INCORPORATING THE MULTI-FUNCTIONALITY CONCEPT IN ENVIRONMENTAL MANAGEMENT AND DECISION-MAKING

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Abstract

It is by now well known in the environmental science community, that nature provides 'life-support services' which do not merely constitute the basis for ecosystem integrity, health and resilience but also the direct and indirect source of goods and services to human societies.

The importance of such multiple outputs, expressed by the human society via their ecological, socio-cultural and economic value, is often ignored or underestimated within the market mechanism because of the public and most of the times incommensurable nature of them.

Moreover, environmental planning and management comprises of complex decision-making tasks, which may involve many social actors, multiple conflicting objectives, a diversity of possible outcomes and sometimes intangible criteria which may vary widely in importance.

Therefore, multidimensional and multi-participative approaches need to be developed, for the assessment of such services and the incorporation of their associated values in the decision-making and planning towards a perspective of their sustainable use and management.

The proposed framework, based on the combination of ecosystem function analysis, multi-criteria analysis (selected method: NAIADE) and qualitative social research, serves as a tool for the identification and categorisation of important aspects of natural ecosystems and the services provided to societies towards the building of a consensus and the development of a socially acceptable option for the management of them.

Keywords: Ecosystem function analysis, multicriteria evaluation, NAIADE method, conflict analysis

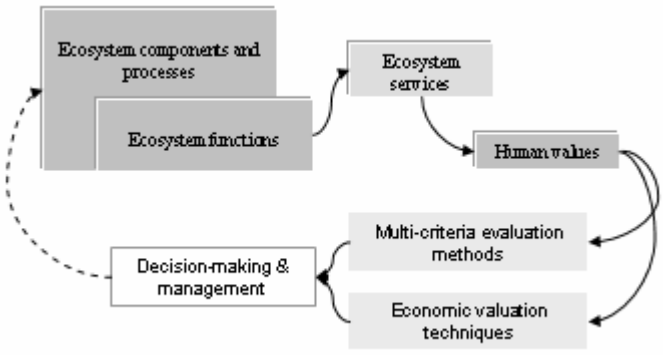
1. Introduction

Like the concept of ecosystem itself, the concept of ecosystem functions and services, which provide a valuable framework for analyzing and acting on the linkages between people and their environment, is relatively recent (Millennium Ecosystem Assessment-MEA, 2003).

Ecosystem functioning, the ecosystem's capacity to carry out its primary processes (capturing, storing and transferring energy, carbon dioxide, nutrients and water), is in turn based on many more processes at a population and community level (Hobbs et al., 1995, Schulze, Mooney, 1993). These processes that are directly related to biodiversity (Loreau et al. 2002), do not merely constitute the basis for ecosystem integrity, health and resilience but also the direct and indirect source of services to human societies (Costanza et al., 1997, Deutsch et al., 2003, De Groot et al., 2003, MEA, 2003).

In particular, within the ecosystem function analysis framework, the ecological complexity (structures and processes) is translated into a more limited number of ecosystem functions, which in turn are reconceptualized as services when human values are implied (De Groot et al., 2002).

Figure 1: Ecosystem functions & services evaluation in the decision-making process



In principle, ecosystem function and services concept has served as a starting point for the assignment of economic values to natural resources, through the use of explicit markets (direct and indirect market pricing), or more indirect means of assessment (stated preference and revealed preference approaches), in order to make it feasible to perform an integrated cost benefit analysis and facilitate decision making regarding the sustainable management of natural ecosystems.

Alternatively, the range and relative importance of the components of ecosystem value can be identified and compared using Multi-criteria analysis (MCA) (Figure 1). In general, MCA methods constitute a tool for dealing with complex decision-making tasks, which may involve many social actors, multiple conflicting objectives, a diversity of possible outcomes and sometimes intangible criteria which may vary widely in importance. As such, MCA has the advantage of being able to provide a framework for insight into the nature of conflicts and possibly for conflict management (Munda, 2004).

There is a great variety of mathematical techniques to tackle with the issue of the aggregation of the different criteria and the choice of action(s)(Salminen et al., 1998). The aggregation procedure is regarded to be, by many authors (e.g. Munda 2004, Guitouni, Martel, 1998,) the one of the most fundamental components of a multi-criteria analysis as it often describes not only the technical but also the theoretical foundations of the MCA method employed. Nevertheless, it also argued that MCA can be seen as a learning tool, which is used rather for helping the structuring of the problem and the evolution of decision process, than concluding to a single decision (Martinez-Alier et al., 1998).

NAIADE (Novel Approach to Imprecise Assessment and Decision Environments) is a discrete multi-criteria evaluation method which performs the comparison of alternative actions on the base of a set of criteria (for further information on NAIADE method see Munda et al., 1994).

2. Analysis of methods and tools

2.1 Ecosystem function analysis: identification of ecosystem services, pressures and related impacts

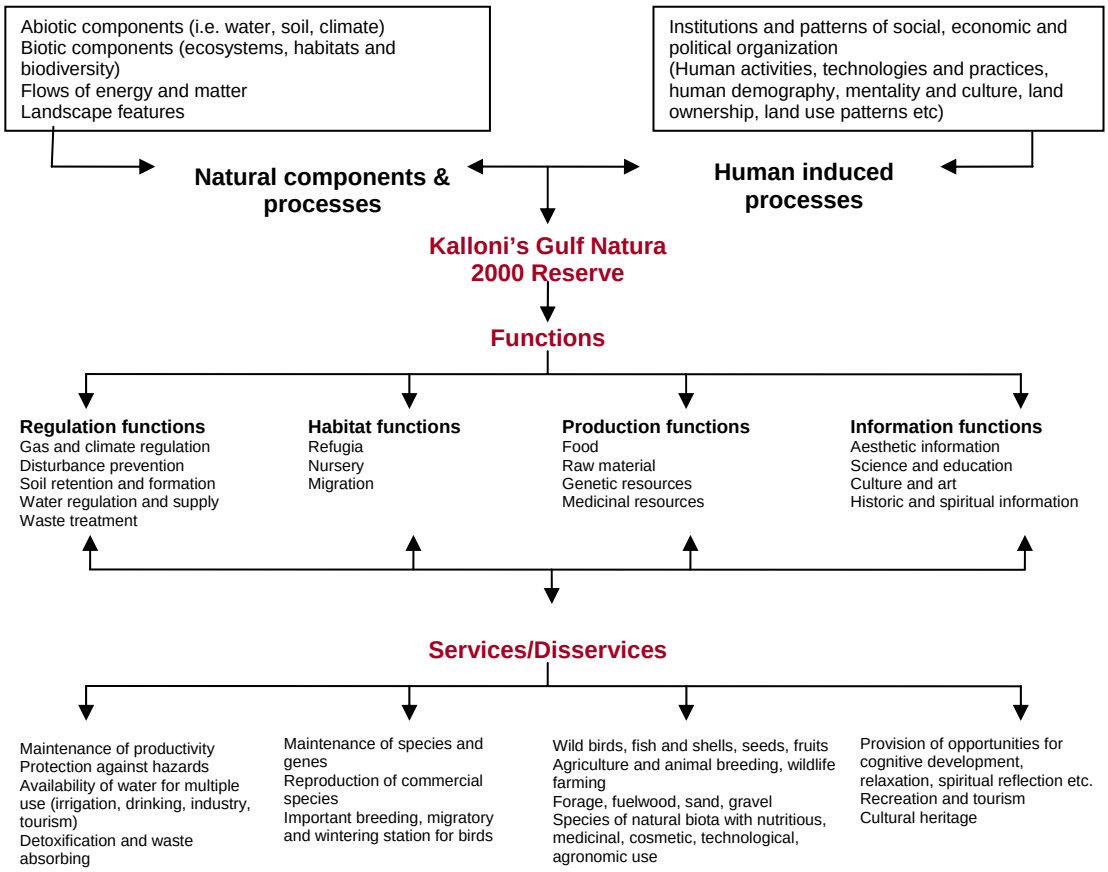
Semi-natural ecosystems, in general, are characterized by their specific components and structure, as well as by the natural and human induced processes that determine their functioning and hence the provision of services (Figure 2).

Within the scope of this study, the concept of ecosystem functions is understood, as a transitional one that tries to perceive the functioning of the ecosystem itself and explain the human needs connected with it. Therefore, it is defined, based on a combination of an ecocentric and anthropocentric perception given by Swift (2004), De Groot (1992) and their colleagues respectively, as ‘the capacity of natural processes and components to ensure the integrity, resilience and perpetuation of the ecosystem itself and hence provide services that sustain and fulfil human life.

In this context, ecosystem services represent the tangible and the intangible benefits human populations derive, directly or indirectly, from ecosystem functions (Costanza et al,. 1997) or simpler, as described by Millenium Ecosystem Assessment (2003), the benefits that people obtain from ecosystems.

Ecosystem functions and services have been classified in several ways according to functional, organisational and descriptive groupings (MEA, 2003). Some of the most representative proposed typologies or commonly referenced, include Pearce and Turner, (1990); De Groot (1992); Daily (1997); Costanza et al. (1997); Noel and O’ Connor (1998); Norberg (1999); Moberg and Folke (1999); De Groot et al. (2002); MEA (2003); De Groot & Hein (2006). For the purpose of this study, it has been adopted a functional grouping based on the classification of De Groot et al. (2002) (Figure 2).

Figure 2: Ecosystem functions analysis framework (Example of Kalloni's Gulf Natura 2000 Reserve)



Within ecosystem function analysis process, ecosystem services generated by a particular ecosystem can be identified and classified, based on available qualitative and quantitative information. Moreover, through field work research, there are revealed those ecosystem services that relevant social actors recognise and consider as important. The degree to which a function is considered important depends on ecological, socio-cultural and economic aspects (De Groot, 2003).

Therefore, perceived values and ecosystem services arise out of the functional ecological processes and components of an ecosystem but are also determined by human perceptions and among others human population pressures on them (Mitsch, Gosselink, 2000).

Information about the exact impacts of human induced processes on an ecosystem and the changes they may cause on its structure or on the particular processes it performs as well as the critical thresholds -the limit upon which the system will not be able to tolerate the disturbance and will generate a different set of ecosystem services or even disservices (Deutch et al, 2003)- are hardly considered as 'known' or given in environmental decision making situation. Still estimations regarding pressures and related impacts have to be done and decisions concerning the management of the natural resources have to be taken.

Moreover, ecosystem functions can be generated at a range of ecological scales (global, landscape, ecosystem, plot, plant) and can be supplied to stakeholders at a range of institutional scales (international, provincial, municipal, family, individual) (De Groot, 2006). Ecosystem processes and the services they deliver are typically most strongly expressed, most easily observed, or have their dominant drivers or consequences at one or more of the aforementioned scales in space (Limburg et al., 2002, MEA, 2003).

Despite the fact that purely local-scale assessments may overlook important dynamics of the system and trends that occur at much larger scales, they contribute more directly to policy interventions and decisions that have to be made at a local level. Of course, where possible a multi-scale approach would be advisable.

In the following table, some examples are given about identified human activities related with particular ecosystem functions, presenting the drivers putting pressure on them and the corresponding impacts on the environment and the human welfare (Table1).

Table 1: Ecosystem functions, human pressure and related impacts to the environment and human welfare

Functions	Examples of human pressure	Examples of related impacts
Water supply and regulation	- Over-pumping of underground water, Illegal drilling -Increase of water intensive crops -Use of fertilizers and pesticides, livestock rearing -Industrial and municipal untreated wastewater discharged in the river and stream beds	-Increased salination of underground aquifers -Potential risks to human health, reduced crop productivity, fish production availability of water
Waste treatment	-Disposal of municipal and agro-industrial liquid waste without processing in the rivers, streams or sewage network -Solid waste generated by population, seasonal visitors and tourists and disposal to uncontrollable landfills	-Pollution of surface, underground and sea water -Degradation of biota habitats -Landscape degradation
Refugia and nursery	-Land clearing and draining -Expansion of tourist settlements, private houses, shops in or at the borders of ecologically sensitive areas -Illegal hunting, over-fishing, fishing & agricultural practices, overgrazing	-Degradation of biota habitats -Decrease of biological and genetic diversity -Reduced populations of commercial species, loss of income
Production of food	-Over-exploitation of natural biota - Practices in agriculture, fishing, animal rearing, hunting, industry (use of inputs, tools, observance of rules and laws etc) -Waste production and untreated disposal	-Degradaion and loss of soil -Pollution of surface and underground water -Reduced productivity and stocks -Income loss
Aesthetic information	-Policy and related land use changes (expansion of urban areas, reduction of agricultural and forested land) -Poorly designed buildings not well integrated in the natural /cultural environment -Uncontrollable or illegal waste disposal to the environment	Landscape degradation Visual pollution

As it can be observed, the same human activities can affect multiple ecosystem functions and thence the services that they generate and multiple activities can, in combination, affect one ecosystem function. Given the complexity of the system itself and the lack of adequate data, there should be chosen, for further elaboration and research, that kind of variables which are most relevant and meaningful for the local actors or the socio-economic context of a given ecosystem.

2.2 Multi-criteria evaluation performed by NAIADE method

The different MCA methods are often presented as a combination of two basic steps: *a.* construction (Information and Modelling process) and *b.* exploitation (Aggregation and Recommendation) (Guitouni, Martel, 1998).

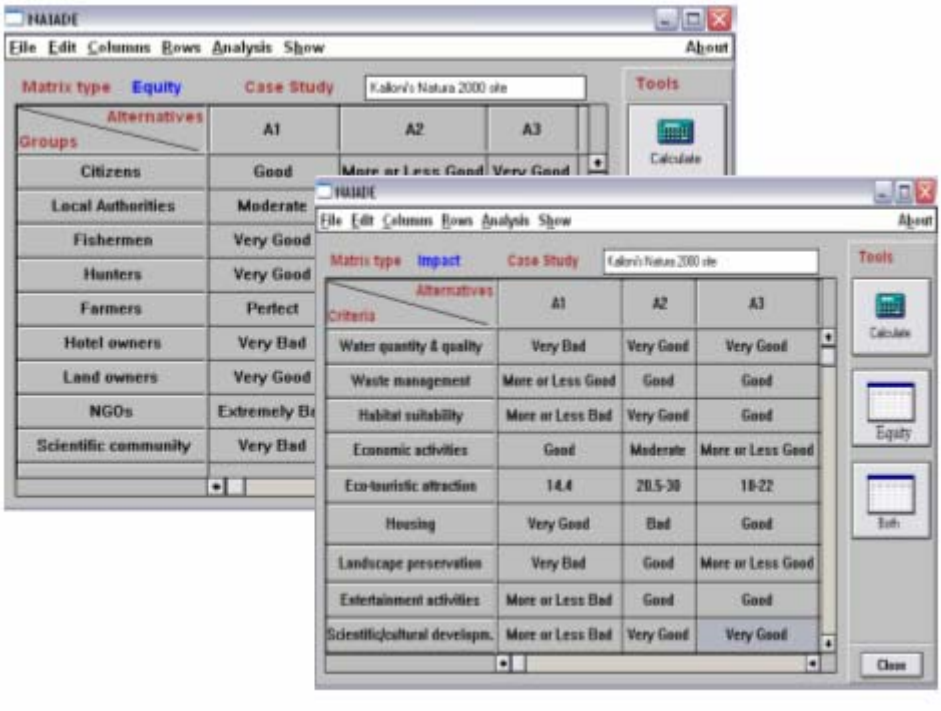
a. Information and modelling process

In the first phase of MCA, the 'issues' has to be thoroughly analysed and structured, the multiple actors have to be identified, taking into account the conflicting preferences and the appropriate criteria and alternatives have to be considered (Marchi et al., 2000, Messner et al., 2004).

At this point of the analysis, ecosystem functions and services and the associated pressures or impacts that have been identified by the scientists and the social actors involved, serve as the criteria for the evaluation of the alternative scenarios. Therefore, the alternative scenarios, which in fact represent the actions that enhance or distort the capacity of the ecosystem to generate services for human welfare, will be evaluated regarding their performance on ecosystem functions.

In NAIADE method, two evaluation matrices are developed: (i) The impact matrix regarding the evaluation of alternatives based on the chosen criteria, (ii) the equity matrix presenting the social actors judgements on the alternative scenarios (Figure 3). The impact matrix may include quantitative, qualitative or both types of information while the equity matrix permits exclusively the use of qualitative evaluations.

Figure 3: Examples of equity and impact matrices in NAIADE



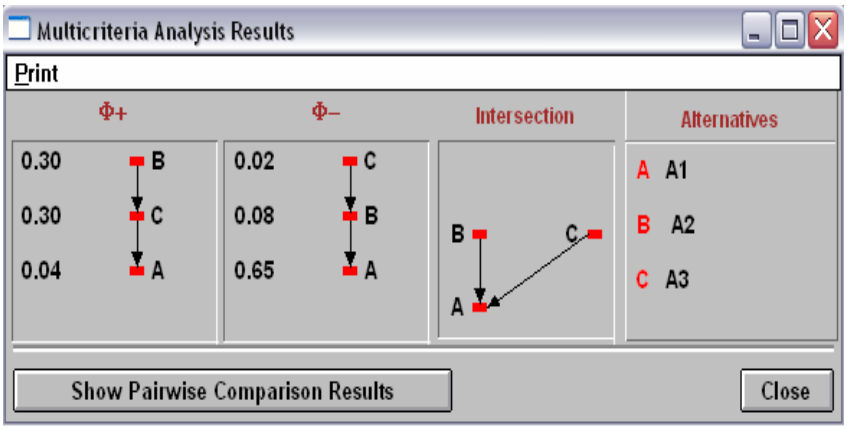
b. Aggregation and recommendation

Once the matrices summarising the performances of potential actions over various criteria or the social actors judgements have been completed, there remains the step involving choice: the comparison of the potential actions to show which is 'the most adequate' for the decision-maker(s). However, since the chosen criteria are conflicting, no action can result in maximal performance over each and every criterion simultaneously.

NAIADE method performs two types of evaluation: the multi-criteria analysis and the equity analysis.

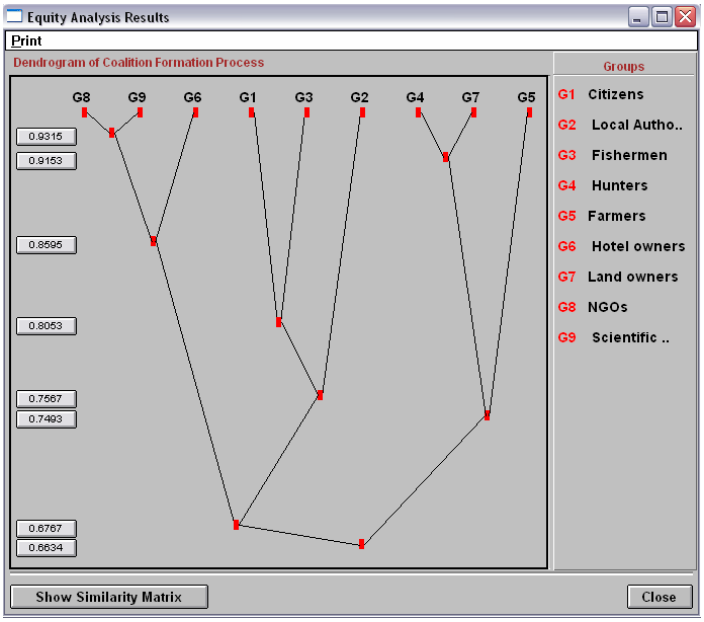
By applying NAIADE to the impact matrix, pairwise comparisons, based on the preference relations that have been defined and the estimation of semantic distances, are carried out and finally a ranking of the alternatives is obtained. The final rankings Φ+ and Φ- and their intersection are presented both graphically and numerically (Figure 4). Moreover, the values of the preferences' intensity index $\mu^*(\alpha, b)$, their entropies $H^*(a, b)$ (variance of credibility indexes) and the degrees of truth $\tau(\omega_{better})$, $\tau(\omega_{indifferent})$, $\tau(\omega_{worst})$ are given for all pairs of alternatives (For a deeper understanding see JRC., 1996).

Figure 4: Example of Multi-criteria ranking results in NAIADE



By applying NAIADE to the equity impact matrix, a coalition formation dendrogram is obtained, indicating the coincidence degree between the relevant interest groups and the overall credibility level of consensus building (Figure 5).

Figure 5: Example of a coalition formation process in NAIADE

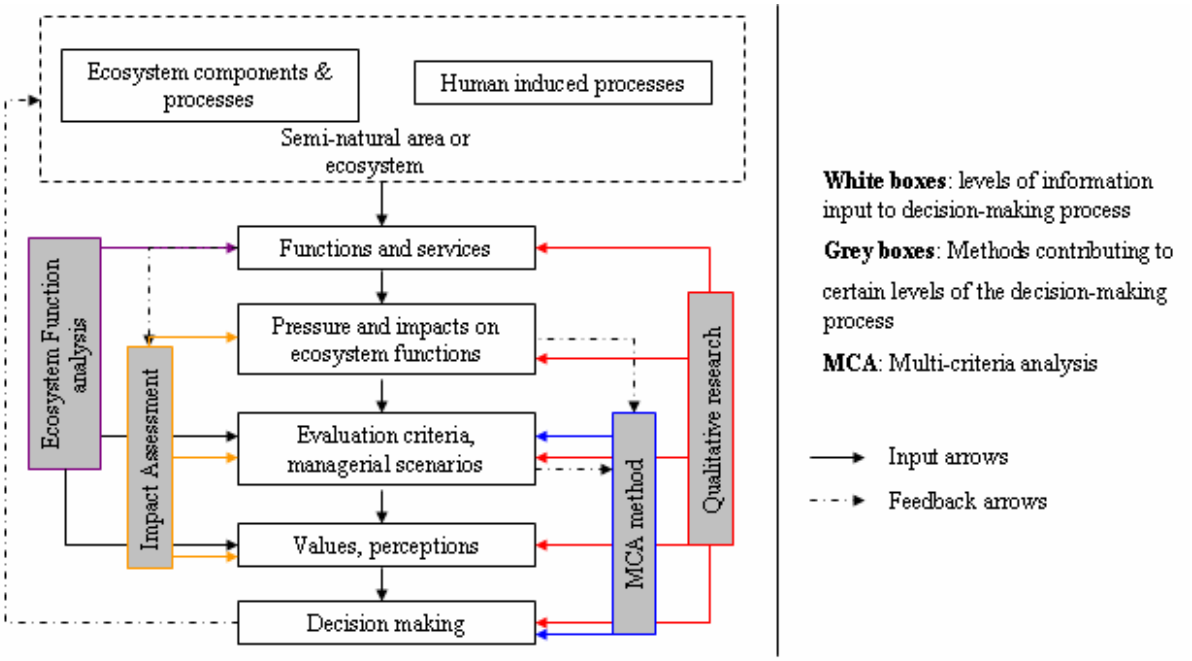


3. The proposed methodological framework

Following the previous analysis, a decision making process can be structured based on five steps: (i) definition of spatial boundaries and related social actors/groups, (ii) identification of ecosystem functions and services, (iii) estimation of pressure and resulting impacts on the environment and human welfare, (iv) development of managerial scenarios and selection of evaluation criteria, (v) evaluation of alternative scenarios, (vi) decision making. It is important to note that the order of the various steps is not strict and there have been continuous feedback loops among them, as the nature of the evaluation process often dictates such circularity (Nijkamp et al., 1990).

The distinct phases of the framework and the methods contributing to each step of the analysis are presented in Figure 6.

Figure 6: Introduction of multi-functionality concept into decision-making and environmental management



4. Discussion

The methodology developed, based on the combination of ecosystem function analysis and participative multi-criteria techniques, and its pilot ratification within the context of a particular case study, has proved to be a valuable tool for a better insight to the problem at hand, the nature of conflicts, the formulated coalitions and the identification of the most socially acceptable options for the management of a site.

In particular, the ecosystem function concept has provided the empirical basis for the identification of important aspects of natural ecosystems to humans, which because of their complex nature would be otherwise difficult to detect and further unfold the underlying values and beliefs related to them.

Besides, an important process within a function analysis framework, apart from revealing the full range of services generated by an ecosystem, is to recognise the actual or potential ones and pinpoint the human processes that may distort or facilitate the provision of them, elements which are considered to be of great importance in the environmental planning process.

Moreover, given the complexity of the system itself, the lack of adequate data and the constraints of time and expenses, multi-criteria analysis and particularly NAIADE method proved to be a very useful tool in order to implement a multidisciplinary approach necessary for natural resource management, to develop a common language between different societal actors and to deal with their approximate evaluations.

Concerning the contribution of the method to the decision-making process, NAIADE allows not only to performing a 'technical' comparison of the alternatives regarding some criteria (multi-criteria analysis) but also demonstrating which can be the most socially desirable or acceptable solution (equity analysis).

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