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Moving from reactive to proactive development planning to conserve Indigenous community and biodiversity values

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ABSTRACT

There is increased awareness of the need to balance multiple societal values in land use and development planning. Best practice has promoted the use of landscape-level conservation planning and application of the 'mitigation hierarchy', which focuses on avoiding, minimizing or compensating for impacts of development projects. However, environmental impact assessments (EIA) typically focus in a reactive way on single project footprints with an emphasis on environmental values and specifically biodiversity. This separation may miss opportunities to jointly plan for and manage impacts to both environmental and social values. Integrated approaches may have particular benefit in northern Australia, where Indigenous people have native title to as much as 60% of the land area and cultural values are closely linked with natural values. Here, we present a novel framework for integrating biodiversity and cultural values to facilitate use in EIA processes, using the Nyikina Mangala Native Title Determination Area in the Kimberley, Western Australia, as a case study. We demonstrate 1) how social and cultural values can be organized and analyzed spatially to support mitigation planning, 2) how social, cultural, and biodiversity values may reinforce each other to deliver better conservation outcomes and minimize conflict, and 3) how this information, in the hands of Indigenous communities, provides capacity to proactively assess development proposals and negotiate mitigation measures to conserve social, cultural, and biodiversity values following the mitigation hierarchy. Based on values defined through a Healthy Country Planning process, we developed spatial datasets to represent cultural/heritage sites, freshwater features, common native animals and plants represented by biophysical habitat types, and legally-protected threatened and migratory species represented by potential habitat models. Both cultural/heritage sites and threatened species habitat show a strong thematic and spatial link with freshwater features, particularly the Fitzroy River wetlands. We outline some of the challenges and opportunities of this process and its implications for the Northern Australia development agenda.

1. Introduction

Large-scale development projects profoundly transform environments, communities, cultures and economies, and often generate social conflict (Hilson, 2002; Bridge, 2004; Hanna and Vanclay, 2013; Franks et al., 2014). These types of development will continue to expand as global population and consumption increase (Oakleaf et al., 2015). Environmental licensing processes, such as Environmental Impact Assessment (EIA), play a critical role in limiting impacts from development projects to both the environment and the affected communities. In most countries, developers are required to get an environmental license before development activities can begin, and EIA has been legally adopted in almost all countries in the world (Morgan, 2012; Villarroya et al., 2014). The scientific community has responded to this requirement with decades of research establishing the mitigation hierarchy and best practices for mitigation of impacts to biodiversity (e.g.

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Kiesecker et al., 2010; Maron et al., 2015; Tallis et al., 2015), as well as conventions and systems for maintaining and sharing biodiversity information (e.g., Dunn and Weston, 2008; Lewis et al., 2008). When applied in the earliest stages of the decision-making process, EIAs can become important project planning instruments, providing information describing the consequences of specific development activities in a way that can inform approval decisions and design mitigation measures.

Since EIA is the most developed policy instrument, backed by a legal framework in many countries, it is increasingly also used to assess the social and economic impacts of planned interventions. Values considered by the EIA processes include primarily environmental values, with a focus on biodiversity. However, there is growing recognition that impact assessments and mitigation requirements should include social and cultural values with systematic frameworks and standards (Arce-Gomez et al., 2015; Vanclay et al., 2015; Partal and Dunphy, 2016). There are already International standards that call for the conservation of cultural and social values, including the UN Declaration on the Rights of Indigenous Peoples, UN Sustainable Development Goals, and the International Finance Corporation Performance Standards (IFC, 2012), andrequire assessment of risks and impacts to cultural values. Additionally, as recognized by the Millennium Ecosystem Assessment (2005), while society's demand for cultural services has continued to grow, the capability of ecosystems to provide cultural benefits has been significantly diminished in the past century. Ecosystem services are generally classified by type as provisioning, regulating, habitat/supporting, and cultural (Millennium Ecosystem Assessment, 2005; TEEB, 2011). Cultural ecosystem services (CES), defined as the non-material benefits of ecosystems and human-environment interactions, are often missing from management policy (Chan et al., 2012, 2016; Pascua et al., 2017).

In recognition of the rights of people to maintain their social and cultural identity, the concept of Free, Prior and Informed Consent (FPIC) has been established as a specific right of Indigenous peoples and is recognized in the United Nations Declaration on the Rights of Indigenous Peoples, the United Nations Universal Declaration of Human Rights, the International Labour Organization Convention 169 (Indigenous and Tribal Peoples Convention, 1989), and the Convention on Biological Diversity. FPIC is intended to enable communities to give or withhold consent to a project that may affect them or their territories and to negotiate the conditions under which the project will be designed, implemented, monitored and evaluated. A key component of the FPIC framework is that consent is sought sufficiently in advance of any authorization or commencement of development operations (Hanna and Vanclay, 2013; Vanclay et al., 2015). But like EIA, FPIC is typically a reactive process not initiated until a government entity or company informs an Indigenous community of their intention to develop within their territory. As a result, the typical project review process does not allow adequate assessment of impacts to social and cultural values because of the time, data, and technical capacity required.

Efforts to conserve biodiversity globally have developed best practices and data systems that facilitate effective impact assessment, such as criteria for threatened species designations based on rarity and vulnerability (Ricketts et al., 2005; Langhammer et al., 2007; IUCN, 2017). These have been widely adopted in EIA law and policy (Villarroya et al., 2014) and are recognized by developers and lenders (IFC, 2012), with resulting benefits for biodiversity conservation. Similar constructs to organize information to inform mitigation of impacts to social and cultural values have not been universally adopted. In many landscapes, biodiversity and cultural/social values are intricately related (Altman, 1987; Asafu-Adjaye, 1996; Garnett et al., 2009; Hill et al., 2013; Moorcroft et al., 2012). The decision-making process will benefit from a more integrated approach, particularly for developments impacting Indigenous communities where cultural values are often of great importance.

Impact assessment that considers environmental, social and economic values requires an integrating framework. In many cases, environmental impact assessment and social impact assessment have operated in separate realms. To date, few unified conceptual frameworks exist to guide the standardized integration of biodiversity and social/cultural values into environmental impact assessments or development proposals, despite Indigenous people owning or having legal title to a large portion of the world's lands and water (Oxfam, 2016; Wily et al., 2017). Geneletti (2015) proposed a conceptual framework for integrating ecosystem services into strategic environmental assessments. Tallis et al. (2015) proposed a framework for integrated biodiversity and ecosystem services mitigation. Pascua et al. (2017) developed and demonstrated a framework for eliciting place-based CES. Principles and guidance exists for how to include social and cultural values in EIAs (Vanclay, 2003; Vanclay et al., 2015; Arce-Gomez et al., 2015) and in the specific context of ecosystem services (Karrasch, 2016), but no systematic approach or analytical precedent for integrating cultural values with biodiversity has been proposed.

Therefore, we see a unique opportunity to advance mitigation for both biodiversity and cultural values jointly, to evaluate and demonstrate: 1) how social and cultural values can be organized and analyzed spatially to support proactive mitigation planning and management decisions, and how this can enable FPIC for Indigenous communities; and 2) how cultural/social and biodiversity values may reinforce each other to deliver effective conservation outcomes that address cumulative impacts at landscape-scales and that better account for social impacts. Here, we outline a method for incorporating biodiversity and cultural/social values into a development planning process, using a case study on Indigenous land in northern Australia. The result is a framework for mapping community-defined social, cultural, and biodiversity values to support EIA by enabling proactive impact analysis and informed negotiation of development proposals. The framework provides data and capacity to an Indigenous community to proactively assess development proposals and negotiate mitigation measures to avoid, minimize, and offset impacts following the mitigation hierarchy.

This framework is novel in two ways. First, it integrates spatial data representing social, cultural, and biodiversity values to enable impact analysis. Second, it provides this information directly to the Nyikina Mangala community and their aboriginal corporation, i.e. the Registered Native Title Body Corporate (RNTBC). As such, we expect that it will improve EIA processes by enabling proactive, informed assessment and negotiation of development plans on their native title lands. We discuss strengths and challenges to the process and applicability to other regions.

1.1. Background

Indigenous land management in Australia, often called ‘Caring for Country’, includes a wide range of environmental, natural resource and cultural heritage management activities undertaken by Indigenous individuals, families, groups and organizations. Resource use over more than 60,000 years occurred in accordance to seasonal and geographic patterns of the land, based on holistic relationships between traditional Indigenous people and their customary land estates—or ‘Country’. This has resulted in close linkages between cultural heritage and environment values (Altman, 1987; Asafu-Adjaye, 1996; Hill et al., 2013).

Traditional Owners hold native title rights to approximately 32% of Australia's total land area, and as much as 60% of northern Australia, through Native Title Determinations as of March 2018 (National Native Title Tribunal, 2018). Native title is the recognition in Australian law that some Indigenous people continue to hold rights to their land and waters that are based on their traditional laws and customs. The *Native Title Act 1993* (NTA) provides a system for the recognition and protection of native title rights and for its co-existence with other land-management and land-use interests. The Australian Indigenous estate has high national environmental significance and includes some of Australia's highest conservation priority lands and a diverse range of

intact ecosystems (Altman et al., 2007).

Australia's northern tropical savannas are considered the largest intact savanna in the world (Woinarski et al., 2007), with high endemism and globally-significant biodiversity (Carwardine et al., 2011, 2012; Pepper and Keogh, 2014), and occupy 99% of their original extent (Woinarski et al., 2011; Bradshaw, 2012). Following European settlement, changes in land-use and subsequent changes in fire regime and introductions of invasive species and novel disease modified significantly the composition and structure of the savannas (e.g., Woinarski et al., 2011). Today, major land uses include extensive pastoral activity, conservation management on Indigenous and public land (including traditional fire management) (e.g. Russell-Smith et al., 2009, 2015; Walton and Fitzsimons, 2015), and smaller areas of mining and irrigated agriculture.

1.2. Study area

The study area follows the boundaries of the Nyikina Mangala Native Title Determination (NTD), an area of approximately 26,100 km^2 that contains the Lower Fitzroy River and delta and the lower quarter (22%) of the Fitzroy River watershed. The Walalakoo Aboriginal Corporation, the Registered Native Title Body Corporate (RNTBC), was established to represent Nyikina and Mangala Traditional Owners interests and Native Title rights over this area (National Native Title Tribunal, 2014). Here, the Nyikina Mangala community faces a convergence of the issues described above that relate to integrated analysis and decisions about protection and management of environmental and cultural values in the face of existing and emerging development pressures. Indigenous rights holders face similar issues across northern Australia (Joint Select Committee on Northern Australia, 2014).

The NTD is located within the Kimberley region in the north of Western Australia (Fig. 1), a landscape rich in cultural heritage developed over more than 60,000 years of habitation and management by traditional owners. The West Kimberley, including the floodplains of the Fitzroy River and its tributaries, has been listed on the Australian National Heritage List for its biological richness, ancient geology and rich and dynamic Aboriginal culture (Australian Heritage Council, 2011). The Fitzroy River has particular cultural significance to the Indigenous community (Morgan et al., 2004; Toussaint et al., 2005; Watson et al., 2011; Jackson et al., 2012), supports diverse and unique native fish fauna (Morgan et al., 2004), and its coastal and floodplain wetlands are important stopping points for migratory shorebirds (Lane et al., 1996; Vernes, 2007). The Camballin/Le Lievre wetlands on the Lower Fitzroy River have been nominated as a Ramsar site (Jaensch and Watkins, 1999; Vogwill, 2015). The NTD study area supports 20 threatened animals and 19 migratory shorebirds protected by the Australian *Environment Protection and Biodiversity Conservation Act 1999* (EPBC) (DoE, 2015, 2016), and 12 animals and 19 plants listed by Western Australia as threatened or priority species (WA DPaW, 2015, 2016a).

The development and improved agricultural productivity of Northern Australia is the focus of multiple State/Territory and Australian government initiatives that aim to double agricultural output over the next 20 years (Joint Select Committee on Northern Australia, 2014). To achieve this goal, the Australian Government suggests new and expanding agricultural projects across 400,000 ha of land (Australian Government, 2015), mirrored by State-funded programs (e.g. Department of Primary Industries and Regional Development, 2017). Given rich mineral and petroleum resources, northern Australia's mining and petroleum developments are expected to expand and will continue to provide a large percentage of Australia's resource exports (Joint Select Committee on Northern Australia, 2014). If undertaken, these development proposals have implications for biodiversity and the ecosystem services of the largely natural landscapes in northern Australia (Morán-Ordóñez et al., 2017), as well as for cultural and social values of people that manage or depend on these landscapes (North Australian Indigenous Experts Panel, 2012).

2. Methods

This study began with a systematic definition of values by traditional owners in the *Walalakoo Healthy Country Plan* (WAC, 2017), a cultural and natural resource management plan that follows the

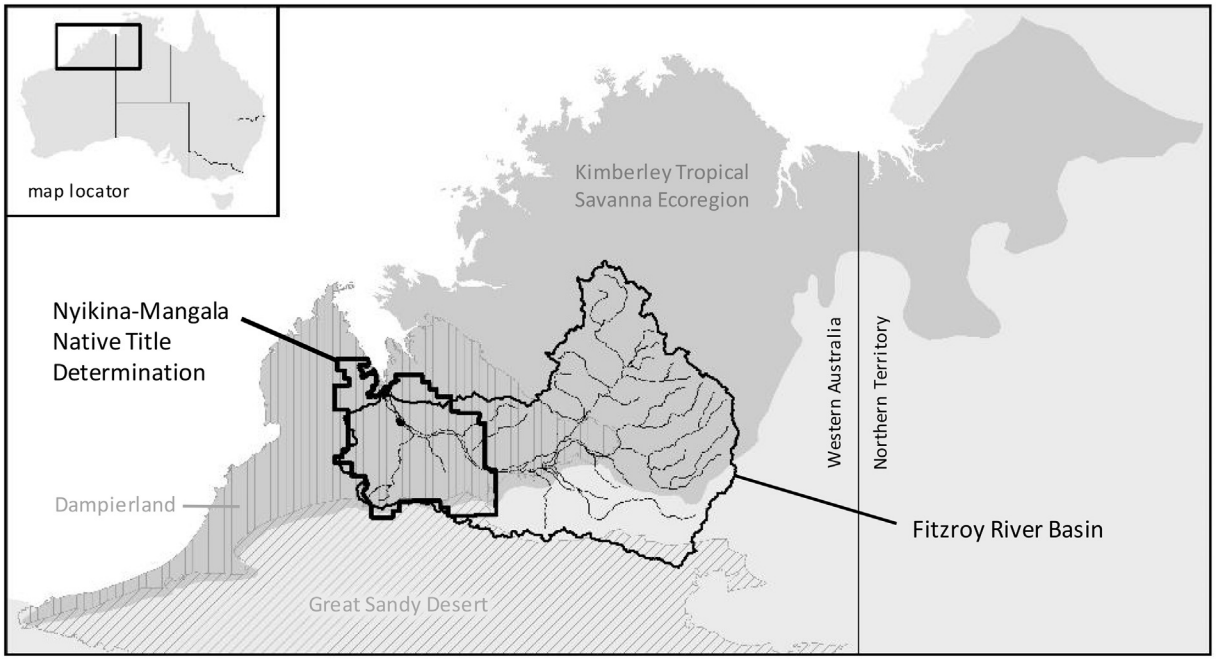

Fig. 1. Location of Nyikina Mangala Native Title Determination (NTD) area and the Fitzroy River Basin within the Kimberley region, north-western Australia. The NTD lies on the southwestern side of the Kimberley Tropical Savanna Ecoregion (Olson et al., 2001) and across two IBRA biogeographic regions (Thackway and Cresswell, 1995; Environment Australia, 2000): Dampierland and the Great Sandy Desert.

Healthy Country Planning (HCP) methodology. Based on this information, the community defined spatial priorities for avoiding development impacts. Last, we organized the spatial datasets in an information system to support community resource management decisions, development planning, and impact mitigation.

Healthy Country Planning is an adaption of Open Standards for the Practice of Conservation (Schwartz et al., 2012), a globally recognized planning framework that guides community and conservation groups through a multi-step participatory process for the development of an adaptive management plan (Carr et al., 2017). Through the HCP process, the community defines conservation values within a participatory planning framework. This facilitates the development of a structured understanding of their vision, values, threats and their interactions. The Healthy Country Planning methodology has been widely adopted throughout Indigenous Australia for the development of management plans for Indigenous Protected Areas and other Indigenous Land Management Initiatives (e.g. Moorcroft et al., 2012; Jupp et al., 2016; Carr et al., 2017; Austin et al., 2017, 2018).

The first step in the HCP process is to engage the community and define values or targets. The Nyikina Mangala community defined a set of seven natural, cultural, and socio-economic targets that collectively represent Nyikina and Mangala people's values and vision for Healthy Country (See Table 1). Following the Open Standards for the Practice of Conservation (Schwartz et al., 2012), all HCP target definitions include key ecological attributes in terms of viability and integrity that include the ecosystem services provided. In terms of ecosystem service categories defined by the Millennium Ecosystem Assessment (2005) and TEEB (2011), all targets provide CES, and several targets also provide provisioning, regulating, and habitat/supporting services. To improve decision-making and the EIA process, we developed spatial datasets to represent and integrate social/cultural and biodiversity targets in an impact assessment framework. A detailed data management and intellectual property agreement was developed prior to gathering and collating information for the study.

To facilitate use in EIA processes we developed spatial datasets to represent cultural, social, and biodiversity values of the Nyikina Mangala community across the Native Title Determination (NTD), specifically four targets defined by the HCP: Cultural and Heritage Sites, Freshwater Places, Native Animals, and Bushtucker/Bush Medicine Plants. The community defined threatened species protected by national and state legislation as nested targets within the target groups Native Animals and Bushtucker/Bush Medicine Plants, in accordance with their traditional view of country. However, threatened species are typically addressed independently by legal regulations and mitigation requirements. For the purpose of this study, we describe cultural/social values and threatened and endangered species separately and analyze the relationship between them. This allows us to assess the additionality of listed threatened species to the larger range of culturally important values.

Table 1
list of targets defined in the Healthy Country Plan.

1. Nyikina Mangala Lore and Culture: Language, dance, song, stories, ceremony, customs
2. Cultural and Heritage Sites: Rock-art, burial sites, massacre sites, old camping places, artefact scatter, old workshops and ceremony sites
3. Freshwater Places: Fitzroy River, springs, wetlands, creeks, billabongs, fish and birds, bush-fruit / medicine plants along the river
4. Native Animals: traditional food-sources and threatened and endangered animal species
5. Bushtucker / Bush medicine Plants: traditional plants used for foods, medicine and tools
6. Right Way Fire Management: Early Dry Season burning implemented by Traditional Owners
7. Being Strong on Country: Being in control of country and being able to gain livelihoods from Nyikina Mangala country

2.1. Cultural/heritage sites

The NTD contains hundreds of sites with significance to Nyikina Mangala lore and culture. These sites range from artefacts and rock art to ceremonial sites to physical features attached to traditional stories. We compiled a database of the locations and attributes of 663 sites identified in 18 surveys between 1983 and 2015, including sites in the register maintained by the Western Australian Department of Aboriginal Affairs (DAA). This dataset includes only survey records. The spatial pattern of site records is largely determined by survey effort, and areas without survey records may contain un-recorded sites.

To facilitate use of this cultural spatial data in EIA processes, the community working group defined areas to avoid development as a 2 km buffer around each cultural/heritage site. The 2 km zone is a placeholder pending a site survey for any development project. Development proposals that go forward must conduct site surveys to redefine the protection zone around each cultural/heritage site based on the specific characteristics of the site and the surrounding landscape.

2.2. Freshwater features

The freshwater places identified by the HCP include the Fitzroy River and tributaries, their floodplains and riverine wetlands, as well as springs and other wetlands and waterbodies occurring across the NTD and associated native flora and fauna. We mapped and classified these as four types of features: floodplains of the Fitzroy River and major tributaries, riparian areas of smaller tributaries, large water bodies and wetlands, and smaller ephemeral water bodies (details in Appendix 1). A national surface hydrology dataset (Geoscience Australia, 2015) delineates major floodplains, water bodies and wetlands at 1:250,000. Permanent and semi-permanent water bodies are critically important for Indigenous subsistence livelihoods, cultural heritage, and biodiversity (Jackson and Robinson, 2009) but locations of those water bodies are not mapped consistently. To address this data gap we delineated the floodplains and riverine wetlands of smaller tributaries with a topographic model (Smith et al., 2008) derived from a digital elevation model (Geoscience Australia, 2011; Gallant et al., 2011) at 1 arc-second (30 m) resolution, and mapped other small and ephemeral water bodies with a supervised multispectral classification of Landsat 8 OLI imagery (USGS, 2015) collected April 2015. The community working group defined freshwater protection zones to avoid development that consist of the floodplains and riverine wetlands of the Lower Fitzroy River, the Fraser Rivers, and their major tributaries that lie within the NTD.

2.3. Plants and animals identified for cultural-socio-economic purposes

'Native animals' include many common animal species that are valued for hunting. 'Bush tucker/bush medicine plants' also include many common plants species that are gathered for food, medicine, utensils, arts/crafts, and fuel. The distribution of common animals and plants generally follow patterns of biophysical habitat. To map the general distribution of common animals and plants, we developed a biophysical habitat classification (Fig. 2) that defines eleven biophysical habitat types across the Fitzroy Basin analysis area, including the freshwater features mentioned above. The classification typology is based on biogeography, landforms, vegetation structure, and surface hydrology (Appendix 1). The resulting mapped biophysical classification is a reasonable proxy for the distribution of common, widespread species and represents landscape-level environmental gradients and the physical template for broad scale processes necessary to maintain habitat (Hunter et al., 1988; Groves et al., 2002). However, the biophysical units will not capture the distribution of rare or sparsely-distributed species or species with habitat requirements that are not well-represented by the biophysical units. As such, the biophysical habitat classification also functions as a coarse filter for biodiversity, following

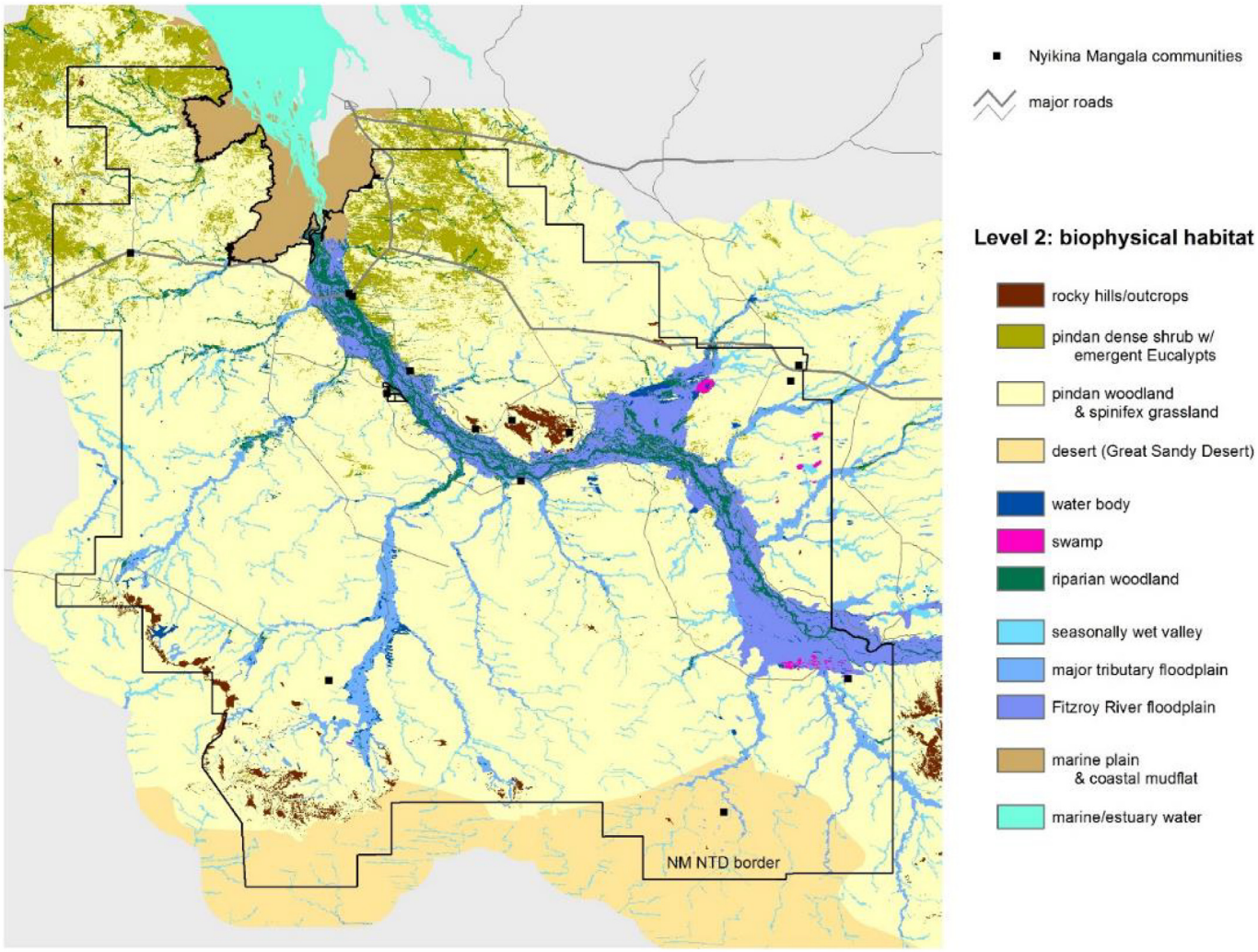

Fig. 2. Biophysical Habitat Classification and Spatial Model. Details in Appendix 1.

a widely used coarse filter/fine filter strategy for conservation planning (Hunter, 1991; Noss, 1996; Groves, 2003), representing a major component of biodiversity: common native animals, plants, and ecological communities.

2.4. Species protected by state and national regulations and international agreements

Species listed as threatened or priority by state and national legislation that occur in the NTD area include 32 animals - 9 mammals, 15 birds, 6 fish, and 2 reptiles (DoE, 2016; WA DPaW, 2016a) and 19 plants (WA DPAW, 2015) as well as 18 migratory shorebirds protected by international agreements (DoE, 2015). State legislation also protects 3 threatened and priority ecological communities that occur in the NTD along the Lower Fitzroy River and have been designated and mapped by WA DPAW (2016b). We defined the threatened animals and migratory shorebirds as focal biodiversity targets, listed in Appendix 2, and developed spatial models of potential suitable habitat based on habitat definitions in literature and existing spatial data compiled in the biophysical spatial model. Because observation data for all these species is absent or very limited, we were not able to develop species distribution models derived from occurrence data. Instead, we developed models of potential suitable habitat for 22 threatened species (6 mammals, 11 birds, and 5 fish) and one model to represent the Lower Fitzroy riverine and estuarine wetlands used seasonally by the 19 migratory shorebirds. Source datasets and method details are listed in Appendix 2. The habitat models were reviewed by the community working group and other experts in the ecology of the Kimberley region and revised accordingly (Sarah Legge, pers. comm.). For the remaining 10 animals and all the rare plants, habitat and distribution are not well-defined in literature or reliably predicted with existing spatial datasets, so we judged these species "data deficient" and did not develop habitat models.

2.5. Comparing spatial patterns of cultural/social values with biodiversity values

To assess the relationships between cultural/social and biodiversity targets, we summarized the thematic associations and spatial relationships between cultural/heritage site attributes, threatened species habitat, and landscape features, and specifically freshwater features. To illustrate distribution patterns of cultural/heritage sites and threatened species habitat across the study area, we created a grid of 3 × 3 km cells and sampled the count of cultural/heritage sites per cell and the count of threatened species with modeled habitat occurring in each cell (Fig. 3).

2.6. Landscape measures of access and disturbance

The availability and provision of native game animals and bush tucker/medicine plants, and any ecosystem service, requires consideration of two components: supply of ecosystem services, and

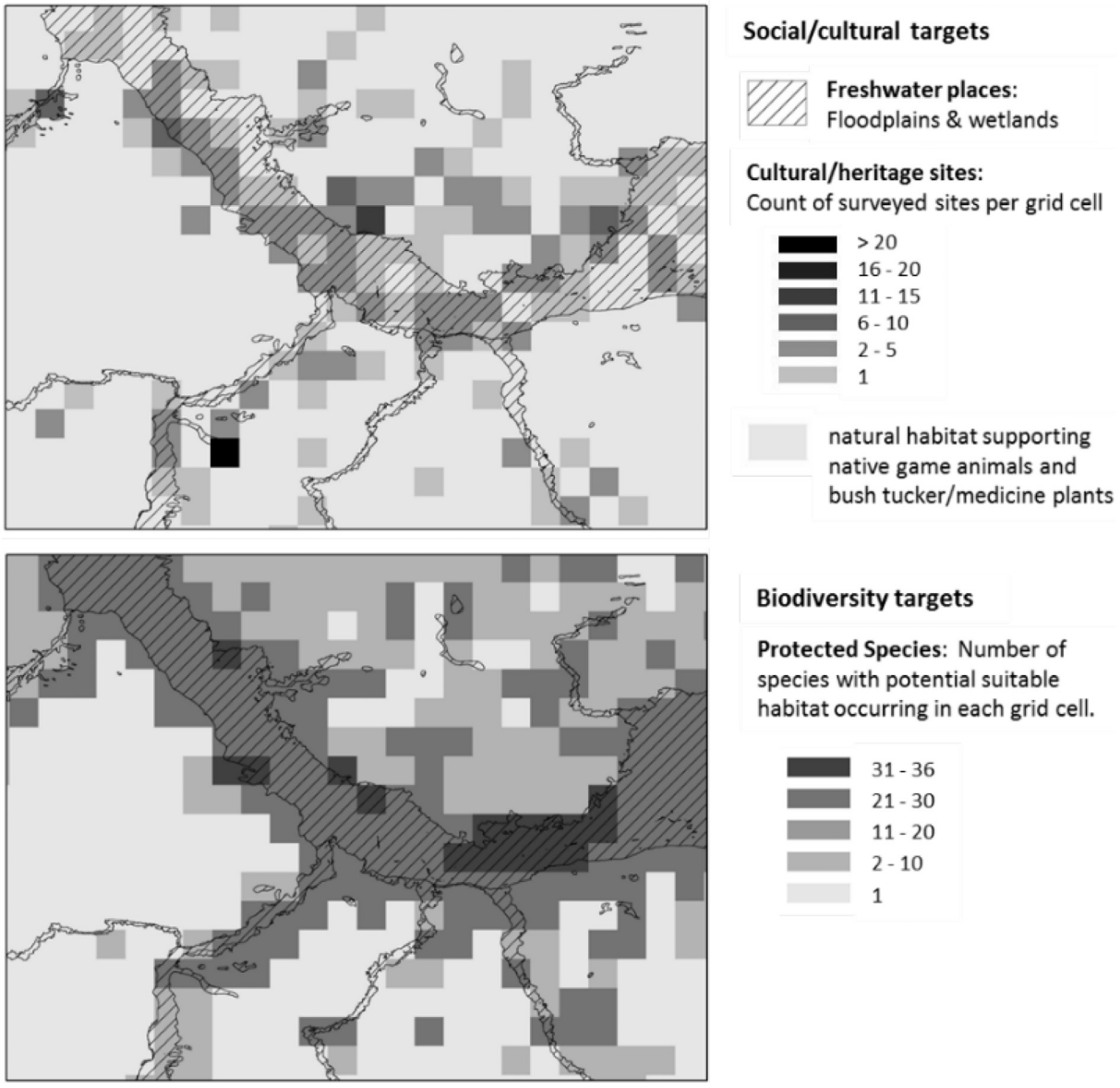

Fig. 3. Spatial pattern of aggregated social/cultural targets and biodiversity targets.

physical and legal access to the services (Tallis et al., 2015). To measure and map the pattern of relative accessibility across the study area, we calculated a spatial metric of access as the sum of proximity to Nyikina Mangala communities and the proximity to roads (Fig. 4), with proximity measured as the inverse of euclidean distance from each population center and road segment to the edge of the NTD. The result is a measure of ecosystem service provision in terms of access for any part of the landscape and any feature. Data sources and calculations are documented in Appendix 3.

Similarly, the abundance and viability of native game animals and bush tucker/medicine plants, and the provision of other ecosystem services, depends on current ecological condition and historic disturbances (Woinarski et al., 2007; Raiter et al., 2014). To estimate and map patterns of ecological disturbance, we developed two spatial measures. The first is a spatial index of disturbance from infrastructure and human land use (Fig. 5) derived from available public spatial datasets representing population centers, roads, mine operations, petroleum operations, local hydrological alteration (dam walls, canals), livestock use (bores, water pumps, tanks), and other infrastructure (airports, power lines, fences). Data sources and calculations are documented in Appendix 3. The result is a coarse, generalized measure of cumulative impacts. The second metric is the frequency of destructive late-season fires between 2000 and 2015 recorded by NAFI (2016), shown in Fig. 6. Late dry season fires occur after July 31, burning hotter and over larger extents than in the early dry season, and are ecologically destructive and an urgent threat to biodiversity in the region (Woinarski et al., 2011; Carwardine et al., 2012; Bartolo et al., 2012). Fires are monitored and recorded in public datasets by NAFI.

2.7. Decision framework for mitigation

Through a series of workshops, the community working group developed a framework to assess development proposals and define conditions for negotiation of mitigation measures according to the types of spatial targets affected and the accessibility and ecological condition of these targets (see Fig. 7). The framework follows steps in the mitigation hierarchy to avoid, minimize, and offset impacts.

To enable the Nyikina Mangala community to conduct rapid spatial analysis of the potential impacts of development proposals, we developed a Geographic Information System (GIS) software application that measures and reports the types and amounts of targets occurring in a user-defined proposed development footprint or impact area. The

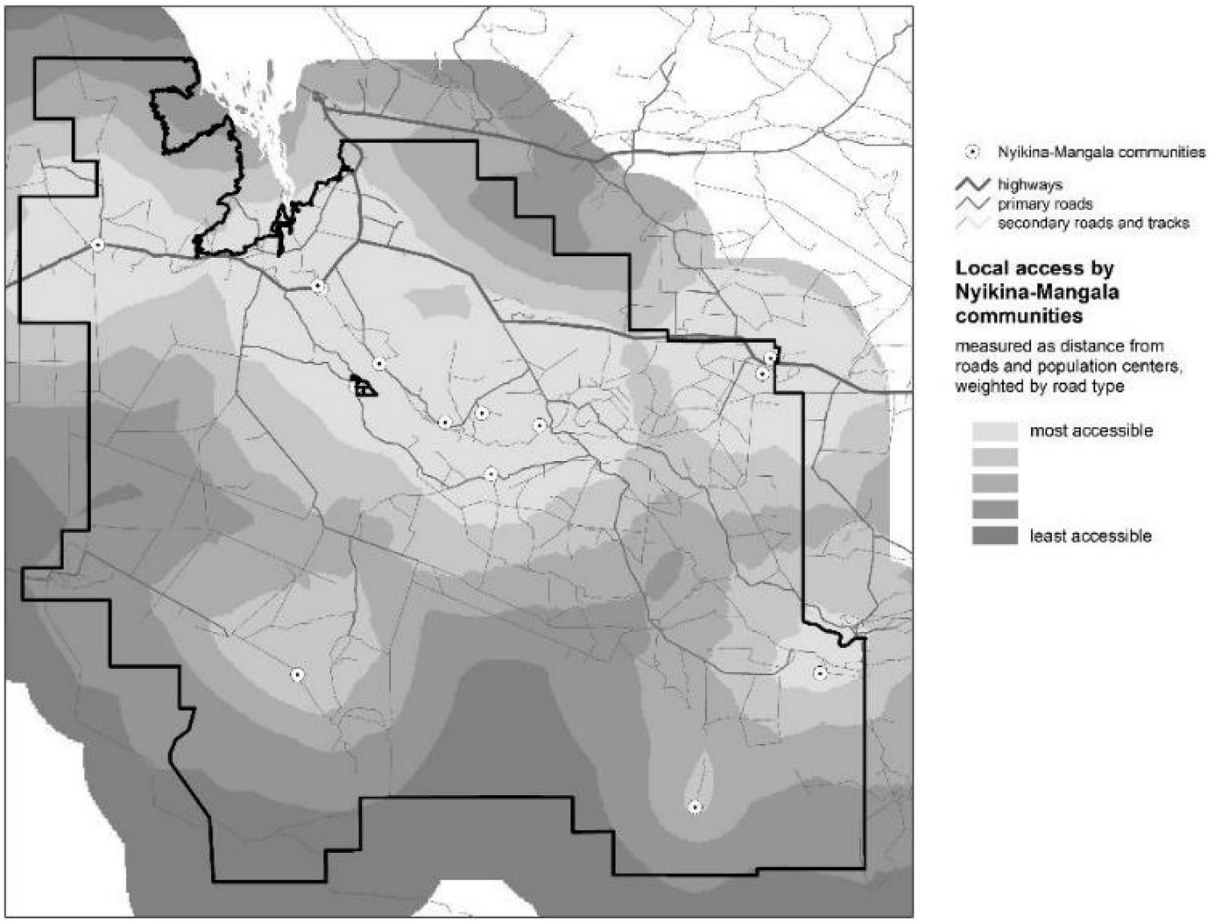

Fig. 4. Spatial index of access based on proximity to Nyikina Mangala population centers and roads.

application also analyses and reports the area of the footprint that lies in each of the three classes of access, three classes of disturbance from the cumulative impacts of land use and infrastructure, and four classes of destructive fire frequency.

3. Results

Based on existing survey of cultural/heritage sites, 41% of sites are thematically linked to freshwater based on the site attributes. Almost 70% of sites occur within a kilometer of a water body or the floodplains and riverine wetlands of the Fitzroy River and major tributaries. Cultural/heritage sites are also more abundant near rocky hills and outcrops.

Of the 22 threatened species for which we developed spatial habitat models, potential habitat of 17 or 77% of modeled species occurs in the Fitzroy River floodplain and riverine wetlands, and for 13 or 60% of those species, potential habitat occurs exclusively in the Fitzroy River floodplain. All 19 migratory shorebirds protected by international agreements also use the Fitzroy River floodplains and riverine wetlands seasonally during the wet season. Potential habitat of four modeled species includes rocky hills and outcrops – Black-flanked Rock-wallabies use rocky hills exclusively, while Northern Quoll and two threatened bat species use rocky hills as refuge habitat and for denning and roosting.

Fig. 3 shows the general distribution of surveyed cultural/heritage sites and potential habitat of protected species in relation to the Fitzroy River floodplain. To protect the specific locations of cultural/heritage sites, the map spans only a 60 × 90 km portion of the NTD and the datasets are resampled in a 3 km resolution grid. Cultural/heritage sites have not been completely or consistently surveyed across the NTD, so gaps and low values are likely areas that have not been surveyed or for which survey data was not available. Social/cultural targets also include native game animals and bush tucker/medicine plants that are present across the landscape but are not quantified in terms of abundance.

The mitigation framework (Fig. 7) defines conditions for negotiation of mitigation measures following steps in the mitigation hierarchy to avoid, minimize, and offset impacts. The community working group defined avoidance areas for developments in the NTD as 1) cultural/heritage sites including a two kilometer buffer zone around each site and 2) freshwater protection zones defined and mapped as the floodplains and riverine wetlands of the Lower Fitzroy River, the Fraser Rivers, and their major tributaries inside the NTD. The defined avoidance areas for cultural/heritage sites and freshwater features cover approximately 13% and 12% of the NTD, respectively. Together, the two protection zones cover 21% of the NTD. The landscape measures of access (Fig. 4) and ecological condition (Figs. 5 and 6) provide measures of ecosystem services provision and inform steps to minimize and offset impacts.

4. Discussion

Environmental impact assessments (EIAs) are intended to minimize risks to environmental values and human rights, lessen adverse impacts, and strengthen positive outcomes of business investments. For an EIA to fulfill this purpose, it must consider the perspectives of everyone affected by a developer's operations. Too often, developers ignore social and cultural impacts, focusing instead on environmental assets that often do not fully represent a community's values, and in doing so, forfeit the opportunity to minimize human rights violations and costly

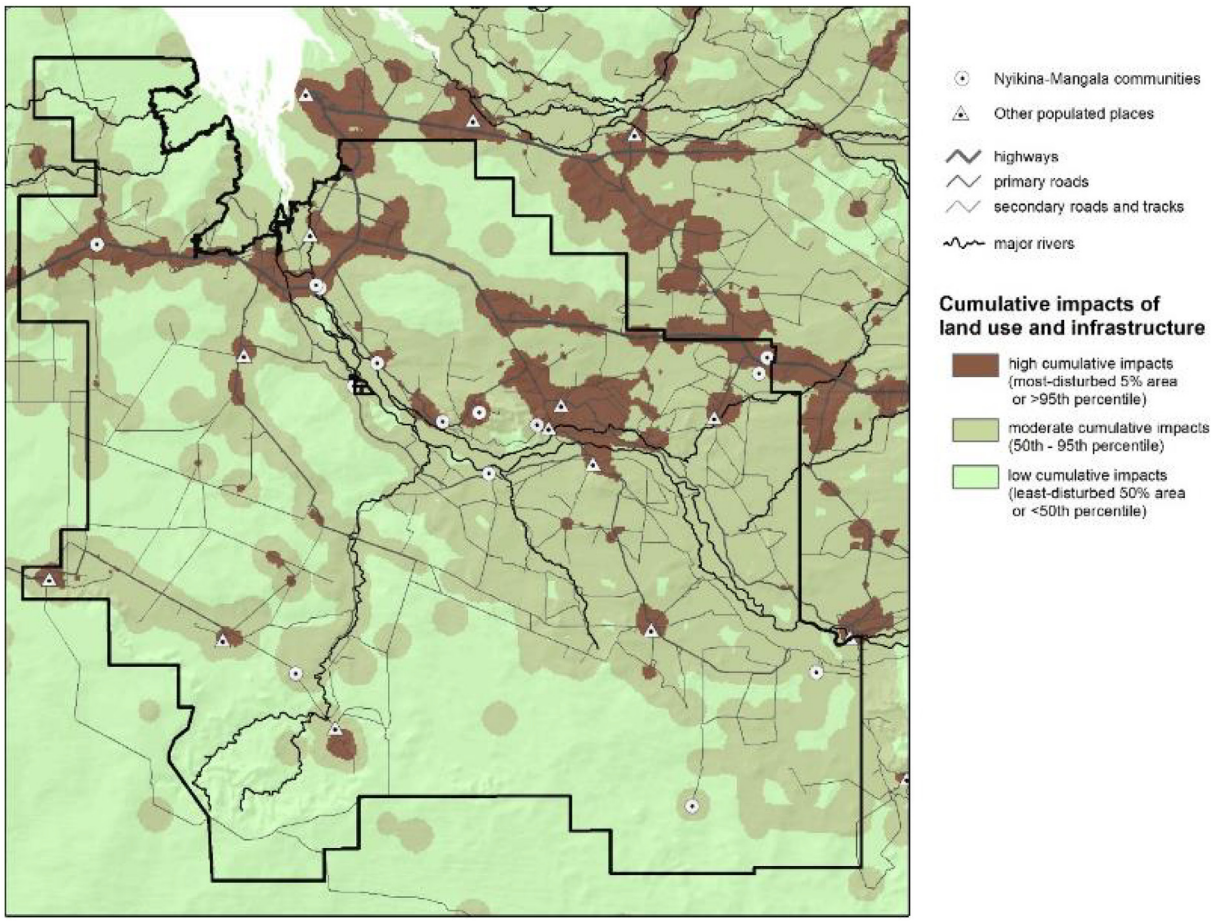

Fig. 5. Spatial index of disturbance representing cumulative impacts of land use and infrastructure derived from existing spatial datasets representing population centers, roads, active mine operations, petroleum operations, local hydrologic alteration, livestock use, and other infrastructure (details in Appendix 3). The result is a coarse, generalized measure of ecological condition.

conflicts. Here we present a practical framework and process that can be applied proactively to assess impacts to environmental, social and cultural values. We discuss application of this proactive planning approach to the Nyikina Mangala Native Title Determination (NTD) in Northern Australia as well as technical capacity needed to expand implementation more broadly.

In the Nyikina Mangala NTD, there is a strong thematic and spatial relationship between cultural/heritage sites and freshwater features, and the Lower Fitzroy River in particular. Biodiversity, represented by potential habitat for threatened animals, is also concentrated in Lower Fitzroy freshwater systems. Both cultural/heritage sites and threatened species habitat also show a strong spatial relationship in rocky hills and outcrops. A significant fraction of cultural/heritage sites are located near rocky hills, and four threatened species use rocky hills, one (Black-footed Rock-wallaby) exclusively.

The concentration of social/cultural and biodiversity values around freshwater features may be expected in arid climates where human settlements, species richness, and ecosystem productivity are highly dependent on water availability (e.g. Davis et al., 2017). The Fitzroy River and its tributaries provide multiple ecosystem services including water, game animals, bush tucker/medicine plants, and habitat for threatened species. Similarly, rocky hills have value for historic human settlements and as unique habitat for native plants and animals (e.g. Fitzsimons and Michael, 2017). However, cultural/heritage sites were not surveyed systematically across the NTD, and there is likely some survey bias for areas near the Fitzroy River and rocky hills due to higher access.

Though the Fitzroy River provides critical social/cultural values and biodiversity values, much of the riparian zone, riverine wetlands and water bodies have been degraded by livestock grazing (Morgan et al., 2004; Watson et al., 2011), and fish passage and freshwater habitat connectivity have been impaired by the Camballin barrage (Morgan et al., 2005). The river is also threatened by future development (Australian Government, 2015; Department of Primary Industries and Regional Development, 2017; Morán-Ordóñez et al., 2017). Water quality and flows are affected by withdrawals, sedimentation, and pollution across the watershed. Although not the focus of the current study, any impact assessment of development projects in the watersheds of the Fitzroy River and Fraser Rivers, including projects in the upper basins outside the NTD, should evaluate impacts to water quality and quantity in the downstream sections of the river inside the NTD.

The decision framework developed here is a means to ensure FPIC is possible for communities within existing mechanisms, and allow communities to shift from a reactive role to a pro-active role in development processes. We mapped targets defined in the Healthy Country Plan: cultural/heritage sites, freshwater features, common native animals and plants represented by biophysical habitat types, and legally-protected threatened and migratory species represented by potential habitat models. The community defined protection zones for cultural/heritage sites and freshwater features that cover 21% of the NTD. To represent differences in provision and viability of native animals and plants and other ecosystem services, we developed spatial measures of access and ecological condition.

This spatial information can be the basis to proactively apply the mitigation hierarchy – first avoid, then minimize, and if appropriate also offset impacts – to balance conservation objectives with impacts

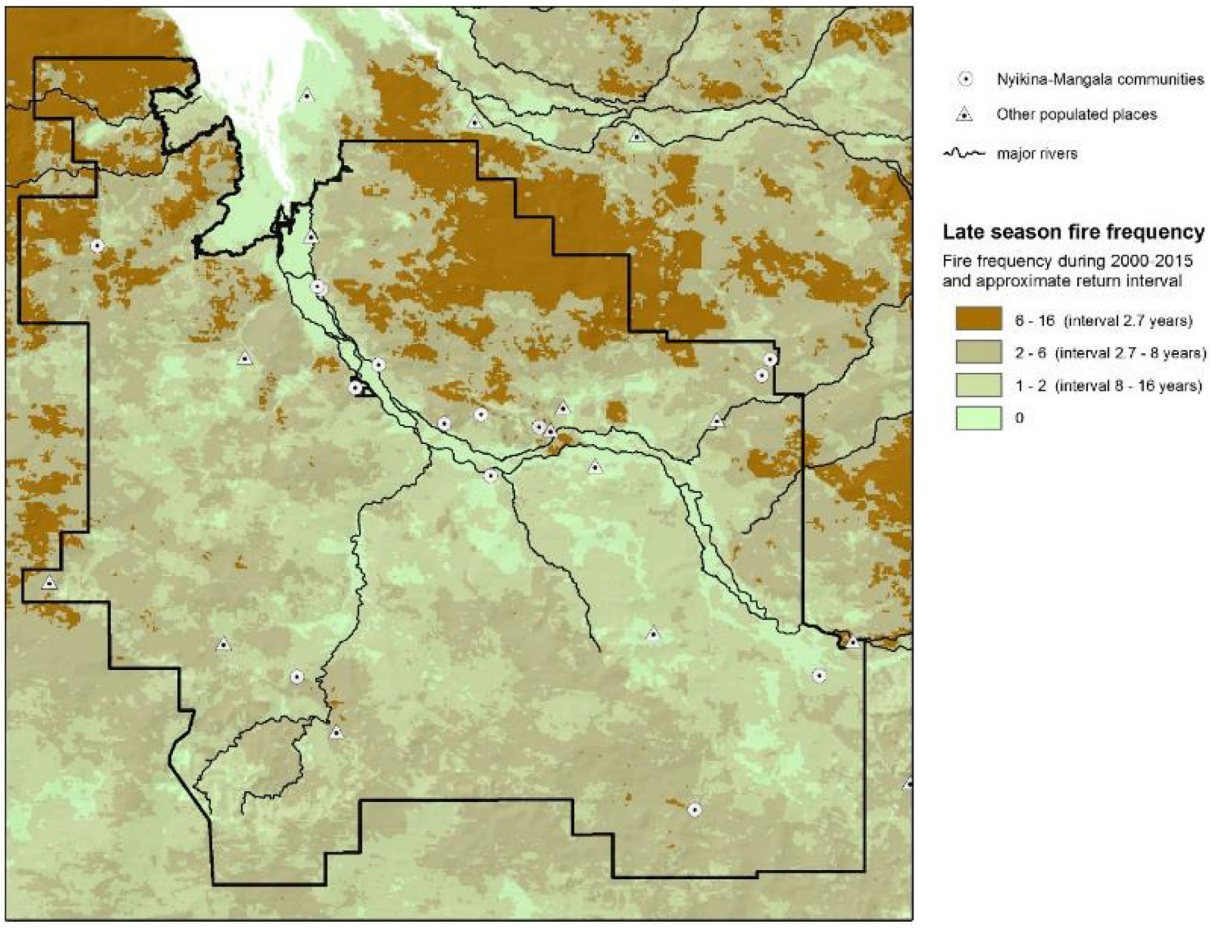

Fig. 6. Frequency of late-season destructive fires between 2000 and 2015 (NAFI, 2016). This is an indicator of ecological condition based on fire regime and fire history.

associated with future potential development (see Fig. 7). The high priority conservation areas identified to avoid development impacts to cultural/heritage sites and freshwater features cover approximately 21% of the NTD. Though the cultural/heritage sites dataset is incomplete and the avoidance area will likely expand, the 21% figure suggests that some conflicts could potentially be resolved by redesigning development footprints to avoid impacts to those conservation targets. Mitigation recommendations can be defined based on the location and the nature and distribution of conservation targets affected. Where proposed development overlaps highly irreplaceable targets, greater emphasis should be given to avoidance than minimization. In some areas and for some targets, offsets may be appropriate to further mitigate impacts.

Biodiversity offsets within the Mitigation Hierarchy have been used by all Australian states and territories, and by the Australian Government where a development is likely to impact on matters of national environmental significance under the *Environment Protection and Biodiversity Conservation Act 1999* (Fitzsimons et al., 2014; Hawdon et al., 2015; Maron et al., 2015). These schemes vary by jurisdiction, in the types of biodiversity matters considered, in the metrics used to assess impact and determine offsets, and instruments and guidance used to implement them (e.g. DSEWPC, 2012). Nonetheless, they typically consider ecological communities (typically vegetation types) or threatened species (and their habitats).

Areas that are more accessible or that support intact habitat in good ecological condition may necessitate a higher requirement for mitigation of impacts from development projects and other land use changes (McKenney and Kiesecker, 2010; Villarroya et al., 2014). Accessibility and ecological condition, as represented by the access and disturbance measures, indicate greater provision ecosystem services or abundance of native plants and animals including rare and threatened species. These measures can inform decisions about the conservation significance and mitigation burden of development in any given location (see examples in Fig. 7).

Packaging cultural and social data at a landscape scale can also guide other management decisions in the NTD. Sites that occur in highly accessible and/or highly disturbed areas could benefit from management plans and actions such as fences, walkways, and signage to reduce risk of degradation. Disturbance measures may also guide restoration and threat management actions such as fire and grazing management and invasive species control. Management actions for biodiversity in the Kimberley region have been studied and prioritized by Carwardine et al. (2012) in terms of cost effectiveness.

Australia was one of the first countries to require free, prior and informed consent in local legislation (MacKay, 2004). Considering the stated plans of national and state governments to further develop northern Australia, there is a timely opportunity to enhance current development assessment processes to better incorporate Indigenous social/cultural values, as outlined in this paper. Considering the significant area in Northern Australia to which Indigenous people have Native Title and rights to FPIC, incorporating such processes would improve the social, cultural and environmental outcomes of development proposals and reduce conflicts.

Some legislative and policy instruments already in place will benefit from proactive planning. For example, Native Title holders have the right to negotiate development proposals that impact their native title rights and interests – which also leads to rights to compensation if there are subsequent impacts on native title rights and interests. Improved

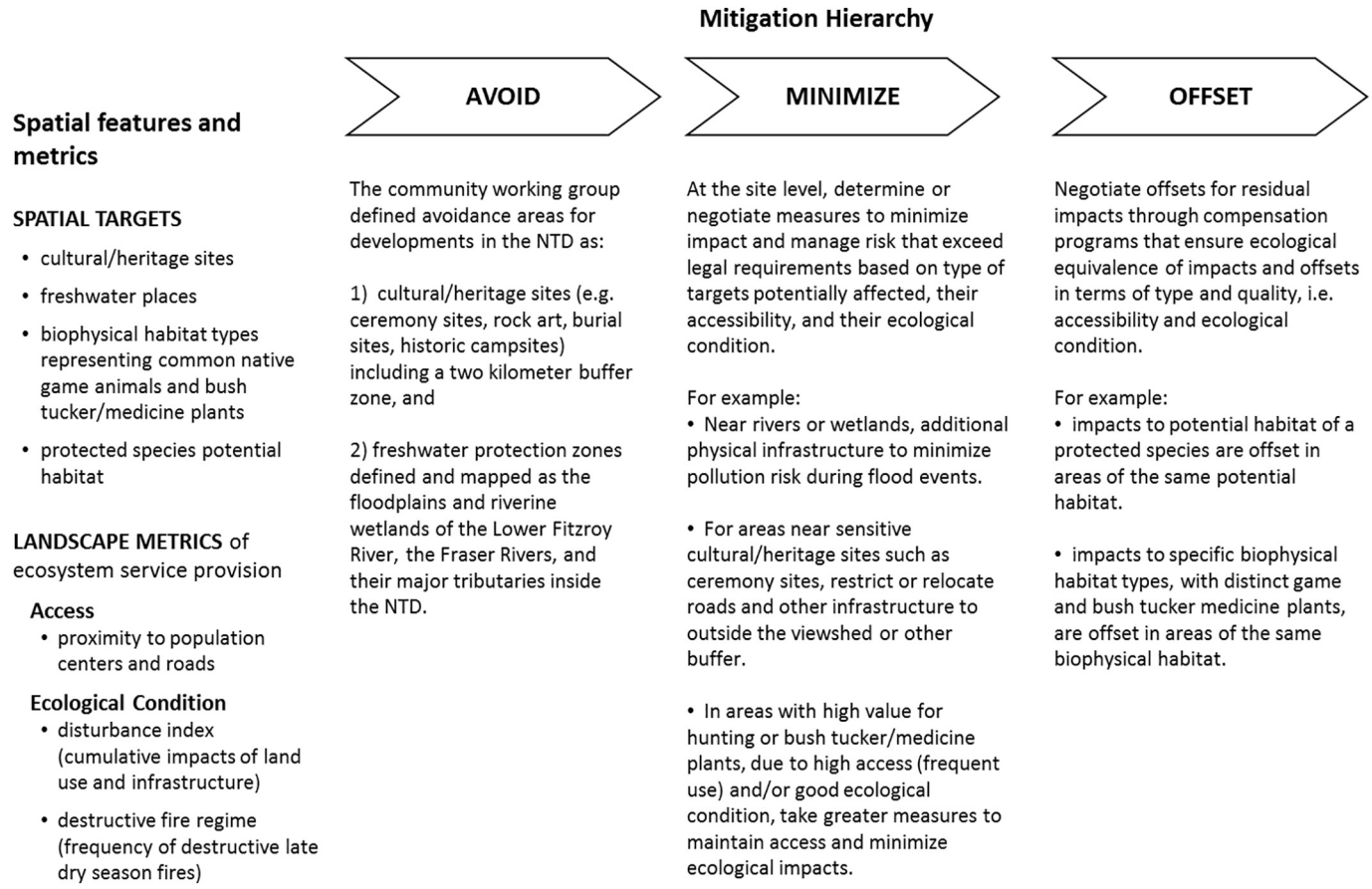

Fig. 7. Spatial framework for integration of social, cultural, and biodiversity values into the mitigation hierarchy. This diagram shows how the spatial framework provides evidence to guide the EIA process and support negotiation of conditions for design and operation of a development project following steps in the mitigation hierarchy.

quality of information and analysis will contribute to more informed negotiation and improve implementation of cultural heritage protection requirements at both Federal and State government levels (e.g. *Federal Aboriginal and Torres Strait Islander Heritage Protection Act 1984*; *Western Australia Aboriginal Heritage Act 1972*). Native Title Representative bodies (NTRB) that hold a statutory role to represent groups of Registered Native Title Body Corporates (RNTBCs) and the RNTBCs themselves are faced with such a high volume of exploration license applications and other development proposals that reviewing and responding to each proposal is nearly impossible due to limited capacity and time. A spatial framework similar to what we have developed that allows identification of areas with high values and high vulnerability would enable NTRBs and RNTBCs to prioritize and focus limited resources on high-risk or high-conflict proposals.

For development projects that are likely to impact biodiversity values such as threatened species and ecological communities, Federal (EPBC 1999) and state or territory (Western Australia Biodiversity Conservation Act 2016) legislation require impact assessments prior to permit application. These assessments are typically made by consulting companies and use existing public datasets, but may collect new biodiversity data depending on the size of the project and the likelihood of impact to a highly threatened species. Governments will then assess the suitability of the proposed development and approve, request modifications, or reject the proposal, depending on the type and range of species affected. This may vary by state/territory jurisdiction. The threatened species potential habitat models developed for this study indicate what legally-protected species might occur in or be affected by a proposed development site, for internal reference by the community, and may inform surveys conducted as part of the impact assessment process.

4.1. Data use, limitations and sensitivities

Proactive planning can benefit both traditional owners and developers. For traditional owners, planning and organization is critical to FPIC, enabling timely decisions about avoidance and mitigation and strengthening negotiating position. These proactive decisions can also steer investments away from areas of conflict, saving time and expense for all parties. However, spatial planning requires spatial data, which is often incomplete. In particular, the coverage of cultural/heritage sites and threatened species records depends on survey effort, and areas without survey records may contain un-recorded sites and species. In this study, the cultural/heritage sites dataset was compiled from 18 different sources with varying survey designs and extents, leaving large portions of the NTD where data was not available. Because the cultural/heritage sites survey reports do not include absence data, it's impossible to estimate or distinguish unsurveyed areas from areas without sites.

Local surveys for cultural/heritage features and threatened species are a critical part of EIA in the exploration phase of any development project, but are limited in extent to each development site. This underscores the need for proactive, landscape-level surveys. Funding for regional survey efforts will be a critical limiting factor if landscape-level proactive planning is to be conducted more widely. A useful precedent for funding proactive regional planning is Healthy Country Planning in Australia that began with several workshop and pilot studies supported by The Nature Conservancy that developed a replicable model and demonstrated its utility. Since then, Healthy Country Planning has been applied in over 140 projects by more than 20 organizations with funds

from various sources including Aboriginal corporations, NGOs, government, foundations, and the private sector (Carr et al., 2017). Technical capacity for collecting and managing survey data has improved across Australia with GPS survey software such as Fulcrum (Spatial Networks, Inc., 2018) and CyberTracker (Ansell and Koenig, 2011) and with online spatial information platforms such as the Atlas of Living Australia (2018), Northern Australia Fire Information (2016), Queensland Globe (Queensland DNRME, 2018), and Western Australia Landgate (Western Australian Land Information Authority, 2018).

The process of compiling general predictive models to map conservation targets can guide survey efforts. Like many parts of the world, the Nyikina Mangala NTD and the Kimberley region lack comprehensive surveys and datasets describing the distribution of native animals and plants, from relatively common game species and bush tucker/medicine plants to rare and threatened biodiversity (McKenzie et al., 2009; Carwardine et al., 2011). The biophysical habitat classification and the disturbance index created as part of this assessment may guide surveys for both site-level impact assessments in the short term and landscape-level sampling designs across the NTD.

Bringing sensitive and threatened features into spatial planning while protecting their locations presents a challenge. For this study, the Nyikina Mangala community compiled a detailed dataset of cultural/heritage sites for internal use and allowed the broad summary of their cultural data for external stakeholders, but have chosen to keep the precise locations private to preserve and protect these values, as there is evidence that publishing locations to aid planning and conservation could harm the same values (Lindenmayer and Scheele, 2017). However, there is already precedent in the fields of paleontology and archaeology that advance restrictions on the publication of site locations and the promotion of government policies and regulations to limit collection and trade in artefacts and culturally sensitive important material. There is also precedent in Australia where the High Court can hear cultural stories in closed sessions in determining connection to country for Native Title determinations. Indigenous communities and aboriginal corporations must have confidence that secure mechanisms are in place for sharing sensitive spatial information to proactively inform and guide development plans while protecting locations. This will require new tools and approaches to data sensitivity and access.

To enable the Nyikina Mangala community to conduct rapid assessments of the potential impacts of development proposals in the NTD, we developed a Geographic Information System (GIS) software application that measures and reports the types and amounts of targets occurring in a user-defined proposed impact area. This allows the Walalakoo Aboriginal Corporation to facilitate community decision-making by reporting and comparing various development scenarios. A capacity-building program is underway that includes application testing, GIS software training, and development of a technical user manual.

Cultural assessments face other methodological challenges in addition to limited availability of comprehensive and current spatial data. Not all cultural values are readily mapped or measured spatially. Intangible values that cannot be mapped such as spiritual beliefs, language, and oral history are necessary to maintain culture (Partal and Dunphy, 2016; Watson et al., 2011). Also, cultural values are not static and will change over time. Threatened species listings will also change over time, as many northern Australian mammal populations are experiencing a decline (Fitzsimons et al., 2010), and many of these species have not yet been listed under state/national threatened species legislation. Therefore, planning frameworks like this must be adaptive and allow for regular updates and revision.

4.2. Future directions/conclusions

There is an urgent need to transform development planning from reactive site-level planning for individual projects to consider landscape-level development scenarios in advance of proposed development projects (Kiesecker and Naugle, 2017; Kiesecker et al., 2017). In view of the FPIC principles, all development projects affecting the lives of Indigenous peoples require their early and sustained input to ensure that projects mitigate impacts to social and cultural values and reflect their choices of development (UN, 2008). With this case study we illustrate that proactively compiling social and cultural values is possible and practical. This can strengthen traditional Indigenous governance systems, reinforcing the role of Indigenous peoples in the decision-making process and improving their position to negotiate with other parties, be they local or national authorities, the private sector, or international development institutions.

First and foremost, Indigenous peoples need an opportunity to strengthen their individual and collective capabilities to exercise their rights and have a greater say in decisions that affect their values and futures. Healthy Country Planning (Carr et al., 2017) can provide a clear articulation of community values and objectives for management of their own land. This provides a foundation for defining and mapping targets in a spatial decision-making framework and analyzing these targets in existing legal and policy contexts, including threatened species and cultural heritage legislation. Spatial planning requires training and capacity building in both the technical aspects of spatial planning and in the effective analysis and interpretation of results is required. Additionally, the effective use of spatial planning for decision-making requires capacity for analysis of results in the context of the relevant legal and policy environment.

The fields of conservation planning and mitigation planning for biodiversity have produced best practices and data systems to help facilitate effective impact assessment. These include criteria for prioritizing protection of species and habitat areas based on concepts of rarity and vulnerability (Tallis et al., 2015) and spatial frameworks that identify conflicts between development proposals and with conservation goals (Saenz et al., 2013). These have been widely adopted in EIA law and policy (Villarroya et al., 2014) and are recognized by developers and lenders (IFC, 2012), with resulting benefits for biodiversity conservation. Similar criteria and frameworks for social and cultural values have not been universally accepted. As Indigenous communities define these criteria, this will help facilitate and strengthen the incorporation of their values into development approval processes.

Given growing global resource demands (Oakleaf et al., 2015), land use conflicts are likely to increase with profound implications for both biodiversity and Indigenous land values. Incorporating the likelihood of future change into land-use planning can alleviate uncertainty and ultimately make societal adaptation to change more efficient and less costly (Kennedy et al., 2016a, 2016b). Predicting and quantifying future impacts can help to justify proactive protection of places important to Indigenous communities and biodiversity and to underscore the consequences of failing to do so (Kiesecker et al., 2017). We hope our study will motivate regulatory agencies and land managers to proactively map social, cultural, and biodiversity values and forecast impacts at the landscape level, and use this information to avoid a business-as-usual development trajectory. Proactive planning to predict and avoid impacts to social and biological values will, in the long run, be the less costly and more sustainable path.

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Declarations of interest

None.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eiar.2018.09.002.

References

Altman, J.C., 1987. Hunter Gatherer's Today: An Aboriginal Economy in North Australia. Australian Institute of Aboriginal Studies, Canberra.

Altman, J.C., Buchanan, G.J., Larsen, L., 2007. The environmental significance of the Indigenous estate: natural resource management as economic development in remote Australia. Centre for Aboriginal Economic Policy Research, Canberra.

Ansell, S., Koenig, J., 2011. CyberTracker: an integral management tool used by rangers in the Djelk Indigenous Protected Area, central Arnhem Land, Australia. Ecol. Manag. Restor. 12, 13–22.

Arce-Gomez, A., Donovan, J.D., Bedggood, R.E., 2015. Social impact assessments: Developing a consolidated conceptual framework. Environ. Impact Assess. Rev. 50, 85–94.

Asafu-Adjaye, J., 1996. Traditional production activities and resource sustainability: The case of Indigenous societies in Cape York Peninsula, Australia. Int. J. Social Econ. 23, 125–135.

Atlas of Living Australia, 2018. http://www.ala.org.au, Accessed date: 21 February 2018.

Austin, B., Vigilante, T., Cowell, S., Dutton, I., Djanghara, D., Mangolomara, S., Puermora, B., Bundamurra, A., Clement, Z., 2017. The Uunguu Monitoring & Evaluation Committee: Intercultural governance of a land and sea management program in the Kimberley, Australia. Ecol. Manag. Restor. 18, 124–133.

Austin, B.J., Robinson, C.J., Fitzsimons, J.A., Sandford, M., Ens, E.J., Macdonald, J.M., Hockings, M., Hinchley, D.G., McDonald, F.B., Corrigan, C., Kennett, R., Hunter-Xenie, H., Garnett, S.T., 2018. Integrated Measures of Indigenous Land and Sea Management Effectiveness: Challenges and Opportunities for Improved Conservation Partnerships in Australia. Conservation and Society 16 (3), 372–384.

Australian Government, 2015. Our North, Our Future: White Paper on Developing Northern Australia. Australian Government, Canberra.

Australian Heritage Council, 2011. West Kimberley Place Report. Australian Government, Canberra.

Bartolo, R.E., Van Dam, R.A., Bayliss, P., 2012. Regional ecological risk assessment for Australia's tropical rivers: Application of the relative risk model. Hum. Ecol. Risk. Assess. 18 (1), 16–46.

Bradshaw, C.J.A., 2012. Little left to lose: deforestation and forest degradation in Australia since European colonization. J. Plant Ecol. 5, 109–120.

Bridge, G., 2004. Contested terrain: mining and the environment. Annu. Rev. Environ. Resour. 29, 205–259.

Carr, B., Fitzsimons, J., Holland, N., Berkinshaw, T., Bradby, K., Cowell, S., Deegan, P., Koch, P., Looker, M., Varcoe, T., Walsh, P., Wiesenberger, F., 2017. CAPitalising on conservation knowledge: Using Conservation Action Planning, Healthy Country Planning and the Open Standards in Australia. Ecol. Manag. Restor. 18, 176–189.

Carwardine, J., O'Connor, T., Legge, S., Mackey, B., Possingham, H.P., Martin, T.G., 2011. Priority threat management to protect Kimberley wildlife. CSIRO Ecosystem Sciences, Brisbane.

Carwardine, J., O'Connor, T., Legge, S., Mackey, B., Possingham, H.P., Martin, T.G., 2012. Prioritizing threat management for biodiversity conservation. Conserv. Lett. 5, 196–204.

Chan, K.M., Guerry, A.D., Balvanera, P., Klain, S., Satterfield, T., Basurto, X., Bostrom, A., Chuenpagdee, R., Gould, R., Halpern, B.S., Hannahs, N., Levine, J., Norton, B., Ruckelshaus, M., Russell, R., Tam, J., Woodside, U., 2012. Where are cultural and social in ecosystem services? A framework for constructive engagement. Bioscience 62 (8), 744–756.

Chan, K.M., Balvanera, P., Benessaiah, K., Chapman, M., Díaz, S., Gómez-Baggethun, E., Gould, R., Hannahs, N., Jax, K., Klain, S., Luck, G.W., Martín-López, B., Muraca, B., Norton, B., Ott, K., Pascual, U., Satterfield, T., Tadaki, M., Taggart, J., Turner, N., 2016. Why protect nature? Rethinking values and the environment. Proc. Natl. Acad. Sci. 113 (6), 1462–1465.

Davis, J.A., Kerezsy, A., Nicol, S., 2017. Springs: Conserving perennial water is critical in arid landscapes. Biol. Conserv. 211 (Part B) 30–35.

Department of Primary Industries and Regional Development, 2017. Water for Food initiative. In: Department of Primary Industries and Regional Development, . http://www.drd.wa.gov.au/projects/Agriculture/Pages/Water-for-Food-initiative.aspx Accessed 8 September 2017.

Department of the Environment, 2015. Wildlife Conservation Plan for Migratory Shorebirds. Commonwealth of Australia, Canberra.

Department of the Environment, 2016. EPBC Act Protected Matters Search Tool. http://www.environment.gov.au/epbc/protected-matters-search-tool. Accessed 14 Jan 2016.

DSEWPC, 2012. Environment Protection and Biodiversity Conservation Act 1999 Environmental Offsets Policy. Department of Sustainability, Environment, Water, Population and Communities, Canberra.

Dunn, A.M., Weston, M.A., 2008. A review of terrestrial bird atlases of the world and their application. Emu 108, 42–67.

Environment Australia, 2000. Revision of the Interim Biogeographic Regionalisation for Australia (IBRA) and Development of Version 5.1: Summary report. http://www.environment.gov.au/system/files/resources/401ff882-fc13-49cd-81fe-bc127d16ced1/files/revision-ibra-development-5-1-summary-report.pdf.

E.P.B.C., 1999. Environment protection and biodiversity conservation act. Commonwealth of Australia.

Fitzsimons, J.A., Michael, D.R., 2017. Rocky outcrops: A hard road in the conservation of critical habitats. Biol. Conserv. 211 (Part B) 36–44.

Fitzsimons, J., Legge, S., Traill, B., Woinarski, J., 2010. Into Oblivion? The disappearing native mammals of northern Australia. The Nature Conservancy, Melbourne.

Fitzsimons, J., Heiner, M., McKenney, B., Sochi, K., Kiesecker, J., 2014. Development by Design in Western Australia: Overcoming offset obstacles. Land 3, 167–187.

Franks, D.M., Davis, R., Bebbington, A.J., Ali, S.H., Kemp, D., Scurrah, M., 2014. Conflict translates environmental and social risk into business costs. Proc. Natl. Acad. Sci. 111 (21), 7576–7581.

Gallant, J.C., Dowling, T.I., Read, A.M., Wilson, N., Tickle, P., Inskeep, C., 2011. 1 second SRTM Derived Digital Elevation Models User Guide. Geoscience Australia. www.ga.gov.au/topographic-mapping/digital-elevation-data.html.

Garnett, S.T., Sithole, B., Whitehead, P.J., Burgess, C.P., Johnston, F.H., Lea, T., 2009. Healthy country, healthy people: policy implications of links between Indigenous human health and environmental condition in tropical Australia. Austral. J. Public Administ. 68 (1), 53–66.

Geneletti, D., 2015. A conceptual approach to promote the integration of ecosystem services in strategic environmental assessment. J. Environ. Assess. Pol. Manage. 17 (4), 1550035.

Geoscience Australia, 2011. DEM-H. 1 second SRTM Derived Products. http://www.ga.gov.au/metadata-gateway/metadata/record/71498. Accessed 1-Dec-2016.

GeoScience Australia, 2015. Surface Hydrology Polygons (Regional). http://www.ga.gov.au/metadata-gateway/metadata/record/83143. Accessed 14-Dec-2016.

Groves, C., 2003. Drafting a Conservation Blueprint: A Practitioner's Guide to Planning for Biodiversity. Island Press, Washington.

Groves, C., Jensen, D., Valutis, L., Redford, K., Shaffer, M., Scott, J., Baumgartner, J., Higgins, J., Beck, M., Anderson, M., 2002. Planning for biodiversity conservation: Putting conservation science into practice. Bioscience 52, 499–512.

Hanna, P., Vanclay, F., 2013. Human rights, Indigenous peoples and the concept of Free, Prior and Informed Consent. Impact Assess. Proj. Apprais. 31, 146–157.

Hawdon, A., Parham, E., Marsh, D., 2015. Biodiversity Offset Schemes Country Summary Report. Flora and Fauna International, Australia.

Hill, R., Pert, P.L., Davies, J., Robinson, C.J., Walsh, F., Falco-Mammone, F., 2013. Indigenous Land Management in Australia: Extent, scope, diversity, barriers and success factors. CSIRO Ecosystem Sciences, Cairns.

Hilson, G., 2002. An overview of land use conflicts in mining communities. Land Use Policy 19, 65–73.

Hunter, M.L., 1991. In: Kohm, K.A. (Ed.), Coping with ignorance: The coarse filter strategy for maintaining biodiversity. Island Press, Washington, pp. 266–281 Balancing on the Brink of Extinction.

Hunter, M.L., Jacobson Jr., G.L., Webb, T., 1988. Paleoecology and the coarse filter approach to maintaining biological diversity. Conserv. Biol. 2, 375–385.

IFC, 2012. IFC Performance Standards Environmental and Social Sustainability. International Finance Corporation, Washington, DC.

IUCN, 2017. The IUCN Red List of Threatened Species. Version 2017–3. < http://www.iucnredlist.org > .

Jackson, S., Robinson, C., 2009. Indigenous participation in water planning and management. In: Stone, P. (Ed.), Northern Australia Land and Water Science Review. *Northern Australia Land and Water* Taskforce and CSIRO, Canberra, pp. 15.1–15.29.

Jackson, S., Finn, M., Featherston, P., 2012. Aquatic resource use by Indigenous Australians in two tropical river catchments: the Fitzroy River and Daly River. Hum. Ecol. 40 (6), 893–908.

Jaensch, R., Watkins, D., 1999. Nomination of additional Ramsar wetlands in Western Australia. Unpublished report from Wetlands International–Oceania to CALM.

Joint Select Committee on Northern Australia, 2014. Pivot North. Inquiry into the Development of Northern Australia - Final Report. The Parliament of the Commonwealth of Australia, Canberra.

Jupp, T., Fitzsimons, J., Carr, B., See, P., 2016. New partnerships for managing large desert landscapes: experiences from the Martu Living Deserts Project. Rangel. J. 37 (6), 571–582.

Karrasch, L., 2016. Matching an ecosystem services approach with Social Impact Assessment. In: Geneletti, D. (Ed.), Handbook on Biodiversity and Ecosystem Services in Impact Assessment. Edward Elgar Publishing, Cheltenham, pp. 86–112.

Kennedy, C.M., Miteva, D.A., Baumgarten, L., Hawthorne, P.L., Sochi, K., Polasky, S., Oakleaf, J.R., Uhlhorn, E.M., Kiesecker, J., 2016a. Bigger is better: Improved nature conservation and economic returns from landscape-level mitigation. Sci. Adv. 2 (7), e1501021.

Kennedy, C.M., Hawthorne, P.L., Miteva, D.A., Baumgarten, L., Sochi, K., Matsumoto, M., Evans, J.S., Polasky, S., Hamel, P., Vieira, E.M., Develey, P.F., Sekercioglu, C.H., Davidson, A.D., Ulhorn, E.M., Kiesecker, J.M., 2016b. Optimizing land use decision-making to sustain Brazilian agricultural profits, biodiversity and ecosystem services. Biol. Conserv. 204, 221–230.

Kiesecker, J.M., Naugle, D.E. (Eds.), 2017. Energy Sprawl Solutions: Balancing Global Development and Conservation. Island Press, Washington DC.

Kiesecker, J.M., Copeland, H., Pocewicz, A., McKenney, B., 2010. Development by design: blending landscape-level planning with the mitigation hierarchy. Front. Ecol.

Environ. 8, 261–266.
Kiesecker, J., Sochi, K., Evans, J., Kennedy, C.M., Heiner, M., Oakleaf, J., 2017. Conservation in the real world: Pragmatism does not equal surrender. In: Kareiva, P., Marvier, M., Silliman, B. (Eds.), Effective Conservation Science: Data Not Dogma. Oxford University Press, Oxford, pp. 152–159.
Lane, J., Jaensch, R., Lynch, R., Elscot, S., 1996. A directory of important wetlands in Australia. https://www.environment.gov.au/system/files/resources/18f0bb21-b67c-4e99-a155-cb5255398568/files/directory-ch12.pdf.
Langhammer, P.F., Bakarr, M.I., Bennun, L., Brooks, T.M., 2007. Identification and gap analysis of key biodiversity areas: targets for comprehensive protected area systems. No. 15. IUCN.
Lewis, D.L., Brocklehurst, P.B., Thackway, R., Hill, J.V., 2008. Adopting national vegetation guidelines and the National Vegetation Information System (NVIS) framework in the Northern Territory. Cunninghamia 10, 557–567.
Lindenmayer, D., Scheele, B., 2017. Do not publish. Science 356 (6340), 800–801.
MacKay, F., 2004. Indigenous people's right to free, prior and informed consent and the World Bank's Extractive Industries Review. Sust. Develop. L. Policy 4, 43–65.
Maron, M., Bull, J.W., Evans, M.C., Gordon, A., 2015. Locking in loss: Baselines of decline in Australian biodiversity offset policies. Biol. Conserv. 192, 504–512.
McKenney, B., Kiesecker, J.M., 2010. Policy development for biodiversity offsets: A review of offset frameworks. Environ. Manag. 45, 165–176.
McKenzie, N.L., Start, A.N., Burbidge, A.A., Kenneally, K.F., Burrows, N.D., 2009. Protecting the Kimberley: a synthesis of scientific knowledge to support conservation management in the Kimberley region of Western Australia. Department of Environment and Conservation, Perth.
Millennium Ecosystem Assessment, 2005. Ecosystems and human well-being. Island Press, Washington, D.C.
Moorcroft, H., Ignjic, E., Cowell, S., Goonack, J., Mangolomara, S., Oobagooma, J., Karadada, R., Williams, D., Waina, N., 2012. Conservation planning in a cross-cultural context: the Wunambal Gaambera healthy country project in the Kimberley, Western Australia. Ecol. Manag. Restor. 13, 16–25.
Morán-Ordóñez, A., Whitehead, A.L., Luck, G.W., Cook, G.D., Maggini, R., Fitzsimons, J.A., Wintle, B.A., 2017. Analysis of trade-offs between biodiversity, carbon farming and agricultural development in Northern Australia reveals the benefits of strategic planning. Conserv. Lett. 10, 94–104.
Morgan, R.K., 2012. Environmental impact assessment: The state of the art. Impact Assess. Proj. Apprais. 30, 1–10.
Morgan, D.L., Allen, M., Bedford, P., Horstman, M., 2004. Fish fauna of the Fitzroy River in the Kimberley region of Western Australia-including the Bunuba, Gooniyandi, Ngarinyin, Nyikina and Walmajarri aboriginal names. Rec. West. Austral. Mus. 22, 147–161.
Morgan, D., Thorburn, D., Fenton, J., Wallace-Smith, H., Goodson, S., 2005. Influence of the Camballin Barrage on fish communities in the Fitzroy River, Western Australia. Murdoch University/Kimberley Land Council/Department of Environment report to Land and Water Australia, Canberra.
National Native Title Tribunal, 2014. Extract from the National Native Title Register WAD6099/1998 http://www.nntt.gov.au/searchRegApps/NativeTitleRegisters/NNTR Extracts/WCD2014_003/NNTRExtract_WCD2014_003.pdf accessed 7-Mar-2018.
National Native Title Tribunal, 2018. National Native Title Register (Determinations) - Boundaries and Core Attributes. Perth, Western Australia. http://www.nntt.gov.au/assistance/Geospatial/Pages/Metadata.aspx?filename=%20NTD_Register_NAT. accessed 7-Mar-2018.
North Australian Indigenous Experts Panel, 2012. Indigenous futures and sustainable development in north Australia. Towards a framework for full Indigenous participation in economic development. Discussion Paper. NAILSMA Knowledge Series 018/2013. North Australian Indigenous Land and Sea Management Alliance Ltd, Darwin.
Northern Australia Fire Information, 2016. North Australian MODIS Late Fire Frequency Mapping 2000-2016. Charles Darwin University, Darwin, Northern Territory, Australia Accessed 18-Feb-2017. http://www.firenorth.org.au/nafi3/.
Noss, R.F., 1996. Ecosystems as conservation targets. Trends Ecol. Evol. 11, 351.
Oakleaf, J.R., Kennedy, C.M., Baruch-Mordo, S., West, P.C., Gerber, J.S., Jarvis, L., Kiesecker, J., 2015. A world at risk: Aggregating development trends to forecast global habitat conversion. PLoS One 10, e0138334.
Olson, D.M., Dinerstein, E., Wikramanayake, E.D., Burgess, N.D., Powell, G.V.N., Underwood, E.C., D'Amico, J.A., Itoua, I., Strand, H.E., Morrison, J.C., Loucks, C.J., Allnutt, T.F., Ricketts, T.H., Kura, Y., Lamoreux, J.F., Wettengel, W.W., Hedao, P., Kassem, K.R., 2001. Terrestrial ecoregions of the world: a new map of life on Earth. Bioscience 51, 933–938.
Oxfam, International Land Coalition, Rights and Resources Initiative, 2016. Common Ground Securing Land Rights and Safeguarding the Earth. Available online. https://landrightsnow.contentfiles.net/media/assets/file/GCA_REPORT_EN_FINAL.pdf (accessed on 1 November 2017).
Partal, A., Dunphy, K., 2016. Cultural impact assessment: a systematic literature review of current methods and practice around the world. Impact Assess Project Appras. 34, 1–13.
Pascua, P.A., McMillen, H., Ticktin, T., Vaughan, M., Winter, K.B., 2017. Beyond services: a process and framework to incorporate cultural, genealogical, place-based, and Indigenous relationships in ecosystem service assessments. Eco. Serv. 26, 465–475.
Pepper, M., Keogh, J.S., 2014. Biogeography of the Kimberley, Western Australia: a review of landscape evolution and biotic response in an ancient refugium. J. Biogeogr. 41, 1443–1455.
Queensland Department of Natural Resources, Mines, and Energy, 2018. Queensland Globe. https://qldglobe.information.qld.gov.au.
Raiter, K.G., Possingham, H.P., Prober, S.M., Hobbs, R.J., 2014. Under the radar: mitigating enigmatic ecological impacts. Trends Ecol. Evol. 29, 635–644.
Ricketts, T.H., Dinerstein, E., Boucher, T., Brooks, T.M., Butchart, S.H.M., Hoffmann, M., Lamoreux, J.F., Morrison, J., Parr, M., Pilgrim, J.D., Rodrigues, A.S., 2005. Pinpointing and preventing imminent extinctions. Proc. Natl. Acad. Sci. 102 (51), 18497–18501.
Russell-Smith, J., Whitehead, P., Cooke, P. (Eds.), 2009. Culture, Ecology and Economy of Fire Management in North Australian Savannas: Rekindling the Wurrk Tradition. CSIRO Publishing, Melbourne.
Russell-Smith, J., Yates, C.P., Edwards, A.C., Whitehead, P.J., Murphy, B.P., Lawes, M.J., 2015. Deriving multiple benefits from carbon market-based savanna fire management: An Australian example. PLoS One 10, e0143426.
Saenz, S., Walschburger, T., González, J.C., León, J., McKenney, B., Kiesecker, J.M., 2013. A framework for implementing and valuing biodiversity offsets in Colombia: A landscape scale perspective. Sustain. For. 5, 4961–4987.
Schwartz, M.W., Deiner, K., Forrester, T., Grof-Tisza, P., Muir, M.J., Santos, M.J., Souza, L.E., Wilkerson, M.L., Zylberberg, M., 2012. Perspectives on the open standards for the practice of conservation. Biol. Conserv. 155, 169–177.
Smith, M.P., Schiff, R., Olivero, A., MacBroom, J.G., 2008. The active river area: A conservation framework for protecting rivers and streams. The Nature Conservancy, Boston, MA Available online at. https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/edc/Documents/ED_freshwater_ARA_NE2008.pdf.
Spatial Networks, Inc, 2018. Fulcrum data collection platform. http://www.fulcrumapp.com.
Tallis, H., Kennedy, C.M., Ruckelshaus, M., Goldstein, J., Kiesecker, J., 2015. Mitigation for one & all: An integrated framework for mitigation of development impacts on biodiversity and ecosystem services. Environ. Impact Assess. Rev. 55, 21–34.
TEEB, 2011. The Economics of Ecosystems and Biodiversity in National and International Policy Making. Edited by Patrick ten Brink. Earthscan, London and Washington.
Thackway, R., Cresswell, I.D., 1995. An Interim Biogeographic Regionalisation for Australia: a framework for establishing the national system of reserves. Version 4.0. Australian Nature Conservation Agency, Canberra.
Toussaint, S., Sullivan, P., Yu, S., 2005. Water ways in Aboriginal Australia: an interconnected analysis. Anthropol. Forum 15, 61–74.
United Nations, 2008. United Nations Declaration on the Rights of Indigenous Peoples. https://www.un.org/development/desa/indigenouspeoples/declaration-on-the-rights-of-indigenous-peoples.html.
USGS, 2015. National Center for Earth Resources Observation and Science (EROS). Available online. http://earthexplorer.usgs.gov/, Accessed date: 19 January 2017.
Vanclay, F., 2003. International principles for social impact assessment. Impact Assess. Proj. Apprais. 21 (1), 5–12.
Vanclay, F., Esteves, A.M., Aucamp, I., Franks, D.M., 2015. Social Impact Assessment: Guidance for assessing and managing the social impacts of projects. International Association for Impact Assessment. Fargo, USA.
Vernes, T., 2007. Establishing priorities for wetland conservation and management in the Kimberley. WWF-Australia, Sydney.
Villarroya, A., Barros, A.C., Kiesecker, J., 2014. Policy development for environmental licensing and biodiversity offsets in Latin America. PLoS One 9, e107144.
Vogwill, R., 2015. Water Resources of the Mardoowarra (Fitzroy River) Catchment. University of Western Australia, Perth.
WA DPaW, 2015. Threatened and Priority Flora Information. Datasets Provided to Walalakoo Aboriginal Corporation on 16-Jan-2015. Records from WA DPaW Threatened (Declared Rare) and Priority Flora (TPFL) database and Western Australian Herbarium Specimen (WAHERB) Database for Threatened and Priority flora species. Government of Western Australia, Perth.
WA DPaW, 2016a. Threatened and Priority Fauna Information. Dataset provided to Walalakoo Aboriginal Corporation on 11-April-2016. Government of Western Australia, Perth, Australia.
WA DPaW, 2016b. Threatened and Priority Ecological Communities Information. Dataset provided to Walalakoo Aboriginal Corporation on 15-April-2016. Government of Western Australia, Perth, Australia.
Walalakoo Aboriginal Corporation, 2017. Walalakoo Healthy Country Plan 2017-2027. Walalakoo Aboriginal Corporation, Derby.
Walton, N., Fitzsimons, J., 2015. Payment for ecosystem services in practice – savanna burning and carbon abatement at Fish River, northern Australia. In: Figgis, P., Mackey, B., Fitzsimons, J., Irving, J., Clarke, P. (Eds.), Valuing Nature: Protected Areas and Ecosystem Services. Australian Committee for IUCN, Sydney, pp. 78–83.
Watson, J., Watson, A., Poelina, A., Poelina, N., Watson, W., Camilleri, J., Vernes, T., 2011. Nyikina and Mangala Mardoowarra Wila Booroo: Natural and Cultural Heritage Plan. Providing information to plan for and manage activities on Nyikina and Mangala country while protecting culture and the environment. WWF-Australia, Sydney.
Western Australian Land Information Authority, 2018. Landgate. https://www0.landgate.wa.gov.au.
Wily, L.A., Dubertret, F., Veit, P., Reytar, K., Tagliarino, N.K., 2017. Water rights on community Llands: LandMark's findings from 100 countries. Land 6 (4), 1–18.
Woinarski, J.C.Z., Mackey, B., Nix, H., Traill, B., 2007. The nature of northern Australia: natural values, ecological processes and future prospects. ANU e-press, Canberra.
Woinarski, J.C.Z., Legge, S., Fitzsimons, J.A., Traill, B.J., Burbidge, A.A., Fisher, A., Firth, R.S.C., Gordon, I.J., Griffiths, A.D., Johnson, C., McKenzie, N.L., Palmer, C., Radford, I., Rankmore, B., Ritchie, E., Ward, S., Ziembicki, M., 2011. The disappearing mammal fauna of northern Australia: context, cause and response. Conserv. Lett. 4, 192–201.