A review of Australian approaches for monitoring, assessing and reporting estuarine condition: II. State and Territory programs

C.S. Hallett [a,] *, F.J. Valesini [a], P. Scanes [b], C. Crawford [c], B.M. Gillanders [d], A. Pope [e], J. Udy [f], J. Fortune [g], S. Townsend [g], J. Barton [e], Q. Ye [h], J. Ross [c], K. Martin [i], T. Glasby [j], P. Maxwell [f]

[a] Centre for Fish and Fisheries Research, School of Veterinary and Life Sciences, Murdoch University, South Street, Murdoch, Western Australia, Australia
[b] Estuaries and Catchments Science Unit, Office of Environment and Heritage, Sydney, New South Wales, Australia
[c] IMAS Fisheries and Aquaculture Centre, University of Tasmania, Hobart, Tasmania, Australia
[d] Southern Seas Ecology Laboratories, School of Biological Sciences & Environment Institute, University of Adelaide, South Australia, Australia
[e] School of Life and Environmental Sciences, Deakin University, Warrnambool, Victoria, Australia
[f] Healthy Waterways, Brisbane, Queensland, Australia
[g] Aquatic Health Unit, Department of Land Resource Management, Palmerston, Northern Territory, Australia
[h] Inland Waters and Catchment Ecology, South Australian Research and Development Institute, South Australia, Australia
[i] Great Barrier Reef Marine Park Authority, Townsville, Queensland, Australia
[j] Port Stephens Fisheries Institute, Department of Primary Industries, Port Stephens, New South Wales, Australia

* Corresponding author. Email: c.hallett@murdoch.edu.au Telephone: +61 8 9239 8808

Abstract

In contrast to Europe, the USA and South Africa, Australia has no specific, overarching federal legislation to underpin a nationally-coordinated framework for monitoring, assessing and reporting estuarine condition. This has resulted in a complex mosaic of diverse approaches and governance structures, hindering the ability to make inter-State comparisons. In this second part of a comprehensive three-part review, we present a systematic appraisal of current and impending approaches for measuring and reporting estuarine condition in each of Australia's States and Territories. A concise summary is provided in each case, supported by extensive appendices containing detailed accounts of relevant monitoring and reporting programs. We synthesise and evaluate this output at the State/Territory level, highlighting areas of improvement and major gaps.

Keywords Estuary, ecological status, health, monitoring, management, reporting

1. Introduction

Consideration and management of water resources across the USA and Europe have changed fundamentally in recent decades following the respective implementation of the Clean Water Act and the Water Framework Directive (WFD). These pieces of legislation have necessitated innovation, refinement and consolidation of the practices and tools that are used to assess and report the condition of aquatic ecosystems, including estuaries (Gibson et al., 2000; Hering et al., 2010; Birk et al., 2012). Most importantly, and despite their many criticisms (Moss, 2008; Hering et al., 2010; Adler, 2013), both the Clean Water Act and the WFD aim to manage water resources in a more holistic, ecologically relevant and environmentally sustainable manner (Hering et al., 2010; Adler, 2013), requiring greater coordination of activities and approaches across large spatial scales.

Recently, several initiatives have been proposed to better integrate estuarine monitoring, assessment and reporting programs across Australia under a common and more holistic framework. These are outlined in Part I of this three-part review (Hallett et al., submitted I). However, and in contrast to the situation in Europe and the USA, Australia has no specific federal legislation to mandate and thus underpin such a framework. Responsibility for environmental management in Australia lies primarily with the States, creating disparities across the nation in the policies, legislation, governance and approaches for monitoring and reporting the ecosystem health of estuaries (Smith et al., 2001; Borja et al., 2008, 2012; Hallett et al., submitted I).

Previous reviews of Australian approaches for monitoring, assessing and reporting estuarine condition have largely been limited to specific ecosystem components, particular regions or States, or have considered only a small number of high-profile programs (e.g. Barton, 2003; Hirst, 2008; Borja et al., 2012). We aim to address this gap through a timely and comprehensive review, focussing in this second part on a systematic description of current and impending approaches in each of Australia's States and Territories. We then synthesise and evaluate this output against characteristics of international best practice (Hallett et al., submitted I), highlighting major strengths and weaknesses within each State. Appendices A–G (supplementary material) provide detailed descriptions of the elements, procedures, thresholds and reporting employed under each of the programs considered in the following text, with extensive referencing of source material.

2. Queensland

South-East Queensland (SEQ; Fig. 1), from the NSW border north to Noosa, has the most intensive water quality monitoring program in Queensland. This monitoring has been synthesised and publicly reported through an annual report card, monthly updates, annual technical reports and various web pages for the past 15 years under the Healthy Waterways Partnership (www.healthywaterways.org). Prior to 1999 and the establishment of the Healthy Waterways Ecosystem Health Monitoring Program (EHMP) in SEQ, much of the monitoring and reporting effort in Queensland was local and intermittent, with limited processes for synthesising or disseminating outputs.

The first step towards a more comprehensive and cohesive monitoring program began in the State capital, Brisbane, in 1997 with the design and implementation of a baseline monitoring program (Dennison and Task DIBM Team, 1999), which grew over several years from a focus on Moreton Bay and its adjoining estuaries to a regional monitoring program that assessed 'ecosystem health' at ~260 estuarine and marine sites throughout SEQ. The EHMP has released annual report cards since 2000, establishing an expectation among community and political leaders for the annual snapshots of waterway health. The independent status of the Healthy Waterways Partnership has facilitated the continuation of the EHMP and annual production of report cards, despite significant political and institutional changes during this period.

The release of the first SEQ Ecosystem Health Report Card in 2000, aligned with growing pressure from communities, politicians and managers, stimulated changes in the monitoring and reporting of water quality across Queensland (Appendix A). Communities and governments were increasingly aware of the negative anthropogenic impacts on waterways and regulators were seeking to reduce environmental pollution, concerned primarily with nutrients, sediment and pesticides. This led to new monitoring programs focused on water quality attributes as management objectives, although regional differences in data collection and reporting approaches remained problematic (Appendix A).

A subsequent major community and political driver of improvements to estuarine water quality focussed on the Great Barrier Reef (GBR), with the release of a Scientific Consensus Statement emphasising the importance and urgency of declining water quality and the connections between land management practices and reef health. This was followed in 2003 by the release of the Reef Water Quality Protection Plan (Reef Plan), which aimed to reverse the decline in the quality of water flowing into the GBR by improving land management practices, and in 2009 by the establishment of the Paddock to Reef Integrated Monitoring, Modelling and Reporting Program (Paddock to Reef Program), which uses

catchment monitoring and modelling of water quality and pollutants, including pesticides, to provide an integrated assessment of the likely pollution load into estuaries, and thereby into the nearshore GBR Lagoon (Appendix A). Catchment monitoring is complimented by monthly water quality monitoring in estuaries that contribute pollutants to the GBR Lagoon, and by a Marine Monitoring Program (MMP) that assesses both water quality and the health of critical habitats, such as seagrass and coral, within the Lagoon (Appendix A; noting that the GBR Lagoon is not considered an estuary for the purposes of this review).

The above developments have helped to stimulate interest, especially from catchment organisations, in the collection and reporting of information on the condition of other estuaries and waterways across Queensland. Most recently, the Fitzroy River Partnership has developed a report card approach for reporting on the condition of both fresh and estuarine waters (Fitzroy Partnership for River Health, 2014), following a similar model to the Healthy Waterways report card (Appendix A). The State Government is also working with local government, industry and community groups in Gladstone Harbour (GHHP, 2014) and the Mackay-Whitsunday region (MWHRRP, 2015) to develop regionally-specific reporting methods that will assess the water quality and environmental condition of estuarine and coastal waterways (Appendix A).

Many of the current regional programs in Queensland are focussing on developing an integrated 'triple bottom line' approach to data collection and reporting that will continue to assess ecosystem health, but will also report on the social benefits and economic aspects of estuaries/waterways (e.g. Healthy Waterways, Gladstone Harbour; Appendix A), to better inform the sustainable development and utilisation of estuarine and nearshore coastal environments.

3. New South Wales (NSW)

Estuary monitoring in NSW is specifically focussed on long term trends in estuary health. It aims to collect a focussed set of data from as many systems as possible, allowing tracking of trends through time and in response to management (NSW DECCW, 2010). Estuary management in NSW is primarily the responsibility of local government, with technical and policy support from State government. Until recently, management has focussed on estuary foreshores and entrances, but in the last decade that has shifted to catchments, reflecting a recognition that they are often the primary source of pressure on estuaries. This represents a problem for local government as managers, since they may not have jurisdiction in the catchments.

Estuary monitoring previously operated under two largely separate programs. From the 1970s to 1990s, Public Works departments collected physical data (e.g. water height, salinity, temperature, bed depth) and environment and fisheries agencies collected biological and water condition data, including fish biodiversity and habitat use and State-wide macrophyte mapping (West et al., 1985; Creese et al., 2009; Appendix B). Environment agencies initially focussed on the impacts of point source pollution on estuarine water quality, which led to an almost complete removal of industrial sources. Since the late 1990s, much government research has focused on the effects of diffuse catchment-based pollution on estuarine ecology.

High-level recognition of the need to better manage threats to NSW estuaries was demonstrated by the Healthy Rivers Commission and particularly its Coastal Lakes Enquiry in the early 2000s (HRC, 2002). In 2006, the NSW 'Monitoring, Evaluation & Reporting' (MER) Strategy was initiated by the State Government to measure progress towards State-wide condition targets (NSW DECCW, 2010). This Strategy implemented a co-ordinated approach to future monitoring and, in 2010, commanded State of the Catchment (SoC) reports from each of the 13 Catchment Management Authorities (CMAs) (Creese et al., 2011; Roper et al., 2011).

The current estuary monitoring design under the NSW MER Strategy is based on a 'pressure-stressor-outcome' model, supported by a range of conceptual models that depict qualitative links between these components. The primary focus of recent and current monitoring and research is on land-derived nutrients and sediments, although localized threats or impact sources (e.g. acid sulfate soils) exist in some areas and require local monitoring and management. Estimates of annual average total nitrogen, total phosphorus, total suspended solid loads and freshwater flows are modelled for each subcatchment of every estuary in NSW, with further data on entrance modification, human population density, shoreline modification, fishing pressure and climate change (Roper et al., 2011; Appendix B).

Estuarine health indicators used in the MER program represent elements of system structure, function and composition and were designed to be cost effective and practicable at a State scale. They include the following.

- eutrophication: microalgal abundance (measured as phytoplankton chlorophyll *a*), macroalgal abundance, water clarity (measured as turbidity)
- habitat availability: extent of seagrasses, mangroves and saltmarshes
- fish assemblages: species diversity, composition, abundance.

State government currently measures a primary indicator suite comprising chlorophyll *a*, turbidity and macrophytes in over 30 different estuaries (plus 10 fixed estuaries) per year, focussing on the north, central and south regions of NSW on a three year rolling cycle (Roper et al., 2011). Monitoring has typically been designed to enable comparisons between locations subjected to different levels of anthropogenic pressures, with data tested against reference systems with little disturbance in their catchments (ANZECC and ARMCANZ, 2000; Scanes et al., 2007). Local government also carries out additional monitoring using standard protocols. Results are presented in report cards using standardised methods of data analysis (OEH, 2013; Appendix B; Fig. 2).

Some of the above indicators (e.g. macroalgal abundance) are still under development, while others such as fish assemblage composition were assessed for the 2010 report cards in a subset of estuaries and are unlikely to be repeated. Interpretation of these indicators and identification of appropriate management directions is facilitated by the contextual data (water heights, salinity, nutrient concentrations, coloured dissolved organic matter, etc.) that are collected concurrently.

Several recent developments have sought to extend the monitoring and reporting of estuarine condition in NSW. The Office of Environment and Heritage are developing indicators of estuary ecological function (Scanes et al., 2010) and modelling the effects of stressors on seagrass. There have also been some new developments in the monitoring of micro-organisms to provide an early warning of ecological impacts (Sun et al., 2012) or help explain patterns in processes such as nitrogen cycling. Finally, NSW has increasingly focused on tools to provide local CMAs and government with an ability to assess the relative risk that land-based activities pose to each estuary, and an ability to test future scenarios of risks posed by development plans, e.g. a Coastal Eutrophication Risk Assessment Tool (CERAT; http://www.ozcoasts.gov.au/nrm_rpt/cerat/index.jsp; Littleboy et al., 2009; Sanderson and Coade, 2010).

4. Victoria

Much of Victoria's past estuarine monitoring effort has focused on four large systems, three of which are essentially marine embayments (Port Phillip Bay, Western Port Bay and Corner Inlet/Nooramunga) and the other of which is one of Australia's largest estuaries (Gippsland Lakes) (Fig. 1). Routine monitoring of Victoria's other estuaries has, however, increased over the last decade, in addition to some regional and system-specific programs addressing select aspects of estuary health. While there have also been some key advances in this area (see

below), a consistent broad-scale monitoring program is yet to be implemented across the State (Appendix C).

Several authors have reviewed the available data, research and/or monitoring programs concerning the health of Victoria's estuaries (Barton, 2003; Mondon et al., 2003; Arundel and Barton, 2007; Arundel et al., 2009; Barton et al., 2008; Hirst, 2008). Various data gaps were identified, and the Victorian Government responded by instigating a major program to compile information on the number, type, physical size, threats and assets of the State's estuaries, including data on the physical and population attributes of their catchments (Barton et al., 2008; Pope et al., 2015). Other data gaps included estuarine water quality and biotic data at appropriate spatio-temporal resolutions, which have precluded testing of causal links between specific threats and condition indicators (Barton et al., 2008; Arundel et al., 2009).

A major step towards standardised monitoring, evaluation and reporting of the condition of Victoria's estuaries occurred in 2009 with the development of the Index of Estuarine Condition (IEC). This composite index integrates indicators from six themes representing different aspects of estuarine condition, i.e. physical form, hydrology, water quality, sediment, flora and fauna (Arundel et al., 2009; Appendix C). It is intended that results from the IEC will support State-wide monitoring of estuarine resource condition, inform management priorities and guide resource allocation for threat mitigation and asset protection. As recommended by Arundel et al. (2009), the measures proposed for the IEC were trialled to ensure they could be sampled adequately across the State, appropriate baseline or reference conditions could be defined and the indicators scored into five condition bands. Individual measures are aggregated at the theme level before the theme scores are aggregated to give an estuary score (Pope et al., 2015). The scale at which the IEC will be applied will be finalised by 2016 and will form part of the Victorian eight-year water strategy cycle, subject to available funding (DEPI, 2013).

Recent changes in Victorian Government policy have also led to a major shift in key strategies for managing the State's estuaries. Prior to this, the major legislation relating to estuaries was the Coastal Management Act 1995 (currently under revision), which enabled strategic planning on the coastal region and led to development of management plans for individual estuaries. In 2013, the Victorian Waterway Management Strategy (VWMS; DEPI, 2013), which integrates State, national and international policy and legislation, replaced the Victorian Catchment Strategy and associated regional plans under the Catchment and Land Protection Act 1994. Regional Waterway Strategies (RWSs) provide the vehicle by which the

VWMS is delivered, and have been developed in five regional areas. They identify appropriate management activities for adapting to sea level rise, mitigating adverse effects associated with coastal land use and development, managing estuary entrances and enhancing connectivity, maintaining and improving environmental condition, setting water quality objectives and determining environmental water requirements, and managing coastal acid sulfate soils (DEPI, 2013).

While the changes in governance and recent work towards a more consistent estuarine assessment, monitoring and reporting approach across Victoria are substantial and positive, issues remain in terms of the uncertainty of future resourcing. Further improvements towards coordinating the coastal management framework are thus required, and continued research is needed to strengthen the evidence base for planning and management.

5. Tasmania

Monitoring of the condition of Tasmanian estuaries has been sporadic, except for several larger and seriously degraded systems and those containing aquaculture operations. According to the latest State of the Environment (SoE) report for Tasmania (Tasmanian Planning Commission, 2009), the condition of the State's estuaries is variable, pressures are generally increasing and information and knowledge is poor for most estuaries.

The longest continuous monitoring program of estuarine condition in Tasmania has occurred in approximately 20 shellfish growing areas since the mid-1980s (the Tasmanian Shellfish Quality Assurance Program; Appendix D). Similarly, compliance monitoring around oyster and salmon farms to quantify their environmental impacts has also provided information on estuarine health. While such monitoring in the 1990s focused on localised effects under and/or near shellfish intertidal racks, salmon cages and/or longlines, the focus since 2000 has been on broad-scale, estuary-wide effects, and particularly those of increased nutrients from salmon farms. Limits on dissolved nutrient emissions from finfish farms in the D'Entrecasteaux Channel and Huon Estuary were introduced by Government in 2009, together with a regulatory monitoring program to assess water quality and sediment condition.

In addition to the above systems, the Derwent and Tamar estuaries have significant, ongoing monitoring programs. The Derwent Estuary (Fig. 1) is one of the most heavy metal-polluted estuaries worldwide, due to past dumping of industrial waste over many decades. The Derwent Estuary Program was established in 1999 to restore the estuary and an ongoing monitoring program has tracked its health, incorporating water quality, ten-yearly sediment

surveys and periodic surveys of phytoplankton, habitats and selected fauna. Findings are communicated via annual report cards and a five-yearly State of the Derwent report (Appendix D). The Tamar Estuary and Esk Rivers Program similarly monitors and reports on waterway health (predominantly focused on water quality), as well as coordinating activities to reduce pollutant loadings. A Tamar Estuary Ecosystem Health Assessment Program was established in 2009 to coordinate data collection across the estuary, and report cards are produced annually, with accompanying technical monitoring reports.

Some smaller estuaries in Tasmania have been periodically monitored, generally over one to two years, during an assessment of conservation status (Barrett et al., 2000), studies of representative Tasmanian estuaries (Murphy et al., 2003), or baseline monitoring programs (Appendix D). Several of these studies have emphasised the need for both water quality and biological data to better assess estuarine condition.

An attempt was made in the mid-2000s to establish estuarine water quality indicators and thresholds specific to Tasmanian conditions by convening a panel of estuarine experts, which led to the development of a Tasmanian Indicator Compendium (Mount et al., 2006). Monitoring and management of Tasmanian estuaries was also investigated as part of the Commonwealth-funded Landscape Logic research hub, which led to the development of an Estuarine Decision Tree for identifying the vulnerability of Tasmanian estuaries to human-induced change and supporting their management by standardizing condition assessments (Crawford et al., 2012). The Tasmanian Environmental Protection Agency is currently preparing interim water quality guidelines for the protection of 'high ecological value' and 'slightly to moderately disturbed' estuaries based on the estuarine decision tree. The interim guidelines for the latter estuaries may also provide aspirational targets for moderately and highly disturbed estuaries.

6. South Australia (SA)

Aside from the iconic estuary at the mouth of the Murray River (see below), much of the current estuarine monitoring in SA occurs in Gulf St Vincent and Spencer Gulf (Fig. 1) which, although actually coastal nearshore areas, are often considered to be inverse estuaries (SA DEH, 2007). Very few of the remaining estuaries in SA currently have monitoring programs in place to detect potential changes. Most water quality monitoring occurs in the freshwater parts of the river systems (e.g. upper and middle catchment), with the majority of monitoring that has been undertaken in estuarine reaches being patchy and/or undertaken by private consultants, community groups, schools and other agencies for specific reasons

(Appendix E). The Department of Environment, Water and Natural Resources (DEWNR) has produced a report card for assessing the status of estuaries throughout SA, including the two Gulfs noted above, but this largely employed the qualitative measures of estuarine condition from the National Land and Water Resources Assessment of 2002. The 2013 report card indicated that estuarine condition was generally poor, that any trends in condition were unknown, and that ongoing monitoring of estuaries was required (DEWNR, 2013). Future reporting measures are unknown.

The SA Environment Protection Authority (EPA) evaluates the consequences of human activities for the ecological condition of SA waters, including estuaries (Goonan et al., 2012; Appendix E). From 1994–2007, a nearshore water quality monitoring, evaluation and reporting program was carried out that involved monthly or quarterly sampling of surface waters, with results reported as a traffic light summary depending on whether variables were below or within national guidelines (e.g. ANZECC and ARMCANZ, 2000). From 2010, the EPA's aquatic ecosystem Monitoring, Evaluation and Reporting Program (MERP) has used a three-tiered approach to assess nearshore coastal threats and condition, using the spatial framework (biounits, 10s–100s km, and bioregions, 100s–1000s kms) of the Integrated Marine and Coastal Regionalisation of Australia (IMCRA v4.0) (Edyvane, 1999, Appendix E). The MERP compares observed condition (from a monitoring program) with predicted condition (based on an assessment of threats) to generate an Aquatic Ecosystem Condition Report (AECR) that rates condition on a six-point scale from excellent (effectively unimpacted) to very poor (highly disturbed). Reporting typically occurs at the biounit scale but can be rolled up to the bioregional scale for SoE reporting (Gaylard et al., 2013b).

To date, AECRs are available for two bioregions, i.e. lower Spencer Gulf (Gaylard et al., 2013a) and Gulf St Vincent (Nelson et al., 2013) (Fig. 1). Whilst the focus is on nearshore marine waters, some of the larger estuaries in these bioregions (e.g. Barker Inlet, Franklin Harbour, Smoky Bay, Tourville Bay, Baird Bay, Venus Bay and Coffin Bay) are included. However, given the scale of reporting, no specific condition ratings are given for individual estuaries. Future AECRs for estuaries are dependent on resources.

The Coorong, Lower Lakes and Murray Mouth region, which includes the estuarine lagoon and the largely freshwater wetlands of the Lower Lakes, is often considered separately from other South Australian estuaries given its iconic status (e.g. SA DEH, 2007). Two major, broad-scale monitoring programs operate in this region.

(i) The Murray Futures Coorong, Lower Lakes and Murray Mouth Recovery program, which is overseen by DEWNR and addresses various environmental issues facing the region,

such as salinization, acid sulphate soils and loss of habitat. Plants, animals and abiotic components of the system have been monitored since 2010 to inform on-going management (Appendix E), though it is unclear if or how this program will continue.

(ii) The Murray-Darling Basin Authority's Living Murray program, which commenced in 2002 and focuses on increasing environmental water flows to improve the health of six important 'icon sites', one of which is the Lower Lakes, Coorong and Murray Mouth. This program is being managed by DEWNR and overseen by the above Authority. Various monitoring projects are undertaken in the Lower Lakes, Coorong and Murray Mouth region, including those for birds, fish, invertebrates, vegetation, mudflats and water quality (Appendix E). Again, there are uncertainties regarding the longevity of the Living Murray program due to funding constraints.

7. Western Australia (WA)

The past decade has seen periodic changes in the governance frameworks and agencies responsible for monitoring and reporting on estuarine condition across WA. The Department of Water (DoW) is now the lead agency for estuary management across WA and coordinates a State-wide water quality program. An exception is the Swan-Canning Estuary, whose management since 1989 has been overseen by a statutory body, the Swan River Trust. In 2013 the Trust was subsumed within newly created Department of Parks and Wildlife and now exists as an advisory body, without statutory powers, within the Rivers and Estuaries division of the Department.

Approaches to estuarine monitoring and reporting in WA have progressed in recent years. Standardised monitoring of various water quality variables has been undertaken at weekly to quarterly intervals across many estuaries in south-western WA since the mid-1990s, and the resulting data have recently been synthesised as estuary condition statements and reports for several key systems (Appendix F). Additionally, new tools are being developed to better assess estuary condition. For example, the DoW is developing estuarine condition assessments based on a Water Quality Index that combines measurements of chlorophyll *a*, DO, Secchi depth, TN and TP as indicators, and is also undertaking applied research to develop indicators of ecological condition based on seagrass (Kilminster et al., 2014) and sediment biogeochemistry (WA DoW, 2013), for possible inclusion in future monitoring programs (Appendix F).

The Swan-Canning Estuary, encompassed by the State capital, Perth (Fig. 1), best illustrates advances for assessing the condition of WA estuaries. Water quality (physico-

chemistry, nutrients and phytoplankton) has been monitored weekly since the mid-1990s throughout the system and at gauging stations in each subcatchment. Extensive assessments of foreshore condition have been undertaken, and several novel approaches for measuring and reporting estuarine condition have been developed (Appendix F). The latter include an annual monitoring regime to assess and communicate ecological condition using multimetric Fish Community Indices (FCI), implemented since 2012 (Hallett et al., 2012; Hallett and Tweedley, 2014; Fig. 3).

There are, however, significant inequalities in the degree of investment, frequency and types of monitoring among WA estuaries. Thus, less urbanised systems to the north of Perth experience little or no monitoring, despite increasing pressures from urbanisation, agriculture and tourism. Moreover, existing monitoring programs remain strongly focused on water quality, restricting most assessments of broader estuarine condition to qualitative statements based on expert opinion (e.g. WA EPA, 2007). These and other basic data gaps have been highlighted frequently (WA DoW, 2007; WA EPA, 2007, 2008; Hugues-dit-Ciles, 2012; OAG, 2014) and have led to growing calls for more holistic and ecologically-relevant approaches for monitoring and reporting estuarine condition (e.g. Government of Western Australia, 2004). Additionally, quantitative monitoring and timely reporting of the human pressures and stressors affecting WA estuaries is minimal (Appendix F), which has hampered efforts to discern the causal mechanisms driving trends in condition. This could be addressed by better translating the data from existing monitoring programs into accessible and user-friendly indicators, such as the Index of Sustainable Functionality that was recently applied to the Swan-Canning Estuary (Kristiana et al., 2012) and the DoW's Water Quality Index, although the latter tool has not yet been publicised or reported (OAG, 2014). There is also considerable scope for improving the communication of monitoring outputs, ensuring they are publicised in a comprehensible and timely manner and more clearly aligned with management actions (Appendix F). This might help to overcome a perceived lack of management actions to address declining water quality in WA's estuaries (Metcalf et al., 2014).

Lastly, while there has been some recent progress led by the Western Australian Marine Science Institution, there is currently no formal mechanism to coordinate estuarine science and monitoring activities across WA, nor the leadership to ensure that strategic long term plans are executed (WA EPA, 2007; Beazley, 2010). These issues have been exacerbated by uncertainty in funding for even core water quality monitoring in several

estuaries across the south-west, emphasising the critical need to 'future-proof' estuarine monitoring and reporting.

8. Northern Territory (NT)

The majority of NT estuaries are in near-pristine condition (NLWRA, 2002), due largely to their distance from major population centres. Management of these estuaries typically focuses on maintaining and protecting their existing condition, but as monitoring is often limited and benchmarks are not well established (Appendix G), there is little quantitative basis for detecting change. Recent years have, however, seen limited investment in baseline condition assessments, monitoring and reporting for a handful of systems in the 'Top End' of the NT, including the Katherine and Darwin regions. For example, the Top End Waterways Project, which commenced in 1995, assesses and reports on the major waterway resources in the Katherine Region, including their estuarine reaches, adapting the river condition and stability approach used in the Queensland 'State of the Rivers' assessment (Faulks, 1998).

The vast majority of monitoring in the NT is centred on Darwin Harbour (Fig. 1) and its numerous sub-estuaries, whose surrounding catchments support a growing population of >130,000 and the largest concentrations of urban, agricultural and industrial activity in the NT. Water quality monitoring has been undertaken by the Department of Land Resource Management (DLRM) and its predecessors since 1987 (Maraud, 2013), whilst regular and more extensive monitoring and reporting commenced in 2008 and 2009, respectively (DLRM, 2013). The DLRM now annually collates results from its own monitoring programs and some of those undertaken by other government agencies and the private sector, to report on the health of Darwin Harbour. Various water quality variables are now measured at >100 sites and compared to objectives set by the Darwin Harbour Water Quality Protection Plan (Fortune and Maly, 2009), to assign water quality grades (A–E) for each region of the harbour (Appendix G), which are published annually via report cards (DLRM, 2013; Maraud, 2013).

Other monitoring initiatives are also currently active or being established in and around Darwin Harbour (DLRM, 2012), addressing several of the data gaps identified in a previous review of environmental monitoring in the region (DHAC, 2005). These include monitoring of sediment quality, mangroves, aquatic pests, phytoplankton, fish, seagrass and dolphins (Fortune and Drewry, 2011; DLRM, 2012; Appendix G).

To date, however, there has been no integration of the outputs from the above biophysical and ecological monitoring programs with the report cards for Darwin Harbour,

448 which remain strongly focused on water quality. Moreover, many of the logistical and
449 administrative barriers identified by DHAC (2005) are still relevant today, including the
450 inaccessibility of monitoring data, fragmented and overly-technical reporting of outputs, and
451 the lack of accountability of monitoring agencies to the community. There also remains little
452 coordination of monitoring activities among the government departments, industry groups
453 and other relevant agencies (DHAC, 2005; Fox, 2011). An Integrated Monitoring and
454 Research Program (IMRP) has thus been proposed for the Darwin region to help address
455 many of these issues and to develop and integrate more ecologically relevant measures of
456 ecosystem condition across marine, estuarine and freshwater habitats (DHAC, 2005; Fox,
457 2011). As with all such endeavours, the success of the IMRP will depend on its ability to
458 overcome the challenges of coordinating numerous stakeholders with divergent interests and
459 ensure funding streams and continuity of management. To this end, the recent securing of $20
460 million of funding for the IMRP over 40 years, as part of an offset agreement between
461 INPEX Corporation and the NT Government, represents a significant step forward.
462
463 **9. Synthesis**
464 State and Territory programs were assessed against the criteria of international best practice
465 established in part I of this review (Hallett et al., submitted I). Large disparities in the degree
466 to which these programs fulfil the evaluation criteria were evident across jurisdictions (Table
467 1). Monitoring and reporting programs in NSW and, to a lesser extent, Queensland generally
468 met many of the criteria, with the former State, in particular, possessing a well-developed
469 legislative and governance framework that links monitoring to management objectives, and a
470 rigorous approach to the selection and implementation of appropriate condition indicators. In
471 contrast, the other States and the NT rarely met most of the evaluation criteria.
472 Some common limitations are apparent across several States, including a continuing
473 lack of ecologically-relevant indicators of habitat, floral and faunal condition, and a failure to
474 ensure that declining estuarine condition triggers practical management interventions.
475 Encouragingly, however, some aspects of Australian monitoring and reporting practices have
476 improved across most States in recent years, and most notably the communication of
477 monitoring outputs via various media. Several impending or recently implemented State
478 initiatives and programs also promise to address many of the identified limitations in the
479 coming years. For example, there is considerable potential for the IEC (Pope et al., 2015) to
480 dramatically improve monitoring and reporting of estuarine condition across Victoria, and the
481 planned expansion of the South Australian MERP to encompass a much greater number of

estuaries will help ensure that monitoring and reporting practices finally fulfil the requirements of the State's Environment Protection Act 1993 (Goonan et al., 2012) and are comparable across the State.

10. Conclusions

Part two of this review has highlighted the enormous diversity of policies and approaches for monitoring, assessing and reporting estuarine condition across the States and Northern Territory of Australia. Common limitations include (i) over-reliance on physico-chemical elements of estuarine condition, and primarily water quality, (ii) failure to quantify pressures across varied and appropriate spatial scales, and (iii) dramatic inconsistencies in the spatio-temporal coverage of monitoring. The latter issue also extends to inter-State comparisons, and greatly impacts the ability to compare estuarine condition over broader spatial scales, e.g. for national State of the Environment reporting. In the final part of this review (Hallett et al., submitted III) we undertake a broader, national-level synthesis and provide a critical appraisal of Australian practices for understanding and reporting estuarine health, culminating with some specific recommendations to improve future approaches across Australia and beyond.

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Tables (*separate file, attached)*

Table 1

Summary assessment of programs for monitoring, assessing and reporting estuarine condition in each Australian State or Territory. Programs are scored on the following basis for each of the performance criteria identified by Hallett et al. (submitted, part I); 0 = criterion never met; 1 = criterion rarely met; 2 = criterion often met; 3 = criterion usually/always met. A summed national score is also provided for each criterion.

Figure captions

Fig. 1. Map of Australia, showing the States and Territories, their capital cities, and the locations of key estuaries and regions referred to in the text and supplementary material.

Fig. 2. Catchment and estuary disturbance index results for the Hawkesbury Shelf Bioregion of New South Wales. Disturbance is rated from very high (red) to very low (dark green) (Roper et al., 2011).

Fig. 3. Mean offshore Fish Community Index scores and resulting condition grades (A, very good; B, good; C, fair; D, poor; E, very poor) for each zone of the Swan Canning Estuary, Western Australia, and for the estuary as a whole, in summer and autumn of 2014. LSCE, Lower Swan Canning Estuary; CE, Canning Estuary; MSE, Middle Swan Estuary; USE, Upper Swan Estuary.

Supplementary material

(See separate appendices A–G; for publication as online appendices)