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Review

A review of Australian approaches for monitoring, assessing and reporting estuarine condition: III. Evaluation against international best practice and recommendations for the future

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ABSTRACT

In this final component of a three-part review, we present a national synthesis and evaluation of approaches for monitoring, assessing and reporting estuarine condition across Australia. Progress is evaluated against objective criteria that together provide a model of international best practice. We critically assess the limitations, inconsistencies and gaps that are evident across Australian jurisdictions, and identify common obstacles to future progress. Major strengths and successes are also highlighted, together with specific examples of best practice from around Australia that are transferable to other States and beyond. Significant obstacles to greater national coordination of monitoring and reporting practices include inconsistent spatial scales of management, pluralistic governance structures and the lack of any overarching legislation. Nonetheless, many perceptible advances have been made over the last decade across Australia in estuarine monitoring and health assessment, and there is great potential for further progress. Finally, we provide a list of recommendations to address some of the most pressing limitations and gaps, and support improved future monitoring, assessment and reporting for Australian estuaries.

1. Introduction

The implementation of the European Union (EU) Water Framework Directive (WFD) in 2000 aimed to harmonize fragmented policies for water resource management across Europe under a coordinated legislative framework. It expanded the scope of water protection to both surface waters (i.e. rivers, lakes, coastal waters, 'transitional waters' such as estuaries and rias) and groundwater, and placed at the forefront of management the goal of protecting the ecological quality of water resources (Chave, 2001; Kallis and Butler, 2001; Hering et al., 2010). By stipulating that water management should be based on river basins, the WFD also seeks to encourage greater coordination of management by replacing systems defined by administrative or political boundaries with those focused on natural geographical and hydrological units (Moss, 2012).

Significantly, the WFD required EU Member States to achieve specific water management objectives by set dates, e.g. achieving 'good chemical and ecological status' for all estuaries and other transitional waters by 2015 (Borja et al., 2012). This has resulted in substantial changes to the assessment, monitoring and reporting of estuarine condition across Europe. The focus on ecological status has engendered a more holistic view of estuarine condition, with 'ecological status' being reflected by five biological quality elements, i.e. phytoplankton, macroinvertebrates, macroalgae, phanerogams, and fishes (Borja et al., 2012). Additionally, the need to define ecological status and the question of how best to quantify it have generated an enormous volume of research to develop and test suitable indicators (Devlin et al., 2007; Schmutz et al., 2007; Pinto et al., 2009; Birk et al., 2012; Pérez-Domínguez et al., 2012). The broad remit of the WFD has also necessitated type-specific reference conditions (Verdonschot, 2006; Hering et al., 2010) and the harmonisation or intercalibration of assessment tools and methodologies (Heiskanen et al., 2004; Birk et al., 2013; Poikane et al., 2014) to enable fair and robust comparison of estuarine status across member States.

As noted by numerous sources, Australian programs for assessing, monitoring and reporting estuarine condition are typically in stark contrast to those described above, with issues around the governance, legislative and funding arrangements for

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estuarine management, and a lack of appropriate tools and robust data for quantifying estuarine condition and trends (NLWRA—National Land and Water Resources Audit, 2002a,b, 2008a,b; Beeton et al., 2006). Consequently, previous assessments of estuary condition across Australia have relied largely upon qualitative criteria (NLWRA—National Land and Water Resources Audit, 2002b, 2008b; Beeton et al., 2006; Borja et al., 2012). Borja et al. (2012) suggested, however, that a large number of emerging projects and programs were likely to address this deficiency in the coming years. In part II of the current review (Hallett et al., 2016c), we systematically documented many of these more recent (and existing) programs, providing State-by-State summaries and supporting detailed Appendices, which now provide a sound basis for evaluating recent Australian progress in this area.

Here, in the concluding part of the review, we provide a national-level synthesis of these Australian approaches to assessing, monitoring and reporting estuarine condition and evaluate them against the objective criteria reflecting international best practice that were established in Part I (Hallett et al., 2016b). We document examples of successes, progress and best practice within Australia, as well as notable weaknesses, gaps, inconsistencies and impediments to progress. Finally, we provide some recommendations to improve future understanding and reporting of estuarine health across Australia, couched within a broader adaptive management framework.

2. Synthesis and evaluation of Australian approaches

The following sections are structured to reflect the list of criteria against which Australian approaches were evaluated (Hallett et al., 2016b). These are listed in Table 1, which provides the detailed evaluation and examples of best practice across Australia.

2.1. Context, objectives and design of monitoring programs

Marine and estuarine management worldwide is typically underpinned by some variant of the DAPSI(W)R(M) framework, a recent development of the DPSIR (Drivers–Pressures–State Change–Impact–Response) approach (Atkins et al., 2011; Wolanski and Elliott, 2015). **D**rivers are basic human needs which generate **A**ctivities; these in turn create **P**ressures, as the mechanisms that lead to **S**tate change of the natural system and **I**mpacts on human **W**elfare. The latter changes then require societal **R**esponses, which are often termed **M**easures, and may include engineering approaches or economic or legal instruments. Any successful implementation of this framework will require effective monitoring, assessment and reporting of pressures, state changes and impacts, and effective management responses that target human activities.

Variants of this framework broadly underpin estuarine monitoring and reporting throughout much of Australia (*Criterion 1*), although the degree to which pressures (sometimes termed stressors) are explicitly quantified and communicated varies greatly among States (Table 1). New South Wales (NSW), for example, is moving towards an integrated strategy that encompasses measurements at each level of the above framework, thus enabling the outcomes of management actions to be assessed and communicated more effectively. However, quantitative data on many relevant pressures and activities are lacking for many estuaries in other States, which has critically hampered development of biotic indicators and the testing of causal relationships between pressures, estuarine state changes and impacts on human welfare (Arundel et al., 2008; Mount, 2008). Moreover, indicators of human impacts and management responses are rarely employed (Table 1), though several planned or recent programs in Queensland aim to incorporate social and economic indicators into their reporting.

Australian estuarine management programs now commonly employ conceptual models (Fig. 1) as a basis for understanding and managing estuaries, enabling managers to identify key environmental values/assets that require protection, and the threatening processes and pressures that impact on them. This allows specific management objectives to be established, around which the supporting monitoring programs are built, and management actions to be subsequently refined as part of an adaptive approach. The adoption of adaptive management practices, involving iterative cycles of monitoring, evaluation and reporting to address specific management objectives (*Criterion 2*), is an encouraging feature of several recent initiatives across Australia, e.g. the Tamar Estuary and Esk Rivers Ecosystem Health Assessment Program in Tasmania. Most notably, the current NSW Monitoring, Evaluation and Reporting (MER) Strategy (NSW DECCW, 2010) has a strong adaptive management focus and includes a Program Performance strand to ensure management practices are constantly evaluated and improved upon (Table 1). An imperative of this strategy is that monitoring data should be promptly analysed and used adaptively to refine the sampling regime and better address the relevant pressures (Roper et al., 2011).

The international examples considered in part I of this review (Hallett et al., 2016b) highlight the importance of national and international legislation in progressing estuarine monitoring and reporting (*Criterion 3*). In contrast, Australian legislative requirements for assessing, monitoring and reporting estuarine condition are generally fragmented (State of the Environment 2011 Committee, 2011), varying greatly not only between States but often between regions within a State (Table 1). This reflects the vesting of responsibility for the environment primarily with the States under the Australian Constitution (HC Coombs Policy Forum, 2011a), which complicates the development of overarching federal legislation that encompasses all aspects of estuarine management. Resulting impediments are widely documented, and include a lack of clarity of roles and responsibilities among federal, State, regional and local agencies, complex statutory frameworks, and issues around the longevity and stability of funding mechanisms and institutional commitment in the context of political cycles at both State and Commonwealth levels (HC Coombs Policy Forum, 2011a, b). Consequently, estuarine monitoring programs in Australia tend to be relatively short term and predominantly focussed on systems with existing major issues and high public profiles (Barton, 2003; Hirst, 2008; Table 1).

2.2. Monitoring elements and indicators

The value of holistic, ecologically-relevant approaches for measuring aquatic ecosystem condition is well-established (*Criterion 4*), underpinning legally-mandated directives for estuarine monitoring in Europe, South Africa and the USA. In Australia, several national-level documents and policies have long espoused a need to move toward a more holistic consideration of aquatic ecosystem health (ANZECC and ARMCANZ, 2000a,b). Bioassessment techniques are relatively well established in programs for monitoring river health or condition across Australia (Halse et al., 2002; Parsons et al., 2002; Bunn et al., 2010), e.g. the macroinvertebrate-based Australian River Assessment System (AUSRIVAS; www.ausrivas.ewater.com.au) (ANZECC and ARMCANZ, 2000a,b; Davies, 2000). Yet, Australia has been comparatively slow to apply bioassessment approaches to the monitoring and management of estuaries, with a persistent bias towards monitoring of physical and chemical aspects of water quality. Although this major gap was highlighted two decades ago (Harris, 1995; Norris and Norris, 1995), few such indicators have since been

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