Riparian conservation management needs habitat quality mapping

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Abstract: Riparian habitat quality has a significant influence on the water quality of rivers, primary resources for urban and agricultural use. River water quality deteriorates where normal ecological functioning is disrupted by harmful impacts from nearby land-use types. Important rivers are typically managed and protected by government-led conservation programs. These programs often lack a key tool for efficient conservation management, habitat quality mapping. The Berg River, an important water source in South Africa, was used as a case-study to assess how habitat quality mapping could broaden the current scope of river conservation programs. The river faces threats from nearby urban settlements, industrial areas, mining, encroachment, and agricultural practices. The aim of this study was to develop habitat quality and habitat degradation maps for a section of the Berg River to assess the value that mapping holds for conservation managers and spatial planners. InVEST modelling software and ArcGIS was used to produce these habitat quality maps based on land-use/land-cover and threat impact data. The resulting maps showed several specific locations of heavily threatened and degraded riparian habitat that had not specifically been included in current government conservation management or spatial planning. Habitat quality mapping is an important tool that conservation managers and spatial planners can use to successfully address habitat degradation and protection while facing resource limitations, such as lack of funding. Oversight of degraded riparian habitats will lead to further decreases in river water quality, adversely affecting human welfare and local economies.
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Introduction

Habitat quality of rivers and riparian zones are subject to degradation when flowing through man-managed landscapes (Tóth 2014). This degradation can cause exponential deterioration of river water quality from biological and physical edge effects that have negative impacts like facilitating entry of invasive species and competitors, pollution, and toxic chemicals (Perry et al. 2018).

Land-use and land management nearby rivers have diverse effects on the ecological functioning of rivers (Perry et al. 2018). Biodiversity loss and declining water quality of riparian habitats occur due to threats like land encroachment into rivers and pollution from adjacent land (Fierro et al. 2017).

Vörösmarty et al. (2010) detailed threats to water catchments and summarized that 80% of the global population faces high levels of threats to water security. Developing countries, such as South Africa, are particularly vulnerable to water threats as relatively little precautionary investment is made in ecological (green and blue) infrastructure and biodiversity conservation (Angelstam et al. 2017).

The Berg River in the Western Cape, South Africa (Figure 1), is used as a case-study in this assessment. The river is an important water source for urban and agricultural use in the Western Cape province and its riparian habitat and water quality face many threats. The Western Cape recently faced a looming water shortage crisis that has impacted widely on water availability and quality which in turn adversely affected agricultural production, harming the stability of local economies and human welfare (Botai et al. 2017).

Agricultural encroachment, agricultural runoff, polluted stormwater runoff from urban settlements, invasive alien species, and poorly treated wastewater effluent are some of the major threats that cause poor water quality in the Berg River (Tererai et al. 2013;
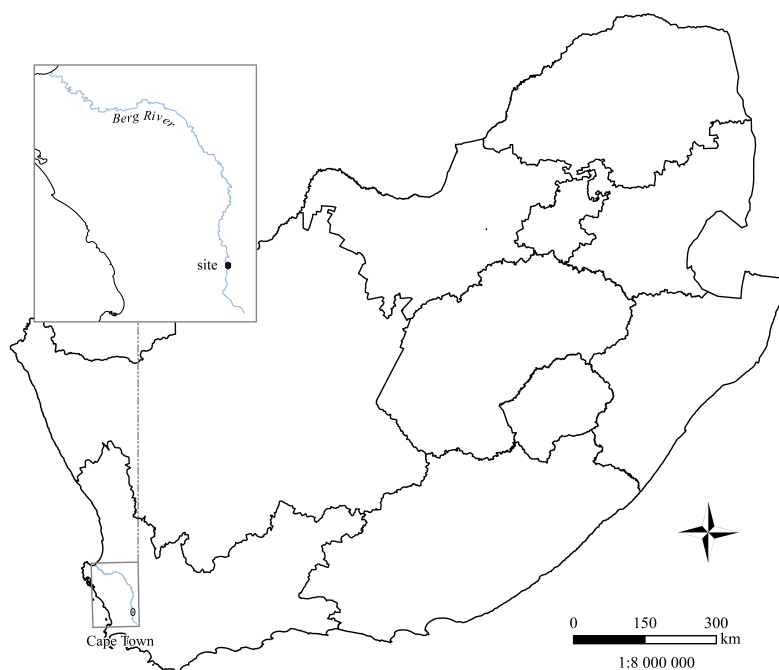
Figure 1. The Republic of South Africa and the location of the study site along the Berg River in the Western Cape province.

Locke 2016). Further habitat degradation is caused by activities associated with certain land-use such as urban settlements, industrial areas, mines, access roads, river encroachment, and agricultural practices (DEADP 2012; McLean et al. 2017).

The Berg River is a highly modified river and subject to increasing environmental degradation from habitat fragmentation, edge effects, and degradation in neighbouring habitats (DWS 2016; Locke 2016). Kamish (2008) discovered that clearing of natural vegetation along the Berg River led to a decrease in overall species richness, as well as increased concentrations of dissolved salts in the river due to a rising of the water table. Other land-use types are linked to an increase in chemical pollutants (ammonium, phosphates, and inorganic nitrates) and E. coli in Berg River water (De Villiers 2007; DEADP 2012; Struyf et al. 2012).

As water is a scarce and valuable resource, the Western Cape provincial government de-

veloped programs to improve the efficient usage and quality of water by alleviating environmental pressures on important water catchments like the Berg River. Government-led programs such as the Berg River Improvement Plan (BRIP) and the Western Cape Biodiversity Spatial Plan (WCBSP) guide land management and the development of river conservation management (DEADP 2012; Pool-Stanvliet et al. 2017). The BRIP aims to support water quality monitoring, upgrade wastewater treatment works, support riparian zone ecological rehabilitation, instil 'best-practices' for land-use types, and improve ecosystem resilience (DEADP 2012). The WCBSP represents ecological infrastructure and priority biodiversity areas that need to be protected over the long-term to fulfil core biodiversity management mandates (Pool-Stanvliet et al. 2017).

These programs strive to support integrative ecological and biodiversity conservation management approaches to rivers and

riparian habitat to regenerate proper biodiversity functioning. Yet, GIS mapping tools designed for this purpose are not utilised by government officials that work as conservation managers in the Berg River catchment. GIS mapping tools have been developed to help conservation managers implement restoration actions and detect location-specific ecological stress (Zlinszky et al. 2015). Such tools are essential in improving water quality as maps assist in discovering direct and indirect sources of impact on riparian zones, such as habitat quality (Geist 2011; Mika and Farkas 2017).

Land-use and land-cover (LULC) data provide area-covering information on variables that impact river habitat quality. Currently, data on land-use and land-cover for South Africa is publicly available as GIS data (CapeNature 2014). Software that works with GIS data formats have been developed that analyse LULC data and produce habitat quality maps. The Habitat Quality InVEST (Integrated Valuation of Ecosystem Services and Trade-offs) Model analyses data on land-use and threats to biodiversity to produce habitat quality and degradation maps. This model is a rapid assessment technique of habitat quality to inform natural resource managers of an area's conservation needs (Sharp et al. 2018).

The aim of this study is to develop habitat quality and habitat degradation maps for a section of the Berg River to assess the value that mapping holds for conservation managers and spatial planners. For this purpose, ArcGIS and the InVEST Habitat Quality Model is used to produce habitat quality maps to determine their utility in current river conservation programs. The output maps are compared to the current WCBSP and BRIP to determine whether degraded riparian areas are considered in the current river conservation program.

Materials and Methods

Study Area

The 7 km² study area, 100 meters above sea level, covers a 3 km stretch of the Berg River in the Western Cape Province, South Africa (Figure 2). The Western Cape (WC) is one of nine provinces of the Republic of South Africa located at the south-western tip of the African continent. It has a dry Mediterranean climate with warm, dry summers and cold, wet winters (mean annual rainfall: 515 mm) (Tyson and Preston-Whyte 2000). The Berg River is the second largest river in the Western Cape province. It is approximately 285 km long with a catchment area of 8 980 km², flowing north from Franschhoek to Velddrif, and opens into the Atlantic Ocean. It is considered to be one of the most important water sources for the agricultural industry and as drinking water for the City of Cape Town (just outside the catchment, c. 70 km to the southwest), with a population of 4,52 million (DWS 2016). About 65% of the Berg River catchment area is under agricultural activities.

Various soil types are found along the Berg River, from sandy sediments in the lower catchments to distinct clay accumulations in the middle catchment (Clark and Ratcliffe 2007). These rich clayey soils have attracted agricultural development that has caused extensive transformation of riparian habitat along the river (Kamish 2008). Conversion of natural vegetation to other land-uses along the Berg River has impacted vulnerable species, endemic to the Cape Floristic Region, leading to a high concentration of threatened species (RHP 2004). SANBI (2006) listed 457 native plant species as threatened within this catchment and 270 of these are listed as either endangered or critically endangered.

The study area falls within the Cape Winelands Biosphere Reserve, forming part of the Swartland Alluvium Fynbos ecosys-
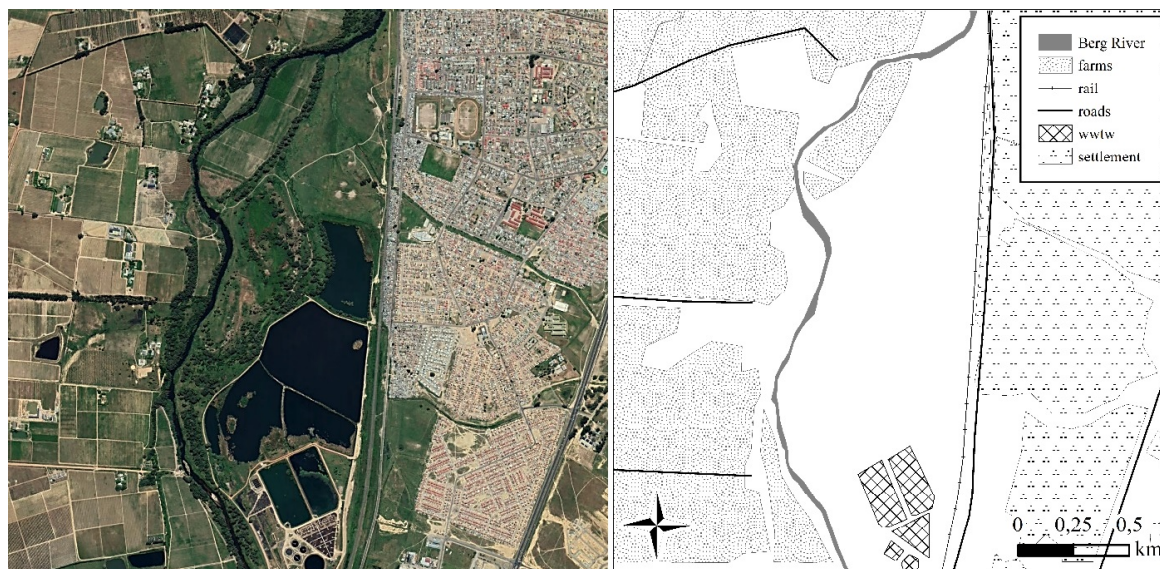
Figure 2. The study site along the Berg River for habitat quality mapping, satellite image (left) and threats map layer (right) (CapeNature 2017; Google Earth Pro 2019).

tem and has Category 1 and 2 terrestrial critical biodiversity areas, as identified by the WCBSP. These are "areas in a natural condition that are required to meet biodiversity targets, for species, ecosystems or ecological processes and infrastructure" (Driver et al. 2012). Vegetation types such as fynbos, renosterbos, and strandveld are characteristic of this region (Mucina and Rutherford 2006).

This study site was chosen due to the presence of sensitive habitats like wetlands and multiple land-use types which may act as sources of environmental degradation, i.e. commercial agriculture (farms), urban settlements, wastewater treatment works (wwtw), roads, and rails. These land-use types threaten habitat quality and biodiversity by directly degrading habitat area, displacing and eradicating species, and endangering population viability (Locke 2016; Fierro et al. 2017).

Process

LULC GIS data was collected from CapeNature, a governmental organisation responsible for maintaining wilderness areas and public nature reserves in the Western Cape Province. This dataset represents the 2014 LULC for the Western Cape and has been updated in 2016 (CapeNature 2014).

The LULC GIS data was converted and transformed with ArcGIS (ESRI version 10.4.1) to create separate layers of the study area as input for the InVEST Habitat Quality Model (naturalcapitalproject.stanford.edu/invest/), as detailed in the InVEST 3.5.0 User Manual (Sharp et al. 2018). The model was used to analyse habitat degradation and quality, with reference to threats and habitat sensitivity to threats. Habitats included grasslands, wetlands, bush, shrubland, and thicket. Threats included commercial agricultural fields, a waste water treatment plant, urban settlements, roads, and rails.

The models' outputs were raster GIS map data which represent the current (1) relative level of habitat degradation, and (2) relative level of habitat quality of the mapped area. These two maps were overlaid and examined to identify critical conservation areas within the study area (indicated as red circles on

Figure 3). The identified critical conservation areas were compared to the current Western Cape Biodiversity Spatial Plan and Berg River Improvement Plan and the associated GIS data layer, the WCBSP Bergrivier [Vector] (CapeNature 2017; Pool-Stanvliet et al. 2017).

Results

The InVEST Habitat Quality Model output maps, the relative level of habitat degradation and of habitat quality, show several specific locations of riparian habitat in need of critical conservation action (Figure 3). In the habitat degradation map, habitat was classified into levels of no concern (nc), least concern (lc), low degradation (ld), medium degradation (md), and high degradation (hd). Habitat classified as not habitat (nt), unsuitable habitat (uh), low quality (lq), medium quality (mq), and high quality (hq) showed the specific distribution of the conservation priority of riparian areas.

Compared to the Western Cape Biodiversity Spatial Plan and Berg River Improvement Plan, specific conservation priority areas like those identified here have not specifically been included in current conservation management and planning. The WCBSP outlines general policy guidelines for land-use and delineates critical biodiversity areas, but excludes location-specific information and does not use habitat quality as an indicator. The Berg River Improvement Plan only summarises management goals, critical success factors, and strategy implementation and omits spatially specific conservation information and planning.

Figure 3 shows red circles which indicate critical conservation priority areas identified by this study that have not specifically been included in local government conservation planning. This result demonstrates the practical use of the InVEST Habitat Quality Model to locate conservation priority areas for on-the-ground conservation action.

Discussion

Maps of the relative level of habitat degradation and quality of the research site indicated conservation priority areas and high threat impact areas, based on LULC data and threats to habitat. Several conservation priority areas important in mitigating environmental degradation were identified in the study site. It was found that current government river conservation plans do not include location-specific details informed by habitat mapping.

Habitat mapping can therefore be added to the WCBSP and the BRIP as spatial data for conservation managers and spatial analysts to work with, with a regional level map on habitat quality of the Western Cape. Habitat Quality modelling provides an opportunity to categorize conservation areas as ordinal conservation sites, i.e. high conservation needs (high priority), intermediate conservation needs (medium priority), and low conservation needs (low priority). This practical application offers a powerful tool to government officials working as conservation managers to identify the most important areas in which to dedicate scarce resources like funding, time, and labour.

The results of this study are similar to results obtained in the studies of Lin et. al. (2016), Terrado et al. (2016), and Li et al. (2019). All three studies found priority conservation sites in riparian zones that were previously overlooked. Terrado et al. (2016) found the InVEST Habitat Quality Model to be highly accurate by validating it with in-field observations and bio-physical sampling. Li et al. (2019) used the model to analyse changes in bird species presence over a decade which was attributed to human-related land-use and activities. Ecological security patterns were calculated by using the model along with structural connectivity designs to produce an efficient ecological network in Lin et al. (2016).
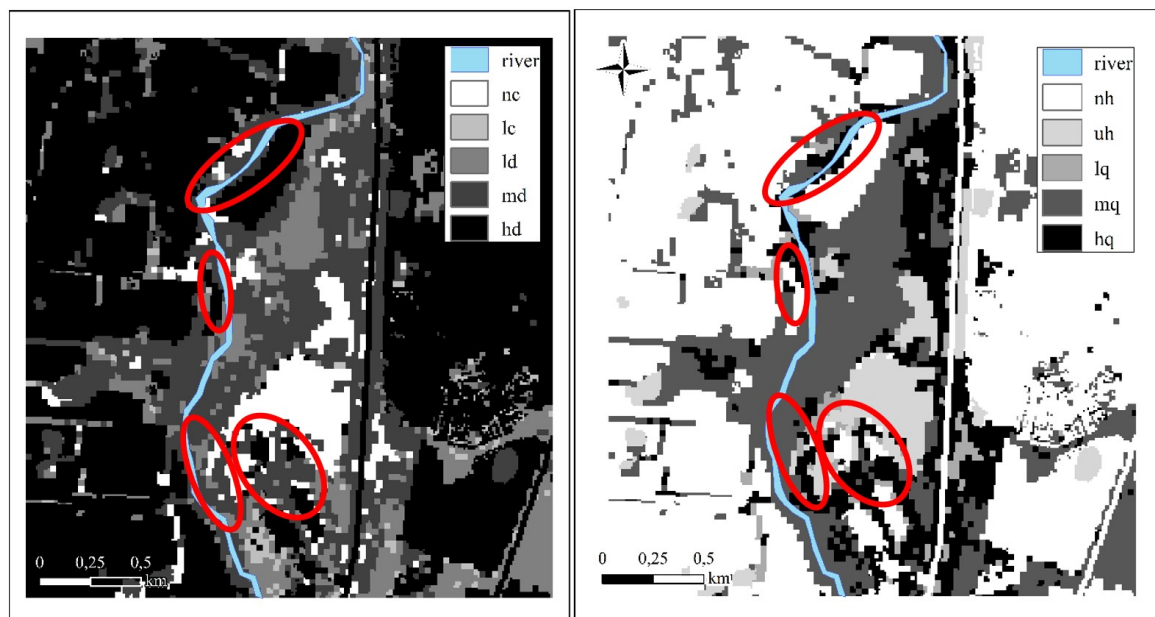
Figure 3. InVEST Habitat Quality Model outputs; Habitat Degradation map (left) and Habitat Quality map (right) with critical conservation priority areas (red circles). Legend; no concern (nc), least concern (lc), low degradation (ld), medium degradation (md), high degradation (hd), not habitat (nt), unsuitable habitat (uh), low quality (lq), medium quality (mq), high quality (hq).

A location-specific river conservation plan for the Berg River has to be developed through habitat mapping. Identifying conservation priority areas is important for improved resource management, conservation, water quality, and habitat protection. Long-term climate change impacts on the Western Cape will decrease water availability and suitable arable land which may result in further land encroachment into the Berg River (Midgley et al. 2005; Weber et al. 2018).

Mapping habitat quality and conservation priority areas provide a visual aid to conservation managers and spatial planners to identify the most important areas for conservation and to monitor environmental pressures and threats (Buhl-Mortensen et al. 2015). This technique can be used to inform which locations require more resources for environmental protection (Zlinszky et al. 2015). Field work can be optimized by detecting changes and allowing pre-selection of sites of interest.

Further research can be done by mapping the impact of long-term land-use change on the Berg River riparian zones. He et al. (2017) have developed a framework for using the InVEST Habitat Quality Model together with cellular automata simulation, this facilitates predictive scenario analysis based on LULC and habitat threats. This method provides an opportunity to test and analyse the impacts of policy interventions and ecological network development on river conservation. Used in conjunction with ecosystem trade-off analysis, managers would better understand which impacts are caused by specific stakeholders (Kovács et al. 2015).

Further riparian habitat quality studies in the Berg River should involve nature-based solutions' transdisciplinary research by following the framework set out by Nesshöver et al. (2017). This integrative, systemic approach allows for efficient natural resource manage-

ment which would lead to a comprehensive, holistic solution to improving river water quality. Given the high probability of land-use change along the river in the future, such research would be invaluable for conservation managers and spatial planners.

The use of InVEST models and mapping software has many advantages; it is free to use, presents a useful visual reference for conservation management, and it allows for sensitivity of habitats to be specified (useful when considering wetlands, grasslands, and forests). The model enables specification of the level of impact of threats to biodiversity and habitat sensitivity to threats. Maps then reflect the diverse impacts of threats such as agricultural runoff, soil erosion, and urban settlements. Limitations of using this mapping technique include poor data presentation on rare or cryptic species and of abiotic environmental conditions, with a cer-

tain level of subjective valuation of biodiversity. These maps are a single snapshot of the spatio-temporal distribution of landscape elements and should always be used in conjunction with in-field validation, research results, and qualitative data collection. Repeated habitat quality mapping over time forms part of a comprehensive ecological monitoring program led by conservation managers and it is a valuable tool for riparian zone and water conservation.

Acknowledgements

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