Development of Continuous, Linear Models for Marine Benthic Macrophytes Description

Tzouvaras N.P.

11, Psaron Str., 10437 – Athens, Greece

e-mail: nptzouvaras@yahoo.gr

Abstract
The European Water Framework Directive has fostered indicator development, pertinent to biological quality elements, for ecological status assessment of coastal waters. For seaweed communities, the CFR index considers composition, abundance and physiological status, through four constituents (Richness, Opportunistic species, Cover, physiological Status) with arithmetically added scores (integers), summing up in [0, 100] and yielding ecological quality ratio (EQR) values in [0, 1]. Quantities C, O and S are expressed as percentages; R as small integer values; each one's range of values is subdivided into 5 intervals, each attributed a score (integer). Discontinuous (step-wise) score values cause CFR (integer) discontinuities in the ranges [0, 10] and [90, 100], affecting pertinent EQR values and precluding certain ones (e.g. 0.04, 0.93, 0.98). Based on the major contribution of quantities C and O to CFR, the present work transforms their combined, discontinuous variation into a continuous, linear model, employing recently used concepts (PRI approach), applied in developing a continuous, linear, composite model for another benthic macrophytic index. Application to CFR underlines the flexibility of the RPI approach.
Keywords: Water Framework Directive, Ecological Quality Ratio, marine benthic macrophytes, CFR model, Ecological Evaluation Index RPI approach

1. Introduction

A one-dimensional analogue of the key concept described in the present work is illustrated in Figure 1(a) as a step-wise discontinuous function, being approximated: in Figure 1(b) by a continuous, 2nd-degree polynomial, using horizontal lines near the independent variable range ends and in Figure 1(c) by a continuous, composite line. This work relates to data description in terms of provisions of the European Water Framework Directive (WFD) for coastal waters ecological status assessment, using marine benthic macrophytes as a biological quality element; pertinent terms, such as Ecological Status Classifications (ESC), Ecological Quality Ratio (EQR) and Reference Conditions (RC) are used as in the WFD (EU, 2000).

The Ecological Evaluation Index (EEI) has been proposed (Orfanidis *etal.*, 2001) for marine benthic macrophytes description, using two independent variables expressing % coverage: Ecological State Group I (ESG I) for perennial species and ESG II for opportunistic ones. The original EEI approach (o-EEI) used a cross-matrix of ESG I and ESG II, yielding discrete EEI values (Figure 1(d)), with a linear transformation for EQR calculation. The continuous EEI (EEI-c) approach (Orfanidis *etal.*, 2011) uses a hyperbolic (2nd-degree polynomial) function (Figure 1(e)), partitioning the [0, 100] ESG values range over the five ESCs of the WFD as shown in Figure 1(f), compressing ESC "Bad" and making use of some a posteriori interventions, in addition to the linear transformation for EQR calculation.

The Reference-domain Partitioning through Inclines (RPI) approach (Tzouvaras, 2018) has been proposed as an alternative to EEI-c, based on a modified partitioning over the five ESCs (Figure 1(g)) and replacing the hyperbolic function by a composite surface consisting of linear, planar segments. As indicated by Figure 1(h) (cf. Figure 1(d)), use of inclines allows transformation of o-EEI to a continuous model; this latter approach is applied in this work to CFR, a discontinuous model describing macroalgae.

2. Model development and preliminary Results

The CFR model (Juanes *etal.*, 2008) involves four discontinuous parts: C, R, O and S (Figure (1(i)). It has been noted (Wallenstein *etal.*, 2013) that the EQR values of CFR (namely CFR/100) show "a discrete scale (0.05)" and that it has a "partial score calculation scheme that results in a non-continuous EQR value". In two-decimal representation, CFR may not obtain EQR values such as 0.04, 0.89, 0.91, 0.93 to 0.95 and 0.97 to 0.99 (Figure 1(j)). EQR values near 1 are important, relating to the WFD provision for RC.

The present work suggests a way to mend the above-mentioned deficiency. It uses CFR constituents C and O and their combined nominal share of up to 70% of the CFR scoring so as to: (a) form a cross-matrix (Figure 1(k)) similar to that in o-EEI (Figure 1(d)) and

(b) produce a continuous model, by means of inclines, as introduced in the RPI approach and conceptualized in Figure 1(h). Continuous EQR values (in two decimal points) available in the [0, 0.70] interval ensure continuous EQR values for the full range [0, 1.00] for CFR. A similar approach applied to the (R, S) pair of CFR constituents leads, in effect, to continuous CFR scoring, as a succession of integers in [0, 100].

Concepts introduced through the RPI approach as an alternative to EEI-c are extended to an additional model for macroalgae description, CFR, allowing it to produce the full range [0, 1.00] of EQR values (as well as continuous CFR scoring, as integer values) and underlining the flexibility and versatility of the RPI approach.

3. Conclusion

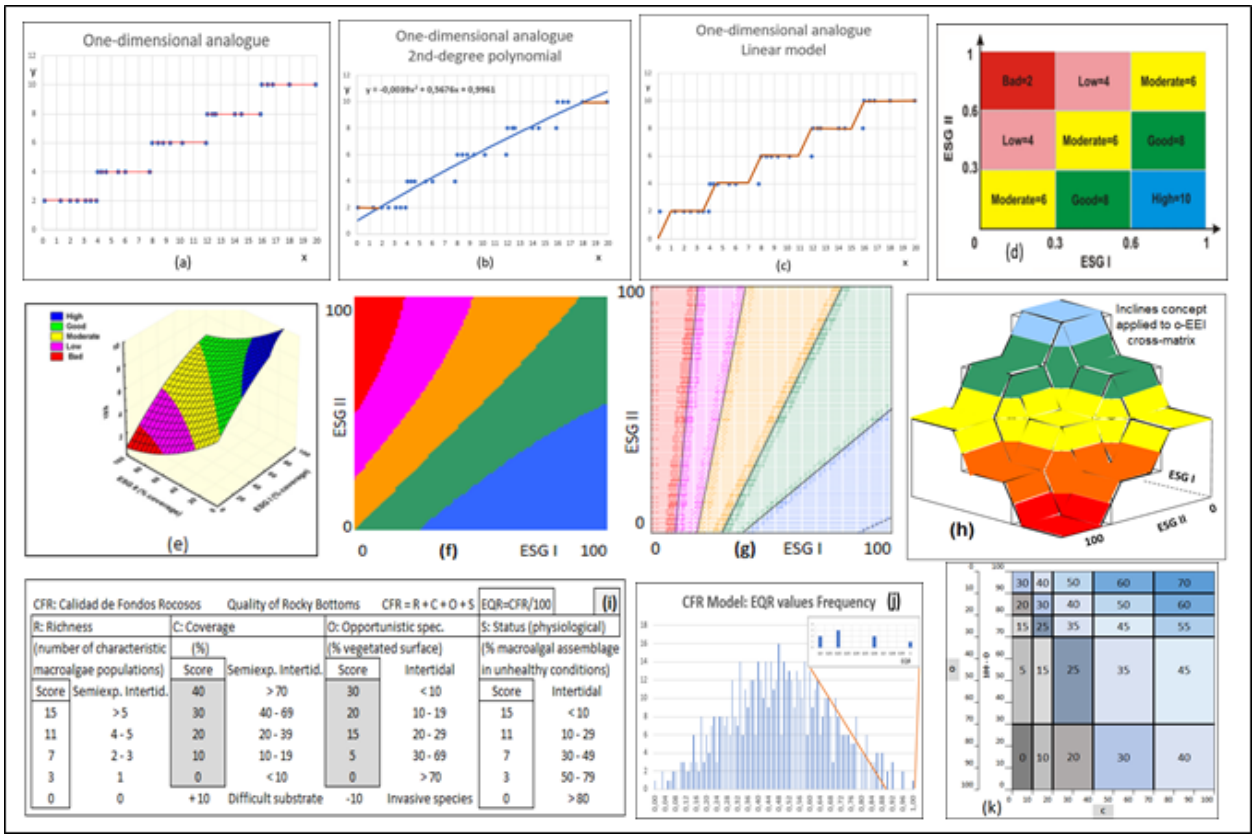

Figure 1. Concepts employed in terms of developing continuity for the CFR model, using linear characteristics from the RPI approach (details are given in the text; images (d) and (e): Orfanidis *etal.*, 2011).

References

EU (2000), Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. *Official Journal of the European Communities* L327, 1-72.

Juanes J. A., Guinda X., Puente A., and Revilla J. A. (2008), Macroalgae, a suitable indicator of the ecological status of coastal rocky communities in the NE Atlantic, *Ecological Indicators*, **8**, 351-359.

Orfanidis S., Panayotidis P., and Stamatis N. (2001), Ecological evaluation of transitional and coastal waters: a marine benthic macrophytes model, *Mediterranean Marine Science*, **2**(2), 45-65.

Orfanidis S., Panayotidis P., and Ugland, K. (2011), Ecological Evaluation Index continuous formula (EEI-c) application: a step forward for functional groups, the formula and reference condition values, *Mediterranean Marine Science*, **12**, 199-231.

Tzouvaras N. P. (2018), An alternative approach to the Continuous Ecological Evaluation Index (EEI-c) for marine benthic macrophytes description, Book of Abstracts 12th Panhel. Symp. Oceanogr. & Fish., (Karachle P. K. *et al*., eds.), Corfu, Greece, 54.

Wallenstein F. M., Neto A. I., Patarra R. F., Prestes A. C. L., Álvaro N. V., Rodrigues A.S., and Wilkinson M. (2013), Indices to monitor coastal ecological quality of rocky shores based on seaweed communities: simplification for wide geographical use, *Journal of Integrated Coastal Zone Management*, **13**(1), 15-25.