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Ecopath with Ecosim as a model-building toolbox: Source code capabilities, extensions, and variations

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ABSTRACT

Ecopath with Ecosim (EwE) is a widely applied food web model that is mostly known as desktop software for the Microsoft Windows platform. The freely available Microsoft .NET source code of EwE, however, provides a range of possibilities to use the model in different ways, to customize and extend the model, and to execute the model on different operating systems.

We provide an overview of the EwE source code, its philosophy, and its technical capabilities, targeted to model builders and advanced users of the EwE software. We showcase novel scientific applications of the EwE model that have been facilitated because of the modular approach of the system. We also present three additional versions of EwE that have been written in different computer languages for dedicated purposes. Lastly, we provide an entry point for users for obtaining and using the source code for custom purposes.

1. Introduction

Ecopath with Ecosim (EwE) is a mainly aquatic food web model, the start of which was conceived more than 30 years ago (Polovina, 1984). The EwE modelling approach consists of three main, linked routines: (i) Ecopath, a static model that represents the energy mass-balance of a trophic web (Christensen and Pauly, 1993, 1992; Polovina, 1984); (ii) Ecosim, a time-dynamic model that obtains some of its initial parameters and assumptions from the Ecopath model to assess temporal dynamics of an ecosystem (Walters, 2000; Walters et al., 1997); and (iii) Ecospace, a spatial–temporal explicit model that applies the Ecosim equations over a grid of spatial cells where cells are connected through biomass exchange using diffusion and migration movement relationships (Walters et al., 1999). Made freely available as desktop software in 1992, two decades of continued development accompanied by a strong commitment to user support and training have turned the EwE approach into the most widely applied model of its kind (Christensen and Pauly, 1992; Christensen and Walters, 2011, 2004; Coll et al., 2008; Walters et al., 1997). EwE is predominantly used for ecological studies and Ecosystem Based Management, and in a recent case, to support an Environmental Impact Assessment (Christensen and Maclean, 2011; Canadian Environmental Assessment Agency, 2015; Link, 2010).

The EwE approach can be used, extended, and applied in an endless number of ways with even only rudimentary software programming experience. In this paper, we introduce a variety of applications that the EwE source code has facilitated, present an overview of novel applications of the model, introduce how the EwE source code can be used to customize applications, and present implementations of EwE in other programming languages, written for dedicated purposes.

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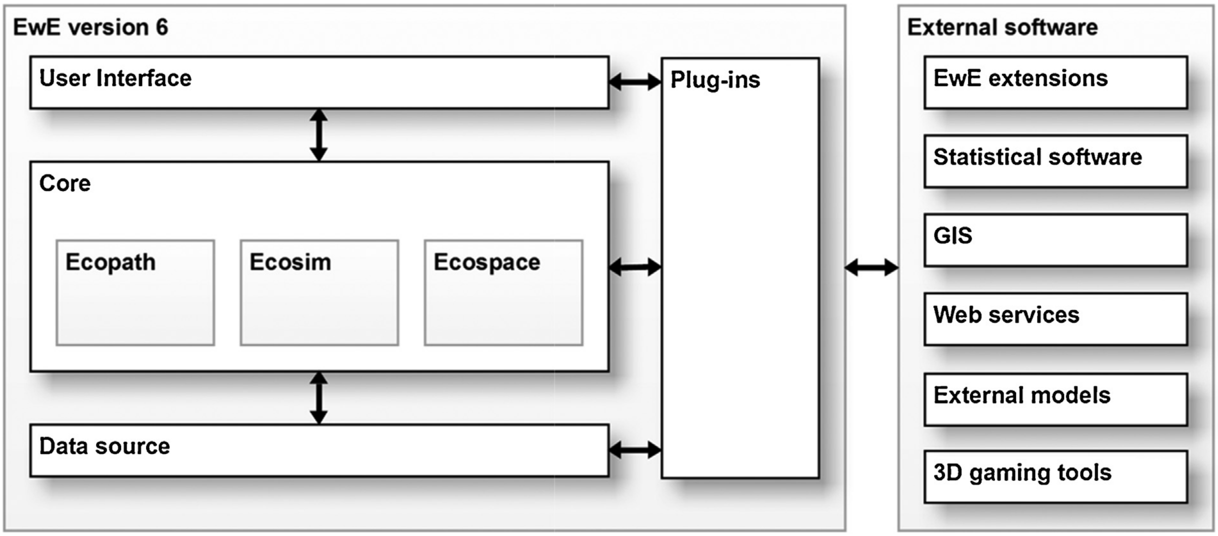

Fig. 1. The modular structure of the Ecopath with Ecosim source code, separating data access, computations, and user interface into exchangeable components. A plug-in system provides the means to extend the EwE model, and to connect to other programs external to the EwE software.

2. Source code organization

As outlined in Christensen and Lai (2007), the EwE modelling software underwent a structural overhaul and partial rewrite from 2005 to 2007. The Ecopath source code was rewritten using the Microsoft.NET framework for a few important reasons.

First, Visual Basic .NET, one of the programming languages under .NET, is structurally compatible with deprecated Microsoft Visual Basic 6, the former programming language of Ecopath. Visual Basic 6 was primarily selected because of its ease of programming, and its ability to deliver user-friendly interfaces. Largely retaining code structures in .NET made it possible to update the programming environment without having to do a complete overhaul of the computational core, while the .NET offered a similar but broader toolset to retain the familiar user interface.

Second, the .NET framework is a long-term technological investment by Microsoft, and has been promoted as the main platform for building applications for Windows since late 2000 (Microsoft Support, 2014). Because of this long-term commitment, there is no foreseen need to rewrite the EwE code again due to discontinued development tools. The .NET framework has attained a large user base worldwide, supported by a large volume of technical resources on the Internet, which aids programming efforts and may make EwE source code attractive for third-party developers.

Third, the .NET framework offers an extensive library of software building blocks. Any program written in .NET, in turn, can provide its own building blocks for reuse in other programs. A version of EwE built in .NET would thus become a programmers' toolbox for model extension and integration.

Fourth, Visual Basic .NET and other .NET framework programming languages are based on the Common Language Infrastructure (CLI), an open standard that defines a structure for high-level programming languages to function on different computer systems without having to adhere to any particular computer hardware architectures (ECMA International, 2012). This means that all .NET programs – if properly adhering to the CLI specifications – can be executed on any computer system for which a CLI runtime environment (such as Mono, http://www.mono-project.com/, and Portable.NET, http://www.gnu.org/projects/dotgnu/pnet.html) is available. CLI-compliance would open the possibility to run EwE on other operating systems, for instance on non-Windows parallel computing clusters. Recently, Microsoft released part of the .NET runtime environment code as open source, and pledged close collaboration with Mono to provide better support for cross-platform deployment of .NET software (Microsoft News Center, 2014). This holds potential for wider applications of EwE and other .NET tools.

The last major benefit of the CLI architecture of .NET is its technical compatibility with over 20 other CLI-based programming languages within and outside the .NET framework, such as C# (C sharp), F# (F sharp), IronPython, IronRuby, C++/CLI, Silverfrost FTN95, Visual Basic.NET, J-script.NET, and Eiffel. The CLI foundation provides high-level interconnectivity between code written in many languages, both for scientific and non-scientific programming purposes.

Because of the factors outlined above, the Ecopath source code was ported to Visual Basic .NET. The original Ecopath, Ecosim and Ecospace data structures and algorithms were preserved, but were wrapped in an object-oriented structure of classes that was designed with reusability and extensibility in mind. The EwE source code was conceptually reorganized, physically separating computational logic, database access, and user interfaces into separate, replaceable, and extendable modules (Fig. 1). The user interface was redesigned. It retains familiar elements but provides a more intuitive workflow. Further, a plug-in system was added to allow third-party programmers to write code modules for EwE without having to change the original EwE source code (Christensen and Lai, 2007). EwE recognizes and integrates plug-in modules into its execution flow and its desktop user interface, allowing for seamless extension of the software (Fig. 2).

The reorganization of the EwE source code and implementation in .NET has opened novel ways to run, integrate, and extend the EwE model.

2.1. Running the EwE model

EwE is most widely known as desktop software available for the Windows platform. This desktop software is written in .NET, and is composed of logical building blocks that can be freely re-used and incorporated in other programs. As such, with some programming experience, it is quite feasible to build custom programs that use EwE code components for their own purposes.

For instance, one can construct small programs to automate EwE-related tasks that would be tedious to perform in the desktop software, such as repeatedly tweaking model input