Marine Environmental Research 100 (2014) 94–111

Contents lists available at ScienceDirect

Marine Environmental Research

journal homepage: www.elsevier.com/locate/marenvrev

# An index based on the biodiversity of cetacean species to assess the environmental status of marine ecosystems

Arianna Azzellino [a, b, *], Maria Cristina Fossi [c], Stefania Gaspari [d], Caterina Lanfredi [a, b], Giancarlo Lauriano [e], Letizia Marsili [c], Simone Panigada [b], Michela Podestà [f]

[a] Politecnico di Milano, DICA, Piazza Leonardo da Vinci, 32, 20133 Milano, Italy
[b] Tethys Research Institute, viale Gadio, 2, 20121 Milano, Italy
[c] Dpt. of Physical, Earth and Environ. Sciences, University of Siena, Via PA Mattioli 4, 53100 Siena, Italy
[d] Università degli Studi di Firenze, Dipartimento di Biologia, Via Madonna del Piano 6, 0019 Sesto Fiorentino, FI, Italy
[e] Institute for Environmental Protection and Research (ISPRA), Via Brancati, 60, 00144 Roma, Italy
[f] Museum of Natural History of Milan, C.so Venezia 55, 20121 Milano, Italy

ARTICLE INFO

*Article history:*
Available online 19 June 2014

*Keywords:*
MSFD
Good Environmental Status
Biodiversity
Anthropogenic pressures
Genetic markers

ABSTRACT

The Marine Strategy Framework Directive (MSFD) requires the assessment of the environmental status in relation to human pressures. In this study the biodiversity of the cetacean community is proposed as MSFD descriptor of the environmental status and its link with anthropogenic pressures is investigated. Functional groups are generally favoured over indicator species since they are thought to better reflect to anthropogenic stressors. Cetaceans are in many situations the most well known component of pelagic ecosystems. Their habitat requirements are known and can be used to evaluate the theoretical biodiversity that should be expected in a certain area. The deviations between the theoretical biodiversity and the actual biodiversity may be used to detect the impacts of human activities. Based on this analysis fishery resulted to be by far the most significant of the existing pressures. Among all the species, bottlenose dolphin was found the most correlated with the fishery sector dynamics.


## 1. Introduction

The EU environmental policies during the last three decades have focused on determining adverse and undesirable changes to the natural system as the result of human activities and then, if such changes are detected, management responses are then foreseen to alleviate those adverse changes. The Marine Strategy Framework Directive (hereinafter MSFD) and before the Water Framework Directive (WFD) might be both considered as components of a suite of environmental controls linked on their own to the Directives for Environmental Impact Assessment, Strategic Environmental Assessment, Nitrates control and the Habitats and Species and Wild Birds Directives (Borja et al., 2010). The MSFD establishes a framework for the development of marine strategies designed to achieve the "Good Environmental Status" (GES) in the marine environment, by the year 2020, using 11 qualitative descriptors. The descriptors are not objectives per se: rather, they describe features of the ecosystem that are widely considered as important, either from a conservation (e.g., biodiversity, food web) or threat (e.g., non-indigenous species, marine litter) perspective that may be useful in developing a specific set of management objectives. Therefore, the MSFD requires the assessment of the functioning of each objective in relation to pressures. Based on this knowledge, appropriate programs of measures might be enforced to control the pressures that significantly affect the marine environmental status. Understanding the mechanism and/or the hierarchical pathways through which specific activities affect descriptor indicators is an essential step in the process of managing their potential impact. This assessment is further complicated by the fact that specific impacts may result from activities associated with numerous sectors (Ban et al., 2010). Thus, the link between sectors, the pressures they generate and the effects that those pressures have on the components of the ecosystem, need to be clearly understood if the impact of a sector and its activities is to be reduced or mitigated to avoid detrimental effects to the ecological characteristics of the ecosystem.

* Corresponding author. Politecnico di Milano, DICA, Piazza Leonardo da Vinci, 32, 20133 Milano, Italy.
*E-mail address:* arianna.azzellino@polimi.it (A. Azzellino).

http://dx.doi.org/10.1016/j.marenvres.2014.06.003
0141-1136/

There are numerous human activities that have the potential to negatively impact marine ecosystems (Halpern et al., 2007), many of which are common to several sectors functioning in Europe's regional seas. MSFD identifies 18 specific pressures, which could be placed into one of eight general pressure groupings based on their shared impact characteristics such as whether the pressure caused physical damage (e.g., abrasion or selective extraction), physical loss (e.g., smothering or sealing) or contamination (e.g., introduction of synthetic compounds) (see Annex III of the Directive [EC 2008] for the full list of pressures and impacts).

Among the other MSFD descriptors, descriptor 4 (D4) addresses the marine food webs and states "*All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity*".

It is well known that human activities may cause direct or indirect changes in food webs (Layman et al., 2005; Raffaelli, 2005). Events such as overexploitation (Pauly et al., 1998), pollution (Boon et al., 2002), eutrophication (Cloern, 2001), habitat fragmentation and destruction (Layman et al., 2007; Melian and Bascompte, 2002), invasions of species (Vander Zanden et al., 1999) and anthropogenic climate change (Kirby and Beaugrand, 2009; Muren et al., 2005) all pose potential threats to the structure and dynamics of food webs, acting at variable spatial scales and affecting food webs in different ways (Moloney et al., 2010).

To successfully identify and then monitor all these processes is extremely challenging. To date, ecologists have proposed several quantitative indicators to describe the status of marine ecosystems. However, strengths and weaknesses of the different indicators are usually only partially known. In many cases, due to the gaps in our knowledge about the relationship of the ecological status with the existing pressures, these indicators fail to support the setting of management objectives and do not allow the provision of scientific advice on how these objectives might be achieved. This is particularly true for indicators based on multiple species. In spite of that, marine food web indicators are becoming increasingly important as a factor in conservation management, particularly concerning the assessment of the ecological risk deriving from human activities (de Ruiter et al., 2005; Sala and Sugihara, 2005). In contrast to the single-species approaches, a system-level approach is in fact considered attractive since both, direct and indirect effects of disturbance are integrated into a single interaction network (Raffaelli, 2005). However, due to the high functional diversity in marine ecosystems and to the food-web complexity, practical applications remain quite rare. Whilst an ecosystem perspective is increasingly used in fisheries management to study ecosystem responses to different stressors and to assure sustainable use of resources (e.g. Coll et al., 2008), similar holistic approaches to evaluate the combined influences of other anthropogenic stressors on food webs are still lacking.

In this study, the biodiversity of the cetacean community is proposed as MSFD D4 indicator (e.g. indicator 4.3.1 Abundance trends of functionally important selected groups/species) and reference points are provided to correlate the environmental status derived by this indicator with the pressures affecting the study area (i.e. naval traffic, pollution, fishing pressure etc.).

### 1.1. The MSFD D4 descriptor and cetacean species

The D4 indicators stipulated in the Commission Decision (European Commission, 2010; 2010/477/EU), following extensive review by the JRC/ICES Task Group (TG4) on food webs (Rogers et al., 2010), address three criteria related to food web structure and energy transfer between different components (Table 1).

**Table 1**
Criteria and associated indicators for the MSFD Descriptor 4 (food webs).

| Attribute | Criterion | Indicator |
|---|---|---|
| Energy flow in the food web | Productivity of key species or trophic group (4.1) | Performance of key predator species using their production per unit biomass (4.1.1) |
| Structure of the food web (size) | Proportion of selected species at the top of the food web (4.2) | Large fish (by weight) (4.2.1.) |
| Structure of the food web (abundance) | Abundance/ distribution of key trophic groups/species (4.3) | Abundance trends of functionally important selected groups/species (4.3.1) |

**Table 2**
List of criteria for selecting key species/groups for indicator 4.3.1 "Abundance/distribution of key trophic species" as proposed by the Commission Decision (2010/477/EU).

| Criterion | Indicator | Selection criteria for key trophic groups/species |
|---|---|---|
| Abundance/distribution of key trophic groups/ species (4.3) | Abundance trends of functionally important selected groups/species (4.3.1) | (i) Groups with fast turnover rates<br>(ii) Groups/species that are targeted by human activities or that are indirectly affected by them<br>(iii) Habitat-defining groups/species<br>(iv) Groups/species at the top of the food web<br>(v) Long-distance anadromous and catadromous migrating species<br>(vi) Groups/species that are tightly linked to specific groups/species at another trophic level |

As shown in Table 1, whereas criterion 4.1 and its associated indicator 4.1.1 is proposed mainly as a proxy measure of energy flow within marine food webs, structural properties of food webs are covered by criteria 4.2 and 4.3 (Table 1). Given that


**Fig. 1.** Study area: The three subregions under the Italian jurisdiction are shown.