A toolbox to evaluate data reliability for whole-ecosystem models

Quality Assessment of Ecosystems

Pierre Bourdaud [a,b], Géraldine Lassalle [a,b,c,*], Blanche Saint-Béat [a], Sébastien Rochette [d], Nathalie Niquil [b]

a LIENSs Littoral ENvironnement et Sociétés; b BOREA; c irstea; d Ifremer

* geraldine.lassalle@irstea.fr

Ecosystem models are simplifications of reality and their application for ecosystem-based management requires standard validation. Ecopath with Ecosim (EwE) (Christensen and Walters, 2004; Christensen *et al.*, 2008) is the most widely used ecosystem model (Dame and Christian 2010; Fulton, 2010). Several methods are now available for this specific modelling software to address the issue of uncertainties in the input data. Among these methods, some are implemented in the Ecopath software while others are detailed in recent scientific publications (Kavanagh *et al.*, 2004; Link, 2010; Niiranen *et al.*, 2012). However, their application has not yet become an integral part of the modelling process. The main aim of this study was to propose to modellers an operational and easy-to-use toolbox checking for data reliability (DataReli toolbox; Lassalle *et al.*, 2014). A suite of complementary analyses covering various aspects of data properties related to their use in static ecosystem models were selected. Then, these analyses were organized in the form of a decision tree with guidelines on how interpreting results in terms of corrections of parameter estimates and restrictions in the model applications.

The DataReli toolbox

Pedigree index
(Funtowicz and Ravetz, 1990)

- Allows categorizing the data origin of each single model input using pre-defined tables
- Inputs from local data have the best confidence and the highest level in the scale
- The overall pedigree index τ ranges from 0 (i.e. low precision information) to 1 (i.e. data and parameters fully rooted in local data)
- τ is the average of the individual pedigree values

Revision of parameters

τ < 0.4

τ >= 0.4

A closer look at values by parameters and compartments is required

PREBAL analysis
(Link, 2010)

- Check for respect of some basic ecological and fisheries principles

Ex: The primary production of an ecosystem forms the basis from which all other productivity is derived

→ The ratio of production/biomass of a taxa on production/biomass of primary producers should be less than 1

- Helps to prioritize parameters needing improvement

Too many ecological incoherencies

Respect of basic ecological and fisheries principles

Some deviations are linked to modeller choices or underlying assumptions of the modelling software

Sensitivity analysis

- Test for robustness of model predictions (sign of the mixed trophic impacts (MTIs)) to small variations in input data (Rochette *et al.*, 2009)
- The MTI matrix quantifies the direct and indirect trophic impacts of each functional group on all other functional groups (Ulanowicz and Puccia, 1990)
- Provides restrictions in the model applications

MTI sign variations leading to model restrictions

No MTI sign variations incompatible with model applications

Application on the EwE Bay of Biscay continental shelf foodweb model

(colors are corresponding with those of boxes on the left)

τ for the Bay of Biscay continental shelf foodweb model is 0.60

Table 1. Categorizing data origins for input parameters for the Bay of Biscay continental shelf foodweb model (Lassalle *et al.*, 2011). Maximum index values are in green

	Biomass	Production/ biomass	Consumption/ biomass	Diet	Catches
Top-predators	6	2	4	3	
	6	2	4	3	
	6	3	4	6	
	6	3	4	6	
	6	3	4	6	5
	6	3	4	6	
	6	3	4	6	5
	6	4	4	5	6
	6	4	4	5	6
	6	4	4	5	6
	6	4	4	5	6
30 compartments	4	4	4	6	6
	4	4	4	6	6
	6	4	4	6	6
	6	4	4	6	6
	6	4	4	6	
	1 CE	3	3	4	6
	1	3	3	4	6
	5	4	1	6	6
	5	4	1	6	
	5	4	1	6	
	5	4	1	6	
	5	4	1	6	
	5	4	1	6	
	6	1	3	6	
	6	1	3	6	
	6	1	3	6	
Low-trophic levels	6	8	1	6	
	6				
	6				

Ecological cohesiveness is generally respected, despite some deviations

Table 2. Foodweb model diagnostics used for the evaluation of the Bay of Biscay continental shelf foodweb model according to Link (2010)

Class of diagnostics	Rules of thumb	Remarks
Biomass across taxa and TLs (detritus omitted)	a range of 5-7 orders of magnitude	
	slope ~5-10% declin along increasing TLs	
	few taxa notably above or below slope-line	Biomass of surface-feeder seabirds too small
Biomass ratios	Predator biomass less than that of their prey	Biomass of phytoplancton less than biomass of zooplankton
	Equitable apportionment of biomass for comparable TL groups in major pathways of trophic flow	Higher biomass of zooplankton compared (~x2) to benthos
Vital rates across taxa and TLs (detritus omitted)	Decline of consumption/biomass, production/biomass and respiration/biomass along increasing TLs	Exception for homeotherms at upper TLs
	A few taxa notably above or below slope-line	Exception for homeotherms at upper TLs
Vital rate ratios	Predator vital rate less than that of their prey	Exception for homeotherms at upper TLs
	Production/biomass across taxa less than production/biomass of primary producers	
	Production/consumption less than 1 for each taxa	
	Production/respiration less than 1 for each taxa	Exception for bacteria
Total production and removals	Total, scaled production, consumption and respiration decline along increasing TLs	Exception for homeotherms at upper TLs
	Consumption exerted on a taxa less than its own production	
	Consumption by taxa greater than its own production	
	Total human removals less than production of a taxa	
	Total human removals less than consumption exerted on a taxa	

Confidence percentages are globally high. The lowest confidence is for the Atlantic mackerel (AM), when considered as an impacting group

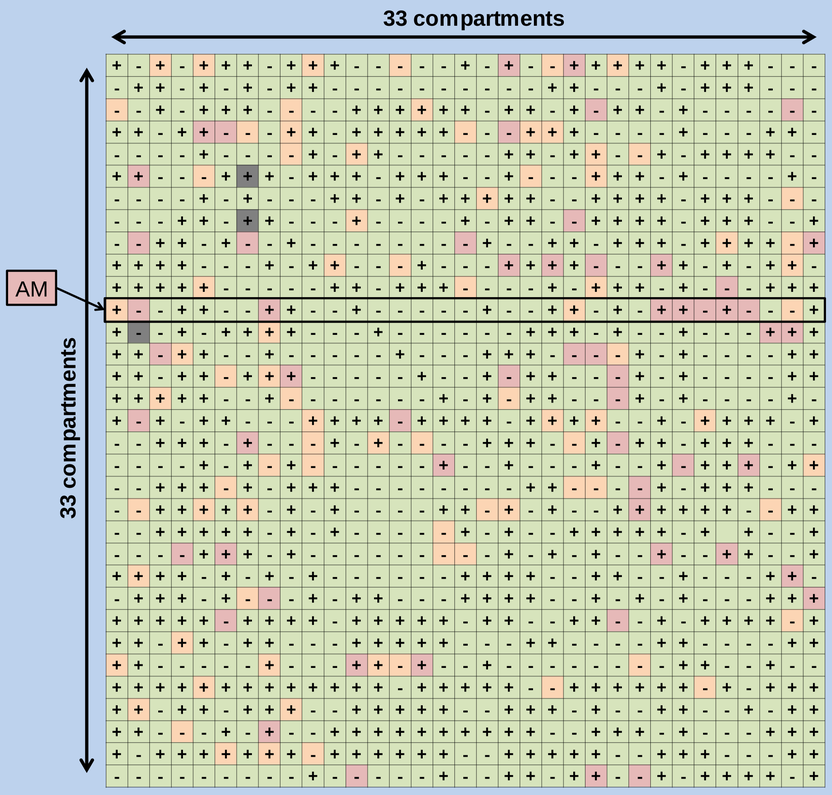

Fig. 1: Probability of obtaining a sign identical to the one reported in the original MTI matrix when applying small variations to the inputs for the Bay of Biscay continental shelf foodweb model

The 'DataReli' toolbox is proposed to ensure the best congruence between the reliability of the input data used during model construction and the purposes for which an ecosystem model was intended.

The Bay of Biscay continental shelf foodweb model was designed to provide understanding of ecosystem structure and functioning with an emphasis on top predators and small pelagics in interaction with fisheries (Lassalle *et al.*, 2011, 2012).

Therefore, improvements should be investigated on parameterizing the mackerel group (Fig. 1) and a gap in cephalopods data (CE; Table 1) has been highlighted.

This research has been mainly supported by the project DEVOTES (DEVelopment Of innovative Tools for understanding marine biodiversity and assessing good Environmental Status) funded by the European Union under the 7th Framework Programme, 'The Ocean for Tomorrow' Theme (grant agreement no. 308392; www.devotes-project.eu)