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PRACTICAL ARTICLE

Assessing, with limited resources, the ecological outcomes of wetland restoration: a South African case

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Resources for evaluating the ecological outcomes of ecosystem restoration projects are often limited, especially within government-funded programs. In order to rapidly assess the ecological outcomes of wetland restoration, an improved approach has been developed, which was applied in the assessment of the ecological outcomes at nine restoration sites of South Africa's Working for Wetlands program. The sites encompass a diversity of restoration problems and land use contexts. The approach begins by distinguishing hydrogeomorphic (HGM) units, for which ecological condition is assessed and reported for hydrology, geomorphology, and vegetation pre- and post-restoration. These three components are closely linked but, as demonstrated at some of the sites, may respond differentially to restoration interventions. For most HGM units, overall ecological condition was improved by between 10 and 30%, with the greatest contribution of restoration generally being to the hydrology component. Having determined the integrity and costs of the interventions, cost-effectiveness is then reported in South African Rands per hectare equivalent restored, which was found to vary by more than an order of magnitude across the HGM units assessed. Cost-effectiveness must be interpreted in the light of the long-term integrity of the interventions, the site's landscape context, and the contribution of restoration to ecosystem services provision. Some sites may be considerably less cost-effective than others, but the cost may nonetheless be justified if the sites make key contributions to ecosystem services provision. The study was conducted in the context of a formative evaluation and the findings are envisaged to improve wetland restoration practice.

Key words: cost-effectiveness, ecological condition, rapid-assessment, restoration interventions

Implications for Practice

- Even when faced with very limited resources for assessment, the contribution of wetland restoration to ecological condition can be tracked using an approach for scoring the hydrology, geomorphology, and vegetation components of ecological condition, which is scientifically defensible but not onerous in terms of data and expertise.
- Expressed as costs per hectare equivalent of ecological condition restored, useful comparisons can be made across different restoration sites.
- However, results must be interpreted in the light of the site's landscape context, type of restoration problems, and the long-term integrity of the restoration interventions.
- The approach has potential to improve future wetland restoration practice, including planning, as well as monitoring and evaluation in relation to specific restoration objectives and ecological condition targets.

Introduction

The widespread degradation of wetlands globally necessitates restoration (Alexander & McInnes 2012) which has been targeted at halting physical deterioration of wetlands from multiple drivers including onsite (e.g. anthropogenic drainage) and off-site (modification of the upstream catchment) factors (Streever 1997; Kotze et al. 2012). However, a lack of evaluation of wetland restoration outcomes is a global problem (Zedler 2007), particularly for government-funded programs in developing countries, where resources for evaluating outcomes are often limited (McConnachie et al. 2013). Such is the case for South Africa's Working for Wetlands (WfWetlands) program, a national initiative within the Natural Resources Management Programs in the Department of Environmental Affairs, which commenced in 2000 to jointly address wetland restoration and poverty alleviation through employment creation.

Since 2003, WfWetlands has monitored the outputs of the program but with very little evaluation of ecological outcomes, a shortcoming which is widespread across ecological restoration programs in South Africa (Ntshotsho et al. 2011). The principal outcome of restoration which needs to be assessed is the

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ecological condition of the ecosystem. The ecological condition of a restoration site refers to present condition relative to an un-impacted reference condition in which the ecosystem shows little or no influence of human actions (Anderson 1991). The un-impacted reference condition is a model which represents the approximate restoration target that, in the absence of a suitable intact ecosystem of the same type, can be derived from multiple sources of relevant information (McDonald et al. 2016). In addition, since there is an inextricable relationship between the condition of an ecosystem and the services it provides, the ecosystem services linked with the improvement in condition also need to be assessed depending on the wetland restoration objectives (Moreno-Mateos et al. 2012).

Thus, there is a need for methods which can be used to assess, with limited resources, the outcomes of wetland restoration. One of the most widely applied methods for assessing wetland ecological outcomes is the hydrogeomorphic (HGM) method (Wardrop et al. 2007), which comprises a suite of several procedures tailored for specific wetland types and regions (e.g. riverine and depressional wetlands in the lowlands of western Washington) (Hruby 2004). However, application of the HGM method in South Africa is constrained in that, although rapidly applied, its establishment requires extensive sampling and the description of several reference wetlands (Wardrop et al. 2007). Given the considerable diversity of bioregions and wetland types in South Africa, for the time being it will not be practical to achieve (Kotze et al. 2012). Thus, a more general method termed WET-Health was developed (Macfarlane et al. 2009; Kotze et al. 2012) which nevertheless attempts to account for a wetland's HGM type and its climatic setting (Kotze et al. 2012).

The first step in a WET-Health assessment is to identify HGM units, which are defined by geomorphic setting (e.g. hillslope), water source, and pattern of water flow through the wetland unit (Brinson 1993; Ollis et al. 2013). The HGM units are assessed individually in respect of their ecosystem health because different HGM units are likely to respond in different ways to stressors, depending on the underlying drivers (Brinson 1993). Given that HGM units are identified in terms of key driving processes, they also provide a useful starting point for the assessment of ecosystem services, as employed in the WET-EcoServices method (Kotze et al. 2009) developed for South Africa.

An approach has been developed for rapidly assessing the outcomes of wetland restoration (Cowden & Kotze 2009; Cowden et al. 2014) in which WET-Health (Macfarlane et al. 2009) plays a central role, and WET-EcoServices (Kotze et al. 2009) a supporting role. This study seeks to further develop this approach, specifically by using a case study to extend its application within the context of a national wetland restoration program. The objectives of this article are to (1) present the approach developed to evaluate, through semiquantitative means and with limited resources, the ecological outcomes of wetland restoration; and (2) demonstrate its application in evaluating outcomes of WfWetlands restoration interventions at multiple sites. For this study, wetland restoration is defined broadly as the process of assisting in the recovery of a wetland that has been degraded (SER 2004) as well as halting the decline in ecological integrity of a wetland that is in the process of degrading. This implies some ecosystem recovery, but restoration of a system to predisturbance state is often an untenable target (Ogden & Rejmanek 2005; Tererai et al. 2013). Wetland restoration interventions refer to the physical outputs (e.g. erosion control weirs) which are intended to achieve wetland restoration objectives.

Methods

Study Sites

Although predominantly valley bottom systems, the sites included in the study represent a diversity of hydrogeomorphic (HGM) types (Table 1). In addition, the sites were drawn from a great diversity of land use and land tenure contexts (Table 1) and encompass a range of different restoration problems, but common to all sites was the desiccation effect of artificial drainage channels, incised stream channels, and/or erosion gullies.

Given that the sites were selected within the context of a "formative evaluation" (Harlen & James 1997) aimed at improving the effectiveness of the restoration activities carried out by WfWetlands, the following site selection criteria were applied: (1) time since restoration interventions; (2) availability of baseline information; (3) restoration objectives clearly articulated; (4) high potential for learning opportunities at the site, based particularly on the availability of original team members involved in the restoration to reflect on the interventions and outcomes; (5) ease of access at least cost; (6) spread of sites across types of restoration/degradation problems; (7) spread of sites across wetland HGM types; and (8) spread of sites across provinces (Fig. 1) to increase the opportunities for WfWetlands staff to learn directly from the assessments.

Data Collection and Analysis

The spatial unit of analysis was the HGM unit, which ranged from 1 to 3 per site and 13 overall in the study. To determine the contribution of restoration interventions, each HGM unit was assessed for two scenarios—without and with restoration. For those sites with active headcut erosion, with no restoration, an advance of the headcut was assumed, commensurate with the level of activity of the headcut and vulnerability of the wetland to erosion (as described in Macfarlane et al. 2009).

In order to promote consistency: (1) assessments were undertaken by ecologists working as environmental consultants who were all trained and experienced in the application of the selected wetland assessment approaches described in the data collection section; and (2) each of the assessments was subject to review by the principal researcher of this article, which resulted in some minor adjustments to scores and greater clarification of some of the assessments, but did not result in any of the sites being removed from the study. Further, in an attempt to control for bias, an ecologist who was not involved in the planning and implementation of the interventions at the site was assigned

Table 1. Location and key features of the selected sites.

Site Name and Location	*Hydrogeomorphic unit/s*	*Land Use and Tenure Context*	*Restoration Objectives*
Boekenhout-fontein 25°34′1.6″S; 27°6′39.8″E	Historically unchanneled valley bottom	Private game farm	Deactivate incised drainage channels in order to reinstate a more natural hydrological regime; and halt the gully erosion of the wetland.
Colbyn wetland 25°44′13″S; 28°15′36″E	Channeled valley bottom	Urban municipal land, open space	Halt channel incision and allow occasional overtopping of the channel during flood events; and halt the advance of the headcut erosion migrating upslope into and through the wetland.
Draaikraal wetland 25°13′21″S; 30°01′28.2″E	Channeled valley bottom	Private farmland, livestock	Deactivate the channel incision and drainage channels to restore the hydrological integrity of the wetland system; and control invasive alien plants in the wetland.
Eselfontein wetland 30°22′53″S; 18°4′52″E	Hillslope seepage feeding into an unchanneled valley bottom	Private farmland, livestock	Clear invasive alien plants to restore hydrological integrity to the seep area and allow reestablishment of indigenous vegetation; and halt the eroding headcut and deactivate the artificial drainage channels so as to allow diffuse flow across the valley bottom area and improve the ecological integrity of the wetland.
Hlatikulu wetland 29°16′9.4″S; 29°41′27.7″E	Two unchanneled valley bottom portions feeding into a floodplain portion	Private farmland, crop production and livestock	Deactivate artificial drainage furrows in order to reinstate a more natural hydrological regime; and halt erosion and the continued incision of the wetland in order to promote the provision of associated hydrogeomorphic services provided by the wetland.
Hogsback wetland 32°33′36.6″S; 26°56′35.0″E	Two seepage slopes	Private forestry company land	Deactivate artificial drainage furrows in order to reinstate a more natural hydrological regime; and arrest erosion and the continued incision of the wetland.
Lake Fundudzi wetland 22°51′31″S; 30°17′35″E	Unchanneled valley bottom	Communal land, rural	Arrest erosion causing the degradation of the peat system, rewet the desiccated portion of the wetland.
Monontsha wetland 28°31′35.56″S; 28°46′41.42″E	Unchanneled valley bottom	Communal land, urban/rural transition	Halt the advancement of erosion and channel incision and protect remaining intact wetland habitat, and return seasonally wet conditions to portions of the wetland affected by channel formation and excavations.
Ratelrivier wetland 34°44′09.98″S; 19°43′11.73″E	Floodplain within a coastal plain	National park	Reinstate the spreading of flow across the wetland and associated level of wetness and control the invasive alien trees threatening the wetland.

the primary responsibility to conduct the assessment. This takes into account Zedler's (2007) caution that evaluating a project in which one was involved can potentially result in biased findings.

For 85% of the HGMs, prerestoration baseline assessment data on ecosystem condition and services were collected since 2009 using WET-Health (Macfarlane et al. 2009) and WET-EcoServices (Kotze et al. 2009) as part of restoration planning. For older wetland restoration sites (2 out of 13 HGMs), a site description report compiled prior to restoration, including qualitative descriptions and photographs of the environmental degradation issues being addressed, together with additional information such as historical aerial photographs and consultation with key informants, were used in 2015 to conduct retrospective WET-Health and WET-EcoServices assessments. Post-intervention assessments were undertaken as rapid field WET-Health and WET-EcoService assessments in 2015. Ecological condition was assessed by scoring the primary components of hydrology, geomorphology, and vegetation, based on a predefined set of indicators for each component (Table S1, Supporting Information), which were consolidated into an overall score ranging from 0 impact (i.e. pristine) to 10 impact (i.e. critically impacted) as specified by Macfarlane et al. (2009). To determine if there was a significant difference between pre- and post-intervention overall condition,

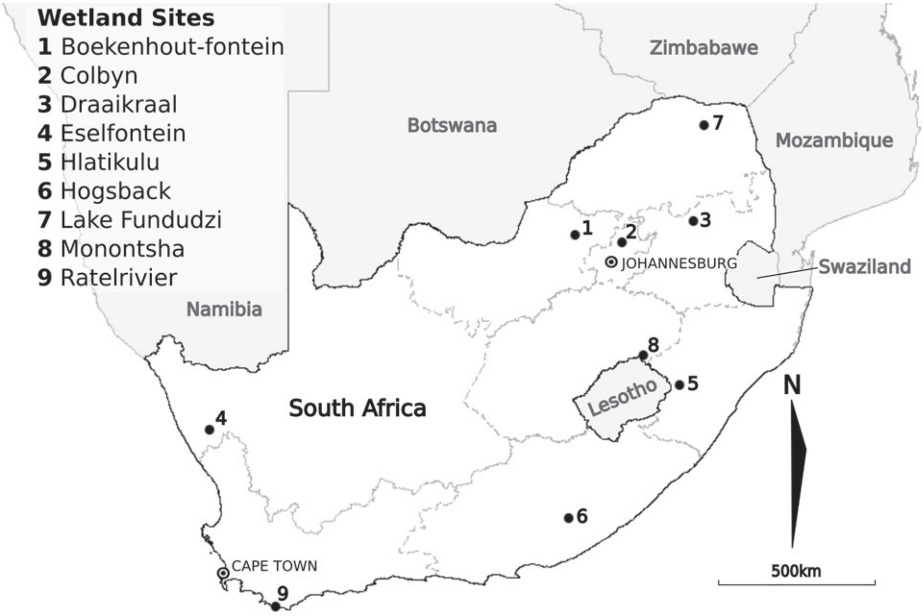

Figure 1. Distribution of the nine study sites across provinces in South Africa.

either a paired Student's t test (normally distributed data) or Mann–Whitney U-test (non-normal data) was used. Normality tests were performed using the Shapiro–Wilk test. To determine if the hydrology, geomorphology, vegetation, or overall condition of wetlands improved with the length of time since restoration, a Pearson correlation (since data were normally distributed) was computed and tested for significance.

The spatial extent of the wetland in hectares was multiplied by the overall condition score to derive what is referred to as hectare equivalents, as described by Cowden and Kotze (2009) and Cowden et al. (2014). Hectare equivalents can be used as a "currency" for measuring the contribution of restoration interventions to overall ecological condition. For example, if a 100 ha wetland had a condition score of 4/10 then this would translate into 40 ha equivalents, and if after restoration the overall condition score improves to 6/10, giving 60 ha equivalents then the difference of 20 ha equivalents would constitute the contribution of the restoration to the ecological condition of the wetland.

The contribution of restoration to ecosystem services provision was also superficially assessed by considering the potential contribution to ecosystem services given in WET-EcoServices (Kotze et al. 2009) and using the indicators recommended by this method (Table S2). These indicators relate to both: (1) the effectiveness of the wetland in performing the service, that is, the supply of the service; and (2) opportunities afforded the wetland for performing the service, that is, the demand for the service. Based on the degree of change of the indicators relating to effectiveness of the wetland in performing the service, each ecosystem service was assigned to one of the following classes: −2 = substantial loss; −1 = slight loss; 0 = no significant effect; 1 = slight improvement; 2 = substantial improvement.

In 2015, each site was also assessed in terms of the structural integrity of the restoration interventions, which refers to degree to which the interventions (e.g. gabion structures) were still intact as intended or damaged and/or washed away. However, it is outside the scope of this study to report on the results of the structural integrity assessments and these are summarized in the Supporting Information Tables S3 and S4.

To determine cost-effectiveness of the restoration interventions at each site, the guidelines given in Cowden and Kotze (2009) were used. The costs of implementation of the interventions, inflation adjusted to 2015 costs, were obtained from WfWetlands records. A value judgment was then undertaken of whether these costs appear to be well justified, moderately justified, or not justified in the light of the contribution of the restoration to ecosystem services assessed using WET-EcoServices (Table S2). As a guiding threshold, if Rands per hectare equivalent exceeded R500 000 and no ecosystem services were substantially improved then in terms of ecosystem services, costs were deemed not justified.

The question of whether the restoration interventions appeared to be achieving their original objectives was assessed for each HGM unit based on the original restoration objectives considered in relation to: (1) the outcomes in terms of ecological condition and ecosystem services provision; and (2) the structural integrity of the interventions. Finally some key lessons learnt were distilled from the assessments.

Results

Ecological Condition of the Sites Without and With Restoration

All of the HGM units showed improvement in terms of ecological condition (Table 2). For most (77%) of the wetland units, restoration contributed to a modest 10–30% improvement in

Table 2. Ecological condition on a scale of 0 impact (i.e. pristine) to 10 impact (i.e. critically impacted) of the 13 assessed HGM units with and without restoration interventions.

				Ecological Impact Score				
Wetland units	*Size (hectares)*	*Age (years)*	*Scenario*	*Hyd*	*Geom*	*Veg*	*Overall*	*Change*
Boekenhout-fontein	54.0	12	Without	8.4	4.8	3.0	5.8	2.8
			With	3.9	2.9	1.8	3.0	
Colbyn	34.0	10	Without	7.5	3.3	3.8	5.2	2.1
			With	3.0	3.0	3.2	3.1	
Draaikraal	86.3	5	Without	6.6	1.2	3.9	4.3	1.6
			With	3.5	1.2	3.1	2.7	
Eselfontein, seep portion	1.8	5	Without	8	2	9	6.6	4.4
			With	0.5	0.5	6.3	2.2	
Eselfontein, valley bottom portion	4.8	5	Without	9	8	7.2	8.2	3.7
			With	5	2	6.3	4.5	
Hlatikulu, Nsonge portion	67.0	3	Without	5	3.8	2.2	3.9	1.7
			With	2.3	2.5	1.7	2.2	
Hlatikulu, Northington West	37.0	6	Without	5	3.8	2.2	3.9	1.7
			With	2.3	2.5	1.7	2.2	
Hlatikulu, Northington East	158.0	6	Without	2.9	1.4	2.6	2.4	0.7
			With	2.0	1.1	1.9	1.7	
Hogsback seep A	4.7	4	Without	4.5	1.8	1.7	2.9	0.4
			With	4.0	1.3	1.5	2.5	
Hogsback seep B	1.7	4	Without	6.5	1.0	2.2	3.7	1.2
			With	5.0	0.0	1.2	2.5	
Lake Fundudzi wetland	7.0	7	Without	8.0	4.8	4.0	5.9	2.6
			With	4.0	3.1	2.4	3.3	
Monontsha wetland	43.0	7	Without	6.0	4.0	6.0	5.4	2.8
			With	3.0	1.3	2.6	2.6	
Ratelrivier wetland	59.3	3	Without	3.7	1.4	7.0	4.0	2.5
			With	1.2	0.9	2.5	1.5	

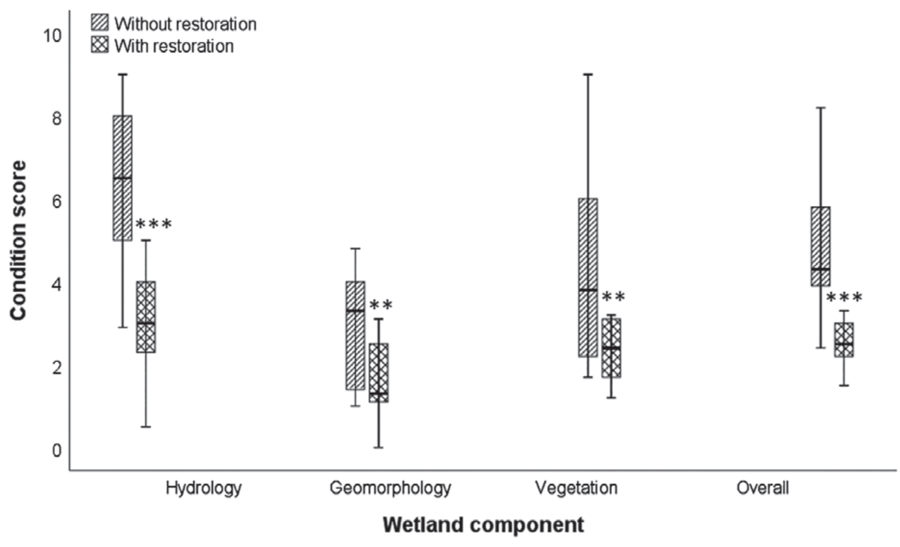

Figure 2. Wetland hydrology, geomorphology, vegetation, and overall condition scores (0—near pristine and 10—critically impacted) without and with restoration at 13 HGM units in South Africa. Significant differences between "without" and "with" restoration condition scores were tested using a paired *t* test because all data were normally distributed. Significance levels: ***$p < 0.05$ and **$p < 0.01$.

ecological condition, which was statistically significant (Student's *t* test, $p < 0.05$) (Fig. 2). For the majority (62%) of units, the greatest contribution of restoration was to the restoration of the hydrology component. Considering post-restoration condition of the 13 HGM units in relation to the pristine natural reference state, the hydrology, geomorphology, and vegetation component scores were on average 31, 17, and 28% lower, respectively, than this reference state. Condition improvement scores (without-restoration scores minus with-restoration scores) of hydrology, geomorphology, vegetation, and overall were not significantly correlated (Pearson correlation; $p > 0.05$) to the length of time since restoration.

Provision of Ecosystem Services Without and With Restoration

At the majority (78%) of the HGM units, the restoration resulted in a substantial improvement to the delivery of at least one of the ecosystem services considered (Table 3). Of all the services considered, erosion control was the one most positively affected across the group of sites (Table 3) and excluding this service, only four (38%) of the HGM units had a substantial improvement for at least one of the ecosystem services considered. For two of these HGM units (Colbyn and Lake Fundudzi wetlands) the demand for the enhanced ecosystem service was particularly high.

Ecological Outcomes Relative to Costs of the Interventions

From Table 4, it can be seen that although most sites cost between R100 000 and R400 000 per hectare equivalent of ecological condition gained/secured (~R13 = 1US$), a few sites were far outside of this range. Within Eselfontein, e.g. the restoration of the seep was two orders of magnitude less costly relative to outcomes than the valley bottom. In terms of the contribution to ecosystem services delivery assessed with reference to the indicators given in Table S2, the costs were subjectively appraised to be well justified in 7 of the 13 HGM units.

The Degree to Which the Restoration Interventions Appear to Be Achieving the Original Objectives

In terms of the level of achievement of the original restoration objectives stated in Table 1, 1 HGM unit (Monontsha) was categorized as low, 2 HGM units (Hlatikulu, Northington East and Hogsback seep A) intermediate and the remaining 10 HGM units moderately high or high. As is evident in Table 1, the objectives for several of the HGM units were to halt the advance of specific erosion, which could be readily observed in 2015 relative to the prerestoration position. The next most common

Table 3. Change scores (−2 = substantial loss; −1 = slight loss; 0 = no significant effect; 1 = slight improvement; 2 = substantial improvement) for regulatory and supporting ecosystem services based on a comparison of without and with restoration interventions.

	Ecosystem Services						
Wetland unit name	*Flood attenuation*	*Phosphate trapping*	*Nitrate removal*	*Toxicant removal*	*Erosion control*	*Carbon storage*	*Biodiversity maintenance*
Boekenhout-fontein	1	1	1	1	2	1.5	1.5
Colbyn wetland	1	2	2	2	1	2	1
Draaikraal wetland	1	1	1	1	1	2	2
Eselfontein seep	−1	0	0	0	0	1	2
Eselfontein valley bottom	1.5	1	1	1	2	1	1
Hlatikulu, Nsonge	1	1	1	1	2	1	0
Hlatikulu, Northington, W	1	0	1	1	2	1	1
Hlatikulu, Northington, E	0	0	1	1	1	0	0
Hogsback seep A	1	0	0	0	0.5	0.5	0
Hogsback seep B	1	0	0	0	2	1	0
Lake Fundudzi wetland	1	0.5	0.5	0.5	2	2	2
Monontsha wetland	0	1	1	1.5	1	0.5	0.5
Ratelrivier wetland	2	0.5	0.5	0.5	1	1	2

Table 4. Costs of interventions at the restoration sites relative to ecological condition contribution and whether considered justified in terms of the contribution to ecosystem services.

			Cost Relative to Outcomes	
Site name	*Cost (South African Rands)*	*Ecological Contribution (hectare equivalents)*	*Ecological condition*	*Ecosystem services*
Boekenhout-fontein	R 3249645	15.12	R 214924 per hectare equivalent	Well justified
Colbyn wetland	R 2404559	7.14	R 336773 per hectare equivalent	Well justified
Draaikraal wetland	R 3368432	13.81	R 243948 per hectare equivalent	Well justified
Eselfontein seep	R 21009	0.79	R 26527 per hectare equivalent	Well justified
Eselfontein valley bottom	R 1124255	1.78	R 633026 per hectare equivalent	Not justified
Hlatikulu, Nsonge	R 1954498	11.39	R 171598 per hectare equivalent	Well justified
Hlatikulu, Northington West	R 2392224	6.29	R 380322 per hectare equivalent	Moderately justified
Hlatikulu, Northington East	R 791486	11.06	R 71563 per hectare equivalent	Moderately justified
Hogsback seep A	R 195662	0.19	R 1040755 per hectare equivalent	Not justified
Hogsback seep B	R 47081	0.20	R 230789 per hectare equivalent	Moderately justified
Lake Fundudzi wetland	R 2673491	1.82	R 1468951 per hectare equivalent	Well justified
Monontsha wetland	R 3619766	12.04	R 300645 per hectare equivalent	Moderately justified
Ratelrivier wetland	R 1074800	14.83	R 72499 per hectare equivalent	Well justified

objective across the HGM units related to hydrological outcomes (Table 1) and achievement of this objective was based on the indicators given in Table S1.

Discussion

A Reflection on the Results of the Assessment

For the HGM units considered overall, while, as reported in the Results section, the improvement in ecological condition was statistically significant, it was somewhat modest, and hydrology and vegetation condition in particular remained well below the pristine natural reference state. These results accord with the general findings of Moreno-Mateos et al. (2012) of a global meta-analysis of 621 wetland sites which showed that biological structure (driven mostly by plant assemblages) and biogeochemical functioning remained on average 26 and 23% lower, respectively, than in reference sites. This may mean that either wetland recovery takes a long time, or postdisturbance systems have moved toward alternative states that differ from reference conditions (Moreno-Mateos et al. 2012). Although, as reported in the results, ecological condition improvement was found not to be significantly correlated with age since restoration, the sites included in this study did not vary considerably in terms of age (most between 3 and 7 years) and greater time will probably be required before reliable conclusions can be drawn regarding the influence of recovery time. In at least one of the HGM units, namely Eselfontein valley bottom, an alternative stable state appears to have been entered which strongly related to invasive species in the unit, including the exotic grass *Pennisetum clandestinum* and indigenous shrub *Elytropappus rhinocerotis*. As shown by Cowden et al. (2014) for a channeled valley bottom wetland in KwaZulu-Natal, South Africa, restoration interventions resulted in a significant improvement in the hydrological condition of the wetland, but vegetation showed little improvement, even after more than 5 years. At both sites invasive plant species already present at the site appear to be constraining vegetation recovery, as observed by Galatowitsch and van der Valk (1996) for native sedge meadow wetlands in the North American prairie pothole region and by Tererai et al. (2013) for riparian areas along the Berg River, Western Cape, South Africa. Further factors potentially constraining the recovery of the native vegetation include heavy livestock grazing (Ramstead et al. 2012), depauperate local native seed banks, and limited intact wetland areas in the surrounding landscape from which unassisted dispersal can occur (Galatowitsch & van der Valk 1996). A key lesson in this is that greater use should be made of active vegetation planting and management rather than focusing only on hydrology and geomorphology with the assumption that vegetation recovery will follow on its own, as has generally been the approach for most wetland restoration projects in South Africa.

Land use activities within a wetland's catchment may further influence restoration outcomes. For the Hogsback Seep B, 65% of the upslope catchment which would naturally be grassland has been converted to tree plantations. This is likely to have substantially reduced water inputs to the seep, as is reported by Grenfell et al. (2005) for a seep wetland in KwaZulu-Natal with a similar HGM and climatic setting. For the Monontsha and Colbyn wetlands, extensive urban development in the catchment is likely to have increased pollutant/nutrient inputs and amplified flood peaks (leading to increased erosion risk). These two catchment impacts, which are generally widely associated with urban development (Verbeirena et al. 2013), may result in high long-term maintenance requirements for the interventions. In terms of the structural integrity assessment, the Monontsha HGM unit was rated poorest, and is most urgently in need of maintenance.

The following key factors were identified as hindering attainment of the restoration objectives: high grazing pressure within five of the HGM units; high land use impacts arising from within the catchment in three of the HGM units; invasive plant species in two of the HGM units; and major structural integrity failures of the restoration interventions at one of the HGM units. A key lesson from this is that greater account needs to be taken of these hindering factors, in particular when planning restoration projects and in anticipating the ongoing maintenance likely to be required.

In terms of ecosystem service delivery, the contribution of the restoration was also generally modest, which is not surprising given the link between ecological recovery (which was also modest) and ecosystem services (Moreno-Mateos et al. 2012). However, it was high at two sites, Colbyn and Lake Fundudzi, both located where high demand existed for regulatory services. This illustrates how the contribution of restoration interventions to ecosystem services delivery may be greatly influenced by the restored wetland's landscape context (McAllister et al. 2000; Moreno-Mateos et al. 2012). An important lesson emerging from this and the urban development at Monontsha and Colbyn is the need to carefully consider the catchment context of a wetland in the planning phase of restoration.

The results show that erosion control is the ecosystem service most positively affected by the restoration interventions across the sites. The demand for erosion control is high because, considered at a global level, the inherent vulnerability of South African wetlands to erosion is generally high (Ellery et al. 2009). An important factor contributing to this is that South Africa has experienced major geological uplift events in recent geological time which have led to a high elevation relative to the sea level, and thus erosion is a key factor contributing to the degradation of South African wetlands (Ellery et al. 2009).

The study also revealed that certain restoration issues are inherently much more costly to address than others relative to the contribution that the interventions make toward ecological condition. Problems requiring hard structural interventions (e.g. concrete) were generally much more costly compared with problems requiring the clearing of invasive alien plants, as an example. Black and Turpie (2016) also found hard structural interventions to be costly. This is not to imply that the "costly" issues should be avoided entirely. Instead, when a set of wetlands are being ranked as candidates for restoration, there is a need to more explicitly recognize the differential costs of different types of restoration issues.

A Reflection on the Approach Applied in the Study

The study demonstrates how ecological outcomes of wetland restoration can be tracked with respect to ecological condition in a semiquantitative manner by rating the hydrology, geomorphology, and vegetation components of ecological condition and by using the currency of hectare equivalents. However, with respect to ecosystem services this was largely carried out in a qualitative manner, limited by the fact that WET-EcoServices does not explicitly include size of the assessed wetland. Therefore, in terms of the study's original objectives, the study was more successful and comprehensive with respect to ecological condition than ecosystem services provision, and the latter is identified as a key area for refinement of the approach for future application. An additional area for refinement of the approach in order to reduce subjectivity is objective setting for wetland restoration projects, which in this case study were largely qualitative.

Further important limitations of the approach need to be recognized, and these are: (1) The ecological assessments are based mainly on rapidly described indicators and subjective scoring of certain indicators rather than on the detailed description of wetland structure and process. This is acknowledged by Kotze et al. (2012) as a limitation of these assessments. However, as described in the methods, for consistency, experienced assessors and a third party review of all assessments were used. (2) The approach does not specify a particular time duration required from completion of the restoration interventions to the follow-up assessment. In 4 of the 13 sites, this was less than 5 years, which is generally acknowledged as an inadequate time for significant ecological recovery to have taken place (Moreno-Mateos et al. 2012). (3) For each HGM unit, the model used to describe the reference ecosystem against which both the pre- and postrestoration systems were compared was "assembled" from various sources of information. While McDonald et al. (2016) regard this as a valid means of describing a reference ecosystem in the absence of a comparable minimally impacted ecosystem, it highlights the need for improving the information base of wetland ecosystems across a range of HGM types and ecological regions. This, in turn, would allow models of reference ecosystems to be developed on a better-informed basis. (4) The approach is lacking in terms of formal comparison with negative control sites, which are comparable with the restored sites in terms of wetland type and degradation but which do not receive any restoration interventions. The prerestoration condition of a site could be taken as a negative control to a limited extent. However, it may serve as a poor negative control in situations where, in the absence of restoration, an ecosystem is on a trajectory of declining ecological condition or where confounding factors such as high climatic variability (as is characteristic of much of South Africa) make it difficult to isolate the specific ecological contribution of the restoration interventions.

This study is mainly formative in nature to foster adaptive management, progressive learning and continuous improvement of the program. It is rooted in the utilization-focused theory—meaning it is conducted in such a way that the findings are readily used (Coryn & Stufflebeam 2014). The approach used in this study aims to feed into continuous improvement of how WfWetlands planning, project design, budgeting, implementation and monitoring, and evaluation are conducted. Some of the mechanisms through which an attempt was made to explicitly contribute to learning and adaptation included the following: (1) WfWetlands staff were involved in the assessments undertaken at several of the sites. (2) WfWetlands staff were presented with the results of the assessment and participated in a field learning workshop. (3) Joint planning sessions were undertaken with researchers and WfWetlands staff to review the approach to determine how it might be refined for wider application.

The approach developed in this study applies existing methods, notably WET-Health, WET-EcoServices, and hectare equivalents of Cowden et al. (2014) across multiple sites, from which key trends are identified and lessons distilled. As far as is known, the study is the first of its kind in Africa. The lessons distilled from the study have important implications in terms of future planning for WfWetlands, influencing the prioritization of restoration problems and how these are dealt with, particularly in terms of key constraints elaborated upon in the discussion. It is suggested that the approach provides a practical basis for addressing the currently skewed emphasis on monitoring of restoration outputs, as identified by Ntshotsho et al. (2011) and has potential for wider application beyond South Africa to include other situations where resources for assessing wetland restoration outcomes are limited and where rapid, but robust and scientifically verifiable methods are required.

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Supporting Information

The following information may be found in the online version of this article:

Table S1: Subcomponents of WET-Health and selected key indicators (adapted from Macfarlane et al. 2009).
Table S2: Supporting and regulating ecosystem services included in WET-EcoServices and selected key indicators (adapted from Kotze et al. 2009).
Table S3: Assessment of the structural integrity of the interventions, based on the checklist of Cowden and Kotze (2009).
Table S4: Classes used for the assessment of the current level of integrity of the restoration interventions.

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