Received: 17 May 2016 | Revised: 1 September 2016 | Accepted: 21 November 2016
DOI 10.1002/aqc.2747

WILEY

SHORT COMMUNICATION

Conservation implications of establishment success of the Critically Endangered Twee River redfin '*Pseudobarbus*' *erubescens* (Skelton, 1974) in an artificial impoundment in South Africa

Martine S. Jordaan[1,2] | Johannes A. van der Walt[1] | Zanné Brink[1] | Sonja Erasmus[1] | Olaf L. F. Weyl[2,3]

[1] CapeNature, Scientific Services, Stellenbosch, South Africa
[2] South African Institute for Aquatic Biodiversity (SAIAB), Grahamstown, South Africa
[3] Center for Invasion Biology, SAIAB, Grahamstown, South Africa

Correspondence
Martine Jordaan, CapeNature Scientific Services, Private Bag X5014, Stellenbosch 7599, South Africa.
Email: mjordaan@capenature.co.za

Funding information
National Research Foundation of South Africa, Grant/Award Number: 77444.

Abstract

1. This study reports the first known record of breeding of the Critically Endangered Twee River redfin '*Pseudobarbus*' *erubescens* in an artificial impoundment. This followed an introduction of 48 individuals into a 10 ha impoundment within the species' native range more than a decade ago.
2. Sampling the impoundment using three fyke nets set overnight yielded 2838 *P. erubescens*, which included both juveniles and adults capable of spawning. Fork length measurements of a subsample of 250 individuals ranged from 29 to 125 mm with length cohorts indicating multiple spawning events.
3. This demonstrates that this species can successfully reproduce in lentic environments and suggests that artificial impoundments could be stocked to provide refugia for *P. erubescens* and other highly threatened small cyprinids while conservation strategies are developed to mitigate against habitat loss resulting from alien fish invasions, increased human use of water, and from climate change in rivers.

KEYWORDS
abstraction, climate change, conservation evaluation, endangered species, fish, red list, reservoir, stream

1 | INTRODUCTION

The Cape Fold Ecoregion (CFE) is one of the five aquatic ecoregions of Southern Africa and is characterized by high degrees of diversity and endemism of aquatic biota (Abell et al., 2008). Of the 28 fish taxa that have been formally evaluated using the IUCN Red List criteria, four are IUCN red-listed as Critically Endangered and 11 as Endangered. The main threats to these fishes are a reduction in habitat quality and quantity and predation by alien invasive fishes (Tweddle et al., 2009). This has resulted in almost all native riverine fish populations being restricted to relatively pristine headwater reaches located above the upper distribution limits of predatory alien fishes (Chakona & Swartz, 2012; Van der Walt, Weyl, Woodford, & Radloff, 2016; Weyl, Finlayson, Impson, & Woodford, 2014). In a recent survey of 578 km of mainstream and tributaries in the Olifants-Doorn River system, for example, native fishes were found to be restricted to less than 20% of their historical distribution (Van der Walt et al., 2016).

One such species is the Twee River redfin '*Pseudobarbus*' *erubescens* (Skelton, 1974) (valid name (Eschmeyer, Fricke, & van der Laan, 2016) for *Barbus erubsecens* following Yang et al., 2015). '*Pseudobarbus*' *erubescens* is a small minnow (up to 105 mm Standard Length (SL)) that is endemic to the Twee River catchment of the Olifants-Doorn River system (Figure 1a). It is relatively short-lived (6 years) and matures in its second year of life at about half its maximum length (50 mm SL; Skelton, 1974). During the spawning season in the Austral spring (October to December) both sexes develop an overall reddish hue to the body and fin bases and small nuptial tubercles develop on the head and upper anterior body (Skelton, 1974).

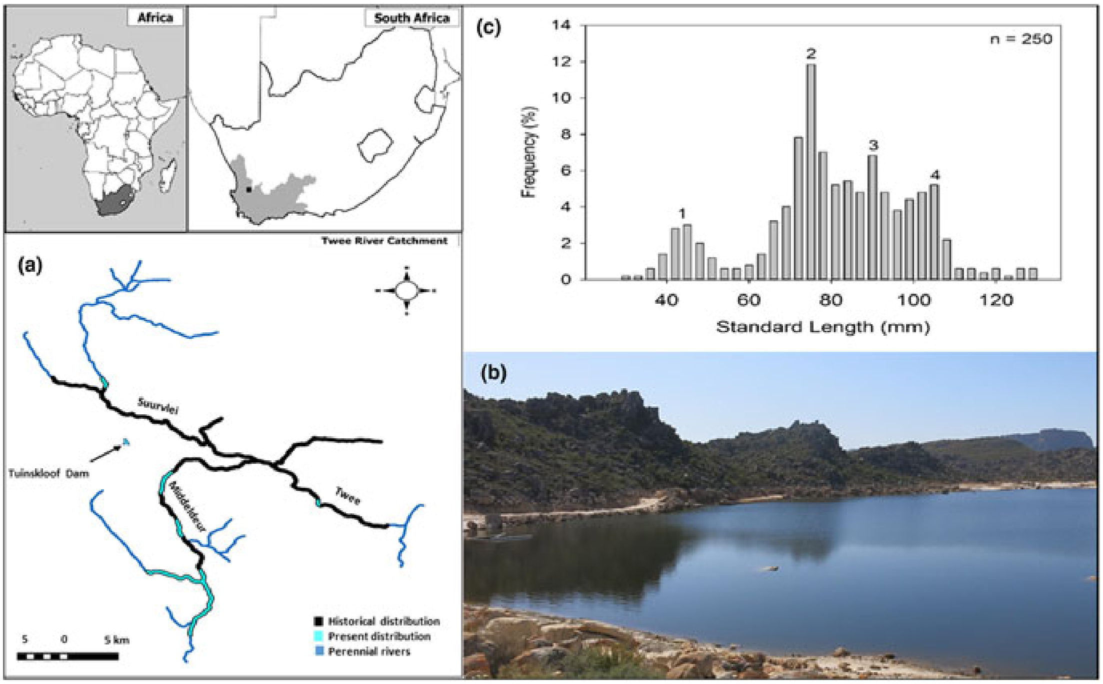

FIGURE 1 (a) Geographical locality of the Twee River catchment in the Cape Fold Ecoregion of South Africa. (b) Tuinskloof Dam, the artificial impoundment where a conservation translocation for '*Pseudobarbus*' *erubescens* was implemented in 2005. (c) Size class distribution of *P. erubescens* sampled in 2015 [Colour figure can be viewed at wileyonlinelibrary.com]

During spawning activity eggs are deposited into cracks and underneath rocks, and histological evidence of asynchronous egg development in the gonads indicates that individuals are capable of multiple spawning during a season (Marriott, 1998).

'Pseudobarbus' erubescens is threatened by habitat loss from water over-abstraction, agrichemical pollution from intensive deciduous and citrus fruit production and by predation from, and competition with, non-native fishes (Impson, Marriott, Bills, & Skelton, 2007; Marr, Sutcliffe, Day, Griffiths, & Skelton, 2009). These multiple stressors have reduced the distribution range and abundance of this species and a survey in 1997 estimated the total population size at 8400 individuals and the total range at less than 10 km^2 (Impson et al., 2007). As a result, *P. erubescens* was evaluated as Critically Endangered (www.iucnredlist.org) and conservation action was identified as an urgent requirement. In response, CapeNature (the local conservation authority) developed a strategy that included plans for the eradication of invasive fish species from part of the river system (Marr, Impson, & Tweddle, 2012), the promotion of land-owner awareness, and the attempt to establish a refuge population in an artificial off-channel impoundment (Impson et al., 2007).

At present there are no documented cases of established populations of small native cyprinids in artificial impoundments in the CFE, and conservation translocation into impoundments has not been a widely implemented conservation strategy for threatened fishes in South Africa. In the Twee River catchment, however, landowner support resulted in the stocking of 48 adult Twee River redfin into the *c*. 10 ha Tuinskloof Farm Dam (32° 39′ 29.96″S, 19° 11′ 33.12″E) by CapeNature in 2005 (Figure 1b), which is an impoundment of a small episodic stream containing rocky substrate and no other fish species.

The fate of these fish was never evaluated but recent assessments of the wild population of *P. erubescens* have demonstrated continued declines in both range and abundance (Marr et al., 2009). An assessment in 2014, replicating the survey of Marriott (1998), has shown that the total range occupied by this species is now reduced to approximately 10 km of river length (CapeNature, unpublished data).

2 | METHODS

In an attempt to identify possible refuge populations, the Tuinskloof Farm Dam (Figure 1) was sampled in November 2015, using three fyke nets (d-ring nets with a base width of 600 mm, two 5 m side panels and a mesh size of 4 mm) that were deployed overnight (14–16 h) at three sites chosen to represent available habitats (sand, mud or rock substrate, boulders and woody debris). Substrate at each site was visually assessed and placed in the following size categories: silt/mud: <0.063 mm; sand: 0.063–2 mm; gravel: 2–64 mm; small cobbles: 64–128 mm; large cobbles: 128–256 mm; boulders: 256–330 mm, as described in Quinn and Hickey (1990). The maximum depth of the dam at the time of sampling was 2.62 m. Water quality parameters (pH, dissolved oxygen and conductivity) were measured at each netting site and three more random sites around the impoundment using an Aqualytic AL15 water quality meter (Aqualytic, Germany). Turbidity and depth were measured using a Secchi disk with a measuring tape and this was done at 15 points (five transects with three readings each).

3 | RESULTS AND DISCUSSION

Measured water quality parameters were: temperature 23.8 ± 1.4°C, secchi depth 0.48 ± 0.04 m, conductivity 23.9 ± 0.7 µS, pH 7.4 ± 0.1 and dissolved oxygen 15.3 ± 2.5%. On retrieval, the fyke nets yielded

2838 *P. erubescens*, a subsample of which were measured to the nearest mm standard length (SL). Large numbers of fish sampled at each of the sites (Site 1 = 208; Site 2 = 1021; Site 3 = 1528) indicate that the fish use a wide range of available habitats including shallow (<1 m deep) channel habitat with sand and mud substrate and woody debris (Site 1), as well as coarse gravel, cobble and boulders with access to deeper water (Sites 2 and 3).

Length structure from a randomly selected subsample of 250 fish is presented in Figure 1c. Length ranged from 29 mm SL to 125 mm SL with evidence for four discernible length cohorts (≤ 49; 50–74; 75–100; >100 mm). The population was dominated by large (>70 mm) individuals and many males had nuptial tubercles (observed but not counted). The largest individuals observed measured 125 mm SL which is larger than the maximum size of 105 mm reported either by Skelton (1974) or Bills (2011) for riverine fish. The length distribution data also demonstrated an established population containing juveniles and multiple length cohorts of fish capable of spawning. As a result, *P. erubescens* can be considered fully established in the reservoir. The 2838 fish sampled in this initial survey represent 30% of the estimated population of this species in the wild. As sampling effort was low, population size in the 10 ha impoundment is likely to be considerable and may even exceed the size of the natural population. The conservation significance of this population requires evaluation because the small founder population (*n* = 48 individuals) may have resulted in a genetic bottleneck and low genetic diversity within the population in this impoundment compared with the diversity of the species in the wild (IUCN, 2013). Future research comparing the genetic diversity in the impoundment relative to the riverine population will be important to determine whether supplemental stocking with wild fish can benefit the Tuinskloof population. Having an indication of the diversity of the Tuinskloof population will also help to guide future decisions on whether to translocate to other impoundments or to supplement the wild population. What is clear, however, is that the small founder population did not hinder establishment in this case and that conservation-motivated translocations into additional off-channel impoundments should be considered as part of a conservation strategy for this species which has already been reduced to 10% of its historical distribution.

The generally poor establishment success of small native cyprinids in impoundments in the CFE has been attributed either to an inability to adapt to lentic environments or to negative interactions with predatory alien fishes that are established in many impoundments (Ellender & Weyl, 2014). While there is a paucity of information on the reproductive biology of small endemic cyprinids of the CFE region (Cambray, 1994), the present study provides support for the hypothesis that the presence of predatory alien fishes in impoundments might be a more relevant constraint than the lack of suitable spawning habitat in determining whether native species can establish successfully. The results of this study are thus significant for the future conservation of other highly threatened small cyprinids in the CFE, of which seven (64%) are listed as Threatened by the IUCN.

There are several examples of conservation successes for freshwater fishes resulting from translocations (Adams et al., 2014; Lintermans, Lyon, Hammer, Ellis, & Ebner, 2015). Adams et al. (2014) demonstrated that the establishment of refuge populations of rare lacustrine fishes in Scotland has played an important role in their long-term conservation. In Australia translocations including wild-to-wild translocation, stocking and rescue, are an important intervention employed to conserve threatened freshwater fish in areas threatened by desiccation during the millennium (1997–2010) drought (Lintermans et al., 2015). In a review of 99 conservation-based introductions in Australia, Lintermans et al. (2015) reported that some 40% had resulted in full or partial success. The view that in regions where global climate change is predicted to result in decreased rainfall and increased temperatures, conservation of narrow-range endemics may need to include managed relocation or assisted colonization, is gaining increased support (Olden, Kennard, Lawler, & Poff, 2010; Seddon, 2010).

This view could be applied to the CFE where predicted increased temperature and decreased precipitation in the future (Engelbrecht, Engelbrecht, & Dyson, 2013; Giannini, Biasutti, Held, & Sobel, 2008) will increase the pressures on native fishes such as *P. erubescens*. Decreased rainfall is likely to increase water abstraction from rivers which, in water-stressed catchments such as the Twee River, can result in the loss of entire riverine communities when basic environmental flow requirements are not met. Reduced surface flows coupled with increased temperatures are also likely to have adverse consequences for water quality, especially in areas subjected to the impacts of agrichemicals such as the Twee River catchment. The establishment of refuge populations of critically endangered fishes in impoundments should thus be considered as a conservation strategy for species at risk from climate change. In the case of *P. erubescens* in the CFE, conservation translocations are a potentially valuable tool for the conservation of this endangered species and should form part of a comprehensive conservation strategy.

Assisted colonization into novel environments is a contested topic with some strong arguments for (mainly relating to mitigation of extinction, Saunders & Norton, 2001), and against (unintended ecological consequences and enabling invasions, Ricciardi & Simberloff, 2009). When considering assisted colonization as a potential conservation tool, it may have greater applicability in aquatic than in terrestrial environments (Olden et al., 2010). As the natural dispersal of freshwater organisms requires connected waters, these species are extremely susceptible to habitat fragmentation and lack of connectivity between suitable habitats. Habitat loss as a result of land-use changes may fragment a species' range to the point where it is unable to respond to climate change and be dependent on assisted colonization in order to use climatically suitable habitats that may become available. It is also the connected nature of aquatic habitats that makes them exceptionally vulnerable to invasion and spread of non-native species. Assisted colonizations may thus enable extralimital invasions that can result in extinctions and ecosystem function loss, which are the same factors that underpin the motivation for the assisted colonization in the first place (Ricciardi & Simberloff, 2009). Thus it is important that introductions are limited to the catchment area within the species' historical range and, preferably, within the same major river basin to prevent unintended ecological consequences for the receiving ecosystem (Olden et al., 2010). Translocations also require the development of a clear strategy to mitigate against the depletion of wild fish from the remaining natural population and the potential loss of genetic diversity in stocked populations. It is important that refuge populations are not viewed as off-sets for a continued focus on developing and implementing a conservation strategy for natural populations. In the case of *P. erubescens*, such a strategy should include optimization of pesticide application programmes, management of irrigation return flows, and the eradication of invasive fishes.

ACKNOWLEDGEMENTS

MJ, JAV, ZB and SE would like to thank Cape Nature and the WWF Nedbank Green Trust for financial support during field surveys. Ms Sheila Henning of CapeNature is thanked for compiling the maps. OLFW would like to thank the National Research Foundation of South Africa (Grant No. 77444) and the South African Institute for Aquatic Biodiversity for their support. The anonymous reviewers are also thanked for their valuable comments on the manuscript.

REFERENCES

Abell, R., Thieme, M. L., Revenga, C., Bryer, M., Kottelat, M., Bogutskaya, N, … Petry, P. (2008). Freshwater ecoregions of the world: A new map of biogeographic units for freshwater biodiversity conservation. *Bioscience*, *58*, 404–414.

Adams, C. E., Lyle, A. A., Dodd, J. A., Bean, C. W., Winfield, I. J., Gowans, A. R. D., … Maitland, P. S. (2014). Translocation as a conservation tool: Case studies from rare freshwater fishes in Scotland. *The Glasgow Naturalist*, *26*, 17–24.

Bills, I. R. (2011). The conservation biology of the Twee River redfin (*Barbus erubescens*). In I. R. Bills, & N. D. Impson (Eds.), *Conservation biology of endangered freshwater fishes - linking conservation of endangered freshwater fishes with river conservation, focusing on the Cederberg*) Report to the Water Research Commission. Report No. K8/592

Cambray, J. A. (1994). The comparative reproductive styles of two closely related African minnows (*Pseudobarbus afer* and *P. asper*) inhabiting two different sections of the Gamtoos River system. *Environmental Biology of Fishes*, *41*, 247–268.

Chakona, A., & Swartz, E. R. (2012). Contrasting habitat associations of imperilled endemic stream fishes from a global biodiversity hot spot. *BMC Ecology*, *12*, 19.

Ellender, B. R., & Weyl, O. L. F. (2014). A review of current knowledge, risk and ecological impacts associated with non-native freshwater fish introductions in South Africa. *Aquatic Invasions*, *9*, 117–132.

Engelbrecht, C., Engelbrecht, F., & Dyson, L. (2013). High-resolution model-projected changes in mid-tropospheric closed-lows and extreme rainfall events over southern Africa. *International Journal of Climatology*, *33*, 173–187.

Eschmeyer, W. N., Fricke, R., & van der Laan, R. (Eds.). (2016). *Catalog of fishes: Genera, species, references*. (http://researcharchive.calacademy.org/research/ichthyology/catalog/fishcatmain.asp) [Accessed 29 August 2016].

Giannini, A., Biasutti, M., Held, I. M., & Sobel, A. H. (2008). A global perspective on African climate. *Climatic Change*, *90*, 359–383.

Impson, N. D., Marriott, M. S., Bills, I. R., & Skelton, P. H. (2007). Conservation biology and management of a critically endangered cyprinid, the Twee River redfin, *Barbus erubescens* (Teleostei: Cyprinidae), of the Cape Floristic Region, South Africa. *African Journal of Aquatic Science*, *32*, 27–33.

IUCN. (2013). *IUCN Guidelines for Reintroductions and Other Conservation Translocations. Version 1.0*. Gland, Switzerland: IUCN Species Survival Commission.

Lintermans, M., Lyon, J. P., Hammer, M. P., Ellis, I., & Ebner, B. C. (2015). Underwater, out of sight: Lessons from threatened fish translocations in Australia. In D. Armstrong, M. Hayward, D. Moro, & P. Seddon (Eds.), *Advances in reintroduction biology of Australian and New Zealand fauna* (pp. 237–253). Victoria, Australia: CSIRO Publishing.

Marr, S. M., Impson, N. D., & Tweddle, D. (2012). An assessment of a proposal to eradicate non-native fish from priority rivers in the Cape Floristic Region, South Africa. *African Journal of Aquatic Science*, *37*, 131–142.

Marr, S. M., Sutcliffe, L. M. E., Day, J. A., Griffiths, C. L., & Skelton, P. H. (2009). Conserving the fishes of the Twee River, Western Cape, South Africa: Revisiting the issues. *African Journal of Aquatic Science*, *34*, 77–85.

Marriott, M. S. (1998). Conservation biology and management of the Twee River redfin, *Barbus erubescens* (Pisces: Cyprinidae). MSc thesis, Rhodes University, South Africa.

Olden, J. D., Kennard, M. J., Lawler, J. J., & Poff, N. L. (2010). Challenges and opportunities in implementing managed relocation for conservation of freshwater species. *Conservation Biology*, *25*, 40–47.

Quinn, J. M., & Hickey, C. W. (1990). Magnitude of effects of substrate particle size, recent flooding, and catchment development on benthic invertebrates in 88 New Zealand rivers. *New Zealand Journal of Marine and Freshwater Research*, *24*, 411–427.

Ricciardi, A., & Simberloff, D. (2009). Assisted colonization is not a viable conservation strategy. *Trends in Ecology and Evolution*, *24*, 248–253.

Saunders, A., & Norton, D. A. (2001). Ecological restoration at Mainland Islands in New Zealand. *Biological Conservation*, *99*, 109–119.

Seddon, P. J. (2010). From reintroduction to assisted colonization: Moving along the conservation translocation spectrum. *Restoration Ecology*, *18*, 796–802.

Skelton, P. H. (1974). A new *Barbus* species from the Olifants River System, Western Cape Province, South Africa. In *J. L. B. Smith Institute of Ichthyology* (pp. 1–12). *Special Publication 13*

Tweddle, D., Bills, R., Swartz, E., Coetzer, W., Da Costa, L., Engelbrecht, J., … Smith, K. S. (2009). The status and distribution of freshwater fishes. In W. R. T. Darwall, K. G. Smith, D. Tweddle, & P. H. Skelton (Eds.), *The status and distribution of freshwater biodiversity in Southern Africa* (pp. 21–37). Gland (Switzerland) and Grahamstown (South Africa): IUCN and South African Institute for Aquatic Biodiversity.

Van der Walt, J. A., Weyl, O. L. F., Woodford, D. J., & Radloff, F. G. T. (2016). Spatial extent and consequences of black bass (*Micropterus* spp.) invasion in a Cape Floristic Region river basin. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *26*, 736–748.

Weyl, O. L. F., Finlayson, B., Impson, D., & Woodford, D. J. (2014). Threatened endemic fishes in South Africa's Cape Floristic Region: A new beginning for the Rondegat River. *Fisheries*, *39*, 270–279.

www.iucnredlist.org. http://www.iucnredlist.org/details/2564/0 [Accessed 13 May 2016]

Yang, L., Sado, T., Hirt, M. V., Pasco-Viel, E., Arunachalam, M., Li, J., … Mayden, R. L. (2015). Phylogeny and polyploidy: Resolving the classification of cyprinine fishes (Teleostei: Cypriniformes). *Molecular Phylogenetics and Evolution*, *85*, 97–116.

How to cite this article: Jordaan MS, van der Walt JA, Brink Z, Erasmus S, Weyl OLF. Conservation implications of establishment success of the Critically Endangered Twee River redfin '*Pseudobarbus' erubescens* (Skelton,) in an artificial impoundment in South Africa. *Aquatic Conserv: Mar Freshw Ecosyst*. 2017. https://doi.org/10.1002/aqc.2747