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Integrating indigenous ecological and scientific hydro-geological knowledge using a Bayesian Network in the context of water resource development

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SUMMARY

The contributions indigenous ecological knowledge can make to better inform water management decisions are currently undervalued leading to an underrepresentation of indigenous values in water planning and policy. This paper outlines a novel approach in which indigenous ecological knowledge informs cause and effect relationships between species and aquatic habitats to promote broader ecosystem understanding. A Bayesian Network was developed to synthesise the seasonal aquatic knowledge of a group of Gooniyandi Aboriginal language speakers, including fish species' availability, condition and required habitat, and integrate it with hydrogeological understanding obtained from research undertaken in a stretch of the Fitzroy River, Western Australia. This river system, like most in northern Australia, is highly seasonal and entirely dependent upon groundwater for maintaining flow during prolonged dry seasons. We found that potential changes in river flow rates caused by future water resource development, such as groundwater extraction and surface water diversion, may have detrimental effects on the ability to catch the high value aquatic food species such as Barramundi and Sawfish, but also that species such as Black Bream may benefit. These findings result from changes in availability of habitats at times when Gooniyandi understanding shows they are important for providing aquatic resources in good condition. This study raises awareness of the potential outcomes of future water management and stimulates communication between indigenous people, the scientific community and water managers by developing a model of indigenous understanding from which to predict eco-hydrological change.

1. Introduction

Interest in the application of indigenous ecological knowledge to contemporary resource management problems is increasing globally (Stephenson and Moller, 2009; Bohensky and Maru, 2011). However, there are few studies of indigenous knowledge that have contributed to water planning (Esselman and Opperman, 2010; Woodward et al., 2012). In those regions of the world where systems of customary resource management remain, indigenous knowledge represents a source of detailed information about local ecosystem patterns and process. Indigenous knowledge, which can be 'geographically and temporally more extensive' (Fraser et al., 2006) than research-based (or scientific) knowledge, may be of value to researchers and water managers for its empirical strength. The potential utility of this form ofknowledge to mainstream natural resource managers can be enhanced when combined with research-based knowledge that relies on quantitative field-sampling techniques and analysis.

The aspect of indigenous knowledge of most interest to scientists and natural resource managers is the tacit, practical knowledge gained from centuries of daily resource use (Butler, 2006; Prober et al., 2011). Esselman and Opperman (2010) for example surveyed the fish biology literature and concluded that indigenous fishermen have the ability to recognise taxa, fish behavioural traits and spatiotemporal changes in species composition across seasons and in addition can attribute scientifically accurate causation to complex limnological occurrences. In under-studied regions, some of this tacit knowledge is likely to be new to science. For example, a study of indigenous knowledge of fish distributions in the Kimberley, Western Australia (Morgan et al., 2004) greatly extended the known range of several fish species.

The literature on indigenous ecological knowledge (Berkes, 2004) emphasises the means by which it is transmitted and the

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longevity of its utility. Many authors also stress its dynamic nature in response to stereotypical images of traditional knowledge as static or unchanging (Butler, 2006). Studies of indigenous ecological knowledge are growing in popularity in current scientific endeavours informing natural resource management in northern Australia (Ens et al., 2012; Russell-Smith et al., 2009; Hill et al., 2012).

The management context for our inquiry is water resource planning. Water is becoming an increasingly valuable resource in the wet-dry tropics and there is growing interest in regulating and diverting water resources, particularly for irrigated agriculture (Blanch, 2008; Stone, 2009; Douglas et al., 2011). The ecological and hydrological impacts of increased human water use are currently poorly understood by the scientific community and data available for developing management recommendations are scarce or completely lacking for most rivers in tropical Australia (Pusey, 2011). Furthermore, indigenous people have distinct and diverse interests in the outcomes of water allocation decisions and therefore need to be involved in deliberating over the consequent costs and benefits of water use scenarios (Jackson et al., 2012a).

We contend that building a tool for both traditional owners and water managers that draws on local knowledge and builds trust and confidence in the process of discussing the impacts of various water development scenarios would be extremely valuable. This paper reports on a multi-disciplinary modelling exercise to integrate knowledge relating to the ecology and hydrology of the Fitzroy River catchment in Western Australia (Fig. 1). This 'proof of concept' analysis builds upon the work of two independent projects: one socio-economic (Jackson et al., 2011) and one hydrogeological (Gardner et al., 2011;), conducted within the Fitzroy River catchment in Western Australia and the Daly River catchment in the Northern Territory over 4 years (2007–2011) under the auspices of the Tropical Rivers and Coastal Knowledge research programme (TRaCK, www.track.gov.au). The socio-economic study had undertaken household surveys of aquatic resource use (Jackson et al., 2012b) and recorded indigenous ecological knowledge in the form of seasonal calendars (as reported by Woodward et al., 2012 for the Daly River region). The hydrogeological study had utilised novel environmental tracer techniques (Gardner et al., 2011) in conjunction with river chemistry and airborne geophysical surveys to investigate pathways for groundwater discharge into the Fitzroy River.

Predicting the ecological outcomes of altered natural systems, whether based on water resources management or climate change, is a complex task. The aim of this study was to investigate whether we could anticipate changes to a range of fish and other aquatic species of specific interest to indigenous people as a result of water development using an indigenous system of ecological understanding. This was achieved by developing an integrated model that draws upon both indigenous and western scientific sources of knowledge to investigate the impact of different water scenarios through change in flow (extraction, diversion and wet season rainfall) on the likelihood that particular habitat types will be present, and persist, at different stages of the annual hydrological cycle.

A Bayesian Network (BN) was chosen as the best modelling approach as it has been successfully used for studies on water resource management (Castelletti and Soncini-Sessa, 2007; Hart and Pollino, 2009) and the influence of management on species (Pollino et al., 2007; Bashari et al., 2009; Chan et al., 2012), as well as a tool to communicate indigenous ecological understanding in northern Australia (Liedloff et al., 2009; McGregor et al., 2010; van Putten et al., 2013). The many benefits of Bayesian Network modelling have been outlined in detail (Korb and Nicholson, 2004; Uusitalo, 2007) and relate to the ability of the model to

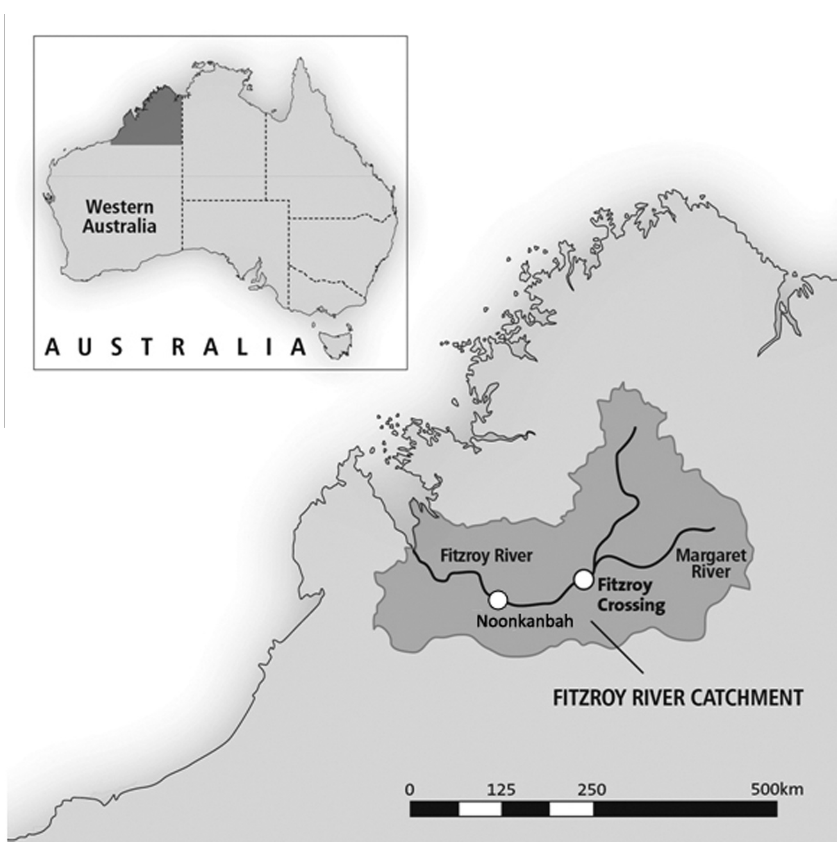

Fig. 1. Map of the Fitzroy River catchment, Western Australia.