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Is an ecosystem services-based approach developed for setting specific protection goals for plant protection products applicable to other chemicals?

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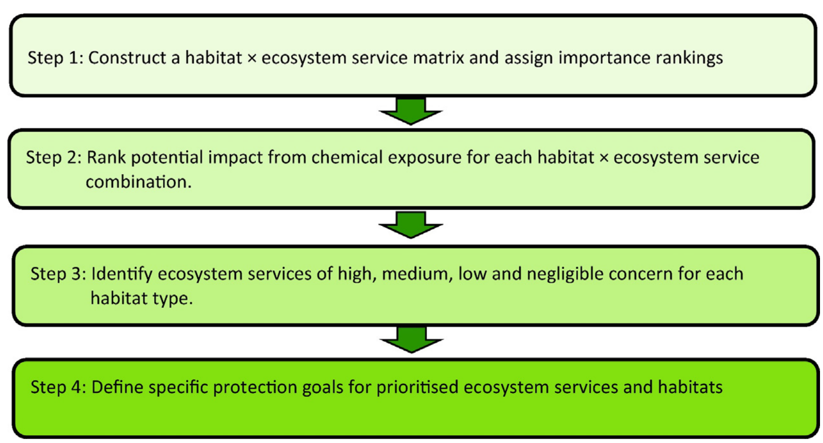
HIGHLIGHTS

- Evaluated an ecosystem services (ES) approach to environmental risk assessment.
- The ES approach was used successfully across different chemical classes
- Potentially impacted habitats and ES were prioritized in 4 case studies.
- Guidance needed on tolerable levels of change in ES and their relative importance.
- Key challenges are SPU selection and extrapolation of SPU impacts to ES change.

GRAPHICAL ABSTRACT



Stepwise process for specifying specific protection goals for use in the environmental risk assessment of chemicals.

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ABSTRACT

Clearly defined protection goals specifying what to protect, where and when, are required for designing scientifically sound risk assessments and effective risk management of chemicals. Environmental protection goals specified in EU legislation are defined in general terms, resulting in uncertainty in how to achieve them. In 2010, the European Food Safety Authority (EFSA) published a framework to identify more specific protection goals based on ecosystem services potentially affected by plant protection products. But how applicable is this framework to chemicals with different emission scenarios and receptor ecosystems? Four case studies used to address this question were: (i) oil refinery waste water exposure in estuarine environments; (ii) oil dispersant exposure in aquatic environments; (iii) down the drain chemicals exposure in a wide range of ecosystems (terrestrial and

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aquatic); (iv) persistent organic pollutant exposure in remote (pristine) Arctic environments. A four-step process was followed to identify ecosystems and services potentially impacted by chemical emissions and to define specific protection goals. Case studies demonstrated that, in principle, the ecosystem services concept and the EFSA framework can be applied to derive specific protection goals for a broad range of chemical exposure scenarios. By identifying key habitats and ecosystem services of concern, the approach offers the potential for greater spatial and temporal resolution, together with increased environmental relevance, in chemical risk assessments. With modifications including improved clarity on terminology/definitions and further development/refinement of the key concepts, we believe the principles of the EFSA framework could provide a methodical approach to the identification and prioritization of ecosystems, ecosystem services and the service providing units that are most at risk from chemical exposure.

1. Introduction

Environmental risk assessment (ERA) of chemicals is based on comparing environmental exposure with potential for adverse effects, and differentiating adverse from non-adverse effects is dependent on what it is we are trying to protect (i.e. the protection goals). Risk assessment, therefore, requires protection goals that clearly specify what to protect, where and when. Regulatory authorities worldwide face the challenge of specifying appropriate environmental protection goals and this challenge has received particular attention recently in Europe (EFSA, 2016). Current environmental protection goals for chemicals in EU legislation are generic and non-specific, including the prevention of 'unacceptable' impacts on 'biodiversity' and 'ecosystems' or the 'the environment as a whole' (Brown et al., 2016). Substantial spatiotemporal variation in environmental conditions, habitat types and species assemblages across Europe, results in generic protection goals being open to differing interpretations across regulatory regions and chemical sectors, which generates considerable uncertainty in how to achieve them (EFSA, 2010; Hommen et al., 2010; Brown et al., 2016). There is a growing consensus that environmental protection goals need to be more specific, to account for the spatial and temporal variation that is inherent in biodiversity and ecosystems (Fremier et al., 2013; Maes et al., 2013; Maltby, 2013).

One approach to accommodating spatial and temporal variation in setting protection goals is to consider what aspects of biodiversity are to be protected in different ecosystems and why? Biodiversity has intrinsic value and contributes to the natural capital that generates the many benefits that ecosystems provide to humans (Mace et al., 2012). These benefits, referred to as ecosystem services, are vital to human health and wellbeing and include provisioning services (e.g. food, clean water), regulating services (e.g. climate regulation, flood protection) and cultural services (e.g. aesthetic value, sense of place) (Costanza et al., 1997; MA, 2005). Ecosystems vary in species composition and hence in the services that can potentially be provided. Moreover, individual species may contribute to more than one ecosystem service and the interrelationships between species and hence the ecological processes they drive, may result in either positive or negative associations between services (Cardinale et al., 2012). As a consequence, the delivery of ecosystem services across a landscape varies in space and time and managing a landscape for one ecosystem service (e.g. food production) may reduce the delivery of other ecosystem services (e.g. flood protection) (Nelson and Roline, 1999; Nelson et al., 2009; Raudsepp-Hearne et al., 2010).

The EU is implementing numerous policies to enhance the sustainable use of natural resources and halt the loss of biodiversity and degradation of ecosystem services, with the EU Biodiversity Strategy to 2020 setting specific targets and policy tools for achieving this (EC, 2011). However, there is still a basic lack of understanding of how protection goals within current EU environmental legislation will ensure that these requirements for halting biodiversity loss or degradation of ecosystem services are met (EFSA, 2010; Hommen et al., 2010). To achieve the targets specified in the EU Biodiversity Strategy to 2020, it is necessary to incorporate ecosystem service thinking into regulatory policy and decision making (Haines-Young and Potschin, 2008; van Wensem and Maltby, 2013). It is also necessary to develop tools and approaches for identifying what needs to be protected and where, to enable the sustainable use of natural capital and ecosystem services (Holt et al., 2016). Aligning chemical ERA to such aims requires the establishment of protection goals and approaches for translating ecotoxicological exposure and effects information into risk management measures for ecosystem service delivery. Assessing the risk of chemical exposure to bundles of ecosystem services enables risk assessors to provide options to risk managers that incorporate the interactions (i.e. synergies and trade-offs) between relevant ecosystem services. This information will enhance the sustainable use of natural resources in multifunctional landscapes by enabling targeted risk mitigation measures and spatially-explicit risk management decisions to be implemented (Maltby, 2013).

In 2010, the European Food Safety Authority (EFSA) outlined how an ecosystem services framework could be used to develop specific protection goals (SPGs) for pesticides (EFSA, 2010), which was later extended to cover invasive species, feed additives and genetically modified organisms (EFSA, 2014; EFSA, 2016). Essentially this framework involves: (1) identifying habitats potentially exposed to the chemical or agent of interest; (2) identifying ecosystem services delivered by potentially exposed habitats; (3) identifying ecosystem components (e.g. species, functional groups, etc.) driving the services potentially affected (i.e. service providing units, SPUs); (4) identifying how service provider attributes (e.g. behaviour, biomass, function, etc.) relate to ecosystem service provision; (5) defining SPGs for SPUs and levels of impact (magnitude, spatial extent and duration) on their critical attributes that would still enable the sustainable delivery of their ecosystem service (Nienstedt et al., 2012; Maltby, 2013).

The aim of this study was to evaluate the applicability of the EFSA framework (EFSA, 2010) to a wider range of chemicals. This was achieved by exploring four case studies, selected to provide a range of chemical classes, emission scenarios and receptor habitats relevant to different chemical industry sectors: (1) oil refinery wastewater discharge exposure in estuarine environments; (2) oil dispersant exposure in ocean, coastal and estuarine environments; (3) complex mixtures of home and personal care products and pharmaceuticals that are discharged down the drain, subsequently exposing a wide range of ecosystems (terrestrial and aquatic); and (4) persistent organic pollutant (POP) exposure via atmospheric transport and condensation in remote (pristine) Arctic environments.

2. Methods

A 4-step approach, similar to that of EFSA (2010), was followed to identify habitats and ecosystem services that are potentially impacted by a variety of chemicals released into the environment. The EFSA approach was modified in order to meet the specific needs raised by each chemical case study and these modifications are highlighted below.