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A simulation interface designed for improved user interaction and learning in water quality modelling software

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ABSTRACT

Traditional simulation software that supports management decisions is configured and run by experienced scientists. However, it is often criticised for its lack of interactivity, not only in the application of decisions but also in the display of results. This paper presents the simulation interface of software with management strategy evaluation capabilities and its capacity to enable resource managers to learn about water quality management as evaluated in a workshop setting. The software 'MSE Tool' is not intended to produce definitive real-world advice but provides a test-bed for managers to interactively design strategies and explore the complexities inherent to water quality management using a simple, yet effective, user interface. MSE Tool has been used in a pilot application that simulated the effects of management strategies applied in catchments and their effects on riverine, estuarine and marine water quality in South East Queensland, Australia. The approach and the software are suitable for reuse in other management strategy evaluation projects.

Software and availability

Name of software	MSE Tool Simulation Interface (MTSI)
Version	2.1
Target system requirements	Microsoft Windows XP, Microsoft.NET Framework 3.5
Development environment	Microsoft Visual Studio 2008 (C# and VB.NET)
Third party libraries	SharpMap version 0.9, Catfood Shapefile 1.0, CenterSpace NMath 4.0, Syncfusion 8.103
Developers	CSIRO Marine and Atmospheric Research, Ecosciences Precinct, Dutton Park, Queensland, Australia
Customer	Healthy Waterways Inc.
Availability	Restricted. Contact CSIRO Oceans and Atmosphere Flagship for details.

1. Introduction

Management strategy evaluation (MSE) is an approach which is well established in the management of natural resources, where it

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is used to support decision-makers assess the trade-offs associated with alternative management and policy options (Smith, 1994). MSE employs computer models to simulate each part of the system using an adaptive management framework (Smith and Walters, 1981; Walters, 1986) and allows managers to test policies and familiarise themselves with alternative outcomes in a safe computer environment (Butterworth et al., 2010; Dichmont et al., 2006; Smith et al., 2007). Key components of an MSE are the simulation of the adaptive management loop, a description of the system under control (monitoring, assessment and decision) and the biological and human response to the determined actions. MSE is grounded around adaptive management (Smith et al., 1999; Walters, 1986)—a key element of natural resource management, and is a type of decision support system (DSS) and, more specifically, an environmental decision support system (EDSS).

MSE has been used for many purposes and case studies; for example, in fisheries (Butterworth and Punt, 1999; Dichmont et al., 2008; Smith et al., 1999), coastal zone management (Jones et al., 2011; McDonald et al., 2008), multiple use management (Fulton et al., 2011b), biosecurity (Dunstan and Bax, 2008) and conservation (Bunnefeld et al., 2011; Milner-Gulland et al., 2010). Several generic tools have been developed for MSE in these different fields, most notably FLR (Fisheries Library for R) (Kell et al., 2007), Atlantis (Fulton et al., 2011a,b) and InVitro (Fulton et al., 2011b; McDonald et al., 2008). Most MSE models have been built for individual examples in a programming language familiar to the scientist.

In its traditional form, MSE relies on an experienced team of scientists and model developers to construct and run the simulation tools in complex software environments that provide model outputs in response to specific requests from decision-makers. Decision-makers are usually consulted on the selection of indicators that reflect the desired objectives, and on reference values for these indicators. The increasing use of computer-assisted simulation to support policy-making in the management of natural resources and environmental issues has seen a growing tendency for managers to also be involved in the model building and model running exercises (Argyris and Schön, 1978, 1996; Boschetti et al., 2010; Brugnach, 2010; Fulton et al., 2013; Jakeman et al., 2008) and has hence created a need for software with less complexity and parameterization but improved user interaction. This is partly a result of progress in computing leading to faster modelling capabilities that allow interactive, stakeholder-driven models to be built more easily. In turn this progress has led to a research stream focused on using participatory modelling in natural resource management (Sandker et al., 2010; Worrapimphong et al., 2010), and to a growing number of applications in which stakeholders and managers themselves can test their ideas. Economic and social models are often integrated within such applications. Results derived from these models, which are based on a limited set of parameters, are not intended to replace the comprehensive advice from an expert team of modellers and scientists. Rather, the results allow the managers to more easily explore the constraints that are imposed by the interactions of their management actions.

Several interactive tools are available for general use under popular operating systems such as Microsoft Windows and Mac OS (e.g. Stella—http://www.iseesystems.com/softwares/Education/StellaSoftware.aspx), as well as in specific applications such as for ecosystems (e.g. EcoPath with EcoSim—http://www.ecopath.org), coastal zone management (e.g. Jones et al., 2011), land use (e.g. CommunityViz—http://www.ebmtools.org/about_ebm_tools.html; ALCES—http://www.alces.ca) and freshwater systems (e.g. SedNet—http://www.toolkit.net.au/tools/SedNet). Selection between these products depends on availability, cost, level of interactivity and relevance to the case study.

The MSE Tool software, which was developed for this project, is an interactive desktop modelling software package for stakeholders and decision makers. Consequently, the approach to modelling used in the MSE Tool occupies a different space in water management modelling, especially in terms of complexity and accuracy. Generally, the MSE Tool is different to a hydrological and hydrodynamic process model in that:

- its primary objective is to engage the user in an interactive, near real-time simulation that conveys a general understanding of the effects of water-quality altering actions on catchments, including the size of change brought about by actions, the time required for actions to take full effect and the economic and social implications of such actions—it is not intended as a tactical tool for determining a single, prescriptive management plan;
- its model outputs are not required to have the same accuracy since they are used to support learning by users rather than for predictive applications;
- its simulation runs are faster and easier to interpret; pre-calculated runs are not necessary since the simulations are designed to respond to a selected, specific suite of parameters and processes—accuracy is traded for responsiveness;
- the application is constrained to a number of pre-defined simulated management actions, but additional actions can be added by the developer with little effort.

1.1. *Simulating water quality management at a regional level*

The MSE Tool's Simulation Interface (referred to as MTSI in the following) is here set in the context of an MSE for use in catchment-to-coast water quality management in South East Queensland (SEQ), Australia (Dutra et al., 2010). The waterways of SEQ comprise 14 large river catchments, and many associated sub-catchments, which flow into Moreton Bay. Together they form an overall catchment area of 21 220 km^2, with complex spatial and ecological interactions (Dutra et al., 2010). The wetlands of Moreton Bay are Ramsar listed (Ramsar Secretariat of the Convention on Wetlands, 2014) and home to a very diverse mix of species (Wetlands International, 1995). The SEQ region includes the major urban centres Brisbane and the Gold Coast, and its population is projected to double from three million in 2010 to approximately six million in 2026 (Office of Economic and Statistical Research, 2011). With this population growth comes increased demand on water resources (Abal et al., 2005) and the threat of contamination due to human development such as sewage, industrial pollution and increased use of fertilisers in agriculture (Moreton Bay Waterways and Catchments Partnership, 2002).

The South East Queensland Healthy Waterways Partnership is a collaboration between government, industry, researchers and the community. It was formed to ensure healthy waterway and catchment ecosystems for SEQ (Moreton Bay Waterways and Catchments Partnership, 2004). To assess the condition of SEQ waterways from catchments to the coast, the partnership established an ecosystem health monitoring program at 19 freshwater catchments, which flow into 18 estuarine areas and 9 marine areas (Smith and Storey, 2001) (Fig. 1). Water quality data is collected twice per year at 135 freshwater sites and monthly at 254 estuarine and marine monitoring sites (South East Queensland Healthy Waterways Partnership, 2009a,b). The partnership produces an annual report card (Fig. 1)—a yearly assessment of the health of each of the waterways using a variety of ecological indicators. Grades are calculated for each of the catchments, estuaries and marine areas by comparing the results of a site to regional