>Bulinus natalensis</i>							5	42	4	1				52	2.76
Bulinidae	<i>Bulinus reticulatus</i>								1						1	0.05
Bulinidae	<i>Bulinus tropicus</i>			15				20	225	8	12	26		1	307	16.30
Burnupiidae	<i>Burnupia brunnea</i>								1						1	0.05
Burnupiidae	<i>Burnupia caffra</i>			4				1	18						23	1.22
Burnupiidae	<i>Burnupia capensis</i>					3		1	32						36	1.91
Burnupiidae	<i>Burnupia capensis natalensis</i>							1	7						8	0.42
Burnupiidae	<i>Burnupia farquhari</i>														1	0.05
Burnupiidae	<i>Burnupia gordonensis</i>			4					1	1					12	0.64
Burnupiidae	<i>Burnupia mooiensis</i> ^a						1								1	0.05
Burnupiidae	<i>Burnupia nana</i>			1				2							4	0.21
Burnupiidae	<i>Burnupia ponsonbyi</i>			1				2	1						5	0.27
Burnupiidae	<i>Burnupia stenochorias</i>								2	1	3				6	0.32
Burnupiidae	<i>Burnupia transvaalensis</i>							3			6				9	0.48
Iridinidae	<i>Chambardia wahlbergi</i>			1	1			1	1	1	3	3	1		12	0.64
Thiaridae	<i>Cleopatra ferruginea</i>							9				1			10	0.53

(Continues)

TABLE 1 | (Continued)

Family	Taxa	1897– 1906	1907– 1916	1917– 1926	1927– 1936	1937– 1946	1947– 1956	1957– 1966	1967– 1976	1977– 1986	1987– 1996	1997– 2006	2007– 2016	2017– 2021	Total	%
Unionidae	<i>Coelatura mossambicensis</i>								1						1	0.05
Cyrenidae	<i>Corbicula africana</i>			1				5	3	4	5		1		19	1.01
Cyrenidae	<i>Corbicula astartina</i>											1			1	0.05
Cyrenidae	<i>Corbicula fluminalis</i>									1		8	2		11	0.58
Sphaeriidae	<i>Euglesa costulosa</i>								10						10	0.53
Sphaeriidae	<i>Euglesa langleyana</i>							2	5					7	0.37	
Sphaeriidae	<i>Euglesa ovampica^a</i>								1					1	0.05	
Sphaeriidae	<i>Euglesa viridaria</i>								6					6	0.32	
Sphaeriidae	<i>Eupera ferruginea</i>			2										2	0.11	
Lymnaeidae	<i>Galba truncatula</i>					1			7					8	0.42	
Planorbidae	<i>Gyraulus andrussovi</i>		1	2										3	0.16	
Planorbidae	<i>Gyraulus chinensis</i>												1	1	0.05	
Planorbidae	<i>Gyraulus connollyi</i>							7	33	3		2		45	2.39	
Planorbidae	<i>Gyraulus costulatus</i>		7	6				30	77	3	5	7		135	7.17	
Planorbidae	<i>Hovorbis coretus</i>								1			1		2	0.11	
Ampullariidae	<i>Lanistes ovum</i>							2		1	1	4	3	11	0.58	
Planorbidae	<i>Lentorbis carringtoni</i>								1					1	0.05	
Thiaridae	<i>Melanoides tuberculata</i>	4		6		2		8	9	3	6	37	2	77	4.09	
Neritidae	<i>Neritina pulligera</i>							1		3		2		6	0.32	
Planorbidae	<i>Pettancylus burnupi</i>		1	1					4					6	0.32	
Planorbidae	<i>Pettancylus cawstoni</i>								1					1	0.05	
Planorbidae	<i>Pettancylus connollyi</i>			4					1					5	0.27	
Planorbidae	<i>Pettancylus fontinalis</i>			1										1	0.05	
Planorbidae	<i>Pettancylus natalensis</i>			1										1	0.05	
Physidae	<i>Physella acuta</i>					1		1	9	3	5	25		44	2.34	

(Continues)

TABLE 1 | (Continued)

Family	Taxa	1897– 1906	1907– 1916	1917– 1926	1927– 1936	1937– 1946	1947– 1956	1957– 1966	1967– 1976	1977– 1986	1987– 1996	1997– 2006	2007– 2016	2017– 2021	Total	%
Planorbidae	<i>Planorbella duryi</i>											3			3	0.16
Ampullariidae	<i>Pomacea bridgesii</i>										2				2	0.11
Lymnaeidae	<i>Pseudosuccinea columella</i>						1	47	151	5	7	59			270	14.33
Lymnaeidae	<i>Radix natalensis</i>	1	1		1			39	171	7	6	41	1		268	14.23
Lymnaeidae	<i>Radix rubiginosa</i>												1		1	0.05
Planorbidae	<i>Segmentorbis angustus</i>								2						2	0.11
Planorbidae	<i>Segmentorbis kanisaensis</i>			2		1						1			4	0.21
Planorbidae	<i>Segmentorbis planodiscus</i>			1						1					2	0.11
Neritidae	<i>Septaria porcellana borbonica</i>														0	0.00
Neritidae	<i>Septaria tessellaria</i>												1		1	0.05
Sphaeriidae	<i>Sphaerium capense</i>							1	4			1			6	0.32
Sphaeriidae	<i>Sphaerium inomitatum</i>								2						2	0.11
Physidae	<i>Stenophysa marmorata</i>										4	5			9	0.48
Thiaridae	<i>Tarebia granifera</i>										5	4	6		15	0.80
Thiaridae	<i>Thiara amarula</i>			1	2			2			2	1			8	0.42
Tomichiidae	<i>Tomichia natalensis</i>								1						1	0.05
Tomichiidae	<i>Tomichia tristis</i>								1	2					3	0.16
Tomichiidae	<i>Tomichia ventricosa</i>						1	1							2	0.11
Unionidae	<i>Unio caffer</i>		5				6	3	1	1	8	1			25	1.33
Neritidae	<i>Vittina gagates</i>			3											3	0.16
Neritidae	<i>Vittina natalensis</i>								1						1	0.05
16 Families	69 species	13	25	75	6	1	17	258	1047	66	95	258	22	1	1884	100

**Burnupia mooioensis* and *Euglesa ovampica* were two species additions from the FBIS database, totalling our records to 69 species.

declining species are those that should have been collected more frequently in the past than in present times (Ewers-Saucedo et al. 2021). Furthermore, this mapping allowed us to validate our findings by comparing the species we identified as potentially declining with those listed as endangered in the Red List (<https://www.iucnredlist.org/>, Table S1), and their status was further analysed.

2.7 | Relative Records Trends

We calculated the changes in the relative number of database records over time to estimate changes in occurrence and distribution. This approach is implemented in GBIF's 'relative observation trends' tool, which we adopted for our investigated data. We used the genus as the higher taxonomic unit to include all available records in our database and tested for significant linear regression trends over time. Significant record trends were considered when the relative number of records changed significantly with regard to genus. Also, species with no geocode data in GBIF, or if existing data did not represent South Africa or cover KwaZulu-Natal, were excluded. These criteria also helped us identify which freshwater mollusc records from South Africa, particularly those from KwaZulu-Natal, are not yet geocoded or represented on GBIF (Table S1).

2.8 | Introduced, Non-Invasive, Invasive and Endemic Species

We also re-evaluated the status of freshwater molluscs in KwaZulu-Natal (Appleton 2003). The status of each species was examined and compared over time to determine whether species were endemic, invasive, non-invasive, or introduced (Appleton and Miranda 2015). We used both the dates of the first collection and the localities where alien species were found, and compared trends over time and whether the status has been reported in the province. We filtered endemic species from the data, noting their collection dates and localities to determine if there was any correlation with the presence of invasive species.

2.9 | Statistical Analyses

We collated all these data and mainly used descriptive statistics to show trends. We also used One-Way Analysis of Variance (ANOVA), linear regression, and percentages generated using Microsoft Excel 2013 to illustrate trends.

3 | Results

3.1 | Data Curation

Initially, the freshwater Mollusca database of the KwaZulu-Natal Museum contained 957 records. We removed records that lacked locality information or contained ambiguous data. After filtering these, we found 607 records from KwaZulu-Natal. Specimen records with collection dates were 356 (59%), while those without dates were 251 (41%). Of the 607 records, many ($n=346$; 57%) were not geocoded but contained a locality description. We

matched these localities with those in the database that have geographical coordinates. Identical localities of 20 records were identified and matched. We geocoded the remaining 326 localities using the GEOLocate online portal (<https://www.geo-locate.org/>; Ziganira 2018).

We also received 1588 freshwater mollusc records for KwaZulu-Natal from the National Freshwater Snail Collection (NFSC), South Africa. Of these, 1260 records met our criteria and had dates of collection, locality, and coordinates. From the East London Museum (ELM), we received 244 South African records, of which only five records of KwaZulu-Natal met our criteria. Similarly, 732 records were received from Albany Museum in Makhanda (AMM), of which 263 records met our criteria. We subsequently merged the four databases from these four institutions, and a total of 1884 records were selected and used in our analyses (Table 1). Furthermore, all records received with coordinates were used for spatial visualisation (Figure 1).

3.2 | Temporal and Spatial Analyses

The large-scale specimen collection and preservation for the 67 freshwater mollusc species appear to have been initiated between 1967 and 1976 (1047/1884, 56%). The lowest specimen collection and preservation appear to be between 1927 and 1946 (7/1884, 0.4%) (Table 1). The number of KwaZulu-Natal freshwater mollusc species found and deposited in the natural history collections reached a maximum between 2007 and 2016, while the number of families remained 16 between 1967 and 2021 (Table 1). After 1967 and 2016, no new family or new species were added to the collection (Table 1). The growth of the specimen's collection, the number of species collected and their associated families displayed an increasing trend from 1897 to 2007. Between 2007 and 2021, no new species or families were discovered through new samplings, maintaining the total of 67 species and 16 families, respectively (Table 1).

Overall, between 1897 and 2021, a total of 1884 specimen records were deposited into the four collections, including collecting dates, coordinates, and locality information. *Bulinus tropicus* (Krauss 1848) recorded the highest (307/1884, 16%), followed by *Pseudosuccinea columella* (Say 1817) (270/1884, 14%), and *Radix natalensis* (Krauss 1848) (268/1884, 14%). A large proportion of the 67 freshwater mollusc species (14/67, 21%) received one record each (Table 1).

3.3 | Database Validation

When comparing the four natural history collections (AMM, ELM, KZNM, NFSC) with the Freshwater Biodiversity Information System (FBIS) for KwaZulu-Natal, the number of species and records did not match as expected (Figure 2). The FBIS database added two species to our list, namely *Burnupia mooiensis* (B. Walker, 1912) and *Euglesa ovampica* (Ancey, 1890), bringing the total to 69 freshwater molluscs. The ELM had the lowest number of freshwater mollusc species and records, while KZNM had the highest number of species, and NFSC contained the highest number of records (Figure 2). Our assumption showed no significant differences between the

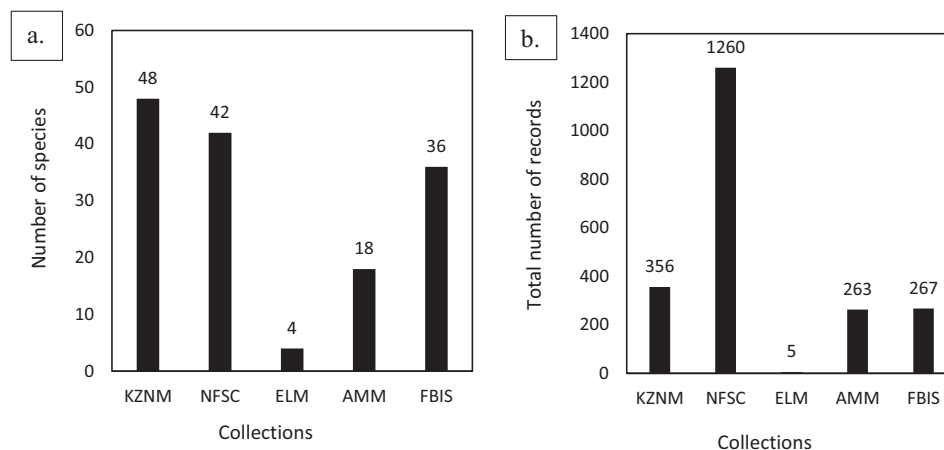


FIGURE 2 | Number of (a) species and (b) number of records in the databases of the Albany Museum in Makhanda (AMM), East London Museum (ELM), KwaZulu-Natal Museum (KZNM), National Freshwater Snail Collection (NFSC), South Africa and the Freshwater Biodiversity Information System (FBIS) for KwaZulu-Natal.

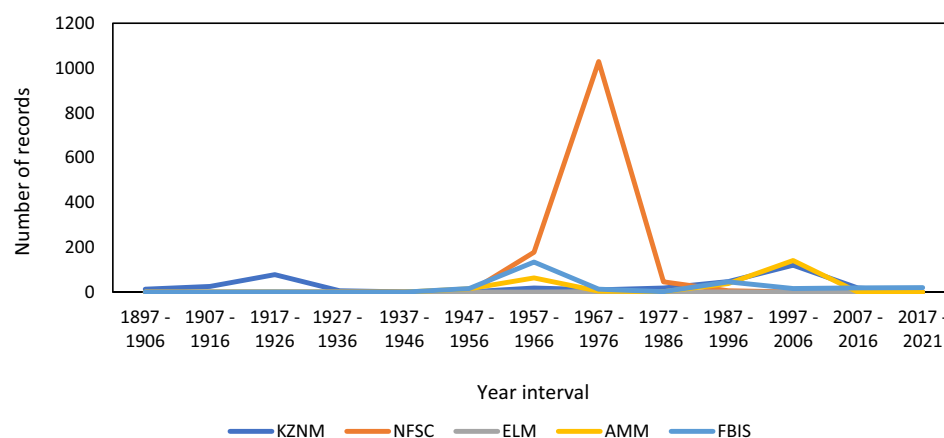


FIGURE 3 | Number of freshwater mollusc database records over time in the Albany Museum in Makhanda (AMM), East London Museum (ELM), KwaZulu-Natal Museum (KZNM), National Freshwater Snail Collection (NFSC), South Africa and the Freshwater Biodiversity Information System (FBIS) for KwaZulu-Natal. The year indicates the collection date.

five groups compared ($p > 0.05$). The relatively low numbers of molluscan species and records in the FBIS database may be because many of the KZNM and NFSC collection records have not yet been shared with either GBIF or directly with FBIS.

Specimens were unevenly collected and preserved at the KwaZulu-Natal Museum, both in terms of space and time. The oldest record, belonging to *Biophalaria pfeifferi* (Krauss 1848) (Planorbidae), was collected near Umbogintwini in 1897 by H.C. Burnup and donated to the museum in July 1926 (catalogue number: NMSA-Mol 003700). Few new specimens were collected, donated, purchased, or deposited in the Mollusca collection of the KwaZulu-Natal Museum between 1917 and the 1960s, but these records provide temporal continuity in the data. From the 1950s to 2006, extensive freshwater mollusc samplings were observed in KwaZulu-Natal and across South Africa. Most of the sampling surveys were conducted by the National Freshwater Snail Collection team between the 1960s and 1980s, accounting for 67% of the specimen deposition used in this study (Figure 3; Table S1). Specimens were unevenly collected and stored both in time and space, showing positive efforts in recent years in the FBIS database for KwaZulu-Natal (Figure 3).

3.4 | Records of Potentially Declining Species

We further analysed our data of the 67 freshwater mollusc species and noticed that 35 species (52%) were deposited less frequently than most records. These 35 species were considered 'potentially declining' among all the species investigated (Table S1). In our long list of species identified as potentially declining, only *Tomichia tristis* (Morelet 1889) (Tomichiidae) and *Tomichia natalensis* (Connolly 1939) (Tomichiidae) are considered Critically Endangered (CR) by the IUCN Red List Categories and Criteria (<https://www.iucnredlist.org>). Nevertheless, their IUCN status is presently unknown. Curiously, we also found that four species considered 'declining' (5/35, 14%): *Burnupia farquhari* (B. Walker 1912) (Burnupiidae), *Eupera ferruginea* (Krauss 1848) (Sphaeriidae), *Pettancylus fontinalis* (B. Walker 1912) (Planorbidae), *Pettancylus natalensis* (B. Walker 1924) (Planorbidae), and *Vittina gagates* (Lamarck 1822) (Neritidae) were deposited at one event in the early 1900s (1907–1926). Their relative number of observations declined over time, and after 1926, they were never deposited in a natural history collection. We also identified four 'declining' species as Data Deficient by the IUCN Red List Categories and Criteria, except *Eupera*

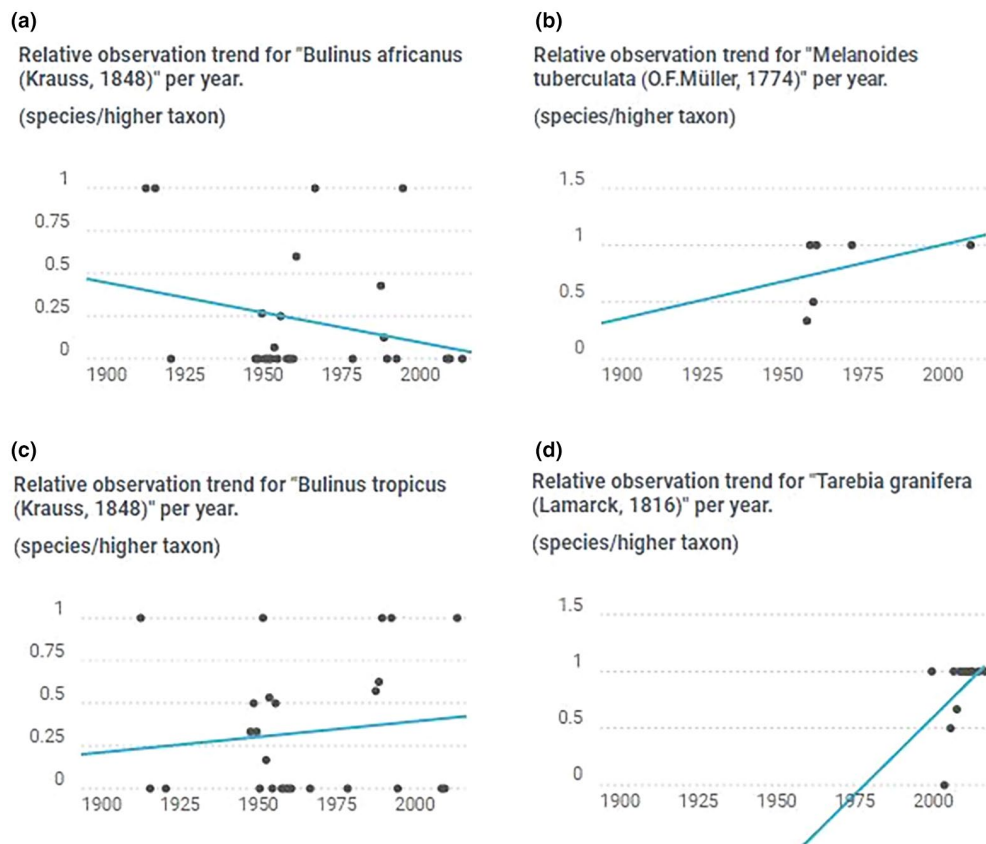


FIGURE 4 | Regression slopes of freshwater mollusc species in KwaZulu-Natal, South Africa, that were significantly declining or increasing using the GBIF relative observations tool between 1900 and 2021, namely (a) *Bulinus africanus* (Krauss 1848), (b) *Melanoides tuberculata* (O.F. Müller 1774), (c) *Bulinus tropicus* (Krauss 1848), and (d) *Tarebia granifera* (Lamarck 1816).

ferruginea (Krauss 1848) (Sphaeriidae), which is considered Least Concern (LC) (Table S1). The proportion of all the 'potentially declining' species lots deposited between 1957 and 2006 was 46% (16/35), with many of them being endemic species collected or deposited only at one event.

The GBIF's relative observation trends tool yielded similar results for only one species (1/35, 3%), namely *Bulinus africanus* (Krauss 1848) (Bulinidae), and its relative number of observations declined over time. 'Stable' status in the proportion of GBIF observations confirmed our findings, except for *Vittina natalensis* (Reeve 1855) (Neritidae), which has only one deposition record (Table S1).

3.5 | Relative Records Trends

Relative record trends were negative, positive, or stable for 11 species. *Bulinus africanus* was the only species with negative GBIF observation trends; its IUCN Red List status is 'Least Concern', and its status is presently unknown. Three species had positive trends, and seven had stable trends. Contrary to our inferences, there were three species with positive GBIF observation trends, with *Bulinus tropicus* (Krauss 1848) having the highest number of specimen records in our data, and it was the most frequently sampled species (Table 1; Figure 4c). The three species were considered Least Concern; *Melanoides tuberculata* (O. F. Müller 1774) had 'unknown' status in the IUCN Red List, while *Bulinus tropicus* (Krauss 1848) had stable status. Only *Tarebia granifera* (Lamarck 1816) was considered increasing by

both the IUCN status and using the GBIF relative records tool (Figure 4).

Of the 35 freshwater mollusc species in KwaZulu-Natal, South Africa, identified as potentially declining, 31 species (89%) had neither geocoded data records nor South African data records on the GBIF relative observations tool between 1900 and 2021. Most of these species had few occurrences and deposition records in the investigated database (Table S1).

3.6 | Indigenous and Endemic Species

The South African freshwater mollusc endemism is low and difficult to assess accurately because of discrepancies among some speciose genera (Herbert 1998; Appleton 2002). As expected, our record database showed a high number of endemic species. Besides *Ferrissia* (B. Walker 1903), now *Pettancylus* (Planorbidae), most of the freshwater molluscs native to KwaZulu-Natal were represented in our database (Table 2). The IUCN Red List Categories and Criteria for most were listed as Data Deficient and Critically Endangered for only *Tomichia natalensis* and *Tomichia tristis* (Table S1).

3.7 | Introduced and Non-Invasive Species

In South Africa, research on introduced freshwater molluscs has focused on the biology of species that have become

TABLE 2 | The total number of endemic freshwater mollusc species and family records occurring in KwaZulu-Natal.

Family	Scientific name	Author	References
Planorbidae	<i>Ancylus</i> sp.	(O.F. Müller 1773)	Appleton (1996), Brown (1967, 1994), Herbert (1998)
Burnupiidae	<i>Burnupia brunnea</i>	(B. Walker 1924)	Appleton (1996), Brown (1967, 1994), Herbert (1998)
Burnupiidae	<i>Burnupia caffra</i>	(Krauss 1848)	Appleton (1996), Brown (1967, 1994), Herbert (1998)
Burnupiidae	<i>Burnupia capensis</i>	(B. Walker 1912)	Appleton (1996), Brown (1967, 1994), Herbert (1998)
Burnupiidae	<i>Burnupia capensis natalensis</i>	(B. Walker 1924)	Appleton (1996), Brown (1967, 1994), Herbert (1998)
Burnupiidae	<i>Burnupia farquhari</i>	(B. Walker 1912)	Appleton (1996), Brown (1967, 1994), Herbert (1998)
Burnupiidae	<i>Burnupia gordonensis</i>	(Melvill and Ponsonby 1903)	Appleton (1996), Brown (1967, 1994), Herbert (1998)
Burnupiidae	<i>Burnupia nana</i>	(B. Walker 1912)	Appleton (1996), Brown (1967, 1994), Herbert (1998)
Burnupiidae	<i>Burnupia ponsonbyi</i>	(B. Walker 1924)	Appleton (1996), Brown (1967, 1994), Herbert (1998)
Burnupiidae	<i>Burnupia stenochorias</i>	(Melvill and Ponsonby 1903)	Appleton (1996), Brown (1967, 1994), Herbert (1998)
Burnupiidae	<i>Burnupia transvaalensis</i>	(Craven 1881)	Appleton (1996), Brown (1967, 1994), Herbert (1998)
Planorbidae	<i>Gyraulus connollyi</i>	(D.S. Brown and Van Eeden 1969)	Appleton (1996), Brown (1967, 1994), Herbert (1998)
Sphaeriidae	<i>Psidium</i> sp.	(C. Pfeiffer 1821)	Appleton (1996), Brown (1967, 1994), Herbert (1998)
Planorbidae	<i>Segmentorbis angustus</i>	(Jickeli 1874)	Appleton (1996), Brown (1967, 1994), Herbert (1998)
Planorbidae	<i>Segmentorbis kanisaensis</i>	(Preston 1914)	Appleton (1996), Brown (1967, 1994), Herbert (1998)
Planorbidae	<i>Segmentorbis planodiscus</i>	(Melvill and Ponsonby 1897)	Appleton (1996), Brown (1967, 1994), Herbert (1998)
Tomichiidae	<i>Tomichia natalensis</i>	(Connolly 1939)	Appleton (1996), Brown (1967, 1994), Herbert (1998)
Tomichiidae	<i>Tomichia tristis</i>	(Morelet 1889)	Appleton (1996), Brown (1967, 1994), Herbert (1998)
Tomichiidae	<i>Tomichia ventricosa</i>	(Reeve 1842)	Appleton (1996), Brown (1967, 1994), Herbert (1998)
Unionidae	<i>Unio caffer</i>	(Krauss 1848)	Appleton (1996), Brown (1967, 1994), Herbert (1998)

invasive or shown potential to become invasive in the future (Appleton 2003; Weyl et al. 2020). Four freshwater mollusc species are presently considered introduced in KwaZulu-Natal (Appleton 2003; Appleton and Miranda 2015; Table 3). In our database, three introduced species were recorded, including *Radix rubiginosa* (Micholin 1831) (Lymnaeidae), *Gyraulus chinensis* (Dunker 1848) (Planorbidae), and *Pomacea bruggessii* (Reeve

1856) (Ampullariidae) (Table 3). Interestingly, *R. rubiginosa* and *G. chinensis* were both collected in 2013 by Miranda in the Amatikulu River after they were introduced into South Africa in 2004 and 2006, respectively (Appleton and Miranda 2015). Four introduced species were confirmed non-invasive, and three of them did not occur in our database, including *Planorbella* (Haldeman 1843) species, *Marisa cornuarietis* (Linnaeus 1758)

TABLE 3 | Updated list of introduced and invasive freshwater gastropod species found in KwaZulu-Natal, with their status in South Africa, year of first collection, earliest publication source, region of origin and year of deposition in the natural history collection.

Taxa	Status in South Africa	Year of first collection	Earliest published source	Region of origin	Year of deposition
<i>Physella acuta</i>	Invasive	1956	Van Bruggen (1966)	North and South America	1968–2021
<i>Stenophysa marmorata</i>	Invasive	1986	Appleton et al. (1989)	South America and some Caribbean Islands. First collected in Durban in 1986	1987–2006
<i>Radix rubiginosa</i>	Introduced, status unknown	2004	Appleton and Miranda (2015)	Southeast Asia	2007–2016
<i>Gyraulus chinensis</i>	Introduced, potentially invasive	2006	Appleton and Miranda (2015)	Southeast Asia	2007–2016
<i>Pomacea diffusa</i>	Introduced, not invasive	1980s	Appleton (2003) as <i>P. bridgesii</i>	South America	1996
<i>Melanoides tuberculata</i>	Indigenous but may be replaced by an invasive morph from Asia (Genner et al. 2004) or a hybrid	No data	Appleton and Miranda (2015)	Southeast Asia and northern Australia	1957–2021
<i>Tarebia granifera</i>	Invasive	1999	Appleton and Nadasan (2002)	Southeast Asia	1997–2021
<i>Pseudosuccinea columella</i>	Invasive	1942	Barnard (1948)	North America	1960–2006
<i>Glyptophysa gibbosa</i>	Unknown	1944	Barnard (1948) as <i>Lenameria dispar</i>	Australia	Not in our database
<i>Biomphalaria angulosa</i>	Unknown	1957	Mandahl-Barth (1957)	East Africa	Not in our database
<i>Planorbella</i> spp.	Non-invasive	1960s	Van Bruggen (1974)	North America	Not in our database
<i>Planorbella durvyi</i>	Non-invasive	1966	Brown (1967)	North America	1997–2006
<i>Biomphalaria glabrata</i>	Introduced	1969	Bruton and Merron (1985) as <i>Biomphalaria</i> spp.; Joubert et al. (1986) as <i>Biomphalaria cf. glabrata</i>	South America	Not in our database
<i>Marisa cornuarietis</i>	Non-invasive	1986	Van Aardt and De Kock (1991)	South America	Not in our database
<i>Pomacea lineata</i>	Non-invasive	No data	Appleton (2003)	South America	Not in our database

(Ampullariidae), and *Pomacea linnaei* (R.A. Philippi 1852) (Ampullariidae). Only *Planorbella duryi* (Wetherby 1879) (Planorbidae) is non-invasive in KwaZulu-Natal, and its records occurred in our database between 1997 and 2006 (Appleton 2003; Appleton and Miranda 2015; Table 3). Similarly, *Pomacea bridgesii* (Reeve 1856) (Ampullariidae) is originally from South America. Our data showed that this species was reported to be distributed on the south coast of KwaZulu-Natal in 1996. This species has not been reported in new localities, confirming its 'non-invasive' status in the province (Appleton 2003).

3.8 | Invasive Species

We identified 15 species, representing 22% of all investigated species, as non-native to South Africa or specifically KwaZulu-Natal (Appleton and Miranda 2015; Table 3). Of those, four species are known invasive species that were introduced into KwaZulu-Natal by people coming from different parts of the world, including Asia, Australia, East Africa, and North, Central, and South America (Appleton and Miranda 2015; Lawton et al. 2018). Of the four invasive species, only *Stenophysa marmorata* (Guilding 1828) (Physidae) had no data available using the GBIF observation trends tool, and its IUCN status is 'Least Concern', assessed in 2011. The IUCN status of the three invasive species, that is, *Physella acuta*, *Pseudosuccinea columella*, and *Tarebia granifera*, is 'Increasing' but 'Least Concern' according to the latest assessments of 2016, 2012, and 2010, respectively.

4 | Discussion

Building on previous work (e.g., Sonamzi et al. 2019), our research demonstrated that evaluating the status and distribution of freshwater molluscs provides a valuable opportunity to utilise natural history collections and their associated data. By analysing the freshwater mollusc specimens deposited in the collection between 1897 and 2021, we discovered a significant inconsistency in the specimen samplings for the 69 freshwater mollusc species. A large proportion of specimen records prior to the 1950s lacked general information, including the year of collection and, in some instances, the location of collection. However, relatively few specimen records lacked this information from 1950 onwards. Other studies using natural history collections have reported similar results. Ziganira (2018) reported that 80% of specimen records in the bivalve collection of the KwaZulu-Natal Museum were not geocoded. A study on mammal collections across museums in the United States of America (USA) revealed that out of 1.6 million specimens, 6% lacked a collection date, while 34% lacked geocodes (Malaney and Cook 2018). In our study, a few records were not geocoded, yet these data were still useful in our analysis.

Specimen deposition began in 1897, with a 7% increase between then and 1926. However, it then steeply declined by 99% in the 1930s, reaching its peak in the 1950s. This sharp increase corresponded with the establishment of the KwaZulu-Natal Museum in 1904, and specimens were acquired through donations, purchases, and field collections. The greatest increase in specimens occurred during the 1960s and 1970s, peaking at 77% of the total of 1884 specimens (Table 1), before declining thereafter. Many

specimens collected during this period were deposited at the National Freshwater Snail Collection of South Africa (NFSC) in Potchefstroom. A national survey of the freshwater Mollusca in South Africa was conducted between 1960 and 1980 by the Bilharzia Research Group of the Council for Scientific and Industrial Research, which was housed at North-West University, Potchefstroom, at the time (Brown 1967; Hadfield 2020). Some studies have shown similar trends. An analysis of 18 years since the establishment of the Mammal Collection at the Federal University of Espirito Santo (UFES-MAM) in Brazil found that specimen deposition into the collection increased when funds were available and decreased as funds were depleted, as well as being affected by strategic changes in policies (Bissoli-Silva et al. 2021). However, this study established that studies using natural history collections can provide a complete picture when all relevant collections are included (Sonamzi et al. 2019).

Additionally, the results of our study showed that the growth of the KwaZulu-Natal freshwater mollusc specimens for the 69 species and 16 families was optimal in 2007, and no new species have been collected since (Table 1). Spatially, few collection points were apparent outside the borders of KwaZulu-Natal and were excluded through our curation and validation criteria. These points were geocoded only to refine the map references, as the locality descriptions of a river or a farm name were associated with a 1:50,000 map reference. These errors are common during the georeferencing protocol. Proper inspection and quality control are essential to prevent such errors, and every record should be thoroughly double-checked. Interestingly, only one mollusc species, *Septaria porcellana borbonica* (Bory de Saint-Vincent 1804), with only a few records in the KwaZulu-Natal Museum's database, had no collection dates. Yet, it was still important to add this species to our comprehensive list (Table 1).

We anticipated that FBIS would provide more data records than the four natural history collections investigated in this study. However, many species records collected before the 1940s were not captured on the FBIS or GBIF. This lack of records in FBIS is because most of these records have not yet been uploaded to GBIF. Additionally, recent data deposition efforts, aimed at adding freshwater mollusc data to the FBIS data repository, are not yet complete (FBIS 2022). This suggests that incorporating the historical records compiled in this study would provide a more comprehensive picture of mollusc distribution and conservation in freshwater ecosystems throughout KwaZulu-Natal, as well as South Africa as a whole. Nevertheless, duplicate information existed in specimen collections and deposition in the four natural history collections and FBIS databases between 1960 and 1980. We assume that FBIS benefited from the national freshwater survey conducted from 1960 to 1980, as specimen records were donated, in addition to receiving digitised records collected in peer-reviewed publications, published reports from the bilharzia project collection effort, and donations or university theses (Dallas and Shelton 2024). Two unique records from the FBIS database, *Burnupia mooiensis* and *Euglesa ovampica*, completed our list to 69 freshwater mollusc species known in KwaZulu-Natal.

The fact that several declining species identified in this study have not been recorded frequently in recent studies and ongoing surveys by FBIS stresses the importance of continuing large-scale samplings and the deposition of specimens into natural

history collections (Brown 1967; De Kock et al. 2004; De Kock and Wolmarans 2005a, 2005b; De Kock and Wolmarans 2005c; De Kock and Wolmarans 2006a, 2006b, 2009; Le Roux 2023). A study utilising natural history collections demonstrated that evolutionary processes revealed a decline in the population of 38 Central American amphibian species over time because of fungal infection (Holmes et al. 2016). We identified 16 declining species considered 'Data deficient' or 'No data,' whose IUCN status was unknown. Additionally, *T. natalensis*, *T. tristis*, and *T. ventricosa* were identified as declining species and are considered 'critically endangered,' while *T. ventricosa* is considered 'Endangered' in South Africa by the IUCN Red List Category assessment of 2007. The present IUCN status of *T. natalensis*, *T. tristis*, and *T. ventricosa* in South Africa is largely unknown (Table S1, Ziganira and Downs 2025). Similarly, a recent study on 242 epibenthic invertebrate species from the North and Baltic Seas, collected over the last 200 years, identified 18 species as declining and considered 'Endangered' or 'Extinct' by the German Red List (Ewers-Saucedo et al. 2021). Their data, which utilises IUCN Red List categories and criteria for 1428 freshwater molluscs, randomly indicates that one-third of the species are threatened with extinction (Böhm et al. 2020).

Our study assigned 20 freshwater mollusc species as endemic to KwaZulu-Natal. These species were represented by seven taxa from five families. Ten *Burnupia* species represented 50% of the endemic species, while three *Segmentorbis* species (*S. angustus*, *S. kanisaensis*, *S. planodiscus*) (15%) and three *Tomichia* species (*T. natalensis*, *T. tristis* and *T. ventricosa*) (15%) were also present. Except for *Segmentorbis* species (*S. angustus*, *S. kanisaensis*, *S. planodiscus*), which are presently considered Least Concern by the IUCN Red List, *T. natalensis* and *T. tristis* are considered Critically Endangered by the IUCN Red List, while *T. ventricosa* is Endangered; their IUCN status is unknown, and their records were not available on GBIF observation trends. Much of the information on South African freshwater mollusc species is not available in GBIF trends, and their IUCN Red List status is unknown. Herbert (1998) suggested that further study for both *Burnupia* species and *Pettancylus* species in relation to the possible existence of narrow-range endemics is urgently needed to understand the mollusc genetic variation among populations and taxa (Brown 1994; De Kock and Wolmarans 2017). Out of the 20 freshwater molluscs identified as endemic in our database, only three species are presently considered endemic gastropod taxa, including *G. connollyi* (Brown and van Eeden 1969), *Tomichia* species, and possibly *S. planodiscus* (Melvill and Ponsonby 1897; Herbert 1998).

5 | Conclusions

Our study reports a decline in freshwater Mollusca specimen collection and deposition, possibly because of decreased financial investment in natural history fieldwork and a decline in taxonomic capacity. We also report that potentially declining species accounted for 52% of the total freshwater mollusc diversity in KwaZulu-Natal, which is a concerning finding. Further constraints and limitations on regular sampling could severely impede future research, management, and conservation plans, as random sampling and donations alone are insufficient. This emphasises the importance of the invaluable efforts of the FBIS

and the need for substantial financial support locally and nationally. Future collections should focus on new sites that have not been previously sampled, allowing for a better understanding of the population dynamics of certain taxa. Our study also highlighted another problem: recent studies on freshwater molluscs in KwaZulu-Natal have not donated voucher specimens and their data to the natural history collections. We therefore advocate that public engagement and the raising awareness about the existence of these collections should be considered, so that collaboration between the general public and research institutions can increase. In addition, increasing financial and skills investment in natural history collections would facilitate wider geographical and temporal sampling, taxonomic updates, as well as data mobilisation and sharing. This is crucial for national programs, such as the River Eco-Status Monitoring Programme (REMP) and the Freshwater Biodiversity Information System (FBIS), which aim to identify and include new key biodiversity sites for biomonitoring biodiversity and emerging diseases of medicinal importance.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data is presented in [Supporting Information](#).

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Table S1:** Total number of collection and preservation records of freshwater mollusc species and families in the Albany Museum (AMM), East London Museum (ELM), KwaZulu-Natal Museum (KZNM) and the National Freshwater Snail Collection (NFSC), South Africa, collected between 1897 and 2021. Number refers to the number of specimens.