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An Ecosystem Health Index for a large and variable river basin: Methodology, challenges and continuous improvement in Queensland's Fitzroy Basin

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ABSTRACT

Report cards are an increasingly popular method for summarising and communicating relative environmental performance and ecosystem health, including in aquatic environments. They are usually underpinned by an Ecosystem Health Index (EHI) that combines various individual indicators to produce an overall ecosystem health "score". As a result of public water quality concerns, an integrated means of monitoring and reporting on aquatic ecosystem health was needed for the Fitzroy Basin in central Queensland, Australia. The Fitzroy Partnership for River Health was formed to address this need, and developed an EHI and report card for the Basin using existing monitoring data collected from various third parties including regulated companies operations and government. At 142,000 square kilometres, the Fitzroy Basin is the largest catchment draining to the World Heritage Listed Great Barrier Reef. The Fitzroy Basin provides an example of how to deliver an effective aquatic ecosystem health reporting system in a large and complex river basin. We describe the methodology used to develop an adaptive EHI for the Fitzroy Basin that addresses variability, complexity and scale issues associated with reporting across large areas. As well, we report how to manage the design and reporting stages given limitations in data collection and scientific understanding.

1. Introduction

Rivers and wetlands globally continue to be degraded by various threats including habitat loss and pollution, and these threats are likely to increase with climate change (Kingsford, 2011). Despite the importance of these diverse habitats, the extent of wetland loss and degradation in Australia was estimated at more than 50% over the 200 years leading to the turn of the century (Finlayson, 2000) and freshwater wetland losses in the catchments of the eastern state of Queensland have been estimated at up to 80% (GBRMPA, 2014). The health of Queensland's rivers and wetlands is critical for protecting the Great Barrier Reef World Heritage Area from land-derived water pollution, and coastal development involving clearing or modifying these habitats has been identified as one of the greatest threats to the Great Barrier Reef ecosystem (GBRMPA, 2010, 2014). Many of the species and ecosystems of the Great Barrier Reef are reported to be declining principally as a result of catchment pollutant runoff, climate change impacts and fishing pressure (Brodie and Pearson, 2016).

In response to the increasingly urgent needs of decision makers and the public for scientifically robust information on waterway health in Queensland and worldwide, report cards have become a popular mechanism for communicating relative environmental performance, as they provide a means to facilitate the transformation of ecological indicators into management tools (Dauvin et al., 2008). For ecosystem health reporting, report cards are normally underpinned by some form of ecosystem health index (EHI),

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designed by combining information from a variety of individual indicators. Report cards that assess, score and report on aquatic ecosystem health are now used widely, with notable examples from South East Queensland, Australia (Bunn et al., 2010), the Gui River, China (International Water Centre, 2012), the Strickland River in Porgera, Papua New Guinea (Porgera Environmental Advisory Komiti, 2009) and Chesapeake Bay in the United States (University of Maryland, 2015). Three report cards are now in place for Queensland's Great Barrier Reef catchments: the Fitzroy Basin Report Card (the subject of this paper), the Gladstone Harbour Report Card (Gladstone Healthy Harbour Partnership, 2015) and the Mackay-Whitsunday Report Card (Healthy Rivers to Reef Partnership, 2015). Public concern around water quality can sometimes work as a catalyst for better environmental reporting, as was the case in most of these national and international examples, including the Fitzroy Basin.

Summarising environmental health into indicators is a challenging task. To be more than simply a "useful means of documenting decline", environmental monitoring and reporting should be adaptive, scientifically current, linked to clear objectives, responsive to changing values and importantly, be capable of guiding management actions and interventions (Bunn et al., 2010). These aims can be challenging to achieve at any scale, but there are particular challenges in river catchments that cover a large area, are geographically complex and are spatially and temporally variable in terms of the factors that influence aquatic ecosystems.

Ideally, an assessment of ecosystem health should be set within a contextual framework that links ecological systems with pressures and changes in a systematic way. Not every EHI is based on a formal framework; in some cases the indicators that form the basis of an index may be chosen by expert consensus or by other informal processes, such as availability.

Within the framework other challenges relate to the selection and combination of indicators to form an EHI. These must cover the full complexity of a system, or at least aim to do so as effectively as possible within current constraints whilst providing direction for future improvements. The balance of indicators selected also needs to be considered in terms of the total number of indicators – too many indicators would be costly to monitor and potentially complex to analyse and describe, while too few indicators may result in avoidable knowledge gaps (Wicks et al., 2010). This is particularly important in large river basins, such as the Fitzroy River Basin, where extensive monitoring in remote locations is costly and logistically challenging.

The case study application reported in this paper provides a demonstration of how to develop an EHI for a large and complex river system. The catchments of the Fitzroy Basin vary in terms of weather patterns, hydrology, geology, wetland types and human impacts. A large portion of the Fitzroy Basin lies above the Permian coal rich Bowen Basin, one of Queensland's most economically important coal deposits. In 2011 there were 48 operating open cut and underground coal mines in the Bowen Basin with another 38 coal projects and advanced coal projects in varying stages of planning or preparation (DEEDI, 2012). In an effort to reduce the amount of water held on site (and in turn, reduce the risk of uncontrolled releases) when operating conditions are met, mine water has been permitted to be released into the freshwater tributaries of the Fitzroy Basin. An uncontrolled mine water release occurred during a major flood event in 2008, where the levee banks of an open cut coal mine near the town of Emerald broke, causing flood water to inundate the mine's coal pit. When the water was discharged from the mine pit into one of the many freshwater tributaries in the Fitzroy Basin catchment, the receiving water quality was affected (Tripodi and Limpus, 2011). Following the 2008 floods, an investigative report into the water quality concerns (Hart, 2008) and a subsequent cumulative impact assessment study (DERM, 2009b), highlighted a need to develop an integrated system for monitoring and reporting on water quality in the Fitzroy Basin.

In 2009, varied stakeholders including coal and gas mining companies, agricultural bodies, government agencies, research institutions and community organisations, drew together to form the Fitzroy Partnership for River Health (FPRH), with an aim to "develop and implement an integrated waterway monitoring programme that will report publicly on waterway health on the catchment scale, and support improved water resource management by all sectors" (FPRH, 2012). The Fitzroy Basin Report Card was developed by FPRH to achieve this aim, and is underpinned by an EHI, described in this paper.

The case of the Fitzroy Basin provides a working example of how to develop and maintain an EHI that can utilise and interpret mixed data sources and deal with the variability, complexity and scale of large catchment areas, to deliver effective aquatic ecosystem health reporting products. This paper describes the methodology for the development of the Fitzroy Basin EHI, and discusses the results, challenges and continuous improvement required when establishing an EHI for a large and variable river basin.

2. Methodology

2.1. Study area

With a combined catchment area of over 142,000 km^2 the Fitzroy Basin is the largest catchment on the east coast of Australia (Noble et al., 2005) and the largest river basin flowing into the Great Barrier Reef lagoon. The Fitzroy is characterised by a highly variable flow regime with ephemeral streams in its upper reaches (Hart, 2008), large tidal volumes in the estuary, and due to its large size and fan like shape, periods of extensive riverine flooding following heavy rains (FBA, 2008). These factors contribute to high suspended sediment volumes (estimated at nearly two million tonnes per annum; Dougall et al., 2014) and turbidity levels, that vary in response to the tidal cycle and most prevalently in response to catchment inflows. Jones et al. (2014) reported that in one of the eleven catchments of the Fitzroy Basin, approximately 90 percent of turbidity data from 2008 to 2013 were above the regional water quality objective (<50 Nephelometric Turbidity Units), and that the extent of potential contaminants transported and/or released by these particulates was not yet known.

The Fitzroy Basin has seven major tributaries (Fig. 1) as well as numerous streams, waterholes and impoundments. The rivers of the Fitzroy Basin are heavily modified, with 28 dams and weirs impacting on ecosystem connectivity. The Basin experiences extremes in weather, with severe droughts during El Nino years and major flooding after heavy rain events (BOM, 2011). High flows may also occur in the Fitzroy Basin outside of flood events, as recorded recently during 2010/11 (Jones and Moss, 2011). The Fitzroy River estuary is shallow and tide-dominated with extensive intertidal marine plains, salt flats and tidal sand banks (Eberhard, 2012).

The catchments of the Fitzroy Basin are characterised by variations in the human impacts between areas, including different patterns of agricultural land use and resource development, as well as the system of dams and barrages that affect natural flows. These factors mean that an EHI has to be designed specifically for the Fitzroy Basin, and for the 11 river catchments within the Basin, rather than be simply transferred from other locations.

Almost 90 percent of land use in the Fitzroy Basin is agricultural – primarily cattle grazing (FBA, 2008). Historical gold, copper and silver mining at Mount Morgan has had significant ongoing impacts on the ecology of nearby freshwater tributaries. Vincente-Beckett et al. (2016) concluded that acid-mine drainage from the abandoned mine at Mt Morgan has contaminated surface and sub-