Evaluation and redirection of a long-term, broad-scale river health monitoring program in Tasmania, Australia

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Key Points

- The Tasmanian State Government has overseen and managed the River Health Monitoring Program (RHMP) since its inception in 1994.
- The RHMP has delivered important information for river management in Tasmania, but the program has several limitations.
- In light of this, a review was undertaken to evaluate and redirect the program.
- The review made 34 recommendations to assist future management and implementation of the program, which includes adjusting locations of monitoring sites and using revised sampling methods.

Abstract

Since 1994, to support sustainable river management the Tasmanian State Government has conducted broad-scale monitoring of river condition across Tasmania under the River Health Monitoring Program (RHMP). The RHMP employs Australian River Assessment System (AusRivAS) protocols, which focus on macroinvertebrate communities and habitat quality. Since the RHMP began, land and water use has changed markedly and river health science has advanced. Therefore, information collected by the RHMP between 1994 and 2016 was reviewed to: (1) document its history; (2) assess applications of resulting data and the applicability of other measures of river condition; (3) evaluate the value of its abiotic and biotic data; (4) examine spatio-temporal patterns in macroinvertebrate communities and river condition; and (5) revise its purpose and design.

To date, outputs from the RHMP have been used for a range of purposes relating to the management of natural resources (especially water), and suggest there have been declines in river condition in several areas of Tasmania since 1994. The review identified several limitations in the RHMP, which have been addressed by increasing the breadth and rigour of monitored parameters. In addition, monitoring sites have been adjusted to target landscapes where land and water use are reasonably intense.

Keywords

AusRivAS, river condition, bioassessment, macroinvertebrates, water use, land use

Introduction

Since 1994, the Tasmanian State Government has conducted broad-scale monitoring of river condition in the State under the Tasmanian River Health Monitoring Program (RHMP). The RHMP is the most extensive and longest running program of river health monitoring in Tasmania and employs Australian River Assessment System (AusRivAS) protocols, which focus on benthic macroinvertebrate communities and habitat quality to assess river condition (Davies 2000; Simpson & Norris 2000; Krasnicki *et al.* 2002). During the life of the

RHMP, the State Government and natural resource management agencies in Tasmania have changed their approaches to managing land and water. This has been influenced by changes in legislation (e.g. Tasmanian *Water Management Act 1999* coming into effect) and policy, several departmental re-structures within the State Government, and the running of various nationally-funded programs (e.g. Natural Heritage Trust's National Landcare Program (1996-2002), National Action Plan for Salinity and Water Quality (2000-2007)).

The value of long-term biological monitoring for managing river systems has been widely advocated in Australia (Davies *et al.* 2010; Nichols *et al.* 2017) and internationally (Buss *et al.* 2015). However, data from broad-scale monitoring programs typically have inherent limitations (Boulton 1999; Bunn *et al.* 2010). For example, the breadth and scale of measured parameters and rigour of assessments (often qualitative instead of quantitative measurements) may restrict the applicability of the results to addressing management issues. Nevertheless, well-designed programs can provide valuable datasets that, when carefully interpreted, enable spatio-temporal variability in measured parameters to be assessed and changes in river condition to be detected (Nichols *et al.* 2017).

The RHMP has been implemented for over two decades, and in this time land and water management in Tasmania has changed substantially. River health science has also advanced, with holistic strategies that integrate measures of several ecosystem components being advocated and commonly employed. This paper provides an overview of a review of the RHMP which was undertaken to evaluate and redirect the program (DPIPWE 2018). Specifically, the review of RHMP aimed to: (1) document its history; (2) assess applications of resulting data and the applicability of other measures of river condition; (3) evaluate the value of its abiotic and biotic data; (4) examine spatio-temporal patterns in macroinvertebrate communities and river condition; and (5) revise its purpose and design.

History of RHMP

The River Health Monitoring Program (RHMP) in Tasmania began in May 1994, with sampling commencing in spring 1994 (Krasnicki *et al.* 2002; DPIPWE 2018). The Tasmanian State Government has been committed to the RHMP from the outset in terms of financial, logistical and staffing resources. In the early years, the RHMP was associated with several state and/or national programs that were components of the National River Health Program (NRHP). The NRHP was a Commonwealth and state collaboration that developed the Australian River Assessment System (AusRivAS) (Davies 1994; Davies 2000; Simpson & Norris 2000; Krasnicki *et al.* 2002).

Following the initial developmental phases of AusRivAS and the RHMP, between 2001 and 2012 the RHMP was associated with the Tasmanian State Government's *TasTogether* 2020 plan. This was a 20-year, community-owned, social, environmental and economic plan for the State (Tasmania *Together* 2006). During this time, AusRivAS outputs from 60 long-term monitoring sites (31 reference sites, 29 test sites; Figure 1) in the RHMP contributed to the assessment of benchmarks under this plan which related to a goal to sustainably manage natural resources (Tasmania *Together* 2006). This plan ceased in 2012 with the *Tasmania Together Progress Board Repeal Bill 2012* repealing the *Tasmania Together Progress Board Act 2001*.

Between 2000 and 2008, data from the RHMP was also used to support projects funded by the National Action Plan for Salinity and Water Quality (NAP) and Natural Heritage Trust (NHT). In addition, results from the RHMP were used for Waterways Reporting and to prepare State of Rivers reports for selected catchments. Since 2012, the RHMP has not been linked to any external funding sources or programs; however, it has continued (with State Government funding and resourcing), largely to provide environmental science to support water management and planning in Tasmania.

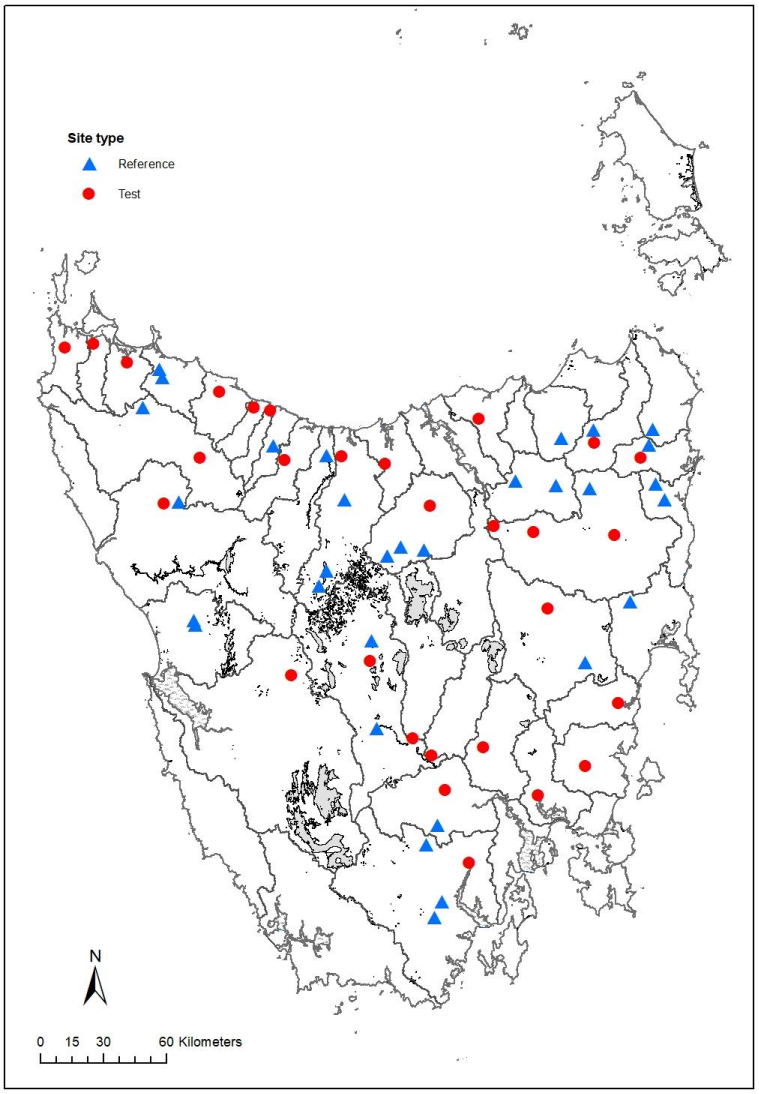

Figure 1. Location of long-term monitoring sites in the Tasmanian RHMP, 1994-2016. 'Test' sites (sites likely or known to be impacted by habitat degradation in areas of interest) and 'reference' sites (pristine or least disturbed sites) are indicated.

Applications of RHMP data and the applicability of other measures of river condition

To date, data from the RHMP, and AusRivAS sampling in Tasmania more broadly, have been used for various applications at a range of spatial scales (Table 1). For example, data from the RHMP and AusRivAS data from other jurisdictions have been used to assess river health across Australia (Norris *et al.* 2007), including for State of the Environment reporting (Harrison *et al.* 2011) (Table 1). While in Tasmania at a state-wide scale, RHMP data have been used to: assess river condition to inform water management, planning and policy (DPIPWE 2016); undertake a bio-regionalisation of macroinvertebrate communities and assess their condition (DPIW 2008); and, examine impacts of land use on macroinvertebrate communities and identify land-cover thresholds to guide land use practices (Magierowski *et al.* 2012). Within Tasmanian catchments, RHMP data are routinely used to document river condition to support water planning (e.g. DPIPWE 2014), and have also been used to prepare State of Rivers Reports (e.g. DPIWE 2003). At finer spatial scales in Tasmania,

Table 1. Examples of applications of data from the Tasmanian RHMP, and AusRivAS sampling in Tasmania, at various scales.

Scale	Application	Application details
Australia	Spatial modelling of river condition	Use of AusRivAS data from jurisdictions to model river condition across most of Australia (Norris *et al.* 2007).
	State of the Environment reporting	Nation-wide assessments of instream biological health using AusRivAS data from jurisdictions (Harrison *et al.* 2011).
Tasmania	River condition assessments	State-wide assessment to inform water management, planning and policy (DPIPWE 2016).
	Bio-regionalisation of aquatic macroinvertebrate fauna	State-wide bio-regionalisation of macroinvertebrate communities and there condition (DPIW 2008).
	Examination of the impacts of land use on rivers	Assess of the impacts of land use on macroinvertebrate communities and identification of land-cover thresholds to guide land use practices (Magierowski *et al.* 2012).
Tasmanian catchments	River condition assessments	Catchment-wide assessments to support environmental flows assessments, and water management and planning (DPIPWE 2014).
	State of Rivers reporting	Catchment-wide assessments to inform water management, stakeholders and broader community (DPIWE 2003).
Tasmanian reaches	Assess impacts of mining operations	Monitoring to assess the impacts of mining operations and/or rehabilitation from historical impacts (DPIPWE 2012).
	Assess impacts of the management of hydro-electric infrastructure	Monitoring to assess the influence of flow regime alterations associated with hydro-electric impoundments and power stations (Hydro Tasmania 2016).

AusRivAS data are used to examine the effects of infrastructure associated with hydro-electric power schemes (e.g. Hydro Tasmania 2016) and point-source pollution from activities such as mining (e.g. DPIPWE 2012).

Since the development of AusRivAS in the 1990s (Davies 2000; Simpson & Norris 2000), techniques to assess river condition have progressed globally. This has involved exploring components of riverine ecosystems, other than macroinvertebrates, which are sensitive to stream degradation (Davies *et al.* 2010; Clapcott *et al.* 2012) and also examining more holistic approaches to assess and rate river condition (Bunn *et al.* 2010). In Tasmania, the development of the Tasmanian River Condition Index (TRCI) (NRM 2009) has somewhat addressed these issues; however, to date it has not been extensively adopted in the State. Recent catchment-based and regional studies in Tasmanian have shown the value of measuring the cover and load of benthic fine sediment and algae when assessing the condition of rivers in the State (DPIPWE 2014, 2016). Therefore, the inclusion of more rigorous measures of the cover and load of benthic fine sediment and algae in the RHMP is worthy of consideration.

Evaluation of RHMP abiotic and biotic data

In accordance with AusRivAS protocols (Davies 2000; Simpson & Norris 2000; Krasnicki *et al.* 2002), to date biotic data from the RHMP primarily focus on the structure of macroinvertebrate communities, and abiotic data relate to water quality and habitat quality (riparian and instream). The macroinvertebrate data underpin standardised results of AusRivAS predictive models (e.g. Observed/Expected (O/E) taxa scores, Stream Invertebrate Grade Number Average Level (SIGNAL) scores, impairment band ratings, etc.) which are key outputs from the RHMP (Simpson & Norris 2000; Krasnicki *et al.* 2002). These outputs are responsive to various disturbances (e.g. dams, mining, land use and water use) and have typically been the focus in applications of RHMP data (Table 1). In addition, recent studies in Australia have shown that analysis of raw taxonomic data from AusRivAS-style macroinvertebrate sampling can be used to examine ecological responses to various types of perturbations, such as the influence of climatic variation (Thomson *et al.* 2012; Chessman 2015), water abstraction (Brooks *et al.* 2011) and land use (Magierowski *et al.* 2012). Therefore,

the current macroinvertebrate sampling and analysis protocols are critical components of the RHMP, which will continue to be employed in the program.

Ninety-three variables relating to sampling sites and habitat assessments are recorded in the RHMP database for each sampling occasion (DPIPWE 2018). These variables describe the topography of sampling sites, habitat within site reaches (100-m stretch of river) and habitat where macroinvertebrate samples were collected (10 m^2 of benthic substrate). Forty-eight of the habitat-related variables were considered to have sufficient explanatory power to warrant evaluation by subjectively rating their value (explanatory power), rigour (likely accuracy and precision of their estimates) and temporal variability at sites (by inspection of data collected at the long-term monitoring sites). In terms of 'meaningfulness' and 'usefulness' (see DPIPWE 2018), this analysis indicated that 17 variables (35%) are poor, 23 variables (48%) are moderate and 8 (17%) are good. Overall, this suggests that the 'habitat assessment' component of the RHMP has several limitations, and therefore the review revised this component of the program.

Spatio-temporal patterns in macroinvertebrate communities and river condition

Spatio-temporal patterns in macroinvertebrate communities in rivers across Tasmania were examined using long-term data (1994-2016) from the RHMP to gain an overview of the condition of rivers in the State and guide the review of the program. (Additional analyses examining environmental factors associated with variation in river condition were also undertaken, but the results are not reported here (see DPIPWE 2018).) The 60 long-term sites were located in 36 of the 48 catchments in Tasmania, sampled on an average of 28 occasions (range = 16-45) and covered a range of topographic characteristics (e.g. ranges: stream class = 2-6, elevation = 10-675 m a.s.l., catchment area = 7-3285 km^2). To summarise and rank the condition of the long-term monitoring sites in the RHMP, the mean and 95% confidence interval (CI) of O/E scores from all samplings at the sites were calculated. The mean of O/E score at each site from recent samplings (2013-2016) was also calculated to examine recent conditions at the sites in comparison to their long-term range in condition (1994-2016).

The monitoring sites in the RHMP sampled between 1994 and 2016 spanned a broad gradient of condition (mean O/E score range = 0.39-1.21; severely impaired to above reference condition; Figure 2). The greater range in the 95% CIs of the more impaired sites (sites with lower mean O/E scores; Figure 2) also indicates that river condition is more variable at these sites compared to the 'healthier' sites (sites with higher mean O/E scores). This may be due to the healthier sites being more resilient to the effects of varying climatic and flow conditions. In contrast, the poorer sites – which are likely to have compromised riverine ecosystems (i.e. lacking riparian vegetation, higher sediment and algal loads, etc.) – are more susceptible to impacts from varying climatic conditions. This is illustrated by comparisons between mean O/E scores during 2013-2016 and the 95% CIs of all samplings at the sites (Figure 2). Twenty-two moderately impaired sites had mean O/E scores for 2013-2016 that were less than the lower bound of the long-term 95% CIs of their respective sites, while three sites had means for 2013-2016 that were greater than the upper bound of the 95% CIs (Figure 2).

RHMP revised purpose and design

As the current design of the RHMP is providing useful information, wholesale alterations to the program were not proposed. Instead, the revision focused on improving the breadth of monitored parameters and the rigour of the methods that are used to monitor some parameters, especially those relating to habitat quality. Thirty-four recommendations were made relating to: the purpose of the RHMP, monitoring sites, monitoring timing and frequency, monitored parameters, river health rating and modelling, RHMP database management and macroinvertebrate sample curation, approaches to analysing RHMP data, reporting results of RHMP and inter-agency communication, and RHMP future considerations (DPIPWE 2018).

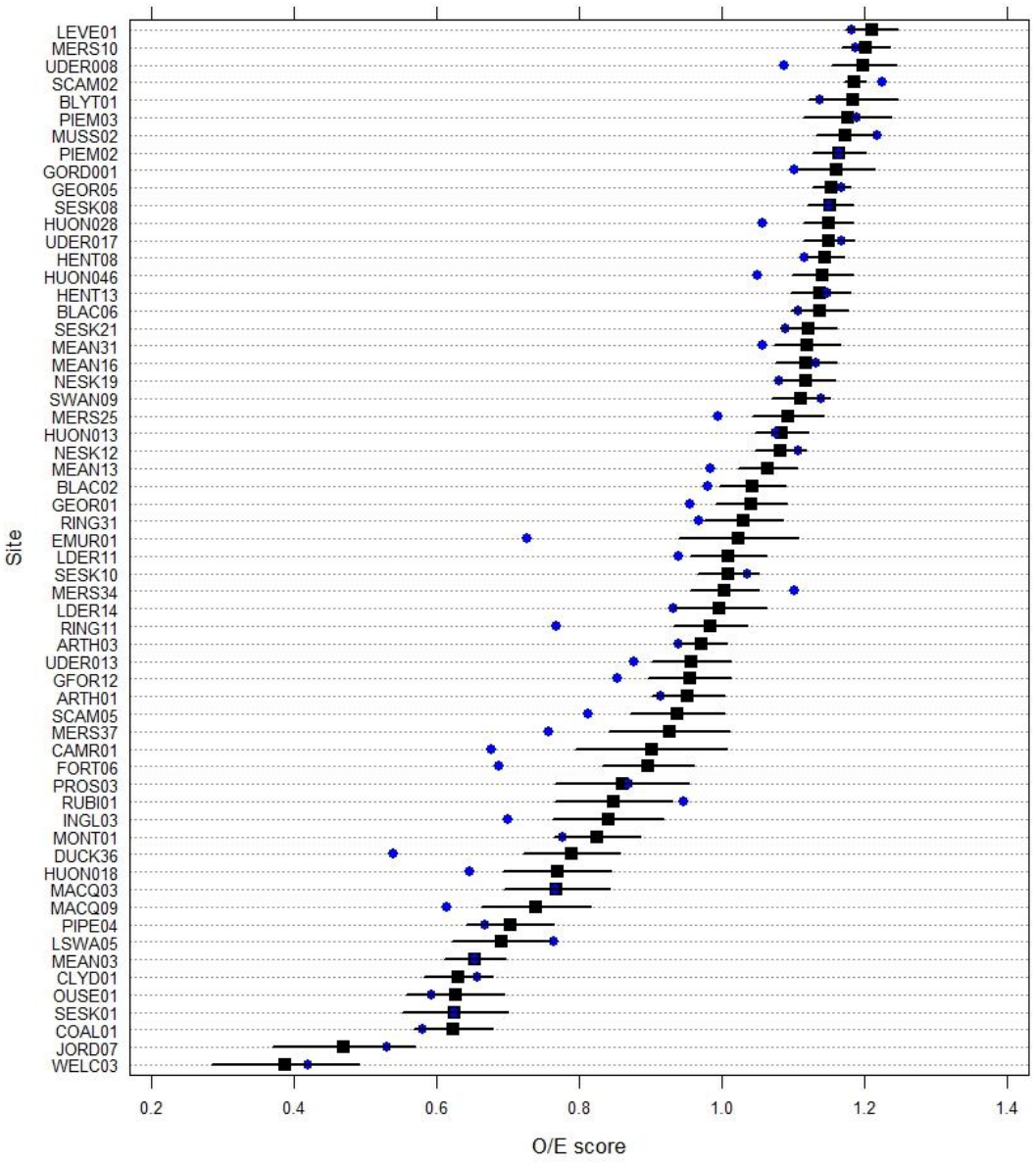

Figure 2. Mean ± 95% CI (closed black squares and black lines, respectively) of O/E scores from long-term sampling in riffle habitat at the long-term monitoring sites, and mean O/E scores from recent sampling (2013-2016) in this habitat at the sites (blue closed circles). Sites are ordered according to their long-term mean O/E scores, with the most impaired sites (i.e. low O/E scores) at the bottom and sites that are in good condition (i.e. high O/E scores) at the top. See DPIPWE (2018) for details of site abbreviations.

In particular, monitoring sites have been adjusted to target landscapes where land and water use activities associated with agriculture are reasonably intense, with a special emphasis on catchments with Water Management Plans. To improve the deficiencies of the current habitat assessment component of the sampling protocols, this review: rationalises the reach- and habitat-scale parameters that are currently measured, recommends using more rigorous methods to measure some parameters, and introduces some new methods to the RHMP that primarily focus on assessing the cover and load of benthic sediment (e.g.

Quorer method; Lambert & Walling 1988) and benthic algae (e.g. scouring sampler; Davies & Gee 1993). These adjustments to the program will enable it to: (1) assess river condition more holistically, (2) examine some of the key ecosystem components that are likely to influence the structure of macroinvertebrate communities, and (3) generate datasets that could underpin the development of predictive models of the health of rivers in Tasmania based on multiple ecological indicators.

Conclusions

This review of the Tasmanian RHMP will assist future management and implementation of the program, and ultimately support sustainable management of water resources and riverine ecosystems in Tasmania.

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