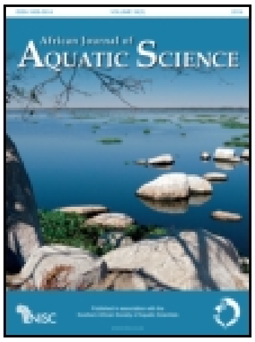

African Journal of Aquatic Science

ISSN: 1608-5914 (Print) 1727-9364 (Online) Journal homepage: https://www.tandfonline.com/loi/taas20

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To cite this article: C Cowden, DC Kotze, WN Ellery & EJJ Sieben (2014) Assessment of the long-term response to rehabilitation of two wetlands in KwaZulu-Natal, South Africa, African Journal of Aquatic Science, 39:3, 237-247, DOI: 10.2989/16085914.2014.954518

To link to this article: https://doi.org/10.2989/16085914.2014.954518

Published online: 02 Oct 2014.

African Journal of Aquatic Science 2014, 39(3): 237–247
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AFRICAN JOURNAL OF AQUATIC SCIENCE
ISSN 1608-5914 EISSN 1727-9364
http://dx.doi.org/10.2989/16085914.2014.954518

Assessment of the long-term response to rehabilitation of two wetlands in KwaZulu-Natal, South Africa

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Assessing the ecological outcomes of wetland rehabilitation activities is an important need recognised by the 'Working for Wetlands' programme in South Africa. An assessment of ecological response was conducted in the Killarney and Kruisfontein wetlands, KwaZulu-Natal, in 2005 prior to rehabilitation in 2006, and again in 2011 and 2012, respectively, following rehabilitation. The assessment criteria included an evaluation of changes in ecological integrity, the supply of ecosystem services, and vegetation composition. Improvements in hydrological and geomorphic integrity were recorded in both wetlands, resulting in improved ecosystem delivery. However, investigation of vegetation composition using the wetland index value and floristic quality assessment index indices showed that, seven years after rehabilitation, Killarney's vegetation composition had improved, but Kruisfontein's vegetation was still largely dominated by pioneer species and appeared to be stable, but in a severely transformed state. The response of these wetlands has shown that sites for rehabilitation should be screened before work begins, and wetlands requiring intensive management of vegetation recovery should be assessed in terms of the objectives and the anticipated benefits of the project.

Keywords: ecosystem services, integrity, rehabilitation outcomes, WIV and FQAI indices

Introduction

Wetlands are important ecosystems within the landscape as they provide ecosystem services directly related to water quantity and quality (Kotze et al. 2007). Nel and Driver (2012) estimated that in excess of 65% of South Africa's wetlands are under threat and that 48% of these are critically endangered. Wetlands in KwaZulu-Natal (KZN), including the priority wetlands of KZN as described by Begg (1989), have been subjected to high levels of modification and destruction (Kotze et al. 1995; Macfarlane et al. 2012). The factors contributing towards the degradation of wetlands in KZN vary greatly, but the predominant ones include urbanisation, water abstraction, damming, cultivation, artificial drainage and over-grazing (Macfarlane et al. 2012).

The recognition of benefits associated with wetland ecosystems and the need to reverse ecosystem degradation has resulted in the initiation of wetland restoration or rehabilitation projects amongst individuals and organisations across the globe (Ramsar 2002). Although often used in similar contexts, Grenfell et al. (2007) describe the terms 'restoration' and 'rehabilitation' from the perspective of interventions within South African wetlands. For this study, rehabilitation was defined as 'the process of reinstating natural ecological driving forces within part or the whole of a degraded wetland to recover former or desired ecosystem structure, function, biotic composition and ecosystem services' (Grenfell et al. 2007, p 43). In an attempt to address historic impacts on wetland ecosystems in South Africa, the Working for Wetlands (WfWet) programme was initiated in 2000. The purpose of the WfWet programme is 'to champion the protection, rehabilitation and sustainable use of South Africa's wetlands through co-operative governance and partnerships' (WfWet 2005a, p 4).

The majority of WfWet's funding is through the Expanded Public Works Programme (EPWP) and, as such, WfWet is bound by limitations imposed by the funding agent, which include defined labour targets as a mechanism for job creation. Monitoring and evaluation within the WfWet programme has been limited to gathering information required for administrative processes of programme implementation. These data include costs, compliance with best management practices, employment details relating to target population groups and remuneration and to training. Despite currently spending more than R80 million annually on the rehabilitation of wetlands, to date, the formal evaluation of the long-term ecological outcomes of WfWet's investment has been very limited. The need to undertake such evaluations is critical to inform the understanding of system response and future rehabilitation efforts. Working for Wetlands have acknowledged the need to develop a

Published online 02 Oct 2014

comprehensive monitoring and evaluation framework to support learning and to report on the ecological outcomes of their activities, based on broad-scale and strategic research across multiple sites. In addition to work by the WfWet programme, wetland rehabilitation is being undertaken by organisations and individuals, generally as a result of conditions of authorisation in terms of the original National Environmental Management Act No. 107 of 1998 (NEMA) and the National Water Act No. 36 of 1998 (NWA) as a means of mitigating the impacts associated with a proposed activity, and the outcomes need to be assessed to determine success or failure.

Guidelines for monitoring wetland rehabilitation (Cowden and Kotze 2009) have been developed with three levels of detail: Level 1 – monitoring outputs; Level 2 – monitoring outcomes at a coarse level, and Level 3 – monitoring outcomes at a detailed level. To date, the monitoring of wetland rehabilitation in South Africa has been confined almost entirely to Level 1 and, to a limited extent, Level 2 assessments. Level 3 assessments have not been undertaken and a systematic evaluation of wetland rehabilitation in South Africa based on a standardised framework has yet to be conducted. It was therefore considered critical that further research be undertaken to support and strengthen the implementation and science of wetland rehabilitation. This research investigated the long-term response of two wetland systems to rehabilitation activities, and included assessments of ecological integrity and ecosystem services supplied, plus a detailed investigation of the response of vegetation to rehabilitation interventions.

Materials and methods

Study areas

The study areas were Killarney wetland, south-western KZN, and Kruisfontein wetland, KZN Midlands (Figure 1), both defined as channelled, valley-bottom wetlands in accordance with the hydrogeomorphic (HGM) types defined by Kotze et al. (2007).

Killarney wetland

The Killarney wetland (30°08'44'' S, 29°26'10'' E) is a tributary of the main body of the Ntsikeni Vlei in Ntsikeni Nature Reserve (NNR), a proclaimed Ramsar site managed by Ezemvelo KZN Wildlife (EKZNW). The wetland drains into the upper reaches of the Lubhukwini River. The NNR originally consisted of farmlands that were proclaimed as a nature reserve in 1978, but was subject to illegal occupation for an extended period thereafter (Begg 1989). During the period of illegal occupation the area lacked a management plan, and was characterised by the presence of erosion gullies. The wetland was identified for rehabilitation by WfWet in 2005, prior to rehabilitation in 2006, with the intention of stabilising the main gully within the system and promoting more frequent flooding of the valley bottom, thereby promoting the re-establishment of plant species associated with the seasonally and permanently wet zones.

Kruisfontein wetland

The Kruisfontein wetland (29°06'45'' S, 30°08'13'' E) includes valley-bottom and seepage wetland areas located at the confluence of two tributary streams with the Mooi River. The wetland is on privately-owned farmland, approximately 17 km north-east of the town of Mooi River in the KZN Midlands. The wetland was greatly modified for cultivation purposes. Two drainage channels had been excavated along its north-eastern and south-western boundaries, and ridge-and-furrow agriculture had been undertaken across the majority of the wetland. Ownership of the farm changed approximately 10 years ago, cultivation of the Kruisfontein wetland ceased and the land owner attempted to rehabilitate the north-eastern portion of the system in 2004. The wetland was subsequently identified as a priority for wetland rehabilitation by WfWet in 2005, prior to rehabilitation in 2006, the focus being to reinstate the hydrological regime in its south-western and central portions by redirecting the flows from the drainage channels across the site. It was anticipated that the redistribution of flows would be adequate to support the re-establishment of native hydric plant species.

Baseline pre-rehabilitation studies were undertaken in 2005 during research by Cowden et al. (2009) and Kotze (2009), using the framework of Cowden and Kotze (2009), and included rapid and comprehensive assessments of the wetland rehabilitation outcomes as determined by the objectives. These studies included the establishment of three transects across the Killarney wetland (Figure 1) and two transects across the Kruisfontein wetland (Figure 1), which formed the basis for the collection of data linked to vegetation composition. The Killarney rehabilitation was implemented by WfWet in multiple phases, and at the time of establishing the baseline monitoring, i.e. that recorded by Cowden et al. (2009), only the initial phase of rehabilitation in the western portion of the system (Figure 1) had been planned, limiting the extent of the baseline monitoring. Follow-up post-rehabilitation fieldwork for each site was conducted during the rainy season, with the Killarney site visit being undertaken in January 2011 and the Kruisfontein site visit being undertaken in February 2012.

Assessment of ecological outcomes

The assessment of the rehabilitation outcomes focused on changes in the ecosystem integrity of the wetlands and the supply of ecosystem services.

Assessment of ecosystem integrity

An assessment of ecosystem integrity was undertaken using 'WET-Health' (Macfarlane et al. 2007). 'WET-Health' is a wetland assessment method that records the amount of deviation from the natural reference condition for three components of health: hydrology, geomorphology and vegetation (Kotze et al. 2012). Ecosystem integrity, as described in 'WET-Health', is aligned with the description of naturalness or intactness by Anderson (1991), where an ecosystem's reference natural condition excludes impacts from human activities. The disturbance units, portraying the extent of different types of disturbance within the wetlands, were mapped using aerial imagery, pre- and post-rehabilitation, in a geographic information system (GIS). These disturbance units were then used to inform the assessment of wetland integrity for the pre- and post-rehabilitation conditions. The scores for each of the

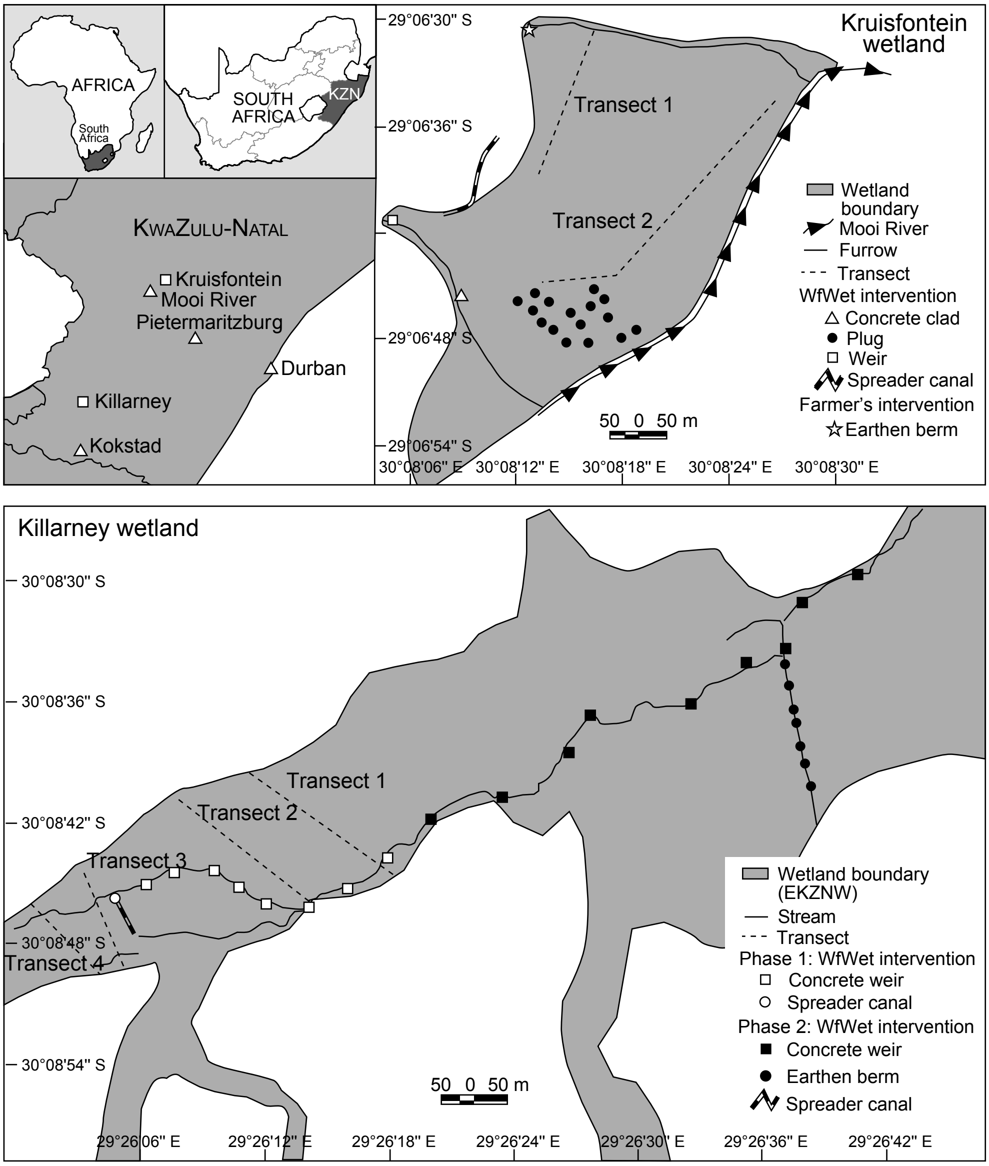

Figure 1: Maps of Kruisfontein and Killarney wetlands, KwaZulu-Natal, South Africa, showing locations of transects and key features per wetland

'WET-Health' components were integrated into a composite impact score, using the predetermined ratio of 3:2:2 (MacFarlane et al. 2007) for the hydrology, geomorphology and vegetation components respectively. This composite impact score was used to derive a health score that provided the basis for the calculation of hectare equivalents according to Cowden and Kotze (2009). Hectare equivalents provided a means of deriving a common unit of 'currency' to measure gains or losses in ecosystem integrity, in response to the various rehabilitation interventions.

Assessment of ecosystem services

The likelihood of specified ecosystem services being supplied by the wetlands was assessed using 'WET-EcoServices' (Kotze et al. 2007), an assessment method that relies on indicators to rate various functionally relevant characteristics of the wetlands and their surrounding catchments (e.g. surface roughness of the wetland), rather than directly measuring the level of ecosystem service supplied. Pre-rehabilitation levels of ecosystem service delivery were compared to post-rehabilitation levels.

Detailed assessment of vegetation outcomes

The objectives of the rehabilitation of both wetlands focused on re-establishing near-natural hydrological conditions and promoting the re-establishment of native hydric plants (Cowden et al. 2009; WfWet 2005b). Therefore vegetation surveys were undertaken at both wetlands. A control area, unaffected by rehabilitation, was present only within the Kruisfontein wetland. In an attempt to identify trends between affected and unaffected areas of the Killarney wetland, an additional transect unaffected by rehabilitation (Transect 4; Figure 1) upstream of the rehabilitation was included in the post-rehabilitation survey.

Vegetation surveys
Vegetation surveys were conducted based on species composition in plots, which were 4 m × 4 m for Killarney and 4 m × 1 m for Kruisfontein, along the existing transects. Different quadrat dimensions were used at the two sites in order to account for heterogeneity in micro-topography. The interpretation of the vegetation data was based on the use of indices, selected to address key questions surrounding the response of wetland ecosystems to rehabilitation efforts. These were: (1) to what extent has there been a shift from vegetation indicating terrestrial conditions to vegetation indicating hydric (wetland) conditions?; and (2) to what extent has there been a shift from vegetation strongly dominated by pioneer/ruderal species to native vegetation?

Wetland index value
The wetland index value (WIV) assesses whether the system has recovered to a point where there is hydric vegetation, based on wetland indicator status (Wentworth and Johnson 1986; Carter et al. 1988). In this instance, the wetland indicator status of the recorded plant species was determined based on the classes defined by van Ginkel et al. (2010). The WIV calculations were undertaken based on the approach defined by Carter et al. (1988).

The rehabilitation activities did not affect water flows across the individual sites uniformly, allowing for differently affected areas to be identified. At Kruisfontein wetland, areas where low and high flows had been reinstated could be distinguished from areas where only high flows had been reinstated. Thus, to determine the response of the wetland system to the rehabilitation activities, the samples were grouped into areas affected by similar processes, using the approach adopted by Campbell et al. (2002). The Kruskal–Wallis test, a non-parametric alternative to a one-way ANOVA (Ashcroft and Pereira 2003), was used to determine if significant differences existed between the means for the different groupings. For Killarney wetland, data were grouped according to transects, as it was anticipated that the response of the system to rehabilitation was likely to vary longitudinally down the length of the system. The Kruisfontein wetland data were grouped according to the nature of the flows received by the areas, as it was anticipated that the response of the system to rehabilitation was likely to vary in accordance with these different 'treatments' (i.e. WfWet rehabilitation high flows only; WfWet rehabilitation high, moderate and low flows; transformed control; untransformed; farmer's rehabilitation). Where statistically significant differences ($p < 0.05$) were identified by the Kruskal–Wallis test, *t*-tests were undertaken to compare different groupings. For the Killarney wetland, *t*-tests were undertaken to compare transects before and after rehabilitation, showing the change over time. For the Kruisfontein wetland, where a control group described as the 'Transformed control' was available, control *t*-tests were used to compare the different 'treatments' to the control in addition to the *t*-tests to compare the groups before and after rehabilitation. All analyses were conducted using PractiStat (Ashcroft and Pereira 2003) and PAST (Hammer et al. 2001) software.

Floristic quality assessment index
The floristic quality assessment index (FQAI) (Miller and Wardrop 2006) addresses whether a system has recovered to a point closer to the reference natural condition based on the abundance of weedy, pioneer or alien invasive plant species. The recorded plant species were assigned a 'coefficient of conservatism', a subjective rating of the plant species' preference for non-degraded natural communities, ranging from 0 to 10, with the higher values assigned to those species less tolerant of degradation (Miller and Wardrop 2006). The coefficient was based on professional opinion, with reference to species descriptions (van Ginkel et al. 2010) and assigned as follows: alien invasive plants (0); ruderal or weedy plants (1); occasionally ruderal or weedy plants (5); and plant species with a low tolerance to disturbance (10). An FQAI score for each plot was derived, based on the weighted average approach outlined by Miller and Wardrop (2006). Statistical analyses of the derived FQAI data were undertaken in the same manner as in the approach adopted for the WIV scores.

Results

Assessment of ecological outcomes

Assessment of ecosystem integrity
Impacts on ecosystem integrity in the Killarney wetland were limited primarily to channel incision, leading to the desiccation of the upstream areas of the system, linked to reduced frequency of overtopping of the channel and a draw-down effect directly adjacent to the channel. The wetland had not been subjected to cultivation and the removal of natural vegetation. In contrast, the Kruisfontein wetland was subjected to extensive ridge-and-furrow agriculture, the digging of artificial drainage channels, and active erosion. These disturbances included the alteration of both the vegetation and hydrological components to critical levels, with almost total loss of indigenous vegetation cover and altered water flows and retention patterns within the system. It was evident from the assessments of pre-rehabilitation ecological integrity (Table 1) that, in comparison to the Killarney wetland, Kruisfontein wetland had been impacted to a greater extent by land-use activities.

The assessments of the post-rehabilitation conditions showed that both wetlands had improved in terms of ecosystem integrity. These improvements were primarily linked to the hydrological component of each of the wetlands, with their scores for hydrology changing the most (Table 1). The major changes recorded in the Killarney wetland were linked to reversal of the impacts of the incised channel, i.e. re-wetting areas of the wetland that had become desiccated. Reversing the impacts of the channel also served to stabilise the identified erosion and promoted the re-establishment of wetland plant species, which improved the geomorphic and vegetation components of the Killarney wetland. Similarly, the redirection of base flows across portions of the Kruisfontein wetland served to improve its hydrological regime, especially in those areas receiving moderate and low flows. However, improvements in the vegetation component were limited due to inadequate recovery of the vegetation, with *Paspalum dilatatum* remaining dominant within the

Table 1: WET-Health impact scores, ranging from 0 (pristine) to 10 (critical), for the hydrology, geomorphology and vegetation components of ecological integrity, and hectare equivalents recorded for Killarney and Kruisfontein wetlands, pre- and post-rehabilitation

	Killarney		Kruisfontein	
	Pre-rehabilitation (2005)	Post-rehabilitation (2011)	Pre-rehabilitation (2005)	Post-rehabilitation (2012)
Hydrology	3.0	1.0	9.0	7.5
Geomorphology	1.6	0.5	2.5	1.8
Vegetation	3.6	2.1	8.2	6.7
Overall impact score	2.8	1.2	6.9	5.6
Hectare equivalents*	30.7	37.5	8.2	11.5
Hectare equivalents reinstated**	6.8		3.3	

* Hectare equivalents = Total wetland area × (10 − overall impact score) ⁄ 10. Total wetland area: Killarney = 42.4 ha, Kruisfontein = 26.4 ha
** Hectare equivalents reinstated = (Post-rehabilitation hectare equivalents) – (Pre-rehabilitation hectare equivalents)

system at the expense of native plant species. In Kruisfontein wetland the geomorphology improved as a result of the stabilisation of active erosion.

Based on the recorded impact scores, the Killarney wetland improved from 30.7 hectare equivalents (ha equiv.) to 37.5 ha equiv., while the Kruisfontein wetland improved from 8.2 to 11.5 ha equiv. (Table 1). The improvement in ecosystem integrity of both wetlands was less than the improvements in hectare equivalents originally predicted, i.e. approximately 8 hectare equivalents (Cowden et al. 2009) and 6 hectare equivalents (Kotze 2009), respectively.

Assessment of ecosystem services

Post-rehabilitation 'WET-Ecoservices' assessments generally reflected improvements in the effectiveness of the rehabilitated wetland in providing ecosystem services (Table 2). For both wetlands, improvements in the effectiveness scores recorded were strongly linked to changes in hydrology. Thus, increases in the effectiveness of the systems to assimilate phosphates, nitrates and toxicants and improved opportunities for water supply and carbon storage were recorded (Table 2). It is important to point out that, although the effectiveness of the Killarney wetland in delivering regulatory services was generally enhanced, the opportunity/demand for carrying out these services was very limited, mainly because of the near-pristine nature of that wetland's catchment. This contrasts markedly with Kruisfontein, where the catchment was much more intensively used for dairy production.

In Kruisfontein wetland the poor recovery of vegetation composition had implications for the provisioning services supplied by the wetland. Specifically, some of the labourers on the farm used the wetland-dependent rush *Juncus punctorius* for weaving. In its pre-rehabilitation state, the extent of *J. punctorius* was very limited, translating into low provisioning scores. Given that *J. punctorius* is specially adapted to permanently or near-permanently saturated conditions, it was anticipated that this species would increase in abundance through rehabilitation, in response to the increased extent of the permanent wetness zone. However, the 2012 vegetation survey showed no such increase. Instead, *Juncus effusus* was relatively abundant in some of the wetter rehabilitated portions of Kruisfontein, but this species is of very low value for weaving (Kotze and Traynor 2012).

Table 2: Percentage change in 'WET-EcoServices' effectiveness scores for ecosystem services at Killarney and Kruisfontein wetlands in 2005, and then 2011 and 2012, respectively. Positive values = increase in score, negative values = decrease in score between pre- and post-rehabilitation states

Ecosystem service	Killarney % change in effectiveness scores	Kruisfontein % change in effectiveness scores
Flood attenuation	25.0	125.0
Stream flow regulation	18.8	6.7
Sediment trapping	25.0	125.0
Phosphate trapping	25.0	28.4
Nitrate removal	45.5	27.3
Toxicant removal	53.3	32.6
Erosion control	10.4	7.7
Carbon storage	60.0	16.7
Biodiversity maintenance	20.8	15.4
Water supply	95.5	25.9
Source of harvestable goods/ resources	0.0	0.0
Source of cultivated goods/ resources	0.0	0.0
Socio-cultural significance	0.0	0.0
Tourism and recreation	15.4	0.0
Education and research	50.0	33.3

Detailed assessment of vegetation outcomes

The proportional abundance of plant species within different areas of each wetland (Tables 3 and 4) highlighted the changes in the dominance of plant species over time in response to the rehabilitation. In Killarney wetland *Eleocharis dregeana*, an obligate wetland species that always occurs in wetlands, increased in abundance, together with other obligate wetland species, in Transects 1 and 2, and thereby reduced the proportional abundance of *Pennisetum thunbergii* (Table 3). *Eleocharis dregeana* also appeared to have displaced *Themeda triandra*, a non-wetland species, as the dominant species in Transect 3 (Table 3). In Kruisfontein wetland obligate wetland species such as *Paspalum distichum* and *Schoenoplectus paludicola* increased in abundance in response to the high, moderate and low flows, as compared to the dominance of facultative and facultative positive plant species in the control area (Table 4). The alien grass *Paspalum dilatatum* remained dominant over most of the wetland since rehabilitation, except for the areas influenced by high, moderate and low flows associated with the WfWet rehabilitation. In addition, the dominant plant species within the area affected by the farmer's pre-2005 interventions had not changed between 2005 and 2011 (Table 4). In contrast to the Killarney wetland, where it is anticipated that, given enough time, the pioneer species will eventually be replaced by native vegetation, the vegetation in the Kruisfontein wetland appeared to be stable in a severely transformed state.

Table 3: Dominant plant species for each transect in Killarney wetland pre- and post-rehabilitation. Species ranked in order of abundance

Transect	Pre-rehabilitation (2005)	Post-rehabilitation (2011)
1	*Pennisetum thunbergii* $^{F+,10}$ *Carex acutiformis* ^{O,10} *Eragrostis planiculmis* ^{O,5}	*Carex acutiformis* ^{O,10} *Eleocharis dregeana* ^{O,10} *Pennisetum thunbergii* $^{F+,10}$
2	*Eragrostis planiculmis* ^{O,5} *Pennisetum thunbergii* $^{F+,10}$ *Helichrysum aureonitens* $^{F+,10}$	*Eleocharis dregeana* ^{O,10} *Pennisetum thunbergii* $^{F+,10}$ *Eragrostis planiculmis* ^{O,5}
3	*Themeda triandra* ^{NW,10} *Helichrysum aureonitens* $^{F+,10}$ *Eragrostis planiculmis* ^{O,5}	*Eleocharis dregeana* ^{O,10} *Helichrysum aureonitens* $^{F+,10}$ *Eragrostis planiculmis* ^{O,5}
4*	–	*Helichrysum aureonitens* $^{F+,10}$ *Eragrostis planiculmis* ^{O,5} *Andropogon appendiculatus* $^{F+,10}$

^{FW} = Facultative wetland; $^{F-}$ = facultative negative; $^{F+}$ = facultative positive; ^{O} = obligate wetland; ^{NW} = not wetland, as per van Ginkel et al. (2010)
^{0} Alien invasive plants; ^{1} ruderal or weedy plants; ^{5} occasionally ruderal or weedy plants; ^{10} plant species intolerant of disturbance
* Transect 4 included in 2011 due to lack of a control in Killarney wetland, in an attempt to identify conditions if rehabilitation had not been undertaken

The vegetation response in Kruisfontein wetland provided valuable opportunities to identify different trends in vegetation recovery as the system included: (1) an area that had been subjected to improved hydrology since 2004 when the landowner independently implemented wetland rehabilitation; (2) a ridge-and-furrowed area that served as a control, as it was unaffected by both the farmer's and WfWet's rehabilitation activities; and (3) a small area of intact vegetation not subjected to ridge-and-furrow cultivation that provided an indication of some of the native plant species that could be expected after recovery, notably *Carex acutiformis*, *Arundinella nepalensis* and *E. dregeana*.

Wetland index value

The Kruskal–Wallis tests of the WIVs, indicating the degree to which hydric vegetation was present, for each of the plots in the two wetlands over time, showed that non-significant differences (p = 0.3318) existed in Killarney wetland and significant differences (p = 0.0137) existed in Kruisfontein wetland.

In Killarney wetland the WIVs recorded in 2005 (Table 5) supported the original observation by Cowden et al. (2009) of a gradient from drier conditions upstream (Transect 3) to wetter conditions downstream (Transect 1). The recorded WIVs also decreased from 2005 to 2011 (Table 5), as the vegetation in Killarney wetland had more obligate or facultative positive wetland plant species, indicating wetter conditions.

Multiple comparisons of pre- and post-rehabilitation 'treatments', in the Kruisfontein wetland showed no significant differences (p > 0.05) in WIVs (Table 6). The comparison of the 2005 control with the other 'treatments' from 2005 showed no significant differences (p > 0.05), but comparison of the 2012 control with other 2012 'treatments' revealed that the area influenced by the high, moderate and low flows was significantly different to the control (p < 0.05), suggesting a change in vegetation composition in that area since the implementation of the WfWet rehabilitation (Table 7).

Table 4: Dominant plant species in Kruisfontein wetland for each treatment pre- and post-rehabilitation. Species ranked in order of abundance

Treatment	Pre-rehabilitation (2005)	Post-rehabilitation (2012)
Transformed control (transformed area unaffected by rehabilitation)	*Paspalum dilatatum* $^{F+,0}$ *Cynodon dactylon* $^{F-,1}$ *Eragrostis plana* ^{FW,5}	*Paspalum dilatatum* $^{F+,0}$ *Cynodon dactylon* $^{F-,1}$ *Eragrostis plana* ^{FW,5}
WfWet rehabilitation high, moderate and low flows*	–	*Paspalum distichum* $^{F-,5}$ *Paspalum dilatatum* $^{F+,0}$ *Schoenoplectus paludicola* ^{O,10}
WfWet rehabilitation – high flows only	*Bidens pilosa* ^{NW,0} *Paspalum dilatatum* $^{F+,0}$ *Cynodon dactylon* $^{F-,1}$	*Paspalum dilatatum* $^{F+,0}$ *Cyperus esculentus* ^{FW,1} *Verbena bonariensis* $^{F-,0}$
Untransformed	*Carex acutiformis* ^{O,10} *Hyparrhenia dregeana* $^{F-,5}$ *Paspalum distichum* ^{O,5}	*Paspalum dilatatum* $^{F+,0}$ *Hyparrhenia dregeana* $^{F-,5}$ *Carex acutiformis* ^{O,10}
Farmer's rehabilitation	*Paspalum dilatatum* $^{F+,0}$ *Juncus effuses* ^{O,5} *Cynodon dactylon* $^{F-,1}$	*Paspalum dilatatum* $^{F+,0}$ *Juncus effuses* ^{O,5} *Cynodon dactylon* $^{F-,1}$

^{FW} = Facultative wetland; $^{F-}$ = facultative negative; $^{F+}$ = facultative positive; ^{O} = obligate wetland; ^{NW} = not wetland as per van Ginkel et al. (2010)
^{0} Alien invasive plants; ^{1} ruderal or weedy plants; ^{5} occasionally ruderal or weedy plants; ^{10} plant species intolerant of disturbance
* Areas affected by high, moderate and low flows were less extensive than anticipated and plots are absent in this area for 2005

The thresholds recommended by Wentworth and Johnson (1986) and applied by Carter et al. (1988) were considered in defining the level of wetness of the two wetlands:

- WIV < 2.5 = wetland
- WIV 2.5–3.5 = transitional
- WIV > 3.5 = non-wetland

Based on these thresholds and the data in Tables 5–7, the WIV values for Killarney wetland were generally those of 'wetland', in contrast to those for Kruisfontein, suggesting that the majority of the latter system, which had a mix of wetland and non-wetland plant species, was 'transitional'.

Floristic quality assessment index

The Kruskal–Wallis tests of the FQAIs for each of the plots in the wetlands, indicating the degree to which the vegetation present reflected the reference natural condition, showed significant differences between transects (p = 0.0034) and 'treatments' (p = 0.0095) in both wetlands. Comparisons over time showed significant differences (p < 0.05) only for Transect 1 in Killarney wetland, although the vegetation composition had generally altered towards non-opportunistic plant species, with the recorded FQAIs increasing for Transects 1, 2 and 3 (Table 8). In the case of Kruisfontein, the comparisons of FQAIs showed that in 2005 there was no significant difference (p > 0.05) between 'treatments' and the control. However, post-rehabilitation in 2012 the area influenced by the high, moderate and low flows and the untransformed area was significantly different (p < 0.05) to the control, suggesting a change in vegetation composition (Table 9).

Table 5: Pre- and post-rehabilitation wetland index values (mean ± standard deviation) per transect in Killarney wetland. Recorded WIVs ranged from 1 (obligate) to 5 (non-wetland) depending on the prevalence of the plant species within each indicator class in the particular plot

Transect	Pre-rehabilitation (2005)	Post-rehabilitation (2011)
1	1.751 ± 0.878	1.661 ± 0.726
2	1.917 ± 0.942	1.755 ± 0.842
3	2.740 ± 1.113	1.625 ± 0.587
4	–*	2.195 ± 0.526

* Sample plots in Transect 4 were sampled only in 2011, not prior to wetland rehabilitation

Discussion

The improvement in ecosystem integrity of the Killarney and Kruisfontein wetlands was less than the improvements in hectare equivalents predicted originally. This suggests that the rehabilitated wetlands have not followed the trajectory of change anticipated during the planning process. In Killarney wetland the hydrology and geomorphology have recovered as anticipated, with the lower than expected gain in hectare equivalents being mostly attributed to the response of the vegetation component. However, it is anticipated that vegetation conditions may improve further if the hydrological state of the wetland is maintained. In Kruisfontein wetland both hydrology and vegetation have not responded as anticipated. The hydrological response in the wetland was inhibited by the ineffectiveness of the spreader canal and the concentration of flows along the western edge of the earthen berms, thereby affecting only approximately half of the anticipated area of wetland, as predicted by Kotze (2009). The limited vegetation response in Kruisfontein wetland is linked to reduced area with improved hydrology and the dominance of disturbance-tolerant plant species, even in extensive areas of the wetland which had been effectively re-wetted, clearly shown by the FQAI results.

Table 6: Wetland index values (mean ± standard deviation) per treatment recorded in Kruisfontein wetland sample plots. No significant differences (p > 0.05) were recorded when comparing pre- and post-rehabilitation. Recorded WIVs ranged from 1 (obligate) to 5 (non-wetland), depending on the prevalence of the plant species within each indicator class in the particular plot

Treatment	Pre-rehabilitation (2005)	Post-rehabilitation (2012)
WfWet rehabilitation high, moderate and low flows	–*	1.335 ± 0.369
WfWet rehabilitation high flows only	3.941 ± 1.169	2.495 ± 0.367
Transformed control (transformed area unaffected by rehabilitation)	2.735 ± 0.574	2.850 ± 0.463
Untransformed	2.185 ± 1.404	2.701 ± 1.213
Farmer's rehabilitation	2.173 ± 0.718	2.405 ± 0.625

* Sample plots in 'WfWet rehabilitation high, moderate and low flows' were sampled only in 2012, not prior to wetland rehabilitation

Table 7: Comparison of wetland index values (mean ± standard deviation) recorded in Kruisfontein wetland sample plots for each treatment, compared with control from the same year. Significant differences (p < 0.05) to the control are shown by different superscript letters within columns

Treatment	Pre-rehabilitation (2005)	Post-rehabilitation (2012)
Transformed control (transformed area unaffected by rehabilitation)	2.735 ± 0.574 ^{a}	2.850 ± 0.463 ^{a}
WfWet rehabilitation high, moderate and low flows	–*	1.335 ± 0.369 ^{b}
WfWet rehabilitation high flows only	3.941 ± 1.169 ^{a}	2.495 ± 0.367 ^{a}
Untransformed	2.185 ± 0.574 ^{a}	2.701 ± 1.213 ^{a}
Farmer's rehabilitation	2.173 ± 1.404 ^{a}	2.405 ± 0.625 ^{a}

* Sample plots in 'WfWet rehabilitation high, moderate and low flows' were sampled only in 2012, not prior to wetland rehabilitation

Table 8: Comparison of floristic quality assessment index values (mean ± standard deviation) recorded in sample plots for each transect and treatment in Killarney and Kruisfontein wetlands pre- and post-rehabilitation. Significant differences ($p < 0.05$) within the rows indicated by different superscript letters. Recorded FQAI values range from 0 (dominated by alien plant species) to 100 (dominated by indigenous plant species intolerant of disturbance)

Killarney wetland transect	Pre-rehabilitation (2005)	Post-rehabilitation (2011)
Transect 1	81.064 ± 11.069 ^{a}	93.643 ± 6.068 ^{b}
Transect 2	75.701 ± 11.858 ^{a}	87.575 ± 9.574 ^{a}
Transect 3	85.188 ± 7.596 ^{a}	87.447 ± 5.458 ^{a}
Transect 4	No comparison possible *	
Kruisfontein wetland treatment	**Pre-rehabilitation (2005)**	**Post-rehabilitation (2012)**
WfWet rehabilitation high, moderate and low flows	No comparison possible **	
WfWet rehabilitation high flows only	19.820 ± 12.182 ^{a}	13.608 ± 9.576 ^{a}
Transformed control	16.963 ± 14.518 ^{a}	22.229 ± 8.487 ^{a}
Untransformed	46.383 ± 35.799 ^{a}	45.413 ± 17.795 ^{a}
Farmer's rehabilitation	30.502 ± 10.474 ^{a}	22.384 ± 14.766 ^{a}

* Sample plots in Transect 4 were sampled only in 2011, not prior to wetland rehabilitation
** Sample plots in 'WfWet rehabilitation high, moderate and low flows' were sampled only in 2012, not prior to wetland rehabilitation

Table 9: Comparison of floristic quality assessment index values (mean ± standard deviation) recorded in Kruisfontein wetland sample plots for each treatment, compared with control from the same year. Significant differences ($p < 0.05$) to the control are shown by different superscript letters within columns

Treatment	Pre-rehabilitation (2005)	Post-rehabilitation (2012)
Transformed control (transformed area unaffected by rehabilitation)	16.963 ± 14.518 ^{a}	22.229 ± 8.487 ^{a}
WfWet rehabilitation high, moderate and low flows	–*	53.556 ± 24.084 ^{b}
WfWet rehabilitation high flows only	19.820 ± 12.182 ^{a}	13.608 ± 9.576 ^{a}
Untransformed	46.383 ± 35.799 ^{a}	45.413 ± 17.795 ^{b}
Farmer's rehabilitation	30.502 ± 10.474 ^{a}	22.384 ± 14.766 ^{a}

*Sample plots in 'WfWet rehabilitation high, moderate and low flows' were sampled only in 2012, not prior to wetland rehabilitation

The improvements in the wetlands' ability to supply ecosystem services were strongly linked to the improvement in regulatory services (e.g. assimilating nutrients). The increased effectiveness relating to regulatory services was directly attributable to the redistribution of flows over larger areas of the wetlands. In addition to the change in effectiveness recorded for the two wetlands, Kotze et al. (2007) suggested that the larger the wetland the greater its provision of benefits and services. In terms of improvements linked to the rehabilitation, it is therefore important to consider also the increase in area of functional wetland within the landscape when assessing improved functioning. The importance of wetland size varies between specific ecosystem services. For water quality enhancement, size is considered to be important (Kotze et al. 2007). The effect of intact wetland spatial extent within a catchment on the assimilation of nutrients has been well demonstrated (e.g. Tiner 2005; Turpie et al. 2010). The increase in regulatory services relating to water quality within Kruisfontein wetland is particularly important if one considers that the area receives effluent from the farm dairy, which may deliver significant pollutants when discharged to streams (Bolan et al. 2009). With the increase in effective wetland size and the increased effectiveness in terms of ecosystem services associated with water quality enhancement, the rehabilitation therefore assists in buffering the Mooi River from nutrients originating from the nearby dairy.

Based on the vegetation surveys, the results obtained for Killarney wetland generally followed expectations where, despite recording non-significant differences in the WIV values along the transects, obligate wetland species such as *E. dregeana* have increased in abundance. It is suggested that non-significant differences were related to obligate wetland species replacing facultative positive wetland species such as *P. thunbergii*, rather than facultative wetland species, as was the case in the moderate- and low-flow areas in Kruisfontein wetland. In addition, *C. acutiformis*, the species characteristic of the intact portions of the wetland, increased in abundance, while the abundance of disturbance-tolerant species decreased, shown by the significant differences in FQAI values observed over time for Transect 1. The response of the vegetation in Killarney wetland therefore appears to be following the wetness gradient described by Cowden et al. (2009), where the historically wetter areas downstream are responding to rehabilitation more rapidly than the drier upstream areas. In contrast to Kruisfontein, it is anticipated that the changes in floristic quality have been facilitated by the presence of nearby intact areas of wetland habitat providing propagules, and the fact that the historical disturbance of the system was linked to desiccation associated with channel incision rather than to long-term, intensive agricultural production. It is anticipated that the wetland vegetation will continue to recover following rehabilitation, since vegetation recovery is often recorded as being slow (Galatowitsch and van der Valk 1996).

A key result for Kruisfontein wetland was that, after seven years of rehabilitation work, the area remained largely dominated by pioneer or ruderal species. This was reflected in the lack of significant differences being recorded for the FQAI values over time. Walker et al. (2006) described how ecosystems may have multiple thresholds and be able to exist in a number of stable regimes. Once certain thresholds are crossed, the ecosystem may be limited in terms of the number of stable regimes it is then able to attain, even with rehabilitation (Walker et al. 2006). The current regime in Kruisfontein wetland can be considered to be an alternative stable regime that would need a threshold to be crossed in order for it to promote a 'desired' regime. The findings at Kruisfontein wetland contradict the assertion, generally adopted by wetland rehabilitation practitioners in South Africa, that if the hydrology of the wetland is reinstated then this will be followed by the natural re-establishment of the native wetland vegetation.

The intensity and duration of human disturbance (i.e. ridge-and-furrow agriculture) preceding the rehabilitation is likely to have depleted the natural seed bank and any vegetative material which may have persisted in Kruisfontein wetland. The duration of the disturbance is likely to have had a critical impact on the wetland vegetation, since the area was developed for cultivation prior to 1940. Weinhold and van der Valk (1989) found that propagules of sedge meadow species persisted in the seed bank for less than 20 years. Therefore the natural re-establishment of native vegetation in areas cultivated for longer than 20 years is dependent on the dispersal of propagules from intact areas elsewhere. At Kruisfontein, nearby intact wetland areas are very limited and, as highlighted by Seabloom and van der Valk (2003) and O'Connell et al. (2013), increased isolation of the wetland as a result of cumulative loss of wetlands in the landscape inhibits its colonisation by dispersal-limited indigenous species. The dominance of the competitive alien species *P. dilatatum* further added to the difficulty for a diversity of native species to become established in the site. Galatowitsch and van der Valk (1996) noted that the competitive grass *Phalaris arundinacea* makes it more difficult for native sedge meadow species to become established should their propagules reach restored wetlands. Galatowitsch et al. (1999) highlighted the profound impact that alien invasive plant species may have on the indigenous flora of wetlands. Although localised sections of Kruisfontein wetland have attained permanent wetness, i.e. a high level of wetness, much of the area is still dominated by seasonal and temporary wetness. The rehabilitation measures therefore failed to create levels of wetness in the wetland sufficient to exclude pioneer, generalist and/or alien invasive plant species, as documented by previous research (Seabloom and van der Valk 2003; Walters et al. 2006, 2011).

Active planting of indigenous vegetation has been shown to play an important role in re-establishing native vegetation, particularly in the less wet areas of a wetland, and is widely practised in wetland rehabilitation projects across the USA (Galatowitsch and van der Valk 1996; Gutrich et al. 2009). For example, *Carex* sp. sedges, which commonly occur on the edge of temperate freshwater wetlands in the USA, do not readily re-establish, and it is unlikely that they will reappear without deliberate reintroduction (Budelsky and Galatowitsch 2000). Active planting is usually not included in wetland rehabilitation projects in South Africa because it is assumed that indigenous vegetation will eventually establish naturally. However, this may frequently not be the case.

Given the possible contributing factors discussed above, what can be done to break the dominance of strongly competitive invasive alien species such as *P. dilatatum*, which serves to trap the wetland in an alternate stable state? A threshold would need to be crossed, whereby *P. dilatatum* is removed or displaced from the system, as described by Ellery and McCarthy (1998), to promote the re-establishment of vegetation within the transformed Boro River system in Botswana, where it was recommended that control structures be put in place to reduce flow velocity, thereby allowing vegetation to colonise the system. Based on the vegetation composition of the areas of permanent wetness within Kruisfontein wetland, increasing the relative proportion of permanently wet areas in the wetland would clearly disadvantage *P. dilatatum*. However, if it was feasible to achieve permanently wet conditions across all of a rehabilitated wetland, it would be counterproductive in terms of re-establishing the native vegetation. Based on information from near-pristine wetlands (Kotze et al. 1994a, 1994b), usually at least 50% of the spatial extent of a wetland comprises temporarily to seasonally wet areas. The different zones have distinctly different assemblages of species (Kotze and O'Connor 2000). Therefore, if a strong bias towards one particular zone in a rehabilitated wetland was created in the long term then such a wetland would become a poor representative example of the native vegetation.

Recommendations

In the light of the preceding discussion on promoting desired vegetation, it is recommended that the less wet areas of Kruisfontein wetland be the focus for replanting, which should be preceded by herbicide treatment of the dominant pioneer species, *P. dilatatum*. The need to address the constraint which invasive alien plant species pose to the re-establishment of native vegetation in the less wet portions of wetlands is also demonstrated by Galatowitsch et al. (1999) and Budelsky and Galatowitsch (2000). Whilst planting is costly, these costs need to be weighed up against the objectives of the rehabilitation project. Should the provision of natural resources within Kruisfontein wetland be seen as a priority, *J. punctorius* would need to be planted into those areas receiving high, moderate and low flows to actively promote its increased abundance.

In terms of the recommended approach to wetland rehabilitation, if the objective of rehabilitation is to re-establish the integrity of the wetland vegetation then it is important to screen the site in terms of the readiness with which the native vegetation is likely to recover, based on an understanding of the factors that contributed towards its loss of integrity. If the readiness for recovery is assessed as low, then a high level of investment is likely to be required, and this needs to be weighed against the objectives and anticipated benefits of the project. If the primary objective of the rehabilitation is to reinstate the regulatory hydrological services supplied by the wetland, then whether the wetland is dominated by *P. dilatatum* or by a diverse mix of native species is probably of little consequence, and therefore costly replanting is unlikely to be justified. If the primary objective is biodiversity conservation, then planting is potentially justified. But, if the project was still in its planning phase, then it might be decided to seek an alternative site where the vegetation is likely to recover more readily. If the objective of a rehabilitation plan is to offset the impacts of a proposed development, an understanding of the thresholds within the system and the lag period for natural responses within the rehabilitated system would be critical. Without this understanding, the outcomes of wetland rehabilitation, especially in terms of timing, could often be overstated.

Conclusion

The assessment of Killarney and Kruisfontein wetlands showed that the rehabilitation undertaken has not reached the anticipated level of integrity predicted by Cowden et al. (2009) and Kotze (2009). The vegetation in Killarney wetland appears still to be in the process of responding to the changes in hydrology, highlighting the extended period of time needed for a rehabilitated wetland to reach the anticipated levels of integrity. In contrast, Kruisfontein wetland appears to be 'locked' in an alternate stable regime dominated by disturbance-tolerant plant species, contradicting the generally accepted statement that if the hydrology is reinstated, the natural re-establishment of native wetland vegetation will follow. The success standards adopted by WfWet should not rely solely on hectare equivalents. Although simple and effective, this approach does not deal explicitly with the supply of ecosystem services and does not necessarily show trends in vegetation response.

Based on the application of the vegetation indices applied in this study, it appears that these indices have particular value for measuring wetland ecosystem response to rehabilitation, and that they provide additional tools to those prescribed by Cowden and Kotze (2009). Furthermore, the indices are likely to have much broader application, such as for wetland delineation and the assessment of current impacts on wetlands.

Acknowledgements — The Water Research Commission is gratefully acknowledged for funding this research project. Ezemvelo KZN Wildlife and Peter and Sandy Ward are acknowledged for the opportunity to visit the wetlands. Anonymous reviewers are also thanked for valuable comments on earlier versions of this manuscript.

References

Anderson JE. 1991. A conceptual framework for evaluating and quantifying naturalness. *Conservation Biology* 5: 347–352.

Ashcroft S, Pereira C. 2003. *Practical statistics for the biological sciences: simple pathways to statistical analyses*. New York: Palgrave Macmillan.

Begg GW. 1989. *The wetlands of Natal (Part 3): the location, status and function of the priority wetlands of Natal*. Pietermaritzburg: Natal Town and Regional Planning Report 73.

Bolan NS, Laurenson S, Luo J, Sukias J. 2009. Integrated treatment of farm effluents in New Zealand's dairy operations. *Bioresource Technology* 100: 5490–5497.

Budelsky RA, Galatowitsch SM. 2000. Effects of water regime and competition on the establishment of a native sedge in restored wetlands. *Journal of Applied Ecology* 37: 971–985.

Campbell DA, Cole CA, Brooks RP. 2002. A comparison of created and natural wetlands in Pennsylvania. *Wetlands Ecology and Management* 10: 41–49.

Carter V, Garrett MK, Gammon PT. 1988. Wetland boundary determination in the Great Dismal Swamp using weighted averages. *Water Resources Bulletin* 24: 297–306.

Cowden C, Ellery W, Kotze D, Grenfell M, McCulloch D, Woods D, Grenfell S, Bambus O. 2009. Performance evaluation of the wetland rehabilitation undertaken at Killarney Wetland in Ntsikeni Nature Reserve, KwaZulu-Natal Province. In: Kotze DC, Ellery WN (eds), *WET-OutcomeEvaluate: an evaluation of the rehabilitation outcomes at six wetland sites in South Africa*. WRC Report No. TT 343/09. Pretoria: Water Research Commission. pp 27–69.

Cowden C, Kotze DC. 2009. *WET-RehabEvaluate: guidelines for the monitoring and evaluation of wetland rehabilitation projects.* WRC Report No. TT 342/08. Pretoria: Water Research Commission.

Ellery WN, McCarthy TS. 1998. Environmental change over two decades since dredging and excavation of the lower Boro River, Okavango Delta, Botswana. *Journal of Biogeography* 25: 361–378.

Galatowitsch SM, Anderson NO, Ascher PD. 1999. Invasiveness in wetland plants in temperate North America. *Wetlands* 19: 733–755.

Galatowitsch SM, van der Valk AG. 1996. The vegetation of restored and natural prairie wetlands. *Ecological Applications* 6: 102–112.

Grenfell MC, Ellery WN, Garden SE, Dini J, van der Valk AG. 2007. The language of intervention: a review of concepts and terminology in wetland ecosystem repair. *Water SA* 33: 43–50.

Gutrich JJ, Taylor KJ, Fennessy MS. 2009. Restoration of vegetation communities of created depressional marshes in Ohio and Colorado (USA): the importance of initial effort for mitigation success. *Ecological Engineering* 35: 351–368.

Hammer Ø, Harper DAT, Ryan PD. 2001. PAST: paleontological statistics software package for education and data analysis. *Palaeontologia Electronica* 4(1): article no. 4 (online).

Kotze D. 2009. Evaluating the effect of rehabilitation of Kruisfontein Wetland (KwaZulu-Natal) on its health and delivery of ecosystem services. In: Kotze DC, Ellery WN (eds), *WET-OutcomeEvaluate: an evaluation of the rehabilitation outcomes at six wetland sites in South Africa*. WRC Report No. TT 343/09. Pretoria: Water Research Commission. pp 174–180.

Kotze DC, Breen CM, Klug JR. 1994a. A management plan for Ntabamhlope vlei. Independent document in: Breen CM, Kotze DC, Klug JR, Darroch MAG, Oellermann RG (eds), *Wetland preservation valuation, and management practices applied to wetlands: South African case studies*. WRC Report No. 501/5/94. Pretoria: Water Research Commission.

Kotze DC, Breen CM, Klug JR. 1994b. A management plan for Mgeni vlei. Independent document in: Breen CM, Kotze DC, Klug JR, Darroch MAG, Oellermann RG (eds), *Wetland preservation valuation, and management practices applied to wetlands: South African case studies*. WRC Report No. 501/5/94. Pretoria: Water Research Commission.

Kotze DC, Breen CM, Quinn N. 1995. Wetland losses in South Africa. In: Cowan GI (ed.), *Wetlands of South Africa*. Pretoria: Department of Environmental Affairs and Tourism. pp 263–272.

Kotze DC, Ellery WN, Macfarlane DM, Jewitt GPW. 2012. A rapid assessment method for coupling anthropogenic stressors and wetland ecological condition. *Ecological Indicators* 13: 284–293.

Kotze DC, Marneweck GC, Batchelor AL, Lindley DS, Collins NB. 2007. *Wetland-Ecoservices: a rapid assessment procedure for describing wetland benefits*. WRC Report No. TT339/08. Pretoria: Water Research Commission.

Kotze DC, O'Connor TG. 2000. Vegetation variation within and among palustrine wetlands along an altitudinal gradient in KwaZulu-Natal, South Africa. *Plant Ecology* 146: 77–96.

Kotze DC, Traynor CH. 2012. Wetland plant species used for craft production in KwaZulu–Natal, South Africa: ethnobotanical knowledge and environmental sustainability. *Economic Botany* 65: 271–282.

Macfarlane DM, Kotze D, Walters D, Koopman V, Goodman P, Ellery W, Goge C. 2007. *WET-Health: a technique for assessing wetland health.* WRC Report No. TT340/08. Pretoria: Water Research Commission.

Macfarlane DM, Walters D, Cowden C. 2012. *A wetland health assessment of KZN's priority wetlands*. Pietermaritzburg: Ezemvelo KZN Wildlife.

Miller SJ, Wardrop DH. 2006. Adapting the floristic quality assessment index to indicate anthropogenic disturbance in central Pennsylvania wetlands. *Ecological Indicators* 6: 313–326.

Nel JL, Driver A. 2012. *National Biodiversity Assessment 2011: technical report. Volume 2: freshwater component*. CSIR Report CSIR/ECO/IR/2012/0022/A. Stellenbosch: Council for Scientific and Industrial Research.

O'Connell JL, Johnson LA, Beas BJ, Smith LM, McMurry ST, Haukos DA. 2013. Predicting dispersal-limitation in plants: optimizing planting decisions for isolated wetland restoration in agricultural landscapes. *Biological Conservation* 159: 343–354.

Ramsar. 2002. Principles and guidelines for wetland restoration. Adopted by Resolution VIII.16 of the Ramsar Convention at the eighth meeting of the Conference of the Contracting Parties to the Convention on Wetlands (Ramsar, Iran, 1971), Valencia, Spain, 18–26 November 2002.

Seabloom EW, van der Valk AF. 2003. Plant diversity, composition, and invasion of restored and natural prairie pothole wetlands: implications for restoration. *Wetlands* 23: 1–12.

Tiner RW. 2005. Assessing cumulative loss of wetland functions in the Nanticoke River Watershed using enhanced national wetlands inventory data. *Wetlands* 25: 405–419.

Turpie J, Day E, Ross-Gillespie V, Louw A. 2010. Estimation of the water quality amelioration function and value of wetlands: A case study of the Western Cape, South Africa. In: Turpie J, Malan H (eds), *Wetland valuation. Vol. II Wetland valuation case studies*. WRC Report No. TT 441/09. Pretoria: Water Research Commission.

van Ginkel CE, Glen RP, Gordon-Gray KD, Cilliers CJ, Muasya M, van Deventer PP. 2010. *Easy identification of some South African wetland plants*. WRC Report No. TT 479/10. Pretoria: Water Research Commission.

Walker B, Gunderson L, Kinzig A, Folke C, Carpenter S, Schultz L. 2006. A handful of heuristics and some propositions for understanding resilience in social-ecological systems. *Ecology and Society* 11(1): article no. 13 (online).

Walters DJ, Kotze DC, Job N. 2011. Mondi state of the wetlands report: a health and ecosystem services assessment of a selection of priority wetlands across Mondi landholdings. Unpublished Report. Mondi Wetlands Programme, Howick.

Walters DJ, Kotze DC, O'Connor TG. 2006. Impact of land use on community organisation and ecosystem functioning of wetlands in the southern Drakensberg mountains, South Africa. *Wetlands Ecology and Management* 14: 329–348.

Weinhold CE, van der Valk AG. 1989. The impact of duration of drainage on the seed banks of northern prairie wetlands. *Canadian Journal of Botany* 67: 1878–1884.

Wentworth TR, Johnson GP. 1986. Use of vegetation in the designation of wetlands. Final Report for the US Fish and Wildlife Service, National Wetlands Inventory, St Petersburg, Florida.

WfWet (Working for Wetlands). 2005a. Working for Wetlands strategic plan 2006–2010. Pretoria: Working for Wetlands.

WfWet (Working for Wetlands). 2005b. Working for Wetlands – Kruisfontein wetland rehabilitation plan. Unpublished report. Eastern Wetland Rehabilitation, Howick.

Manuscript received 10 September 2013, revised 30 May 2014, accepted 16 July 2014
Associate Editor: F Kansiime