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A visualization tool to support decision making in environmental and biological planning

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A B S T R A C T

Large-scale ecosystem management involves consideration of many factors for informed decision making. The EverVIEW Data Viewer is a cross-platform desktop decision support tool to help decision makers compare simulation model outputs from competing plans for restoring Florida's Greater Everglades. The integration of NetCDF metadata conventions into EverVIEW allows end-users from multiple institutions within and beyond the Everglades restoration community to share information and tools. Our development process incorporates continuous interaction with targeted end-users for increased likelihood of adoption. One of EverVIEW's signature features is side-by-side map panels, which can be used to simultaneously compare species or habitat impacts from alternative restoration plans. Other features include examination of potential restoration plan impacts across multiple geographic or tabular displays, and animation through time. As a result of an iterative, standards-driven approach, EverVIEW is relevant to large-scale planning beyond Florida, and is used in multiple biological planning efforts in the United States.

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Software availability

The EverVIEW Data Viewer is freely-available for Windows, Mac OS X, and Linux operating systems from the Joint Ecosystem Modeling (JEM) website: http://jem.gov.
Also available on the JEM website are the CERP NetCDF metadata conventions and supporting Java NetCDF libraries.
All desktop applications require the Java Runtime Environment. Users wanting to stay informed of software updates and releases can sign up to the email distribution list on the website.

1. Introduction

The development of decision support tools (DST) and decision support systems (DSS) has been ongoing for several decades to help with the structuring of problems and decision making in a complex natural world (Rizzoli and Young, 1997). Decision theory calls for the identification of objectives before developing and evaluating alternative plans of action (Keeney, 1992). Decision analysis, when applied, includes optimization routines to provide best solutions against specified objectives. Decision support does not necessarily provide optimization for best solutions but can provide means to organize, display, and manipulate information used in decision making (Diez and McIntosh, 2011). Regardless of its form, an effective DST or DSS should be tailored to the decision problem (Sojda et al., 2012) and developed for and with targeted end-users (Lautenbach et al., 2009).

Florida's Greater Everglades (hereafter "Everglades"), a broad wetland ecosystem of national and international importance, has a history of more than a century of human intervention (Davis and Ogden, 1994). In the early 1970s, concern rose within the scientific community over deteriorating environmental conditions as a result of such intervention (Chimney and Goforth, 2001). By the 1990s, planning was underway to remove almost 400 km of levees and canals, and return the 28,000 km^2 wetland ecosystem to its natural state (Gunderson et al., 1995). This ongoing restoration effort is expected to continue for decades and cost billions of dollars (National Research Council, 2008).

Water patterns and their effect on habitat are a major driving force in Everglades restoration. To aid in selection for

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implementation among alternative restoration plans, scientists have collected data on the Everglades ecosystem and developed ecological models to forecast potential impacts of restoration on species of interest (e.g., DeAngelis et al., 1998; Romañach et al., 2011). Running these models against hydrologic patterns that represent alternative restoration plans allows decision makers to explore the impacts restoration plans might have on important components of the ecosystem. As more data are collected and more models are developed, a subsequent challenge has emerged to effectively use the vast amount of available information in the plan selection process.

In response to the need to compare alternative restoration plans against restoration objectives, natural resource managers and decision makers from various agencies (e.g., South Florida Water Management District, US Fish and Wildlife Service, National Park Service) in the Everglades became interested in the development of a DST that would allow them to evaluate the potential effects of plan implementation. Specifically, interest was expressed in the ability to view and interrogate ecological simulation model outputs on a user's personal computer. In the past, where visualizations of model outputs were available, they were often in the form of static maps which illustrated results for one species at a single point in time. Decision makers found this format to be ineffective, resulting in a limited understanding of the impacts a proposed restoration plan might have over a spatially and temporally dynamic wetland with a suite of restoration objectives.

Several factors impeded the adoption of existing software as a common DST for the Everglades community. By the late 2000s, many modelers in the Everglades had begun using the Network Common Data Form (NetCDF) (Rew and Davis, 1990) file type for their model output. At the time, several visualization applications and frameworks existed (e.g. Unidata Integrated Data Viewer [Murray et al., 2003], GRASS GIS [Neteler and Mitasova, 2008], uDig [Ramsey, 2006], and Ncvtk [Pletzer et al., 2005]) that fully supported NetCDF, and others (e.g. ArcGIS, ParaView, MATLAB) only partially supported NetCDF through supplementary converters, or were too technical for most users. None of these tools, however, enabled accurate comparison of ecological and hydrologic model outputs produced from alternative restoration plans. Additionally, no existing software was available to be rapidly developed and iteratively updated in response to active end-user feedback. Finally, the lack of formal agreement over NetCDF metadata conventions hindered collaboration among scientists and presented another barrier to widespread acceptance of a common DST.

1.1. The role of EverVIEW

The EverVIEW Data Viewer (hereafter "EverVIEW") was developed as a DST to aid restoration planners in evaluating alternative restoration plans. Many organizations (such as federal and state agencies, local municipalities, and universities) and individuals have been involved in Everglades restoration planning. A subset of individuals, including scientists and decision makers, developed a set of ecological objectives that define a restored Everglades (Doren et al., 2009). Performance metrics were assigned to those objectives

to allow decision makers to evaluate restoration success. In keeping with decision theory, alternative restoration plans were designed to help achieve restoration objectives (Keeney, 1992). Ecological models were developed by agency and university scientists to help illustrate the potential consequences of each restoration plan.

EverVIEW is designed to minimize the challenges associated with adoption of a common Everglades DST by enabling decision makers to visualize model outputs and consequences of alternative restoration plans, and to select a plan that best meets restoration objectives (Fig. 1). The software helps bridge the information gap between ecological modelers and restoration planners (see Liu et al., 2008; Thackway et al., 2013; Matzek et al., 2014) by enabling model output from widely varied sources to be readily consumed and made available for evaluation of alternative plans in the decision making process. The modular architecture underlying EverVIEW enables rapid feature development based on end-user feedback. Support in EverVIEW for community-adopted NetCDF metadata conventions ensures consistent visualization output for end-users and reinforces community adherence to conventions. This paper explores the success of EverVIEW as a DST, its core features, limitations, and examples of use in the context of Everglades restoration planning.

2. Development and features of EverVIEW

EverVIEW is a cross-platform desktop application that helps decision makers easily compare output from ecological and hydrologic models (as ecological model inputs) on their own computers (Joint Ecosystem Modeling, 2009). As a DST, EverVIEW has features that enhance and improve the decision-making process while leaving decisions to the informed end-user.

2.1. Challenges and development cycle

In a position paper by McIntosh et al. (2011), the authors provide a list of challenges and recommendations for the development of a successful Environmental Decision Support System (EDSS). Their recommendations come from challenges related to (1) engagement of end-users and stakeholders, (2) adoption and use of the EDSS, (3) cost and technology related to making the EDSS sustainable in the long-term, and (4) evaluation and measures of success of the EDSS. These same challenges apply to the development of a DST like EverVIEW.

One of the most critical tasks in successful DST or DSS development is ensuring use by targeted end-users (Lautenbach et al., 2009; McIntosh et al., 2011). Identification of potential end-users for an Everglades DST was relatively straightforward because many agencies and individuals in the Everglades modeling community had similar needs. Furthermore, the prior development and subsequent adoption of the Comprehensive Everglades Restoration Plan (CERP) NetCDF metadata conventions highlighted the need within this community for tools which facilitated deeper comparison of alternative plans and easier communication of findings to restoration decision makers. The exact functional specifications for the proposed DST (now known as EverVIEW) were not readily
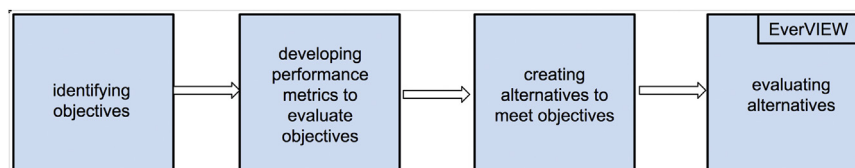

Fig. 1. EverVIEW is used as a DST to evaluate performance of alternative restoration plans and guide the decision process. Figure adapted from Keeney (1992), Fig. 6.1.