A collaborative approach to integrating science, management and communities for improving river health in coastal catchments

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Key Points

- Coastal aquatic ecosystems are ecologically, socially and economically valuable, but globally, the ecological condition of many freshwater and estuarine ecosystems is under threat.
- Ecohealth is a comprehensive estuarine and freshwater monitoring program that reports on the health of coastal rivers and estuaries in Northern NSW. It brings together a partnership for the standardised, region-wide reporting and communication of waterway health.
- Ecohealth was established in 2009 and has been successfully completed in seven catchments, partnering with 13 Local Councils, North Coast Local Land Services, NSW Office of Environment and Heritage, DPI Fisheries, National Parks and Wildlife Service and Solitary Islands Marine Park Authority.
- Our aim is to develop advances in aquatic ecology, more effective and sustainable management of aquatic systems, and improve the broader community acceptance for waterway management decisions and actions.

Abstract

Coastal aquatic ecosystems are ecologically, socially and economically valuable, but are commonly degraded by landuse activities. The strong longitudinal connectivity of catchments means that rivers and estuaries can be significantly impacted by upstream issues. Most of the coastal catchments in NSW encompass more than one local government area, so it can be difficult for Councils to prioritise and strategically invest in management to improve aquatic ecosystem health at the catchment scale when the source of degradation is often outside their management area.

Ecohealth is a standardized monitoring program based on a framework of physical, chemical and biological indicators to assess aquatic ecosystem health across coastal NSW Northern Rivers. We present catchment health report cards produced by the Ecohealth program that show scores for water quality, micro- and macroinvertebrate, fish, geomorphic and riparian condition at site, river, sub-catchment, freshwater and estuary, and catchment scales. Condition scores quantify key stressors and identify their spatial extent. This enables Councils and state agencies to collaborate so that investment strategically targets the causes of aquatic ecosystem degradation at the appropriate spatial scale. The production of a report card for each council provides an effective education and communication tool for natural resource management. Investment in long-term (return monitoring every 4 years) and large-scale (>400 sites in northern NSW rivers and estuaries) Ecohealth monitoring provides natural resource management, community education and research (e.g., development of regional water quality trigger values; reference condition for riparian vegetation) outcomes for partners.

Keywords

Ecohealth, restoration, catchment report cards, ecological indicators.

Introduction

Coastal aquatic ecosystems are ecologically, socially and economically valuable, but globally, the ecological condition of many freshwater and estuarine ecosystems is under threat from a complex array of interacting pressures and stressors. Drivers of change vary greatly in their spatial and temporal intensity, ranging from human actions (e.g., chemical pollutants, land use change and intensification, river regulation) through to climate change and natural variability, and combined these drivers influence how various pressures and associated stressors modify the condition of aquatic ecosystems at various scales (Harris and Heathwaite 2012). To be effective, monitoring programs need to be underpinned by an understanding of the causal factors that influence the condition or health of environmental, human and social values of aquatic ecosystems (Bunn et al. 2010). Existing monitoring programs to underpin the assessment of aquatic ecosystem condition are focused on the collection of data to support management goals, yet the data collected are variable in their quantity and quality (Dafforn et al. 2016), their outcomes poorly integrated within and among aquatic systems, and communication and education paths for results rarely considered in such programs (Parsons et al. 2016).

Monitoring and assessment of aquatic ecosystem health must be based on metrics that quantify the cumulative effect of stressors on ecosystem structure and function, and be able to inform management, restoration and policy decisions. This is difficult in aquatic systems where different stressors acting at multiple spatial and temporal scales interact to affect water quality, biodiversity and ecosystem processes (Bunn et al. 2010). Therefore indicators need to be selected to inform a diagnosis of the probable cause of the measured ecological condition which in turn informs management actions. Water quality and structural measures of biota (e.g., algal, macroinvertebrate, and fish metrics) have traditionally formed the bases for river and estuary monitoring and bioassessment programs (Heino 2015) and are based on well-developed methods and reference conditions. The longitudinal linkages that connect the pressures and disturbances in river headwaters to the health of estuaries must also be embedded in indicator selection and monitoring program design. Yet the literature abounds with studies on freshwater (see review in Growns et al. 2013) and estuary monitoring (see review in Adams 2014), but very rarely both, despite the fact the two are intrinsically linked by river flow and tidal exchange. Designing monitoring programs that require freshwater and estuarine ecologists to interact will no doubt improve the management of aquatic systems as well as advancing aquatic science (Ryder et al. 2010).

We outline an approach created with extensive consultation and engagement with state agencies, local government and interest groups to develop a monitoring program based on rigorous science and a shared understanding of important environmental assets and values in the North Coast Bioregion of NSW.

The Northern Rivers Bioregion

The Northern Rivers region is located in the north-east corner of NSW and covers over 50,000 km^2, of which 60 % is freehold tenure and 21,500 km^2 is managed as Crown land, National Park or State Forest. The region extends from the Queensland border, south to the Camden Haven River and inland to the New England Tablelands (Figure 1). Aboriginal nations within the region include the Bundjalung, Anaiwan, Birpai, Dunghutti, Gumbainggar, Gwaegal, Guyambal and Yaegl people. The river, estuary and marine regions are important to the region's economy, providing the natural resources that support industries such as tourism, and recreational and commercial fishing.

There are nine major river catchments in the region - the Tweed, Brunswick, Richmond, Clarence, Coffs Harbour Waterways, Bellinger-Kalang, Nambucca, Macleay and Hastings-Camden Haven, including 196 sub-catchments within these major valleys. The region also includes significant coastal lakes, estuaries and river systems, such as the lagoons of the Camden Haven River, Lake Cathie and Lake Innes, Lake Ainsworth, the Tweed's Terranora Broadwater, and Lake Hiawatha and Minnie Water in the Clarence valley. Nearly all the rivers in the region are unregulated resulting in predominantly natural flow regimes that contribute to the

maintenance of local biodiversity. The region has a diversity of landscapes, natural resource values and land use types, ranging from grazing and cropping in tableland areas to sugar cane, animal and tropical fruit production in the coastal regions.

The Northern Rivers Bioregion is known for its extensive coastal river systems and high biodiversity. The region is a National Biodiversity Hotspot, as the third most biodiverse region in Australia and home to 380 species, 5 populations, as well as 13 communities listed as endangered or vulnerable under the NSW Threatened Species Conservation Act (TSC) 1995. The region has a number of significant sites including a World Heritage Areas (Central Eastern Rainforest Reserves of Australia (CERRA)), Ramsar Wetlands including Little Llangothlin Lagoon on the northern tablelands, and 25 wetlands listed on the Directory of Nationally Important Wetlands. There are 196 reserves and conservation areas within the Northern Rivers region.

Figure 1. NSW Northern Rivers Bioregion covers an area of over 50,000 km^2 and contains 9 major river catchments.

Ecohealth: measuring, reporting and communicating river and estuary health

The development of a standardised protocol for collecting, analysing and presenting riverine, coastal and estuarine assessments of ecological condition has been identified as a key need for coastal Local Government Areas and government agencies who are required to monitor and report natural resource condition. Ecohealth is a comprehensive estuarine and freshwater monitoring program that brings together the aquatic sampling programs of government and other natural resource management agencies and partners into a standardised, region-wide system for reporting and communicating the ecological condition of waterways. Ecohealth enhances the ability of natural resource managers to monitor, measure and report on ecosystem health by establishing a statistically-valid and quality assured sampling regime through a standardised, region-wide program that includes:

- consistency and efficiency in design, sampling, analysis and reporting
- improved management, access, sharing and interpretation of data among all partners
- region and catchment-wide reporting from upland streams, large rivers, coastal lagoons and estuaries
- improved evidence-based decision making on NRM activities and investment, including improved long-term management of catchments and waterways through undertaking Ecohealth monitoring at regular intervals
- enhanced communication about waterway health between NRM agencies, local government, other stakeholders and the community
- improved public information on waterway health and management actions in local catchments.

The Ecohealth Program was established in 2009 and has been successfully completed in seven of the nine catchments in the Bioregion, partnering with 13 Local Councils and NSW Office of Environment and Heritage, DPI Fisheries and Solitary Islands Marine Park Authority.

Indicators

The Ecohealth program includes a number of physical, chemical and biological indicators to determine the health of waterways. The combination of waterway health indicators that identify short-term (water chemistry), intermediate-term (zooplankton, macroinvertebrates), and long-term responses (fish, geomorphology and riparian vegetation) provides a robust program for quantifying, reporting and communicating waterway health, and prioritising management actions.

Figure 2. Sampling freshwater macroinvertebrates. Macroinvertebrates are important indicators of ecosystem health as they integrate physical, chemical and biological responses to stressors such as habitat loss and water pollutants.

- Water chemistry identifies trends in nutrient (nitrogen and phosphorus), chlorophyll a, suspended solids, dominant ions contributing to water quality issues (e.g., sulphur and aluminium linked to acid sulphate soils) and coliform values, as well as static variables such as pH, salinity, dissolved oxygen and temperature.
- Macroinvertebrate assemblages collected biannually from freshwater sites in Autumn and Spring are used to assess longer-term condition of water quality and instream habitats (Figure 2). The taxonomic richness, abundance and diversity are reported, as well as health indicators using SIGNAL2 scores and percent EPT (Ephemeroptera, Plecoptera, Trichoptera) to identify taxa sensitive to disturbance.
- Fish assemblages are recorded from freshwater sites and reported as indicators of Expectedness (relative to pre-European disturbances), Nativeness (native vs introduced taxa), Recruitment (size distribution) and an overall health score.
- Zooplankton assemblages are used as biological indicators in estuary reaches and coastal lagoons, measuring the abundance of size categories, rather than taxa or trophic levels, as an indication of the health of the system and response to disturbances such as nutrient enrichment, algal blooms and floods (see Moore & Suthers 206).
- Riparian Condition assessments provide information for freshwater and estuarine sites on the cover, composition, structure, habitat and connectivity of streambank and instream vegetation.
- Geomorphic Condition provides information on the physical condition of banks and channels at site, reach and catchment scales (see Ryder et al. 2016 for detailed indicator metrics).

Design

The Ecohealth program is designed so that it can be tailored to systems throughout coastal NSW. A technical reference group (TRG), comprising scientific peers from state government agencies and universities, along with local government representatives, has been established to provide advice on aspects of the program such as sampling procedures, a base set of indicators, strategic sampling locations and data analysis, reporting and management procedures. An advisory committee has also been established with representation from local and state government, and Local Government Areas (LGAs) to provide advice on the overall direction of the Ecohealth program.

The design of the Ecohealth catchment monitoring program is based on the NSW Monitoring, Evaluation, Reporting (MER) protocols for Rivers and Estuaries (Roper et al. 2011, NSW OEH 2011). The number and location of sample sites is designed to be statistically robust, and as such, provides a data set that can be used

to assess spatial and temporal variability of individual catchments, as well as placing this in a regional context (Figure 3). The aim of developing and applying criteria for site selection is to facilitate the reporting of waterway health (and therefore identify management actions required) at a number of spatial scales. Using the criteria below, it is possible to provide scientifically robust health scores at region, catchment, sub-catchment, river/estuary/lagoon, reach and site scales.

- Represent major tributaries, or systems identified by stakeholders as of interest for management-social-cultural values.
- Identify longitudinal change within the main stem of each river and estuary system, through the use of multiple sites from headwaters to confluence (including a focus on the tidal limit) where sub-catchments are greater than 600 km^2.
- Identify end-of-system flows from rivers joining the main catchment river or entering the estuarine environment as a minimum requirement if the sub-catchment is <600 km^2. Sites located adjacent to hydrometric NoW gauges will allow the calculation of 'water quality loads' such as the amount of nutrients or sediments exported from the system.
- Locate sites within dominant and representative River Styles, Condition and Recovery Potential, and elevations within and across catchments. Prioritising freshwater sites within the dominant River Style and understanding the spatial extent of this geomorphic setting allows the data collected from a site to be applied to a larger reach of river.
- Facilitate comparison with historical datasets and additional information (e.g., discharge gauges).

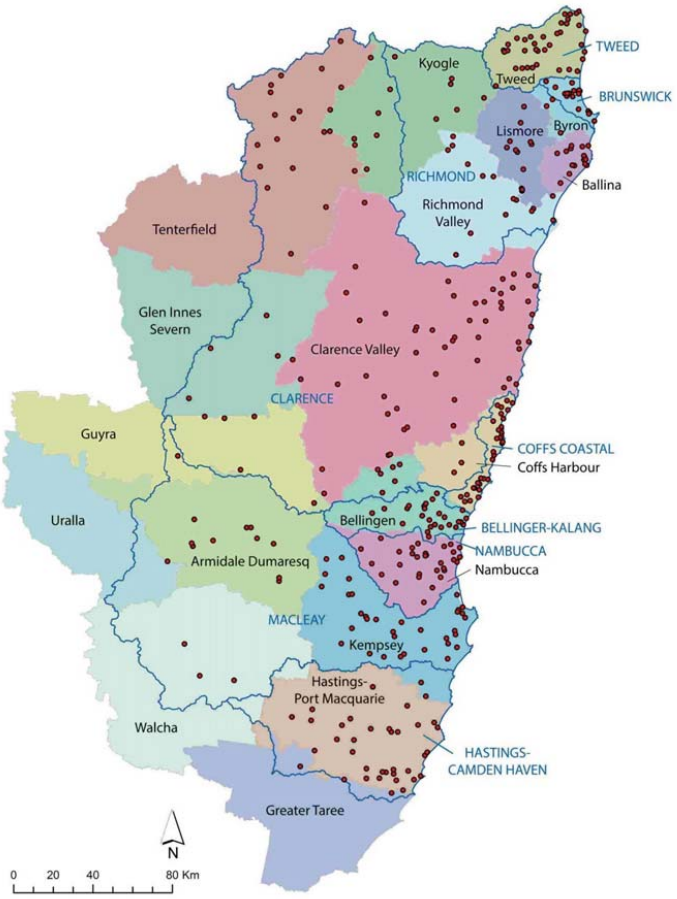

Figure 3. Location of over 400 established Ecohealth monitoring sites in the Northern Rivers Bioregion.

- Locate ecological changes at the point of the tidal limit. The inclusion of a monitoring site at the tidal limit is essential, as this is often the most-impacted reach in a catchment.

Scientific, management and communication products

The calculation and reporting of Ecohealth grades involves the synthesis of up to 14 different indicators each with regionally-developed trigger values. A robust and consistent method for summarizing these data is required because of the large number of ecological values and the difficulties in their interpretation. Scores are calculated for individual sites, but also must fulfill the broader aims of wider-scale reporting at river, sub-catchment, catchment and regional scales. To produce an Ecohealth grade, the value for each index – Water Quality, Zooplankton, Macroinvertebrates, Fish, Geomorphology and Riparian – is transformed into a standardized score that takes into account differing physical conditions, scales of measurement among indices and prevailing climate conditions. The result is a scoring system from 0 to 100, where 0 represents the

most 'unhealthy' condition and 100 indicates a 'healthy' waterway based on regionally-developed trigger values and reference conditions.

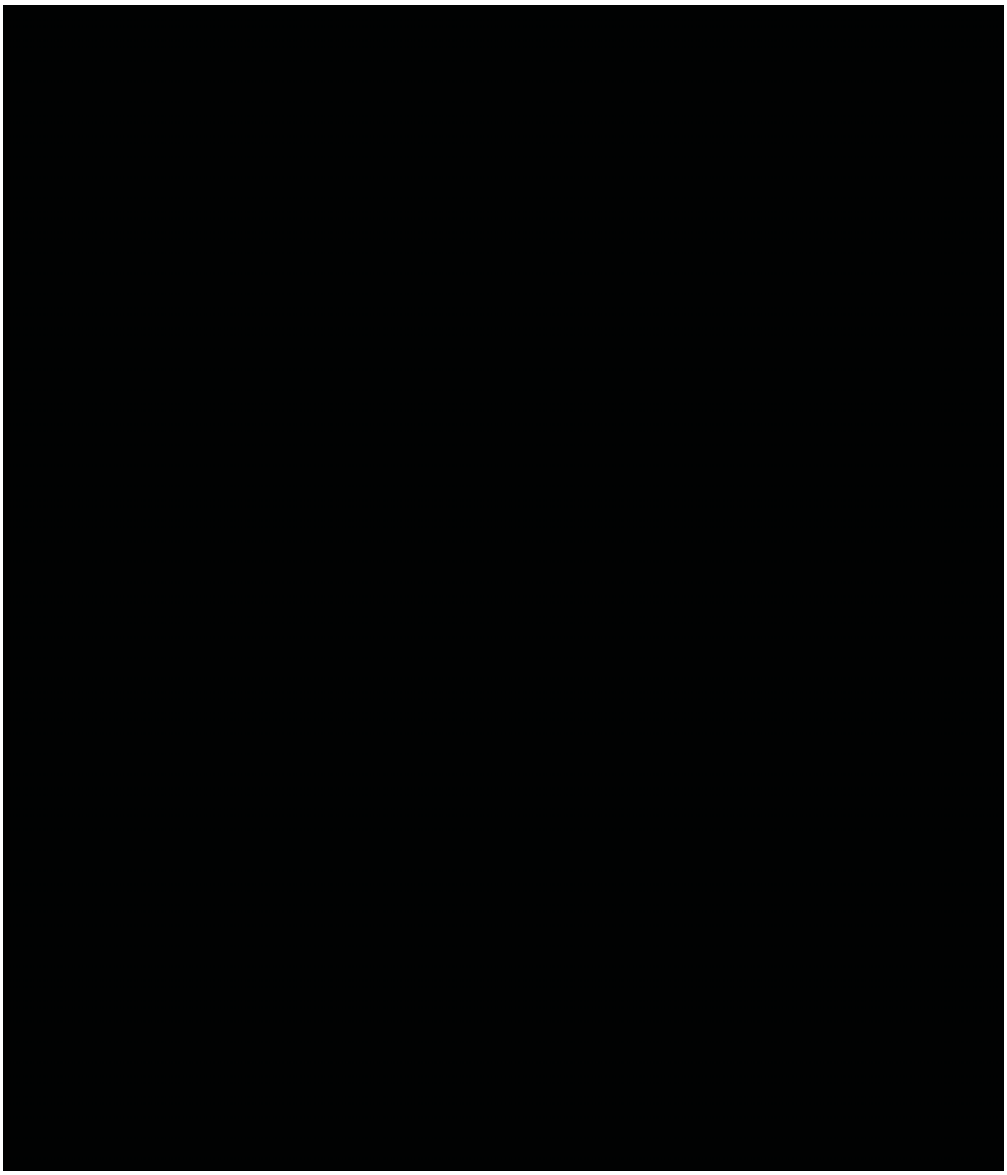

Figure 4. Example of an Ecohealth report card communicating health scores for water quality, riparian, geomorphic and macroinvertebrate indicators ate site, sub-catchment and catchment spatial scales.

The products generated by the Ecohealth program cover high-level scientific technical reports that provide an in-depth presentation and analysis of data collected, as well as Ecohealth Report Cards that aim to clearly disseminate waterway health outcomes and management initiatives to engage with local communities. Regular sampling updates and factsheets are also provided to partner organizations throughout the program. The Ecohealth Report Card (Figure 4) is designed to inform communities about the health and specific needs of waterways in their local catchments. It provides quality information in an easy to understand summary format. Report Cards are developed in conjunction with each partner, and can be designed to report on catchment, freshwater and estuary, river, reach and site scales. Report Cards have been designed as folded flyers to partner with rates notices mailed to ratepayers, A4 flyers located at council offices, through to A0 posters in schools and community halls. All Report Card outputs are also hosted by project partner websites.

Ecohealth also provides a scientifically robust dataset for use in State of Catchment (SoC) and State of Environment (SoE) reporting in NSW. The NSW Natural Resources Monitoring, Evaluation and Reporting Strategy 2010-2015 (www.environment.nsw.gov.au) guides the efforts of LGA's and Local Land Services (LLS) to better understand whether the overall health of the natural resources of NSW are changing and to assess the effectiveness of remedial action in reversing observed trends. The NSW State-wide natural resource condition targets provide the structure for the SoE and SoC reporting requirements. The study design and reporting of catchment-based Ecohealth monitoring programs are developed in conjunction with state-wide MER programs and provide LGAs and other agencies with a dataset and reports to fulfil these requirements.

Employing the Ecohealth monitoring program on a 3-4 year cycle within a catchment provides information for report card production to inform local communities, technical information to guide on-ground management, and data for SoE and SoC reporting requirements.

Conclusions

The Ecohealth Monitoring Program outlines a framework for the development of a catchment-based aquatic health monitoring program for rivers and estuaries with the aim of providing consistency in monitoring and reporting, and establishing the partnerships required for local and regional dissemination of outcomes. The Ecohealth Program was established in 2009 and has been successfully completed in seven of the nine catchments in the Bioregion, partnering with 13 Local Councils and NSW Office of Environment and Heritage, DPI Fisheries and Solitary Islands Marine Park Authority. Over 50,000 report cards have been produced and distributed to stakeholders, community groups, government agencies and even distributed to all ratepayers through its inclusion in local rates notices. The development and application of specific monitoring frameworks, and standardised data collection, analysis and reporting underpins the Ecohealth program. Our aim is to develop advances in aquatic ecology, more effective and sustainable management of aquatic systems, and improve the broader community acceptance for waterway management decisions and actions.

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