

ICT Index® V1.0: An Integrated Framework for Assessing Marine Trophic Network Integrity under the Marine Strategy Framework Directive

Short communication

Serena Anselmi 1,
Monia Renzi 2, *

1, Bioscience Research Center, via Aurelia Vecchia, 32, 58015 Orbetello, GR, Italy

2, Dipartimento di Scienze della Vita, University of Trieste, 34127 Trieste, Italy

* Corresponding author: mrenzi@units.it



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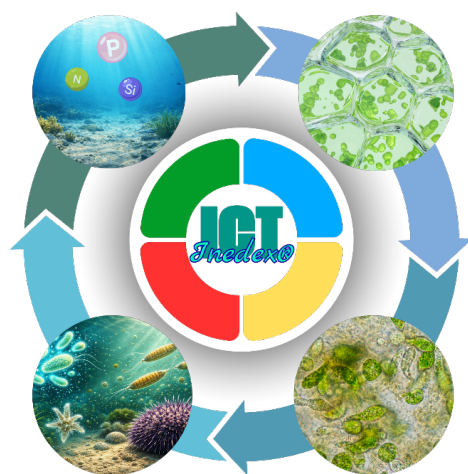
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Abstract: The Directive 2008/56/EC (Marine Strategy Framework Directive – MSFD) establishes the European framework for achieving Good Environmental Status (GES) of marine waters. Descriptor 4 (Food webs) requires that all elements of marine food webs, insofar as they are known, occur at normal abundance and diversity levels capable of ensuring long-term ecosystem functioning. However, despite the clarity of this ecological objective, the Directive does not define a standardized operational methodology for assessing trophic network integrity in an integrated manner. This short communication presents the ICT Index® V1.0 (Trophic Continuity Index) as a methodological proposal designed to address this gap by providing a normalized, transparent and ecologically structured framework for evaluating functional trophic continuity in marine ecosystems.



Keywords: ICT Index® V1.0; Marine Strategy Framework Directive; Descriptor 4; ecosystem-based assessment; primary production; phytoplankton community structure; ecotoxicological response; Weight of Evidence; coastal monitoring.

1. Rationale and Regulatory Context

Implementation of Descriptor 4 under the MSFD remains methodologically challenging. While numerous indicators are available – such as nutrient concentrations, chlorophyll-a, biodiversity metrics, and ecotoxicological endpoints – these are often assessed independently or only partially integrated. As a result, the interpretation of food web integrity frequently lacks systemic coherence.

The ICT Index® V1.0 was developed to overcome this fragmentation by integrating multiple lines of evidence into a unified functional framework. Rather than reconstructing detailed species-specific trophic interactions, the index evaluates the functional continuity of matter and energy flows across key ecological compartments.

2. Conceptual Structure of the ICT Index® V1.0

The index is based on the fundamental ecological sequence (Figure 1) that characterizes marine coastal systems:



Figure 1. Graphical ecological sequence in marine coastal systems

Accordingly, the ICT Index® V1.0 integrates four independent yet ecologically interconnected functional nodes:

- **Node 1** – Trophic base availability, assessing dissolved nutrient coherence relative to expected natural variability;
- **Node 2** – Primary production, based on chlorophyll-a concentration as a proxy for phytoplankton biomass and energy input;
- **Node 3** – Phytoplankton community structure, expressed through diversity, evenness and dominance indices, reflecting system resilience;
- **Node 4** – Continuity toward higher trophic levels, based on a multi-trophic ecotoxicological battery integrated through a Weight of Evidence approach.

The objective is not to model food web topology but to assess whether energy transfer remains functionally coherent across successive compartments.

3.

Methodological Principles

The ICT Index® V1.0 is defined as a normalized synthetic index ranging from 0 to 1, obtained through the weighted integration of the four nodes. Each node is independently normalized on a 0–1 scale (0 = altered condition; 1 = fully functional condition), ensuring spatial and temporal comparability.

The construction of the index follows four core principles:

- **Prior normalization**, ensuring dimensional consistency and comparability;
- **Functional independence of nodes**, reducing informational redundancy;
- **Ecologically motivated weighting**, assigning greater influence to central energy-flow components (primary production and community structure);
- **Safeguard (anti-compensation) criterion**, preventing severe impairment in one node from being fully offset by high scores in others.

Thus, the ICT Index® V1.0 is not a purely descriptive arithmetic mean but a structurally informed metric grounded in ecological hierarchy and precautionary assessment logic.

4. Ecological Interpretation

The ICT Index® V1.0 represents the degree of systemic trophic continuity.

High values indicate that:

- nutrient availability is coherent with natural variability;
- primary production operates within expected physiological ranges without persistent bloom signals;
- phytoplankton community structure maintains diversity and balance;
- no convergent ecotoxicological stress signals are detected across trophic levels.

Intermediate values reflect physiological variability or localized discontinuities, whereas low values indicate functional impairment due to chemical imbalance, production instability, structural simplification or toxicological interference.

The index therefore integrates bottom-up processes and stress-mediated responses within a unified functional perspective.

5. Classification of the ICT Index® V1.0

The final value of the ICT Index® V1.0 is interpreted according to ecologically defined functional classes (Table 1).

Table 1. Classification of the ICT Index® V1.0.

ICT Index® V1.0 Range	Functional Class	Ecological Interpretation
≥ 0.85	Fully functional trophic network	Systemic continuity of energy flows; coherence among all nodes; absence of trophic bottlenecks
0.65 – 0.84	Stable trophic network with physiological variability	Natural coastal fluctuations; no convergent critical signals
0.50 – 0.64	Possible local discontinuity	One or more nodes show significant deviations; alteration not necessarily systemic
< 0.50	Functional alteration	Impaired trophic continuity; convergence of imbalance signals across compartments

5.1 Safeguard Criterion

If at least one node scores < 0.50 , the ICT Index® V1.0 cannot be classified as “Fully functional trophic network”, even if the weighted average exceeds 0.85.

This anti-compensation rule enhances ecological consistency and prevents misleading interpretations due to mathematical compensation among functionally independent compartments.

6.

Relevance for MSFD Implementation

The absence of a harmonized integrated method for assessing food web integrity under Descriptor 4 highlights the need for structured and precautionary frameworks. The ICT Index® V1.0 provides a scientifically grounded and operationally applicable approach aligned with ecosystem-based management principles.

The index does not replace existing indicators; rather, it organizes them within a coherent functional scheme focused on trophic continuity. Its structure is compatible with Weight of Evidence methodologies widely adopted in European environmental assessment systems.

7.

Conclusions

The ICT Index® V1.0 represents a methodological proposal for quantitatively assessing marine trophic network integrity in the context of the MSFD. By integrating chemical, productive, structural and ecotoxicological components into a normalized and precautionary framework, the index translates the qualitative objective of Descriptor 4 into an operational tool.

In a regulatory context where the need to evaluate food web integrity is clearly stated but not operationally defined, the ICT Index® V1.0 may provide a transparent, reproducible and ecologically coherent approach for marine monitoring and ecosystem-based management.

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