Ecosystem Services 20 (2016) 69–81

Contents lists available at ScienceDirect

Ecosystem Services

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

A conceptual framework for assessing the ecosystem service of waste remediation: In the marine environment

Stephen C.L. Watson [a,b,*], David M. Paterson [b], Ana M. Queirós [a], Andrew P. Rees [a], Nicholas Stephens [a], Stephen Widdicombe [a], Nicola J. Beaumont [a]

[a] Plymouth Marine Laboratory, The Hoe Plymouth, Prospect Place, Devon PL1 3DH, UK
[b] Sediment Ecology Research Group, Scottish Oceans Institute, University of St Andrews, East Sands, St. Andrews, Fife KY16 8LB, UK

ARTICLE INFO

Article history:
Received 6 May 2015
Received in revised form
24 June 2016
Accepted 28 June 2016

Keywords:
Ecosystem services
Waste remediation
Marine, Shelf-seas
Human wellbeing

ABSTRACT

In the marine environment, the ecosystem service of Waste Remediation (WR) enables humans to utilise the natural functioning of ecosystems to process and detoxify a large number of waste products and therefore avoid harmful effects on human wellbeing and the environment. Despite its importance, to date the service has been poorly defined in ecosystem service classifications and rarely valued or quantified. This paper therefore addresses a gap in the literature regarding the application of this key, but poorly documented ecosystem service. Here we present a conceptual framework by which the ecosystem service of WR can be identified, placed into context within current ecosystem classifications and assessed. A working definition of WR in the marine context is provided as is an overview of the different waste types entering the marine environment. Processes influencing the provisioning of WR are categorised according to how they influence the input, cycling/detoxification, sequestration/storage and export of wastes, with operational indicators for these processes discussed. Finally a discussion of the wider significance of the service of WR is given, including how we can maximise the benefits received from it. It is noted that many methods used in the assessment, quantification and valuation of the service are currently hampered due to the benefits of the service often not being tangible assets set in the market and/or due to a lack of information surrounding the processes providing the service. Conclusively this review finds WR to be an under researched but critically important ecosystem service and provides a first attempt at providing operational guidance on the long term sustainable use of WR in marine environments.

Contents

* Corresponding author at: Plymouth Marine Laboratory, The Hoe Plymouth, Prospect Place, Devon PL1 3DH, UK.
E-mail address: stw@pml.ac.uk (S.C.L. Watson).

http://dx.doi.org/10.1016/j.ecoser.2016.06.011

1. Introduction

Of the many definitions of Ecosystem Services (ES) Fisher et al. (2009) produced a widely used formulation of "the aspects of ecosystems utilised (actively or passively) to produce human well-being". This paradigm of ES is an increasingly prevalent concept, but one poorly defined ES is the service of Waste Remediation (WR). In the marine environment, the ES of WR enables humans to utilise the natural functioning of ecosystems to process wastes, potentially without detrimental effect. Without this service humans would either have to process all wastes on land or suffer serious health implications of wastes remaining in a toxic and available state. This would not only impact human wellbeing directly, but would also impact the overall ecological health of marine ecosystems. Whilst preserving the ES of WR is vital in its own right, it is also important for ensuring the provision of a whole host of additional marine ES and benefits that the service provides including: food security, raw materials, recreational amenity, shoreline protection, sequestration of carbon and an equable environment. The sustainable exploitation of benefits provided by WR depends on our ability to manage waste inputs in relation to the capacity of ecosystems to remediate wastes. This no-damage limit or "capacity for assimilation" is highly variable depending on the ecosystem, waste types, and other pressures on the given environment (Islam andTanaka., 2004; Nellemann et al., 2008). There is also an added complication that loading limits are dependent on human judgments as to what is an acceptable level of human health risk or structural change to an ecosystem. While it is in society's interest to ensure that discharges of waste into the ocean are minimal (and in turn reduce the need for the service of WR), in an increasingly human dominated planet there is a growing necessity to utilise and value all aspects of the natural environment to improve health and well-being.

Previously the ES of WR has been defined by the Millennium Ecosystem Assessment (MA) as the service of "Water purification and waste treatment" but as "Water quality regulation" by the UK's National Ecosystem Assessment classification (NEA); and more recently as "Mediation of waste, toxics and other nuisances" by the Common International Classification of Ecosystem Services (CICES). While many of these classifications are remarkably similar, having been built using the same principles, and are frequently referenced in the literature they are often poorly understood and rarely quantified (Beaumont et al., 2008). It is considered that one of the causes of this is that there are so many classifications available causing confusion and creating an illusion of complexity. More specifically in the case of WR there has also been a lack of application of these sub-classifications in terms of assessing, quantifying and valuing the contribution WR has on the wider marine environment, due to a lack of information surrounding the processes providing the service. This is a fundamental problem for environmental practitioners with the service of WR often being undervalued in policy design and implementation and is therefore at risk of being ignored in future policy decisions.

As a central component to communicating any subject is a readily understandable terminology that is applied consistently, this paper aims to clarify some of the potential confusion surrounding the application of the service of WR and provide a provide a utilitarian guide for academics and policy makers who wish to understand and utilise the ES of WR in the marine environment. Whilst there is always a risk of simply developing another classification, there are obvious benefits of combining the knowledge inherent within different classification systems to develop a more comprehensive understanding of a particular service. This review therefore begins by giving abroad overview to the different waste types present in the marine environment to ensure consistency of understanding. This is followed by drawing on the current literature and previous analyses of ecosystem services frameworks to provide a coherent definition WR in the context of marine ecosystems. Following classification, the mechanisms and ecosystem processes involved in the provision of the WR alongside suitable indicators and methods of assessment are then detailed and discussed. Finally a general discussion of the wider significance of the service of WR is given, including how we can maximise the benefits received from it, and possible future research directions for managing it sustainably. Overall as the decision-making context will differ substantially from place to place, issue to issue, and over time, the framework is designed to be sufficiently general to ensure that it can be applied across a wide range of situations, and flexible enough to encourage the user to develop and adjust the classification as required, for example by adding new components if required, and potentially repositioning components within the classification as required. This will result in a situation specific classification of WR that can be developed according to the purpose of the ecosystem service assessment (Costanza, 2008; Fisher et al., 2009; Johnston and Russell, 2011).

While WR occurs in all marine environments; from estuaries to the continental shelf, pelagic, demersal and deep sea habitats the focus of this paper will be on continental shelf ecosystems and their associated sea-beds with the rationale that many of the ecosystem benefits provided directly or indirectly by the service (e.g. clean water, recreational amenity, shoreline protection, fish and shellfish (food)) will be realised by humans on land or in areas surrounding the continental shelf margins (Pauly and Christensen, 1995; Martínez et al., 2007). Equally, there is extensive evidence that specific habitats found in brackish and coastal water habitats (e.g. saltmarshes and mangroves) can provide an important bioremediation function, (Agunbiade et al., 2009; Santos et al., 2011; Mucha et al., 2011; Ockenden et al., 2012; Wu et al., 2014 Ribeiro et al., 2014). While these habitats will not be discussed in detail here (as they are well-referenced elsewhere), the fundamental principles considered in this paper can still be applied to these habitats.

Further, in previous ES classifications there has been a tendency to limit ES to biotic components, with abiotic outputs often receiving less attention or being addressed inconsistently in ES classification systems (Van der Meulen et al., 2016). However abiotic processes such as fluid advection and photochemical transformations play an important role in the provision of WR