Supplementary Material

Materials and methods

Habitat and connectivity map for inclusion in municipal spatial planning systems

A map was produced as a Geographic Information System (GIS) spatial coverage for use in municipal planning processes that indicated the most important areas for the conservation of *H. pickersgilli*. Wetlands in which *H. pickersgilli* have been recorded [as per the records in the Ezemvelo KZN Wildlife (EKZNW) Biodiversity Database] and linkages between these and between them and other potentially suitable wetlands for the species were delineated using ESRI World Imagery (2015–2020) and Google Earth imagery (various dates) in ArcGIS Pro Version 2.8 (Environmental Systems Research Institute, Inc., 2021, Redlands, California, USA). This delineation was guided by the wetlands identified in the EKZNW vegetation map (Scott-Shaw & Escott 2011) and by information presented in Tarrant and Armstrong (2013), in particular: (1) the position and extent of the wetlands that had a relative suitability of 0.5 ('typical habitat') or higher for *H. pickersgilli*, as determined by the model (see Figure 2 of Tarrant & Armstrong 2013), and (2) the friction map produced in accordance with the friction classes presented (see Table 1 and the example of Figure 4 of Tarrant & Armstrong 2013). These wetlands were buffered where possible by 400 m width (providing the landcover was suitable for the dispersal or foraging of *H. pickersgilli*), to ensure that the ecological functionality of the wetlands and the microhabitats for the frog species are maintained (Semlitsch & Bodie 2003). Some of the wetland extents had to be edited because those wetlands were extensively modified. Untransformed areas were identified for each linkage (of a minimum of 200 m in width where possible) and were the most suitable landcover classes present for the dispersal or foraging of *H. pickersgilli* (in accordance with Table 1 of Tarrant & Armstrong 2013). Site-specific information from a variety of sources was used to modify the map for those sites if necessary. The coverage (map) was divided into sections in accordance with the boundaries of the various municipal areas in which *H. pickersgilli* occurs and instructions on how to use the coverage provided for each of these divisions.

Ranking of wetlands where *H. pickersgilli* was known to occur in 2019

A prioritisation exercise was conducted to rank sites where *H. pickersgilli* occurred (as of 25 April 2019) in terms of conservation importance. Values for a range of variables (Table S1) were assigned to each of these wetlands. The scores for each wetland were averaged to give a final score per site and the wetlands were ranked from highest to lowest score.

Updating the predicted distribution map for *H. pickersgilli*

The predicted distribution map of Tarrant and Armstrong (2013) was updated to include new distribution records. One hundred and fourteen accurate (within 250 m) occurrence records for *H. pickersgilli* were extracted from the EKZNW Biodiversity Database on 24 February 2020. Literature was consulted to assess which environmental predictors would be most likely to influence the distribution of the species (Raw 1982; Armstrong 2001; Elith et al. 2011; Tarrant & Armstrong 2013; IUCN SSC Amphibian Specialist Group, South African Frog Re-assessment

Table S1. Scores for variables included in the ranking scheme for conservation intervention at wetlands with Pickersgill's reed frog, *Hyperolius pickersgilli*, subpopulations to ensure their long-term viability (NEMPAA = National Environmental Management: Protected Areas Act)

Variables	Categories	Score (out of four)
Protection status	NEMPAA protected	4
	Conservation zonation	2
	Conservation influenced	1
	Not protected	0
Management	Continuous directed management	4
	Continuous general management	3
	Intermittent directed management	2
	Intermittent general management	1
	No management	0
Habitat size (ha)	> 100 ha	4

Table S1. Scores for variables included in the ranking scheme for conservation intervention at wetlands with Pickersgill's reed frog, *Hyperolius pickersgilli*, subpopulations to ensure their long-term viability (NEMPAA = National Environmental Management: Protected Areas Act) (continued)

Variables	Categories	Score (out of four)
Habitat size (ha) (continued)	> 10 to 100 ha	3
	> 1 to 10 ha	2
	≤ 1 ha	1
Land use context	Mining	0
	Commercial agriculture	1
	Commercial sylviculture	1
	Subsistence agriculture	2
	Low density residential	3
	High density residential	1
	Intact natural	4
	Modified natural	3
	Industrial	1
	Transport infrastructure	1
Ownership	Private	3
	Traditional authority	2
	State	4
	Commercial	2
	Municipal	2
Threats	Habitat destruction extent	1–4
	Habitat fragmentation extent	1–4
	Pollution extent	1–4
	Climate change resilience	1–4
	Siltation extent	1–4
	Alien plants coverage	1–4
Connectivity	Isolated	0
	Poorly connected	2
	Well connected	4
Vegetation integrity (present ecological state)	Poor	1
	Fair	2
	Moderate	3
	Good	4
Other fauna of conservation importance present?	Yes	4
	Likely	3
	Unknown	1
Stakeholder willingness to implement	Yes	4
	Unknown	1
	No	0
	Uncertain	2

Group (SA-FRoG) 2016; Du Plessis et al. 2022a, 2022b). The continuous variables (Schulze 2007) chosen for use in developing a distribution model for *H. pickersgilli* and the reasons were as follows: average summer and average winter, mean daily minimum temperature (°C; Ezemvelo KZN Wildlife 2014f, 2014h; *H. pickersgilli*, especially the tadpole, is sensitive to low temperatures, and temperature and regulation of water loss are important for amphibian biology); average summer and average winter, mean daily maximum temperature (°C; Ezemvelo KZN Wildlife 2014a, 2014d; *H. pickersgilli* breeds in summer and is a small frog so may be susceptible to high temperature, or in winter, low maximum temperatures, and regulation of water loss is important for amphibian biology); average summer and average winter, mean daily average relative humidity (%; Ezemvelo KZN Wildlife 2014b, 2014c; *H. pickersgilli* requires fairly high relative humidity for survival, especially in summer when it breeds, for regulation of water loss); mean annual precipitation (mm; Ezemvelo KZN Wildlife 2014e; *H. pickersgilli* requires fairly deep water for reproduction and the tadpole is aquatic); number of days with rainfall greater or equal to 10 mm (Ezemvelo KZN Wildlife 2014g; *H. pickersgilli* requires fairly deep water for reproduction and the tadpole is aquatic). Summer was defined as October to March and winter as from April to September. The environmental space of *H. pickersgilli* was defined using a mask. *Hyperolius pickersgilli* is a coastal species confined to the Indian Ocean Coastal Belt (IOCB). Therefore, the IOCB in KwaZulu-Natal (IOCB extract from Scott-Shaw & Escott 2011) defined the mask, even though this region is larger than the currently known distribution range of *H. pickersgilli*. The projection of the coverages was the Transverse Mercator lo31 central meridian on the WGS84 datum, and the pixel size was 20 × 20 m.

MaxEnt version 3.4.1 (Phillips, Anderson & Schapire 2006; Phillips & Dudik 2008) was used to develop the distribution model. Five cross-validate replicates were run with the maximum number of iterations set at 1 000 to ensure algorithm convergence; the logistic output type was selected, and the default settings were used for all the other relevant parameters except that the regularisation multiplier was varied. The regularisation parameter was given the following values: 0.5, 1, 1.5, 2, 3, 4, 5, 6, 10, 15. The default feature classes were used due to the number of data points per fold being relatively few (Phillips & Dudik 2008). Post-processing of the output was conducted in TerrSet® Version 19.0.4 Idrisi Geographical Information System (Eastman 2020). The KwaZulu-Natal 2017 landcover coverage (Ezemvelo KZN Wildlife 2020) was used to classify landcover classes into two categories: (1) landcover classes that were suitable for the feeding and/or dispersal of *H. pickersgilli* and (2) unsuitable land cover classes. The areas of landcover unsuitable for *H. pickersgilli* were removed from the distribution model output.

Assessments of health and biodiversity and management efficacy at selected wetlands where *H. pickersgilli* occurs

Wetland health and biodiversity assessments were conducted to determine the state of priority wetlands for *H. pickersgilli* and determine relevant site-specific management activities. Annual wetland assessments have been conducted at four sites (Adam's Rural, Isipingo, Mount Moreland and Widenham) since 2016, providing a measure of habitat health and function, and providing a basis from which to develop rehabilitation plans for *H. pickersgilli* habitat (Edwards, Pike & Mncwabe 2023). The WETHealth tool was used to assess the health of priority wetland sites, combining indicators of three components, namely hydrology, geomorphology and vegetation, which make up an overall impact score (Macfarlane et al. 2009). All the components add up to a total score of 10, where a score of 0 indicates that the wetland has not been modified and is in a natural state, and a score of 10 means that the wetland has been completely modified. These impact scores were then used to assign the wetland to an ecological category or present ecological state (PES), as shown in Table S2.

Table S2. Wetland present ecological state (PES) categories (Macfarlane et al. 2009)

Impact score	Ecological category	Description
0–0.9	A	Natural state
1–1.9	B	Largely natural with a few alterations
2–3.9	C	Moderately modified but the basic ecosystem functions are still unchanged
4–5.9	D	Largely modified. A large loss and change in the habitat, biota and basic ecosystem functions
6–7.9	E	Seriously modified. The loss and change of habitat, biota and basic ecosystem functions are extensive
8–10.0	F	Critically modified. Modifications have reached a critical level and the lotic system has been modified completely with an almost complete loss of natural habitat and biota

Further to this, the Management Effectiveness Tracking Tool (METT-4; Stolton, Dudley & Hockings 2021) was used to assist with the development of site-specific management plans for sites where habitat protection processes have been undertaken. The METT methodology is a rapid assessment based on a scorecard questionnaire. The scorecard incorporates six components of management including: site context, planning, inputs, process, outputs and outcomes. The needs, constraints and priority actions to improve management of priority wetlands for *H. pickersgilli* were determined through the METT and the WET Health Assessments and formulated into site management plans.

The efficacy of management activities was monitored using Ecological Goods and Services (EGS) Quality Assessments conducted through locally employed community members who, through a participatory science approach, conducted continuous assessments on the quality of EGS. Data were collected through an application, which automatically provided a quality score of between 1 (poor) and 5 (good) according to specific indicators, including indigenous and invasive alien vegetation, faunal diversity, soil erosion and land disturbance, and these scores were used to determine the quality of EGS within priority sites (Acker-Cooper et al. 2019).

An environmental compliance monitoring system (Acker-Cooper, Little & Roxburgh 2021) was used to determine state of environmental compliance within priority sites and to track changes in non-compliance. Non-compliance incidents were categorised according to a theme, e.g., agriculture, water, which relate to specific restricted activities as specified in environmental legislation. Records were given geographic tags and used to assess and verify the extent of an activity. The site-specific databases provided an inventory of compliance issues and assisted towards prioritising non-compliance issues for investigation and enforcement action by the mandated authority. A waste monitoring system (Acker-Cooper & Roxburgh 2022) was used to track changes in illegal waste dumping incidents in wetlands and watercourses within priority sites.

Management of natural resource harvesting at a wetland with *H. pickersgilli* in a protected area

Certain natural resources associated with wetland habitats outside of protected areas in KwaZulu-Natal have declined because of the lack of management of the wetlands and harvesting of the resources and because of land transformation. As a result, pressure has been put on protected areas to meet the natural resource needs of local communities. Vocalisations and sightings of *H. pickersgilli* were recorded in a major wetland plant harvesting area at Umlalazi Nature Reserve early in 2022. Prior to the harvest event in May 2022, the harvest area was surveyed for *H. pickersgilli*. A refuge area for *H. pickersgilli* of 2500 m^2 (100 × 25 m) was demarcated by barrier tape to ensure that the harvesters did not enter this refuge during the weeklong harvest.

Assessment of the vulnerability of *H. pickersgilli* to climate change

The potential vulnerability of *H. pickersgilli* to climate change was assessed by using Google Earth® and plotting the accurate *H. pickersgilli* occurrence records as of 25 April 2019 on a coverage derived from downscaling of the HadCM2 climate model of the environmentally defined floristic domains of Jewitt et al. (2015), ranked in terms of vulnerability to climate change according to a vulnerability framework [see Jewitt et al. (2015) for further details]. The downscaled HadCM2 model predicted an average 2.1 °C mean annual temperature increase and a mean annual precipitation decrease of 90 mm by 2050 (Jewitt et al. 2015). The four categories of the vulnerability framework were 'Robust' (high Climate Stability Index and high Habitat Intactness Index), 'Susceptible' (low Climate Stability Index and high Habitat Intactness Index), 'Constrained' (high Climate Stability Index and low Habitat Intactness Index) and 'Vulnerable' (low Climate Stability Index and low Habitat Intactness Index). The number of the 38 localities where *H. pickersgilli* occurred that fell into each category of the vulnerability framework could then be determined and the vulnerability of the species to climate change until 2050 assessed according to the downscaled HadCM2 climate model.

Monitoring of *H. pickersgilli* at selected priority wetlands

Frog calls are species-specific, and observers can use calls to locate and identify different species of frogs easily and reliably within a study area (Tarrant 2021). Most species of frogs use calls to attract mates and establish breeding habitats (Du Preez & Carruthers 2009). The implementation of the protocol developed in 2013 and refined in 2020 (Tarrant & Armstrong, unpublished), took place over several years and at several wetland sites, including at Mount Moreland, Simbithi Eco-Estate, Adam's Rural, Widenham and Gingindlovu (Umgavusa Protected Environment), as well as at sites at which captive-bred *H. pickersgilli* were released [River Horse Valley (Durban) and Buffelsdraai]. PAM allows for the automated recording of the soundscape at set times and intervals using equipment designed for biodiversity monitoring (Browning et al. 2017). Recordings taken between 2016 and 2020 produced more than 8 000 hours of call data, subsamples of which were initially listened to manually to confirm the presence of

H. pickersgilli, as well as to identify other frog species that share habitat with *H. pickersgilli*. The data were stored digitally and analysed as part of three UKZN Honours projects in 2020 (Tarrant 2021).

Releases of captive-bred *H. pickersgilli* to the wild within its geographical range

Two standard operating protocols were developed and implemented before any captive-bred *H. pickersgilli* were released to the wild. The first was a risk assessment before release and the second was a release protocol. The breeding and releases were done under a Memorandum of Agreement signed between Ezemvelo KZN Wildlife and the Johannesburg Zoo. Sampling for chytrid fungus testing by SANBI National Zoological Garden staff was done in the field at the site of capture of breeder adults, when the breeders first arrived at the Johannesburg Zoo, and a month prior to release of captive-bred *H. pickersgilli* to the wild. A faecal float was done weekly by Johannesburg Zoo staff for six weeks before release to check for internal parasites. Only frogs that passed these health checks could be released to the wild. Between 6 and 8 weeks prior to the release of the frogs to the wild, the captive environmental conditions and food were changed to more closely simulate that of the natural receiving environment (e.g., the food was changed from crickets to free-living fruit flies and feeding was skipped from time to time, additional lighting was provided for irregular periods, temperature and humidity were varied but maintained within the ranges in their natural habitat during the current season). These pre-release methods were used to prepare the captive *H. pickersgilli* for, and to improve their chances of survival in, the wild. Further details can be found in Du Plessis et al. (2022a). The genetics study (Kotze et al. 2019) indicated that individuals from any subpopulation could be released at any suitable site within the native distribution range of the species.

Marking of frogs to be released was by visible injectable elastomer (VIE). The VIE was premixed and less than 1 ml was subcutaneously injected by a veterinarian in the inner side of the hind thigh. A period of two weeks was provided for the skin to heal before the specimens were handled in preparation for the transport to the release site. Two colours were used in combination with the injection site being the left or right hind leg to identify the generation and year of hatching. Transportation by road of the captive-bred specimens from the Johannesburg Zoo to the release site was done at night because the frogs would be less stressed owing to the cooler temperatures, lower carbon dioxide levels and the darkness. The captive frogs were transported in clear plastic 5-litre jars with perforated screw-on lids. Paper towel dampened with reverse osmosis (RO) water was placed in the jars to maintain adequate humidity of no less than 65% and temperatures of between 15 °C and 18 °C. Each jar housed more than 15 adult specimens or 20 subadult specimens. The dampened paper towel was replaced every three hours when the jars were wiped down inside and misted with RO water. All jars were placed in carton boxes to ensure stability of the jars.

Monitoring of the *H. pickersgilli* individuals released to the wild was based on the calling of released males at sites where no *H. pickersgilli* calls had been recorded prior to the release, by sightings of released *H. pickersgilli* marked using VIE, and through metabarcoding analysis of two water samples from River Horse Valley by NatureMetrics (United Kingdom). Monitoring was conducted by the observers listening for calls and by actively searching for and sighting *H. pickersgilli* adults, as well as by setting up SongMeters (SM3, Wildlife Acoustics, Inc., Maynard, USA) in suitable positions to record the soundscape and by analysing the recordings using Kaleidoscope Pro software (version 5.1.2, Wildlife Acoustics, Inc., Maynard, USA) to detect calls of *H. pickersgilli*.

A release site was identified at River Horse Valley, Durban, based on the rehabilitation of the habitat to include some suitable for *H. pickersgilli* and the proximity of the site to the destroyed type locality for the species, located upstream less than 4 km away in a northeasterly direction as the crow flies (Figure S1). No *H. pickersgilli* were present at this recently rehabilitated site immediately before the release. An advantage of releasing the captive-bred frogs at the River Horse Valley site was that the released frogs would be easy to monitor by listening for their calls and searching for them, and any *H. pickersgilli* calling in the wetland would be released frogs. We hoped that eventually other *H. pickersgilli* would be attracted to this site by the calling of the released frogs and so increase the population size at the site. Fifty captive *H. pickersgilli* were released there at night on 5 March 2019. Seventy more *H. pickersgilli* (including 20 tadpoles) were released at River Horse Valley on 18 February 2020. At the latter release, in the early afternoon the frogs were evenly divided between two netted enclosures. Each enclosure was suspended just above the water surface amongst the emergent reeds at two places in suitable habitat to acclimatise for some hours. All the tadpoles were confined to one plastic tadpole enclosure with a perforated lid to allow gaseous exchange so that the tadpoles could breathe, as they had lungs at that stage of their development. The enclosure was semi-submerged in the water at one of the release places and tethered to the vegetation. This enclosure was left in situ for some hours for the tadpoles to acclimatise to the release environment. Water quality readings were taken, and the water quality shown to be ideal for *H. pickersgilli*. The team returned to River Horse Valley after dusk and

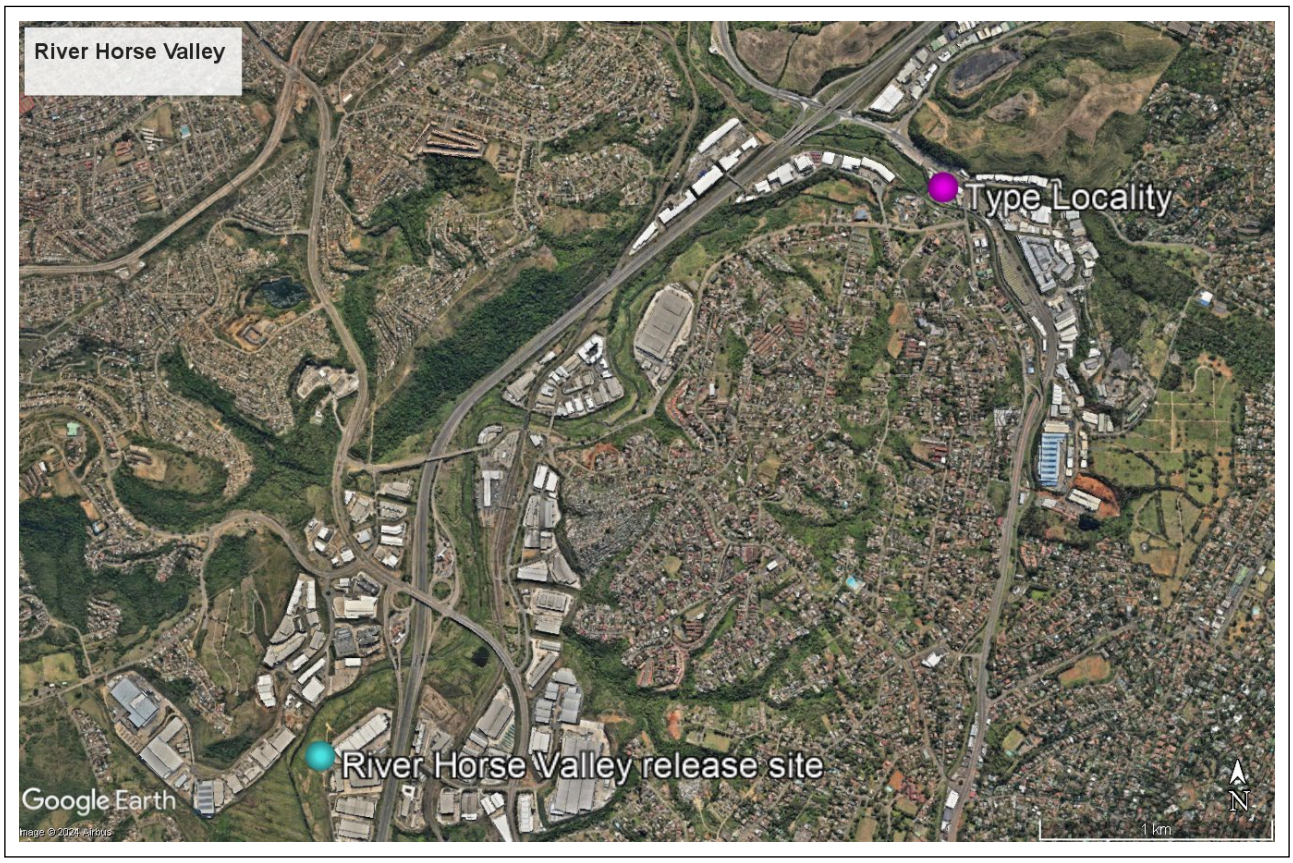


Figure S1. The site (cyan dot) at River Horse Valley, Durban, South Africa, where captive-bred Pickersgill's reed frogs *Hyperolius pickersgilli* were released in relation to the type locality (magenta dot).

released the 50 frogs into the habitat and started the acclimation process for the tadpoles by slowly mixing the purified (RO) water in which they were contained with the wetland water. After half an hour the process was complete, and the tadpoles were seen to be acclimated to the water. The plastic enclosure was perforated at the sides to allow water flow through the enclosure and left semi-submerged as before. A further 396 adult *H. pickersgilli* were released at the River Horse Valley site on 10 November 2020.

Awareness campaign and education programme about *H. pickersgilli*

An integrated education system was developed by the EWT to inform various community sectors within *H. pickersgilli* priority sites. Efficacy of environmental education was measured through formal knowledge assessments and environmental attitude assessments. A functionalist approach was used to determine the attitudes of people towards their environment (Drews 2002). A questionnaire was compiled including 42 questions intended to rate five attitude dimensions (strongly agree to strongly disagree) of people towards their environment (adapted from Tarrant, Kruger & Du Preez 2016). Three different scales were developed, assessing a person's liking, knowledge and cultural beliefs and these were incorporated into the questionnaire (Tarrant, Kruger & Du Preez 2016). Depending on the response, the answer was assigned a score of -1 (strongly disagree), -0.5 (disagree), 0 (unsure), 0.5 (agree) or +1 (strongly agree). The values attributed to the responses to the 42 questions were added together and an attitude score was calculated. The average attitude scores of all the respondents were calculated for each site.

Structured environmental education

A school-based environmental education programme was developed to align with the Department of Education curriculum. The education programme, Frogs in the Classroom, specifically targets learners from Grade 3–7. 'Frogs in the Classroom' consists of three lessons, with formal and summative assessments used to evaluate knowledge gained through the modules.

Outreach and events

Structured social media campaigns and community events based on environmental calendar days, including the 'Leap Day for Frogs' campaign and frog tourism events, were designed to promote appreciation for frogs and their habitats through the direct involvement

of the public, with an emphasis on experiential learning for youth. In addition, unstructured social media campaigns on key *H. pickersgilli* management highlights were intermittently shared through EWT and other partner platforms to broaden public knowledge around amphibian conservation efforts.

Conservation conversations

Conversations were held with community members living in the vicinity of project sites, including Isipingo and Adam's Rural, to build knowledge and understanding of the importance of wetlands and related biodiversity. Conversations were recorded and digitally analysed according to sentiment and strength of sentiment to determine if the emotional tone of the message is positive, negative or neutral.

Signage

A BMP-specific signboard was developed in collaboration with key project partners including DFFE, EWT, Ezemvelo KZN Wildlife, Johannesburg Zoo and SANBI, and placed at various locations, as well as location-specific signboards at Umhlanga Lagoon Nature Reserve and Umlalazi Nature Reserve (Figure 6B). Pickersgill's Reed Frog Custodian agreements were signed with Simbithi and Zimbali eco-estates and included the display of custodian signboards.

Skills and capacity development

Site-specific community members were upskilled through tailored learning programmes accredited with the South African Qualification Authority. The learning programmes provided essential skills in environmental monitoring, compliance and invasive alien plant control to support rehabilitation activities.

Employment

Community members were employed by the Endangered Wildlife Trust as biodiversity protection, environmental compliance and invasive alien plant control officers at priority sites to perform specific ecological rehabilitation functions.

Results

The scores for each variable and the final ranking for each of the 38 wetlands known to have *H. pickersgilli* as of 25 April 2019 are provided in Table S3. Those wetlands in protected areas proclaimed in accordance with the National Environmental Management Protected Areas Act ranked at the top, whereas those in sugar estates ranked at the bottom. This ranking allows for informed decision-making in terms of where resources should be allocated to ensure the long-term survival of *H. pickersgilli*. This ranking does not mean that wetlands known to have *H. pickersgilli* and that are low ranked are unimportant. The provincial ecosystem status of much of the Indian Ocean Coastal Belt where *H. pickersgilli* occurs is Critically Endangered (Jewitt 2018). All habitat for this species should be protected in perpetuity to achieve the goal of having the species downlisted to Least Concern in accordance with the IUCN Red List process.

The scores for the annual wetland health (AWH) and Ecological Goods & Services (EGS) Quality Assessments are presented in Table S4. The Adams Rural Wetland had consistently high AWH and EGS scores, while the continued degradation of the Isipingo Wetland was indicated by its declining scores.

The results of the monitoring of released captive-bred *H. pickersgilli* at River Horse Valley in Durban are presented in Table S5. Of the fifty adult frogs that were released towards the end of summer on 5 March 2019, none were recorded in the subsequent summer when monitoring commenced. After the release of 50 adults and 20 tadpoles on 18 February 2020, all the tadpoles were found drowned on 19 February 2020 owing to the large amount of rain that had fallen overnight, resulting in a rise in the water level that covered the perforated lid of the plastic tadpole enclosure. Only two of the marked adult frogs were seen on that same day, after the flood, although one was being eaten by a spider. None were recorded on subsequent monitoring occasions. A further release of 396 adults was effected at the same site on 10 November 2020. Few were recorded on subsequent monitoring occasions and after a month none were recorded again.

Table S3. Ranking of sites with Pickersgill's reed frog, *Hyperolius pickersgilli*, according to the ranking criteria (Table S1). PS = protection status, Man. = type of management, Size (ha) = habitat size (ha), Land use = land use context, Owner = ownership, Conn. = connectivity, PES = vegetation integrity, Other fauna = other fauna of conservation importance, Will = stakeholder willingness to implement

Wetland	PS	Man.	Size (ha)	Land use	Owner	Threats	Conn.	PES	Other fauna	Will	Overall score	Rank
St Lucia Estuary	4	3	4	4	4	3	4	4	4	4	3.82	1
Mapelane Forest Reserve, Mapelane camp, next to road near reception	4	3	3	4	4	3	4	4	4	4	3.73	2
Mtunzini, Raffia palm forest	4	3	3	4	4	3	2	3	4	4	3.38	3
Umlalazi Nature Reserve	4	4	3	4	4	3	2	3	3	4	3.38	3
Mt Moreland, Froggy Swamp	2	2	2	3	3	2	4	3	4	4	2.93	5
Simbithi Eco-Estate, Shaka's Rock	1	4	2	3	3	2	2	4	4	4	2.90	6
Port Durnford area	1	2	3	1	3	3	4	3	3	4	2.68	7
Adam's Rural Wetlands	1	2	3	3	2	2	2	3	4	4	2.62	8
Zulti South – Forestry Station (eSikhawini) Wetlands (W11)	0	2	3	0	3	2	4	3	4	4	2.50	9
Mt Moreland, Lake Victoria	2	2	3	1	3	2	2	2	4	4	2.47	10
Lake Nsezi (James Harvey)	0	1	4	1	3	2	4	4	3	2	2.37	11
Mtunzini, Forest Lodge	1	1	3	3	3	3	2	3	3	2	2.35	12
Golokodo East, towards Eston	0	2	2	3	2	2	2	3	3	4	2.32	13
Golokodo West, towards Eston	0	2	2	3	2	2	2	3	3	4	2.32	13
Mtunzini, Zini Estate	1	1	2	3	3	2	2	3	3	2	2.23	15
Mahunu, near eSikhawini	0	0	3	2	2	3	4	3	3	2	2.20	16
Zimbali Estate, North Coast	1	1	1	3	3	2	2	3	4	2	2.18	17
Empisini Nature Reserve	4	1	2	1	2	2	0	2	3	4	2.10	18
Widenham Wetland, Umkomaas	1	2	2	3	2	2	2	2	1	4	2.08	19
Zulti South – Kraal Hill (Wetland 4)	0	0	3	2	2	2	4	3	3	1	2.03	20
Nkomba Conservation Area, Pennington, South Coast	1	1	2	3	2	2	2	2	1	4	1.97	21
Zulti South Mine Lease Area, Wetland 8	0	0	1	2	2	2	4	3	3	2	1.93	22
District DC28, uMhlathuze Local Municipality (KZN282), Nyembe, Kraal Hill	0	0	3	2	2	3	2	3	3	1	1.88	23

Table S3. Ranking of sites with Pickersgill's reed frog, *Hyperolius pickersgilli*, according to the ranking criteria (Table S1). PS = protection status, Man. = type of management, Size (ha) = habitat size (ha), Land use = land use context, Owner = ownership, Conn. = connectivity, PES = vegetation integrity, Other fauna = other fauna of conservation importance, Will = stakeholder willingness to implement (continued)

Wetland	PS	Man.	Size (ha)	Land use	Owner	Threats	Conn.	PES	Other fauna	Will	Overall score	Rank
Richard's Bay	0	1	2	3	2	2	2	2	3	2	1.87	24
Richards Bay, John Ross Bridge, Nseleni River	0	0	4	1	2	2	4	1	3	2	1.87	24
Fibres Road North, Durban South, DDOP site	0	0	3	1	3	1	2	1	4	2	1.72	26
Isipingo Tributary Wetland	0	2	2	1	2	1	2	1	4	2	1.72	26
District DC28, uMlalazi Local Municipality (KZN284), Fairbreeze (Tronox)	0	3	2	0	1	2	2	1	3	2	1.57	28
SAPREF, Durban South basin (DDOP site)	0	0	1	2	3	2	0	2	4	2	1.55	29
Prospecton Wetland, Durban South basin (DDOP site)	0	0	3	1	3	2	0	1	4	2	1.55	29
Stanger	0	0	3	1	4	2	2	1	1	2	1.55	29
Fibres Road South, Durban South, DDOP site	0	0	2	2	3	1	0	1	4	2	1.52	32
Groutville	0	0	4	1	2	2	2	1	1	2	1.45	33
Amatikulu, Proposed prawn farm, N of Amatikulu mouth	0	0	3	1	3	2	2	1	1	1	1.38	34
Senla Sugar Estates, N bank of Zinkwazi River Mouth, in vlei surrounded by cane	0	0	2	1	3	1	2	1	1	1	1.22	35
Tugela River Mouth (3.5 km W of the mouth)	0	0	2	1	3	1	2	1	1	1	1.22	35
Nonoti, Nonoti Sugar Estate	0	0	1	1	3	1	2	1	1	1	1.12	37
Sezela	0	0	1	1	3	1	2	1	1	1	1.12	37

Table S4. Results of the annual wetland health (AWH %) and Ecological Goods & Services Quality Assessments (Score: 1 = poor to 5 = excellent)

Site	District	2018		2019		2020		2021		2022	
		AWH	EGS	AWH	EGS	AWH	EGS	AWH	EGS	AWH	EGS
Adams Rural Wetland	eThekwini	81.6	-	82.1	3.92	-	3.99	-	4.04	79.2	3.77
Widenham Wetland	eThekwini	42.0	-	46.2	-	-	-	-	-	47.6	3.68
Isipingo Wetland	eThekwini	23.2	-	21.6	-	-	-	-	3.76	20.3	3.28
Froggy Swamp Wetland (Mt Moreland Wetland)	eThekwini	67.6	-	-	-	-	-	-	-	-	-
Nyoni	iLembe	-	3.2	-	3.25	-	2.94	-	-	-	-
Groutville	iLembe	-	2.7	-	3.25	-	3.25	-	-	-	-
KwaDukuza	iLembe	-	2.2	-	-	-	-	-	-	-	-

Table S5. Results of the monitoring for released captive Pickersgill's reed frogs, *Hyperolius pickersgilli*, at the River Horse Valley release site

Date of release (number released)	Monitoring date	Type of monitoring	Number of *Hyperolius pickersgilli* detected
5 March 2019 (50)	25 September 2019	Manual acoustic	0
	26–28 September 2019	Automated acoustic	0
	13–15 December 2019	Automated acoustic	0
	3 February 2020	eDNA (2 water samples)	0
18 February 2020 (70, including 20 tadpoles)	19 February 2020	Visual	2
	24 February 2020	Manual acoustic	0
	9 March 2020	Manual acoustic	0
10 November 2020 (396)	12 November 2020	Manual acoustic	1
	24 November 2020	Manual acoustic	6
	9 December 2020	Manual acoustic	3
	29 December 2020	Manual acoustic	0

Table S5. Results of the monitoring for released captive Pickersgill's reed frogs, *Hyperolius pickersgilli*, at the River Horse Valley release site (continued)

Date of release (number released)	Monitoring date	Type of monitoring	Number of *Hyperolius pickersgilli* detected
10 November 2020 (396) (continued)	22 January 2021	Manual acoustic	0
	22 February 2021	Manual acoustic	0
	12 October 2021	Manual acoustic	0
	26–29 October 2021	Automated acoustic	0
	27 January 2022	Manual acoustic	0

Table S6. Additional details from the SWOT analysis described in the main text

Strengths	
Collaboration between stakeholders	Partners were afforded freedom to work on projects and were given support from the provincial biodiversity authority (Ezemvelo KZN Wildlife) in terms of the permits granted and stakeholder engagements undertaken. Collaborative efforts also led to tangible action on the ground and the resulting actions brought about positive processes with participating stakeholders, e.g., the rehabilitation of the Widenham wetland site by a varied group of stakeholders and agriculturalists working together to proclaim wetland habitat on their farms in Gingindlovu as a Protected Environment. The groundwork and engagement with communities by the EWT in areas where the habitat of *H. pickersgilli* was located provided the platform to work from and build on. Community buy-in for the conservation of *H. pickersgilli* and its habitat is vital and the development of meaningful relationships with traditional authorities and communities and the engagement of the community assisted in the conservation management of *H. pickersgilli*. There was local support from eThekwini Municipality, which led to the proclamation of a wetland owned by the municipality as a nature reserve.
Knowledge sharing and awareness gains	The participation of local schools at Adams Mission in an education and awareness programme developed by the EWT and inclusion of *H. pickersgilli* project updates in the EWT's annual integrated reports was effective in spreading knowledge of the species amongst people who did not know about the frog and its plight. Since the process to develop the BMP was initiated in 2013, there has been extensive media coverage related to the species. At least nine television and online documentary visual media outputs were produced (Earth Touch Insider, Euro News, TRT News, CNN Inside Africa, SABC The Agenda, SABC 50/50) and hundreds of popular articles (Euro News, TRT News, CNN Inside Africa, SABC The Agenda, SABC 50/50). The EWT's Wild Chat series on frogs featured three episodes with a total of 751 views. Numerous social media posts were used to make the public aware of the Johannesburg Zoo's Amphibian Research Project (ARP). On an international level, some articles were published through the Amphibian Ark platform relating to *H. pickersgilli* in the ARP. An updated signboard with BMP partner logos displayed with details about *H. pickersgilli* was produced in 2021 and has been erected at two wetland sites where the species occurs, namely Umlalazi Nature Reserve and Umhlanga Lagoon Nature Reserve.

Table S6. Additional details from the SWOT analysis described in the main text (continued)

Strengths (continued)	
Knowledge sharing and awareness gains (continued)	Students visiting the zoo for World Environmental Day, Wetland Week and Water Week programmes were introduced to the Johannesburg Zoo ARP's biosecure breeding facility. People's Weather channel featured the documentary '400 Frogs' on the ARP's captive breeding and release programme during March 2021. Interviews were conducted by some media outlets at various times of the year. The programme '400 Frogs' continued to be screened on national television with good feedback from numerous members of the public that have seen the programme on national television. Telephonic interviews with radio stations highlighted the conservation project and its success. Numerous information and awareness talks were conducted within the zoo to staff, as well as to members of the public.
Habitat gains	Three sites where *H. pickersgilli* occur (Sobonakhona, 503 ha; Widenham Wetland, 3 ha; Umgavusa, 127 ha) qualified for Protected Environment category through the Biodiversity Stewardship process, potentially significantly increasing the area under formal protection should all these sites be gazetted in the protected area category. A Protected Area Management Plan (PAMP) was drafted for the Umgavusa Protected Environment (Acker-Cooper, Tarrant & Mbuyisa 2022) and approved by the landowners in 2022, as were the land use map and provisional management actions. After the public participation process was completed, the site was proclaimed as a Protected Environment in May 2023. The Widenham Wetland has been rezoned to 'Conservation Reserve' status by the eThekwini Municipality and a PAMP, with the site being declared in April 2024 as Protected Environment, developed. In addition, the eThekwini Municipality has agreed to the rehabilitation of the Widenham Wetland, for which a conceptual rehabilitation plan was commissioned (Edwards et al. 2023). Previously unknown *H. pickersgilli* subpopulations were discovered at various protected or secure sites including Amatikulu Nature Reserve, Umgavusa Protected Environment, Empisini Nature Reserve, Meycol Nature Reserve, Ongoye Forest Reserve, Simbithi Eco-Estate, TC Robinson Nature Reserve (Scottburgh) and Umhlanga Lagoon Nature Reserve. Habitat loss caused by development was mitigated through commenting on development applications at five sites with *H. pickersgilli* and through the application of the environmental impact assessment mitigation hierarchy at one site.
Improved wetland health	Restoration projects targeting the removal of invasive alien plants (IAP) were implemented at three sites, Adam's Rural, where 20 local community members were employed, Groutville and Nyoni (iLembe District Municipality), where 10 local community members were employed at each. Wetland habitat and ecological goods and services (EGS) assessments were implemented at each site to determine the effectiveness of clearing activities. Invasive alien plant clearing was disrupted in 2020 due to the Covid-19 pandemic. The habitat assessments showed improved conditions where IAP control was implemented. The eThekwini Municipality has agreed to the rehabilitation of the Widenham Wetland, for which a conceptual and detailed rehabilitation plan was commissioned. Approximately 951 ha were cleared of invasive alien plants (IAPs) at four priority coastal wetlands in the eThekwini Metropolitan Area (± 636 ha) and the iLembe District (± 315 ha) over the 5-year period. An IAP management plan was developed for four wetlands in the iLembe District Municipality. Annual wetland health and Ecological Goods & Services (EGS) assessments were conducted at four sites with *H. pickersgilli*, along 4 597 transects with 17 495 quadrants (Table S4). The EGS Quality Assessment toolkit and application (Acker-Cooper et al. 2019) was used by local community members employed as Biodiversity Protection Officers to capture data on the state of the natural resources based on a score ranging from 1 (bad condition) to 5 (excellent condition). Results showed that there was a gradual increase in the quality of ecological resources at the Adam's Rural study site since 2018 where IAP clearing was implemented and where social surveys were conducted: environmental attitude surveys (n = 377); community engagement surveys (n = 528); sentiment assessments (n = 879). Based on the continuous social and wetland assessments, the interrelationship between people and their environment was demonstrated, supporting the importance of maintaining or rehabilitating wetlands within areas inhabited by people (Acker 2022). Long-term data comparing amphibian diversity in relation to wetland health indicated that generally amphibian diversity decreased as habitat condition decreased supporting the importance of restoration or rehabilitation of degraded habitat (Acker-Cooper, Tarrant & Mbuyisa 2022). Assessments of habitat integrity were made at project sites following severe flooding in 2022 in KwaZulu-Natal, which showed that wetlands with poor present ecological state (PES) had a lower ecological resilience to extreme climatic events when compared to wetlands with good PES.

Table S6. Additional details from the SWOT analysis described in the main text (continued)

Improved wetland health	A situational analysis was conducted through the One Health Forum to investigate the use of disposable diapers in communities. A comparative report to inform management and policy actions required to address disposable diaper waste was produced (Acker-Cooper et al. 2023). *Juncus kraussii* is weaved to produce traditional sleeping mats, baskets, beer strainers and other craftwork items by the Zulu people. This sedge species is in great demand because of its cultural and economic value and has been extensively and unsustainably harvested in the wild. In recent years, the wetland vegetation composition at the Umlalazi Nature Reserve has changed, including because of increased eutrophication through inflow of sewerage. A wetland rehabilitation programme was started in 2022, to ensure that *J. kraussii* debris mats that remain post-harvest are thinned out to promote vegetation regrowth. The effective management of natural resource stocks has the advantage of providing sustainable benefits to local communities while simultaneously protecting biodiversity. Engaging with the harvesters during the harvesting event is critical to them understanding the reasons for the management of the harvest. This knowledge-sharing is to ensure the sustainable supply of natural resources while conserving biodiversity, highlighting the importance of protected areas in this regard. Both Simbithi Eco-Estate and Zimbali Coastal Resort have signed agreements with the EWT as Pickersgill's Reed Frog Custodians. At Zimbali Coastal Resort, Ballito, removal of woody species and invasive alien plants from wetlands, the supplementary planting of vegetation and storm water control into wetlands, the minimizing of the area of maintained space within and adjoining wetlands and expanding the natural wetland habitat space for *H. pickersgilli* and other frog species was conducted (Brendan Smith, pers. comm., 26 May 2022).
Research, monitoring and improved security for the wild *H. pickersgilli* population	Passive acoustic monitoring (PAM) was conducted at Adam's Rural, Mt Moreland, Nyoni, Simbithi Eco-Estate (Acker-Cooper & Tarrant 2022), Gingindlovu, the Widenham wetland, and the River Horse Valley and the Buffelsdraai Landfill Site buffer zone release sites (for monitoring the success of the release of *H. pickersgilli*), as well as manually on an *ad hoc* basis at several sites. More than 8 000 hours of call data have been collected using PAM and subsets of these data were analysed for three honours projects through UKZN in 2020. Passive acoustic monitoring was found to be a useful tool in analysing the species richness of frogs at different sites (Du Toit 2020). Automatic classification was possible for *H. pickersgilli*. No geographic variation in *H. pickersgilli* call variation was documented, indicating that the set of unique acoustic identifiers, namely call duration, number of pulses, peak frequency, call period and inter-pulse interval are suitable unique acoustic identifiers, which can be pooled across geographic localities to detect the species. PAM is therefore feasible for this species and automated detection/classification algorithms, such as machine learning approaches, will be applicable in the future (Padayachee 2020). Acoustic resource partitioning was clear in four of the five studied assemblages, in which no overlap occurred, and species were well separated in acoustic space. The main call components associated with the discrimination of the species were the dominant, fundamental, start- and end-frequencies (Silver 2020). Regarding the Johannesburg Zoo's captive breeding and insurance population project, 140 mature adults were collected from the wild and transported to the zoo. From these, 786 offspring were bred, with a mortality of 2% (15 individuals died) and a productivity of 98 %. A total of 550 skin swab samples were taken from the captive *H. pickersgilli* to determine the presence or absence of the chytrid fungus *Batrachochytrium dendrobatidis*. All samples were negative and this ensured that the breeding population was free from this fatal disease.

Table S6. Additional details from the SWOT analysis described in the main text (continued)

Strengths (continued)	
Research and implementation planning	More than 1 000 individuals should be released at a site for the chances of the release to be successful, and movement of the released frogs away from the release site should be impeded if possible (Germano & Bishop 2009; Berger-Tal, Blumstein & Swaisgood 2020). An assessment of predation pressure should be conducted prior to release to ensure that the site is suitable and the effects of stress in the frogs after release needs to be considered (Germano & Bishop 2009; Berger-Tal et al. 2020). Plentiful spiders that include amphibians in their diets (although usually present at sites with *H. pickersgilli*), and predatory fish and birds were present at River Horse Valley, as determined through metabarcoding analysis of water samples and by observation. Translocations have variable success rates, and several key factors need to be considered to maximise chances of success. They also need to be supported by additional conservation interventions to tackle the initial threat of habitat loss. Natal habitat preference induction is known in a few amphibian species and captive-bred released amphibians may search for habitat with similar cues to their natal habitat (Davis & Stamps 2004; Stamps & Swaisgood 2007). Enrichment of the captive breeding environment should therefore mimic conspicuous cues to be found at the release site, such as vegetation structure and auditory cues (e.g., recordings from the release site could be played during the evening in the biosecure facility). Appropriate predator-avoidance response may need to be developed in the captive frogs before release.
Funding and employment	For example, finance was provided to the Johannesburg Zoo for the breeding of *H. pickersgilli* while funding was received by EWT from the DFFE's Natural Resource Management (NRM) programme between 2015 and 2020 for alien clearing at wetlands where *H. pickersgilli* occurs. This funding enabled the employment and upskilling of more than 140 local people for the removal of invasive alien plants. The KZN Frog Route was initiated based on wetland sites in the distribution of *H. pickersgilli*, including a strong foundation for the Adam's Rural Tour Guides eco-tourism initiative. Four people from the Adam's Rural site have been accredited site guides. The EWT's Pickersgill's Reed Frog Recovery Project employed nine full-time local community members at sites where *H. pickersgilli* occurs in the eThekwini Municipality and supported four sustainable livelihood enterprises, including a bursary for early childcare development. Three young women from the Zamani Camp community in Isipingo were selected for SMME development in 2018. The Zamani Community Skills Development Centre was launched in 2020 to replace the SMME development programme. To date, three workshops have been held with 128 participants, but this initiative was discontinued in 2020 due to the Covid-19 pandemic. EWT also hosted three water placement graduates and one research assistant during the reporting period and trained 98 traditional leaders from 18 authorities in KwaZulu-Natal on environmental compliance legislation to strengthen civic responsibility actions in support of the BMP for *H. pickersgilli*. Several organisations contributed funding in kind.
Weaknesses	
Stakeholder participation	Some members of the PRFF were uncertain of their roles during the implementation of the BMP and did not understand that they were part of a team, both within an organisation and between organisations. Project implementation depended on the willingness of members to assist; some members needed to be more aware of and own their responsibilities.
Opportunities	
Partnership development	Estates could expand residential support by meeting with residents to understand and improve buy-in from the estates. Linking residents and visitors with the natural environment through educational walks (as has been the case at Simbithi Eco-Estate) will help build emotional attachment to the wetlands that might otherwise be drained and may spearhead inclusions of environmental management considerations and actions within estate grounds management systems. Brainstorming sessions, including estate boards and environmental managers, would assist in this regard.

Table S6. Additional details from the SWOT analysis described in the main text (continued)

Opportunities (continued)	
Government support	Formalisation of systems that have been developed already by BMP partners, e.g., technical tools useful for compliance (Acker-Cooper, Little & Roxburgh 2021) and EGS monitoring and BDS management, and learning programmes, could occur through adoption by local government and eventually by provincial and national departments.
Research and monitoring	We need to know how events caused by climate change could impact the *H. pickersgilli* population, including by assessing the outcomes from climate change modeling for amphibian species. The opportunity to expand the predictive distribution model for *H. pickersgilli* in relation to climate models is now ripe. Understanding catchments better will enable the exploration of opportunities that will reduce the risk of climate change to *H. pickersgilli* and its habitat, e.g., the dispersal routes maps that have been included in municipal Spatial Development Frameworks, which could be shared with all BMP stakeholders. Postgraduate students need to be motivated and inspired to conduct research on *H. pickersgilli* and its habitat and on the threats of climate change to the species, building on the six post-graduate studies already completed on various aspects of *H. pickersgilli* and its ecology since 2012.