Chemical Risk Assessment – Ecosystem Services

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SUMMARY

Over the last 10 years there has been increasing emphasis both on the sustainable use of natural resources and on the recognition that humans are dependent on ecosystems for their well-being. This dependence extends beyond the resources provided by ecosystems (water, food, fibre, minerals, energy) to benefits such as climate regulation, flood control, pest and disease regulation, clean air and recreation. Benefits that flow from ecosystems, ecosystem services, are a function of the biophysical components of ecosystems and are underpinned by biodiversity. There are several national and international initiatives moving rapidly toward integrating the assessment of ecosystem services into decision-making processes. The EU is implementing policies to enhance the sustainable use of natural resources and halt the degradation of ecosystem services. The 2020 EU Biodiversity Strategy has a headline target of "By 2020 the loss of biodiversity in the EU and the degradation of ecosystem services will be halted and, as far as feasible, biodiversity will be restored" and sets out specific targets and policy tools for achieving this.

Environmental risk assessment, ERA, traditionally focusses on impact functions (i.e. environmental exposure assessment) and response functions (i.e. ecological effects assessment), although the endpoints measured are generally not selected to enable quantification of ecosystem service delivery. Adopting an ecosystem services approach means that ERA needs to be extended to include the link to ecosystem services. This may involve: (1) refining existing methodologies to assess more relevant endpoints; (2) developing new approaches for assessing effects on the structure and functioning of ecological entities; (3) enhancing and applying ecological understanding of causal relationships between biophysical structure, functioning and service provision; (4) developing models to translate outputs from ecotoxicological studies to estimates of ecosystem service delivery. However, in order to ensure that future developments are fit for purpose, it is essential that the focus of the ERA, i.e. the protection goal, is clearly defined within an ecosystem services framework.

There is an acceptance that protection goals specified in current EU legislation are very general and that more specific protection goals need to be developed in order to guide risk assessment and inform risk management decisions. In 2010, the European Food safety Authority, EFSA, produced a scientific opinion outlining how an ecosystem services framework could be used to develop specific protection goals for the environmental risk assessment of pesticides and more recently, has extended this approach to invasive species, feed additives and genetically modified organisms. This growing interest in using ecosystem services to help define and communicate protection goals will inevitably influence chemical regulation. Therefore, it is timely for the chemical industry to engage in this topic, together with other stakeholders, to help determine and influence developments.

The aim of the Task Force was to investigate the applicability of the EFSA framework for developing specific protection goals for a wide range of chemicals. The EFSA approach is based on a structured framework for identifying which ecosystem services might be affected by chemicals, using this assessment for setting specific protection goals and subsequently informing the scope and needs of risk assessment. The Task Force approached the assessment of the applicability of the EFSA framework to a broad range of chemicals and typical environmental exposure scenarios by working through four case studies, i.e. "learning by doing". The focus on case studies enabled the Task Force to identify where the steps of the framework worked well and

where development is needed. The four different case studies (oil refinery emissions, oil dispersants, down the drain chemicals and persistent organic pollutants) were selected to provide a range of emission scenarios and receptor habitats. A 5-step approach was followed to identify habitats and ecosystem services potentially impacted by emissions of these chemicals.

The Task Force found the EFSA framework to be conceptually straightforward and logical. However, there were many points in the framework where additional information and more detailed guidance will be required for general applicability to all chemical sectors, including pesticides. Furthermore, a strong theme throughout the Task Force application of the framework was the importance of prioritising at each step in order to manage the time and effort required. The key development needs identified at each step are summarised below.

Steps 1 and 2: Construct a habitat x ecosystem service matrix and assign importance rankings

The development of a reference table of habitats and assigning their importance for ecosystem service provision is essential for the framework approach. It is clear that the habitat x ecosystem service matrix as used by EFSA requires further work to extend the assessment to all combinations of habitats and ecosystem services, especially for the marine habitats (i.e. marine inlets and transitional waters; coastal areas; shelf; open ocean).

The use of all types of ecosystem services in the initial steps of the framework, as recommended by EFSA, was considered important in identifying the key service providing units. The Task Force did not consider the completeness of the list but did not identify any gaps arising from the four case studies. Deviations from the EFSA approach included the combining of primary production with photosynthesis where the Task Force considered the service providing units to be essentially similar and the exclusion of abiotic ecosystem services such as oil (for fuel) and flowing water (for power generation), since these were not provided via biotic service providing units. Including service providing units that provide supporting and other intermediate services was considered a more explicit and informed approach to deriving key groups of service providing units and, therefore, in any subsequent identification of testing strategies for risk assessing the potential impacts on specific protection goals.

The treatment of biodiversity in the habitat x ecosystem service matrix was identified as a topic requiring further discussion. The Task Force adopted the approach that biodiversity underpins the delivery of all ecosystem services that are dependent on biotic processes and specific components of biodiversity are explicitly addressed in many individual ecosystem services (e.g. genetic resources, ornamental resources, pollination, pest control, aesthetic value etc). Biodiversity, as defined by the Convention on Biological Diversity, was considered part of natural capital and not an ecosystem service *per se* as its inclusion as an ecosystem services would lead to the protection of 'everything, everywhere', which is too generic and vague to be useful for scientific risk assessment. Familiarity with the definitions of ecosystem services and other terms is an important requirement if the EFSA framework is to be applied correctly and efficiently.

Step 3: Ranking potential impact for habitat x ecosystem service combinations using exposure and effects information

The Task Force found the preparation of schematic diagrams of potential routes of exposure helpful in assessing and communicating the relative level of exposure each of the habitats could experience from specific chemicals in the case studies. The use of a three coloured traffic light approach proved adequate in ranking and differentiating levels of concern. Experience and additional guidance would help minimise differences between individuals scoring habitat x ecosystem service combinations.

The Task Force initially aimed to only use the relative level of exposure to rank the level of concern for each habitat x ecosystem service combination. Although exposure was acknowledged as the main driver along with importance of habitats for ecosystem service provision, additional chemical-related factors were also identified and applied.

Assessing the level of potential impact due to chemical exposure was difficult for some ecosystem services. This was particularly pertinent for cultural services where there can be differences in how different cultures perceive and value ecosystem services.

Step 4: Categorising the level of concern for exposed ecosystem services

In order to streamline the assessment of exposed habitat x ecosystem service combinations, the Task Force devised a prioritisation matrix. To focus the Task Force resource, only those combinations assessed as medium or high concern were investigated further in the case studies. Including prioritising steps into the framework is an important option to help align resources to the required level of assessment.

At this step the Task Force ensured that potentially impacted service providing units in habitat and ecosystem service combinations identified as medium and high concern were identified at a suitable level of resolution for subsequent specific protection goal description. Access to reference tables of the key service providing units likely to occur in specific habitats helps complete this task and aids consistency.

Step 5: Defining specific protection goal for ecosystem services of high and medium concern

The Task Force considered that the six dimensions in EFSA's guidance (ecological entity, attributes, magnitude of effect, temporal and spatial scale of effect and the degree of certainty required) provide a good basis for describing specific protection goals. However, derivation of specific protection goals was achieved with a high degree of uncertainty because of the lack of detailed guidance and knowledge in deciding ecological entities, their attributes and especially the scale of potential impact. Adopting the ecological threshold option focuses on identifying the maximum tolerable impact on the entity/attribute of concern in order to protect the ecosystem service of interest. The scientific challenge here is to have sufficient knowledge to be able to link ecological changes to changes in ecosystem service delivery (i.e. ecological production functions) and to identify thresholds of ecological change at which ecosystem service delivery is affected. Given the uncertainties associated with identifying thresholds, a precautionary approach is to assume that 'maximum tolerable impact' is 'no/negligible impact'. Adopting the recovery option considers some impacts at limited spatial and temporal scales to be acceptable assuming that full recovery occurs. The scientific challenge here, in addition to establishing ecological production functions, is understanding recovery processes within a landscape context and the spatio-temporal dynamics of ecosystem service delivery. In addition, there is a need for dialogue with risk managers to agree on specific protection goals and to clarify which bundle of ecosystem services is to be protected where and at what level.

The scope of the Task Force objectives effectively concluded with the derivation of specific protection goals for selected case studies. How these specific protect goals might be used in subsequent chemical risk assessment (prospective and retrospective) was not considered, but this is a key next step in practical application of the EFSA framework. In addition to the development of testing and modelling approaches needed to assess impacts on the service providing units that underpin specific protection goals, there is a need to define acceptable effects from unacceptable 'adverse' environmental effects, e.g. using retrospective or diagnostic methods.

Applying the ecosystem services concept to derive specific protection goals brings the potential for greater spatial resolution in chemical risk assessment, i.e. specific protection goals can be derived for specific land-uses or landscape typologies. It, therefore, could facilitate increasing the environmental relevance of risk assessments, a need identified by several scientific advisory groups, e.g. EC Scientific Committees. Whilst increasing environmental relevance in this way has scientific merit, the practical outcome of defining spatially explicit protection goals to inform risk assessment for a range of chemical sectors requires further investigation and evaluation. The Task Force recommends that such further work is initiated to more fully determine the practical application of the ecosystem services approach.

The EFSA framework represents a top-down approach for deriving specific protection goals for habitats that can be expected to be exposed to specified anthropogenic chemicals. In principle, the framework can be applied to a broad range of chemicals and exposure scenarios. With modifications, clarity on terminology / definitions and further development, the framework could provide a methodical approach for the identification and prioritisation of ecosystems and services that are most at risk. Prioritised habitats and key service providing units could then form the focus for subsequent risk assessment.

1. INTRODUCTION

1.1 Background

Assessing the risks of chemicals to man and the environment is based on comparing exposure to chemicals with their respective hazardous properties. However, there are differences in the criteria for deciding whether the level of exposure represents an acceptable or unacceptable risk. For man, decision criteria are focused on protecting the individual and regulations are applied relatively consistently around the globe. For the environment, protection goals are less clearly defined and not consistent across regional regulations. Regional environmental policies take a cost-benefit approach to environmental impacts. There are two possible extremes for doing this: i) a precautionary approach aiming for zero release of chemicals into the environment (costs judged to be more important than benefits); ii) uncontrolled release with no effective management to mitigate impacts (benefits judged to be more important than costs). Most environmental regulatory schemes adopt an approach somewhere between these extremes. For example, some effects on individuals may be accepted if the population is unaffected or if it recovers from episodic exposure. For this approach to make sense, protection goals need to be suitably defined. Reviews of current regulations indicate that protection goals are only generally defined leaving a lack of clarity on how to achieve such protection (EFSA, 2010; Hommen *et al*, 2010).

Discussion of current chemical regulation schemes has led to calls for changes in the way environmental toxicity thresholds are derived. The use of a limited number of species toxicity tests together with application factors is tenuously linked to protection goals and will be over-protective in some cases and potentially under-protective in others. Given that there are relatively few examples of major impacts (e.g. TBT, DDT, diclofenac), from the regulated use of thousands of chemicals in commerce, it may be that the current approach tends to be over-protective. This could be restricting the societal benefits of chemicals. On the other hand, the uncertainties in the approach may underestimate effects, for example, in potentially sensitive ecosystems such as coastal marine reefs or in assessing endocrine disruption of chemical mixtures.

1.2 Changing policy context

Over the last 10 years there has been increasing emphasis both on the sustainable use of natural resources and on the recognition that humans are dependent on ecosystems for their well-being (Cardinale *et al*, 2012; CEFIC, 2013). This dependence extends beyond the resources provided by ecosystems (water, food, fibre, minerals, energy) to benefits such as climate regulation, flood control, pest and disease regulation, clean air and recreation. Benefits that flow from ecosystems, termed ecosystem goods and services (often combined as ecosystem services), are a function of the biophysical components of ecosystems and are underpinned by biodiversity. The Millennium Ecosystem Assessment (2005a) drew attention both to the reliance of human well-being on ecosystem services and to the widespread degradation of ecosystems and the services they provide. For example, more than 60% of the Earth's ecosystem services have been degraded in the last 50 years and in the EU, 88% of fish stocks are fished beyond maximum sustainable yields and only 11% of protected ecosystems are in a favourable state (EC, 2011a).

The publication of UNEP's Millennium Ecosystem Assessment in 2005 and its ongoing project – The Economics for Ecosystems and Biodiversity (TEEB) – have been extremely influential. The Millennium Assessment emphasised the need for robust scientific understanding of how ecosystems affect human well-being and TEEB has demonstrated the economic benefits of ecosystem services to human well-being as well as the economic costs of environmental degradation and habitat loss. Following UNEP's lead, the European Union, along with the United States of America, are moving rapidly toward integrating the assessment of ecosystem services into their decision-making processes (Olander and Maltby, 2014).

The EU is implementing a number of policies to enhance the sustainable use of natural resources and halt the degradation of ecosystem services. The 2020 EU Biodiversity Strategy has a headline target of "By 2020 the loss of biodiversity in the EU and the degradation of ecosystem services will be halted and, as far as feasible, biodiversity will be restored" and sets out specific targets and policy tools for achieving this (EC, 2011b). These are: fully implement the Birds and Habitats Directives to conserve and restore nature (Target 1); incorporate green infrastructure into spatial planning to maintain and enhance ecosystems and their services (Target 2); use CAP reforms, sustainable forest management plans and the Marine Strategy Framework Directive to ensure the sustainability of agriculture, forestry and fisheries (Targets 3 and 4); introduce a new legislative instrument to combat invasive alien species (Target 5); address the global biodiversity crisis by alleviating pressure on biodiversity emanating from the EU (Target 6). Achieving these targets will require full implementation of existing EU legislation as well as action at national, regional and local level.

The EU Roadmap for a Resource Efficient Europe states that the Commission will "significantly strengthen its efforts to integrate biodiversity protection and ecosystem actions in other Community policies with particular focus on agriculture and fisheries". It also states that Member States will "work towards the objectives of the Biodiversity Strategy by integrating the value of ecosystem services into policymaking" (EC, 2011a). The EU Marine Strategy Framework (Directive 2008/56/EC) outlines a transparent, legislative framework for an ecosystem-based approach to the management of human activities and supports the sustainable use of marine ecosystem services (EC, 2008a). Whereas the Green Infrastructure Strategy recognises that land in both rural and urban areas provides multiple ecosystem services and promotes green infrastructure through several policy areas including, climate change and environmental policies, disaster risk management, health and consumer policies and the Common Agricultural Policy (EC, 2013).

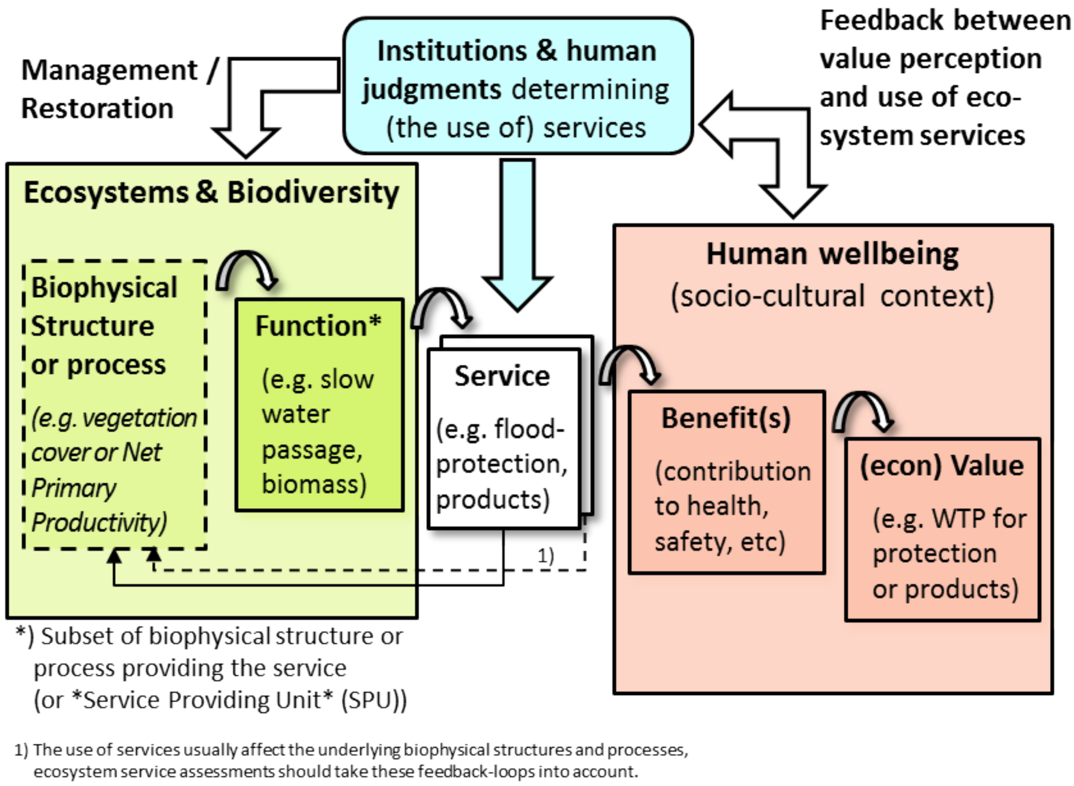
The EU has substantial legislation requiring the achievement of good ecological status for water by 2015 (Water Framework Directive [EC, 2000]) and marine ecosystems by 2020 (Marine Strategy Framework Directive [EC, 2008a]), and for regulating chemicals and their effects on the environment (e.g. REACH [EC, 2006a]). However, the implementation of this legislation may be revisited to ensure that the headline target of halting the loss of biodiversity and the degradation of ecosystem services is met. This process has already begun for plant protection products (EFSA, 2010) and the European Commission joint Scientific Committees report "Making Risk Assessment more Relevant for Risk Management" has highlighted the need for risks be "expressed in terms of impacts or entities that matter to people … such as changes in ecosystem services." (SCHER/SCENIHR/SCCS, 2013). EU regulations relevant to the authorisation, release and management of chemicals in the environment are discussed further in Chapter 3.

1.3 Natural capital and ecosystem services

Human wellbeing and economic prosperity depend on the sustainable use of ecosystems. The biophysical components of ecosystems – land, water, air, minerals, species, genes – provide the stocks of natural capital from which flow benefits (i.e. ecosystem services), such as clean air and water, food and fibre, disease suppression and climate regulation. Natural capital may be renewable (e.g. ecosystems) or non-renewable (e.g. mineral deposits) and renewable natural capital may be depletable (e.g. fish stocks) or non-depletable (e.g. wind) (Maes *et al*, 2013). Each natural capital asset may provide one or more ecosystem service, which may be combined with other capital inputs (e.g. built, human, social) to produce goods that people use. Many of these ecosystem services are used almost as if their supply is unlimited. They are treated as 'free' commodities, their economic value is not properly accounted for and therefore they continue to be overly depleted or polluted, threatening our long-term sustainability and resilience to environmental shocks.

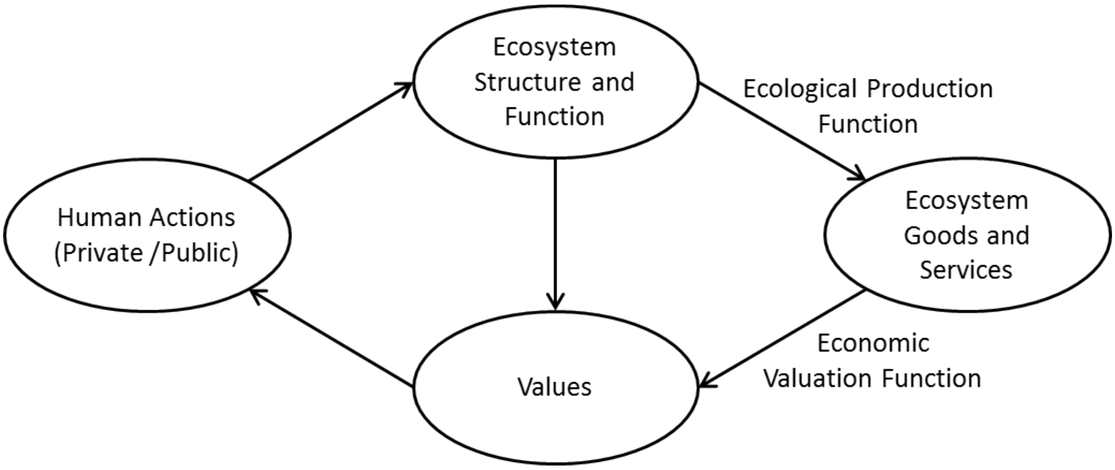
There is no single agreed definition of ecosystems services (Nahlik *et al*, 2012). Some authors consider services to be the outputs of ecosystems that are used to derive benefits, whereas others consider services to be the same as well-being benefits. In this document we adopt the TEEB (2010a) definition, which is used by the EU: *ecosystem services are the direct and indirect contributions of ecosystems to human well-being*. The TEEB definition, which is illustrated in Figure 1.1, places ecosystem services between the natural and human systems and identifies benefits for people flowing from services delivered by ecosystems. In addition, this definition separates benefits and values and clearly shows that ecosystem services are derived from interactions between biotic and abiotic components of ecosystems.

Figure 1.1: The TEEB overview diagram from Braat and de Groot (2012)



A single human well-being benefit may depend on several ecosystem services. The production of wild berries, for example, depends on pollination, pest and disease regulation, climate regulation, nutrient cycling and primary production, amongst others. However, several of these services also contribute to other benefits so in order to avoid multiple accounting when valuing services, a distinction has been made between final services (those that are used directly and therefore valued) and intermediate services that contribute to the final service (Boyd and Banzhaf, 2007). Whereas direct quantification of final services may be sufficient for accounting purposes, if ecosystems are to be managed for service delivery, it is important to know what changes in biophysical structure and processes are resulting in changes in intermediate and final services. The translation from ecosystem structure and function to ecosystem services is referred to as the ecological production function (Figure 1.2) (National Research Council, 2005; Tallis and Polasky, 2009).

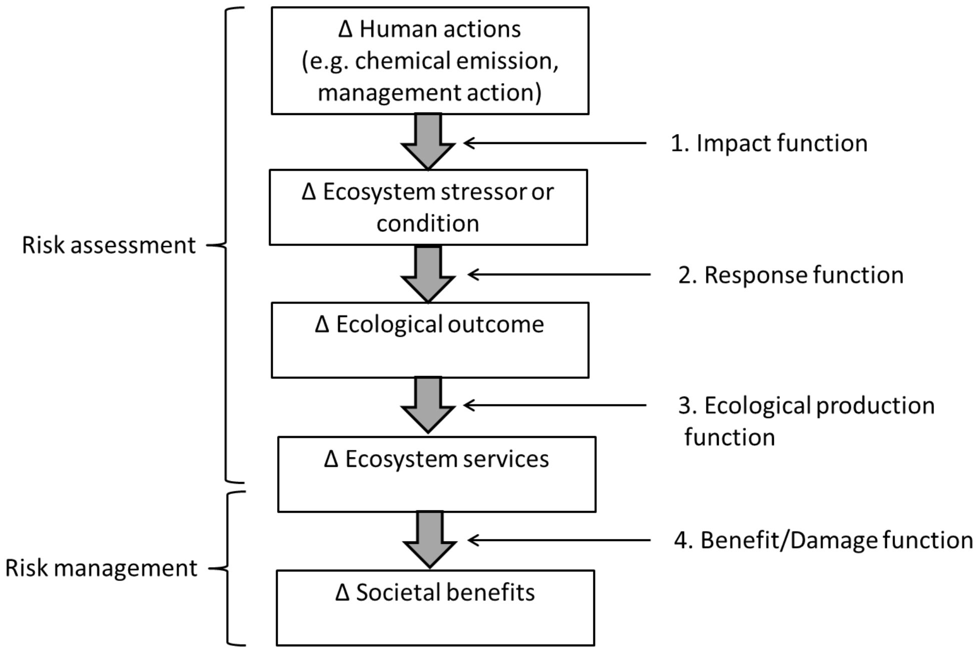
Figure 1.2: Linkages between the components of ecosystem valuation: ecosystem structure and function, goods and services, human actions, and values (source: National Research Council, 2005)



Wainger and Mazzotta (2011) present a modification of the National Research Council (2005) scheme illustrated in Figure 1.2 in which they highlight four key functions (i.e. empirical data or models) linking a change in human actions to resulting change in social welfare: impact functions, which connect human actions to increases or decreases in stressors; response functions, which demonstrate how changes in stressors result in ecological changes that underpin ecosystem service delivery; ecoservice production functions, which translate ecological changes into outcomes that people use or value (i.e. final services) and benefit functions, which demonstrate what people would be willing to pay (WTP) to achieve a gain or avoid a loss in an ecosystem service. The distinction between ecological production functions and ecoservice production functions is that, whereas ecological production functions define services in terms of biophysical measures only, ecoservice production functions also consider the potential for a service to be used at a specific location and time.

It is proposed that, in general, ERA should focus on ecological production functions rather than ecoservice production functions, the rationale being that whereas the former is based on ecological information and may be extrapolated between similar ecosystems, the latter requires ecological information to be evaluated within the context of location-specific social and economic factors and can only be applied to site-specific assessments. A modification of the Wainger and Mazzotta (2011) framework in which ecological production function replaces ecoservice production functions is presented in Figure 1.3.

Figure 1.3: Framework to assess the risk of chemical exposure resulting from change in human action on ecosystem services and societal benefits (adapted from Wainger and Mazzotta, 2011)



Environmental risk assessment traditionally focusses on impact functions (i.e. environmental exposure assessment) and response functions (i.e. ecological effects assessment), although the endpoints measured are generally not selected to enable quantification of ecosystem service delivery. Adopting an ecosystem services approach means that ERA needs to be extended to include the link to ecosystem services. This may involve: (1) refining existing methodologies to provide information on more relevant endpoints; (2) developing new approaches for assessing the effects of chemicals on structure and functioning of ecological entities of interest; (3) enhancing and applying ecological understanding of causal relationships between biophysical structure, functioning and service provision; (4) developing models to translate outputs from ecotoxicological studies to estimates of ecosystem service delivery. However, in order to ensure that future developments are fit for purpose, it is essential that the focus of the ERA, i.e. the protection goal, is clearly defined within an ecosystem services framework.

1.4 Protection goals and risk assessment / management

The EU has highly developed and complementary environmental regulations, which are applied to distinct 'eco-regions' (EC, 2000; Meissle *et al*, 2012; Maes *et al*, 2014) each typified by different 'ecologically relevant' species (Chapman, 2002; Meissle *et al*, 2012; Ibrahim *et al*, 2013). The benefits of adopting more ecologically holistic and spatially explicit approaches for chemical ERA has been recently articulated in the European Commission's discussion paper *Addressing the New Challenges for Risk Assessment* (SCHER/SCENIHR/SCCS, 2012). In parallel with the drive to improve chemical ERA, the European Commission has developed a Biodiversity Strategy which recognises the need to protect biodiversity and ecosystem services (Section 1.2). However, there is still a basic lack of understanding of how protection goals within current EU environmental legislation will ensure that this need is met (EFSA, 2010; Hommen *et al*, 2010).

1.4.1 Evolution of the ecosystem approach

It is unclear how the traditional extrapolative (bottom-up) or reductionist (top-down) approaches to environmental risk assessment and management address the aspirational goals for protecting 'biodiversity', 'ecosystems' or 'the environment as a whole', set by legislation for the registration and authorisation of chemicals (Chapter 3). Although there is a recognition that more holistic, ecosystem-level approaches are needed (SCHER/SCENIHR/SCCS, 2012), these are beset by the inherent variation and complexity of ecosystems (Table 1.1), presenting a conundrum for environmental risk assessors and managers.

Table 1.1: Major sources of uncertainty in environmental risk assessment

Natural background variability in the environment
• Spatial variation, including geology, topography / bathymetry, habitat and climate.
• Temporal variation, including environmental stochasticity, diurnal and seasonal cycles, longer-term environmental change e.g. climate change.
Representation of chemical exposure profiles
• Numerous possible environmental exposure scenarios, influencing both the exposure (environmental fate, bioavailability) and effects of chemicals.
• Spatial and temporal variability associated with chemical exposures. (Constant exposure is normally assumed in ERA).
Extrapolation of chemical effects
• Laboratory to field extrapolation i.e. from ecotoxicological tests conducted under controlled conditions (generally in the laboratory) to populations in the wild.
• Endpoint extrapolation from organism-level effects to population-level effects and above.
• Species extrapolation from a few sensitive 'model' species to all species in the environment, beset by inter-species and intra-species (i.e. inter-population and site-specific) variation in vulnerability to chemicals.
Ecological factors, including interactions
• Variation in species' ecological life-histories, which influence chemical exposure, effects and recovery.
• Interactions among different stress factors (physical, biological and other chemical factors) that may affect ecosystem health and interact with chemical effects.
• Interactions among individuals, populations and biological communities potentially leading to indirect ecological exposures (e.g. bioaccumulation and biomagnification) and chemical effects within food chains and ecosystems.

Adapted from Chapman, 2002; Hommen *et al*, 2010; SCHER/SCENIHR/SCCS, 2012

The mandate for an 'ecosystem approach' for sustaining the Earth's biological resources, alongside economic and social development, came in 1992 with the United Nations (UN) Convention on Biological Diversity (UN, 1992a), but the concept dates back to the 1950s (Waylen *et al*, 2014). Crucially, the ecosystem approach recognises the importance of sustainable, self-organising and complex ecosystems, which "maintain a degree of stable functioning across time", and that "a system is healthy if it maintains its complexity and capacity for self-organisation" (Norton, 1992). Furthermore, since ecosystems are complex systems with multiple feedback loops, trade-offs and interactions, it is not feasible to manage or protect individual species in isolation (Slocombe, 1993). Over the last two to three decades, the terms 'ecosystem management', 'ecosystem approach' and latterly the 'ecosystem services approach' have been used increasingly and often inter-changeably, despite subtle differences (Waylen *et al*, 2014).

1.4.2 Applying an ecosystem services approach to chemical ERA

In this report we follow EFSA's lead in adopting an ecosystem services approach for deriving protection goals and for informing ERA (EFSA, 2010). We acknowledge that this approach is anthropocentric and that it does not address all 12 principles of the ecosystem approach – focusing on ecological rather than socio-economic principles (Waylen *et al*, 2014). However, it may be argued that all management decisions, whether establishing protected areas, changing land use or regulating commercial activities, are based on human value systems and are therefore anthropocentric in nature. The difference is more to do with the cost-benefit trade off accepted, rather than a fundamental difference in approach. An ecosystem services approach, however, is not the most appropriate tool to identify conservation effects for specific (iconic) species, although integrating ecosystem services within conservation mechanisms adds value by conserving both nature and other benefits to people.

In order to achieve the 2020 EU Biodiversity Strategy target and longer-term vision, it is necessary to incorporate ecosystem service thinking into regulatory policy and decision making. It is also necessary to develop tools and approaches for identifying what needs to be protected where, in order to enable the sustainable use of natural capital. Aligning chemical risk assessment to such aims requires the establishment of protection goals and approaches for translating ecotoxicological exposure and effects information into risks for ecosystem service delivery.

In general terms, the 'ecosystem services approach' involves establishing "the linkages between ecosystem structures and process functioning … which are understood to … lead directly or indirectly to valued human welfare benefits" (Turner and Daily, 2008). The main perceived benefits of adopting such an approach in ERA include: (i) *Improved linkage between ERA and risk management* by focusing on protection of entities that matter to people (SCHER/SCENIHR/SCCS, 2013); (ii) *Systematic and transparent identification of specific protection goals* for ecosystems and biodiversity, which require protection according to new and recently amended EU regulations (Chapter 3); (iii) *Quantification of potential environmental impacts, taking into account ecological trade-offs and spatial variation,* acknowledging that delivery of all ecosystem services cannot be maximised at the same place and time e.g. food production is maximised in agricultural systems at the expense of some other services (EFSA, 2010); (iv) *Quantification of socio-economic impacts and trade-offs* following the valuation of ecosystem services (Hanley and Barbier, 2009).

The utility of the ecosystem services approach for weighing the environmental risks versus the benefits of chemicals is most apparent for plant protection products, since their benefits in terms of enhancing crop yields in smaller, more intensively managed agricultural systems can be assessed directly against their positive and negative impacts on the surrounding landscape. However, the approach also has potential application for other chemical use classes, which offer socio-economic and environmental benefits, including supporting or enhancing ecosystems services, such as biocidal products designed for water purification, pest regulation and invasion resistance and medicinal products used for disease regulation. The main difference for these other chemical use classes is that impacts tend to occur 'downstream' in the environment, rather than in proximity to their use, therefore trade-offs between risks and benefits may be more difficult to assess. Nevertheless, the identification of non-target species assemblages or functional groups, which may be vulnerable to chemical exposure, enables specific protection goals to be identified 'where' ecosystem services are most likely to be affected, both spatially and ecologically (i.e. at the population, functional group, community or habitat level).

There is an acceptance that protection goals specified in EU legislation are very general (Hommen *et al*, 2010) and that more specific protection goals need to be developed in order to guide risk assessment and inform risk management decisions (EFSA, 2010). In 2010, EFSA produced a scientific opinion outlining how an ecosystem services framework could be used to develop specific protection goals for the environmental risk assessment of pesticides (EFSA, 2010; Nienstedt *et al*, 2012) and more recently, has extended this approach to invasive species, feed additives and genetically modified organisms (EFSA, 2014a, 2015). This growing interest in using ecosystem services to help define and communicate protection goals will inevitably influence chemical regulation. Therefore, it is timely for the chemical industry to engage in this topic in order to determine and influence developments.

Current risk assessment approaches focus on the exposure-response relationship for a limited number of assessment endpoint and species. Whereas some standard species may be directly involved in delivering services of concern (e.g. bees and pollination, earthworm and soil formation; fish and recreational fishing), the link between the biological response measured in a toxicity test and ecosystem service delivery is often unclear. In order to obtain more relevant data for an ecosystem services evaluation it is necessary to: (1) identify the habitats potentially exposed to the chemical of interest; (2) identify ecosystems services provided by those habitats that are potentially affected by the chemical of interest; (3) identify ecosystem components (individual species, functional groups etc.) driving the services potentially affected (i.e. service-providing units, SPU); (4) identify how service provider attributes (e.g. behaviour, biomass, function etc.) relate to ecosystem service provision; (5) design studies to assess the toxicity of the chemical to SPUs and their key attributes (Maltby, 2013).

Ecosystem services are derived from the complex interactions between biotic and abiotic components of ecosystems. No single species, group of species or individual ecosystem can provide the full suite of ecosystem services and therefore the application of an ecosystem services framework to risk assessment and risk management requires consideration of multiple species across multiple ecosystems. Most ecosystems can provide a number of different services, several of which may be potentially affected by chemical exposure. Furthermore ecosystem services are not independent and there may be synergies and trade-offs between them. The risk assessment should therefore provide information on a number of landscape-scale scenarios, including possible mitigations, which the risk manager can then consider when deciding which ecosystem services to protect, where and when.

1.5 Aims of the Task Force

The aim of the Task Force was to investigate the applicability of the EFSA framework for developing specific protection goals for environmental risk assessment of pesticides (EFSA, 2010) to a wider range of chemicals. The EFSA approach, as described in Section 1.4.2 is based on a structured framework for identifying which ecosystem services might be affected by chemicals, using this assessment for setting specific protection goals and subsequently informing the scope and needs of risk assessment.

The Task Force work programme was organised into 3 phases:

Phase 1 – Develop a Framework for the chemical industry applicable to all sectors by considering the following:

- Description of key exposure scenarios and ecosystems including continuous and intermittent exposures, seasonality in receiving environments, spatial differences and scales.
- Identification of the main stressors driving ecological status.
- Establishment of current and potential uses of the environment in terms of ecosystem services. What does the local society use?
- Definition of spatially explicit protection goals. Use case examples to exemplify, e.g. direct discharge of untreated sewage and no-impact scenarios for down the drain chemicals in different regions. Prioritise / select case examples for phase 2.
- Identification of key service-providing units. What are their attributes / dimensions?

Phase 2 – Case studies to show how the framework would be used:

- Receiving environments to include freshwater, marine, soil.
- Exposure scenarios to include down the drain (pharmaceuticals, home and personal care products representing constant exposure), episodic exposure in terrestrial and aquatic environments (pesticides), intermediate exposure scenarios (biocides), multiple sources of exposure from industry value chains (e.g. oil and/or mining companies).
- Also consider multiple stressors to explore relative contributions of chemicals to overall ecosystem stress.

Phase 3 – Recommendations on how Risk Assessments Schemes need to be evolved:

- There is scope to incorporate greater ecological relevance in risk assessment in order to achieve protection goals, e.g. population metrics, community structure. If the ecotoxicological community is about to develop more ecologically relevant paradigms for chemical risk assessment, we should combine the approach with consideration of the ecosystem services we wish to protect.

The Task Force adopted this phased approach and considered most of the work programme listed above. Notable deviations and omissions include the following:

- A pesticide focused case example was not developed since EFSA have addressed this chemical sector.
- A case example with a metals focus was initiated but dropped before completion due to resource constraints of the relevant Task Force member.
- A case study addressing a chemical value chain was not developed to keep the work load manageable.
- Multiple stressors were not fully explored although certain aspects of chemical mixtures were considered.

2. CONCEPTUAL FRAMEWORK AND APPROACH

2.1 Introduction

The Task Force approached the assessment of the applicability of the European Food Safety Authority (EFSA) framework (EFSA, 2010) as applied to a pesticide exposure scenario, to a broad range of chemicals and typical environmental exposure scenarios by working through four case studies, i.e. "learning by doing". The focus on case studies enabled the Task Force to identify where the steps of the framework worked well and where development is needed. The four different case studies were selected to provide a range of emission scenarios and receptor habitats:

1. **Oil refinery:** Exposure of aquatic habitats, including wetlands to the chemicals present in waste water from a single refinery in an estuarine location.
2. **Oil dispersants:** Exposure from the use of dispersants in ocean and estuarine / transitional environments, not including the impact of spilt oil.
3. **Down the drain chemicals:** Continuous exposure of a wide range of ecosystems to a complex mixture of chemicals from the disposal of consumer products / pharmaceuticals via household waste systems into the municipal wastewater treatment / disposal infrastructure.
4. **Persistent organic pollutants:** Potential impacts to POP-type chemicals in remote (pristine) areas, e.g. high altitude alpine and Arctic regions. One chemical will be studied that has relevant properties.

A 5-step approach, similar to that of EFSA (2010), was used to identify habitats and ecosystem services potentially impacted by chemicals released into the environment. The approach is outlined in Figure 2.1 and each step is described in the following sections.

Figure 2.1: Stepwise process for specifying specific protection goals

1. Construct a habitat x ecosystem service matrix using published habitat and ecosystem service typologies.

2. Assign importance rankings to each habitat x ecosystem service combination using published information.

3. Rank potential impact for each habitat x ecosystem service combination.

4. Identify habitat x ecosystem service combinations of high, medium, low and negligible concern.

5. Define specific protection goals for each ecosystem service of high and medium concern.

2.2 Step 1: Construct a habitat x ecosystem service matrix was using published habitat and ecosystem service typologies

2.2.1 Ecosystem services typologies

There are several schemes for listing and classifying ecosystem services, the most widely used and well known typology, being that developed by the Millennium Ecosystem Assessment. The Millennium Ecosystem Assessment typology, which was used by EFSA (2010), classifies ecosystem services into four categories: provisioning services (e.g. products such as food, fuel, fibre); regulating services (i.e. benefits arising from the regulation of ecosystem processes e.g. climate regulation, natural hazard regulation, water purification); supporting services (e.g. nutrient cycling, primary production, soil formation) and cultural services (i.e. non-material benefits such as recreational, spiritual, aesthetic services) (Millennium Ecosystem Assessment, 2005b).

The Economics of Ecosystems and their Biodiversity (TEEB) project, which followed on from the Millennium Ecosystem Assessment, also grouped ecosystem services into four broad categories. However the TEEB classification replaced 'supporting services' with 'habitat or supporting services', which comprise 'habitats for species' and 'maintenance of genetic diversity' (TEEB, 2010b). More recently, there has been a proposal for a Common International Classification of Ecosystem Services (CICES), which builds on existing classifications (Haines-Young and Potschin, 2013). CICES has been developed to support the work of the European Environment Agency on environmental accounting and is linked with the UN System of Environmental Economic Accounts (SEEA). It therefore focuses on services that are used directly (i.e. final services). CICES groups services into 3 sections: provisioning (nutrients, materials, energy); regulating and maintenance (mediation of waste, toxics and other nuisances; mediation of flows; maintenance of physical, chemical, biological conditions) and cultural (physical and intellectual interactions with biota, ecosystems and land/seascapes; spiritual, symbolic and other interactions with biota, ecosystems and land / seascapes). It is a nested typology with CICES v4.3 resolving 3 sections (main service categories) via 8 divisions (main types of output or process) and 20 groups (biological, physical or cultural type or process) to 48 classes (http://cices.eu/). A cross tabulation of Millennium Ecosystem Assessment, TEEB and CICES classification systems is presented in Appendix A.

CICES has been adopted by the Mapping and Assessment of Ecosystems and their Services (MAES) process at the EU level and has been applied to six pilot studies (Maes *et al*, 2014). As a result of these pilots, it was concluded that the hierarchical structure of CICES was very useful to bundle services at class level and could be used for data poor systems where indicators may only be available at division or group level. However, conceptual difficulties were encountered when assessing regulation and maintenance services, especially in aquatic systems, and in addressing services delivered by agriculture (e.g. discriminating between the amount of provisioning service supplied by agro-ecosystems and the role of human energy inputs in contributing to total yield). MAES (Maes *et al*, 2014) suggested that separate classifications for both ecosystem functions (which underpin ecosystem services) and for ecosystem benefits or beneficiaries are developed in order to distinguish between the supply of and the demand for ecosystem services.

The ecosystem services considered in this project are listed in Table 2.1. It has been argued that ecosystem service assessments should focus on final ecosystem services to avoid double accounting in valuations (Boyd and Banzhaf, 2007). However, we have followed the EFSA (2010) approach and recent recommendations by MAES (Maes *et al*, 2014) by considering all types of services (i.e. including supporting and other intermediate services) and by basing our list of ecosystem services on the Millennium Ecosystem Assessment typology. This list is not exhaustive and other services may be added if sufficient information is available to evaluate their importance in specific habitats (see Step 2). Future developments may refine the list of services considered to prioritise final services for each habitat type, an approach adopted by the US EPA (Landers and Nahlik, 2013) and implied by the use of CICES by the MAES process. If required, the protection goals generated using the Millennium Ecosystem Assessment typology can be translated to the CICES typology using the information in Appendix A.

Finally, the Task Force recognised the importance of addressing biodiversity in relation to ecosystem services adopting the position that biodiversity underpins the delivery of all ecosystem services that are dependent on biotic processes and that specific components of biodiversity are explicitly addressed in many individual ecosystem services e.g. genetic resources, ornamental resources, pollination, pest control, aesthetic value etc. (Devos at al, 2015; Science for Environment Policy 2015). Biodiversity, as defined by the Convention on Biological Diversity, was considered part of natural capital and not an ecosystem service *per se* as its inclusion as an ecosystem service would lead to the protection of 'everything, everywhere', which is too generic and vague to be useful for scientific risk assessment.

Table 2.1: Ecosystem services considered in case studies. Services and explanations are taken from the Millennium Ecosystem Assessment (2005b)

Category	Ecosystem service	Explanation
Provisioning services	Food	Food products derived from plants, animals, and microbes.
	Fibre and fuel	Materials including wood, jute, cotton, hemp, silk, and wool. Biological materials providing sources of energy e.g. wood, dung.
	Genetic resources	Genes and genetic information used for animal and plant breeding and biotechnology.
	Biochemical / natural medicines	Medicines, biocides, food additives such as alginates.
	Ornamental resources	Animal and plant products (e.g. skins, shells, and flowers) are used as ornaments. Whole plants used for landscaping and ornaments.
	Fresh water	People obtain fresh water from ecosystems. Fresh water in rivers is also a source of energy.
Regulatory services	Pollination	Ecosystem changes affect the distribution, abundance, and effectiveness of pollinators.
	Pest and disease regulation	Ecosystem changes affect the abundance of human pathogens and disease vectors and the prevalence of crop / livestock pests and diseases.
	Climate regulation	Ecosystems influence climate both locally and globally. At a local scale, for example, changes in land cover can affect both temperature and precipitation. At the global scale, ecosystems play an important role in climate by either sequestering or emitting greenhouse gases.
	Air quality regulation	Ecosystems both contribute chemicals to and extract chemicals from the atmosphere, influencing many aspects of air quality.
	Water regulation	The timing and magnitude of runoff, flooding, and aquifer recharge can be strongly influenced by changes in land cover.
	Erosion regulation	Vegetative cover plays an important role in soil retention and the prevention of landslides.
	Natural hazard regulation	The presence of coastal ecosystems (e.g. mangroves and coral reefs) can reduce the damage caused by hurricanes or large waves.
	Water purification / soil remediation / waste treatment	Ecosystems can be a source of impurities but also can help filter out and decompose organic wastes introduced into ecosystems. They can also assimilate and detoxify compounds through biological processes.
Cultural services	Spiritual and religious values	Many religions attach spiritual and religious values to ecosystems or their components.
	Education and inspiration	Ecosystems and their components and processes provide the basis for both formal and informal education in many societies. Ecosystems provide a rich source of inspiration for art, folklore, national symbols, architecture, and advertising.
	Recreation and ecotourism	People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes.
	Cultural diversity and heritage	The diversity of ecosystems is one factor influencing the diversity of cultures. Many societies place high value on the maintenance of either historically important landscapes ('cultural landscapes') or culturally significant species.
	Aesthetic values	Many people find beauty or aesthetic value in various aspects of ecosystems.
	Sense of place	Many people value the 'sense of place' that is associated with features of their environment, including aspects of the ecosystem.
Supporting services	Primary production, photosynthesis	Primary production is the assimilation of energy and nutrients by biota. Photosynthesis produces oxygen required by most living organisms.
	Soil formation and retention	Because many provisioning services depend on soil fertility, the rate of soil formation influences human well-being in many ways.
	Nutrient cycling	Approximately 20 nutrients essential for life, including nitrogen and phosphorus, cycle through ecosystems.

2.2.2 Ecosystem / Habitat typologies

Article 2 of the Convention on Biological Diversity defines an ecosystem as 'a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit' and a habitat as 'the place or type of site where an organism or population naturally occurs' (UN, 1992a). We follow the approach adopted by the UK National Ecosystem Assessment and classify ecosystems using broad habitat types (UK National Ecosystem Assessment, 2011). For this project, habitat types have been defined according to the MAES typology (Maes *et al*, 2013) and the European Nature Information System (EUNIS).

EUNIS brings together data on species and habitats from several European databases and organisations (http://eunis.eea.europa.eu/index.jsp). It is part of the Biodiversity data centre of the European Environment Agency and aids implementation of EU biodiversity strategies and the General Union Environment Action Programme to 2020 – *Living well, within the limits of our planet* (EC, 2014). The EUNIS habitat classification covers both natural and artificial pan-European habitats and groups them into 11 broad categories:

A. Marine habitats
B. Coastal habitats
C. Inland surface waters
D. Mires, bogs and fens
E. Grasslands and lands dominated by forbs, mosses or lichens
F. Heathland, shrub and tundra
G. Woodland, forest and other wooded land
H. Inland unvegetated or sparsely vegetated habitats
I. Regularly or recently cultivated agricultural, horticultural and domestic habitats
J. Constructed, industrial and other artificial habitats
X. Habitat complexes

This hierarchical classification, which was revised in 2012, divides the 11 broad habitat categories into 5282 distinct habitat types (http://www.eea.europa.eu/themes/biodiversity/eunis/eunis-habitat-classification).

The MAES project, which is mandated to coordinate and oversee Action 5 of the EU 2020 Biodiversity Strategy, has proposed a typology that distinguishes 12 main ecosystem types based on the higher levels of the EUNIS Habitat Classification (Table 2.2). The MAES typology was applied in six pilot studies covering forests, agriculture, fresh waters and marine systems. It was concluded that, whereas the MAES typology worked well for forests, questions were raised about the appropriateness of combining arable land and permanent crops into a single category (i.e. cropland). The challenges of defining boundaries for freshwater systems was highlighted and several weaknesses with the marine typology were identified that require further refinement (e.g. typology solely based on bathymetry due to limited mapping information) (Maes *et al*, 2014).

The MAES typology is used in the current project, with the slight modification that the category 'Rivers and lakes' is subdivided into standing (EUNIS C1) and running (EUNIS C2) waters for the 'Down the drain' case study and coastal wetlands (i.e. saltmarshes and saline reedbeds; EUNIS A2.5) are separated out from the 'marine inlets and transitional waters' category for the oil refinery case study.

Table 2.2: Proposed MAES typology of European habitats and corresponding EUNIS habitat code (Appendix B). Adapted from Maes* et al *(2013)

Habitat type	MAES description	EUNIS code
Urban	Areas where most of the human population lives and it is also a class significantly affecting other ecosystem types. Urban areas represent mainly human habitats but they usually include significant areas for synanthropic species, which are associated with urban habitats. This class includes urban, industrial, commercial, and transport areas, urban green areas, mines, dumping and construction sites.	J
Cropland	Main food production area including both intensively managed ecosystems and multifunctional areas supporting many semi- and natural species along with food production (lower intensity management). It includes regularly or recently cultivated agricultural, horticultural and domestic habitats and agro-ecosystems with significant coverage of natural vegetation (agricultural mosaics).	I
Grassland	Dominated by grassy vegetation (including tall forbs, mosses and lichens) of two kinds – managed pastures and (semi-)natural (extensively managed) grasslands.	E
Woodland and forest	Dominated by woody vegetation of various age or they have succession climax vegetation types on most of the area supporting many ecosystem services.	G
Heathland and shrub	Areas with vegetation dominated by shrubs or dwarf shrubs. They are mostly secondary ecosystems with unfavourable natural conditions. They include moors, heathland and sclerophyllous vegetation.	F
Sparsely or unvegetated land	All unvegetated or sparsely vegetated habitats (naturally unvegetated areas). Often these ecosystems have extreme natural conditions that might support particular species. They include bare rocks, glaciers and dunes, beaches and sand plains	B, H
Inland wetlands	Predominantly water-logged specific plant and animal communities supporting water regulation and peat-related processes. This class includes natural or modified mires, bogs and fens, as well as peat extraction sites.	D
Rivers and lakes	Permanent freshwater inland surface waters. This class includes water courses and water bodies.	C
Marine inlets and transitional waters	Ecosystems on the land-water interface under the influence of tides and with salinity higher than 0.5 ‰. They include coastal wetlands, lagoons, estuaries and other transitional waters, fjords and sea lochs as well as embayments.	X01-X03 A1-A5, A7
Coastal areas	Coastal, shallow, marine systems that experience significant land-based influences. These systems undergo diurnal fluctuations in temperature, salinity and turbidity, and are subject to wave disturbance. Depth is up to 50-70 m.	A1-A5, A7
Shelf	Marine systems away from coastal influence, down to the shelf break. They experience more stable temperature and salinity regimes than coastal systems, and their seabed is below wave disturbance. Depth is up to 200 m.	A5, A7
Open ocean	Marine systems beyond the shelf break with very stable temperature and salinity regimes, in particular in the deep seabed. Depth is beyond 200 m.	A6-A7

X01: Estuaries; X02: Saline coastal lagoons; X03: Brackish coastal lagoons; A1: Littoral rock and other hard substrata; A2: Littoral sediment; A3: Infralittoral rock and other hard substrata; A4: Circalittoral rock and other hard substrata; A5: Sublittoral sediment; A6: Deep-sea bed; A7: Pelagic water column.

2.3 Step 2: Assign importance rankings to each habitat x ecosystem service combination using published information

The relative importance of broad habitats for delivering ecosystem services have been classified as '+' small (+), intermediate (++), large (+++) or unknown (?) based on the following publications: UNEP (2006); Haines-Young and Potschin (2008); Vandewalle *et al* (2008); IFPRI, GIPB (2008); EFSA Panel on Plant Protection Products and their Residues (2010); Harrison *et al* (2010); Wali *et al* (2010); UK National Ecosystem Assessment (2011); KPMG, NVI (2011) and Gómez-Baggethun *et al* (2013). The resulting matrix (Table 2.3) was used for all case studies.

The EFSA Panel on Plant Protection Products and their Residues (2010) evaluated the relative importance of 30 ecosystem services in five components of European agro-ecosystems: within crops, edge of field margins, terrestrial habitats away from field, small edge of field surface waters, large surface waters. The UK National Ecosystem Assessment (2011) provided information on the relative importance of 8 broad habitats (mountains, moorlands and heaths, semi-natural grasslands, enclosed farmland, woodlands, freshwaters, urban, coastal margins, marine) in delivering 16 final ecosystem services. The marine and coastal ecosystems synthesis report from the Millennium Ecosystem Assessment provides examples of significant amounts of service provision by 12 coastal and marine habitats (UNEP, 2006) and ecosystem services provided by urban areas have been classified and described by Gómez-Baggethun *et al* (2013). Ranking of productivity across habitats is based on Wali *et al* (2010).

Haines-Young and Potschin (2008) evaluated ecosystem service provision by UK terrestrial and freshwater Biodiversity Action Plan (BAP) habitats. A questionnaire survey of BAP lead-authors was used to elicit information about the potential ecosystem services or benefits associated with each habitat. This information, which was supplemented by a literature review and a series of expert workshops, was used to identify associations between 28 services and 19 broad habitats.

The EU 6th Framework Project RUBICODE, performed a detailed review of 31 ecosystem services provided by European terrestrial and freshwater biodiversity (Vandewalle *et al*, 2008). The relative importance of services was first evaluated using information from an extensive literature search. The results of the literature search were then considered by international scientific experts at a workshop and via an e-conference. The agreed qualitative importance rankings for 23 ecosystem services provided by 8 ecosystems – agro-ecosystems, forests, semi-natural grasslands, heathlands / shrublands, mountains, soil systems, rivers and lakes, wetlands – are presented in Harrison *et al* (2010).

Few studies have evaluated the role of sparsely vegetated land in delivering ecosystem services and therefore the relative importance of this habitat for providing many ecosystem services is unknown (Table 2.3). For this reason, sparsely vegetated land was not considered in the case studies.

Table 2.3: The relative importance of broad habitats for delivering ecosystem services (+ small; ++ intermediate; +++ large; ? unknown). Blank cells indicate that the habitat is not considered important for delivering the ES of interest

Ecosystem service		Terrestrial						Freshwater	Marine			
		Urban	Cropland	Grassland	Woodland and forest	Heathland and shrub	Wetlands	Rivers and lakes	Inlets and transitional waters	Coastal	Shelf	Open ocean
EUNIS habitat code		**J**	**I**	**E**	**G**	**F**	**D**	**C**	**X01-X03, A1-A5, A7**	**A1-A5, A7**	**A5, A7**	**A6, A7**
Provisioning services	Food	++	+++	++	+	++	++	++	++	++	++	++
	Fibre and fuel	++	+++	++	+++	++	++	+	++	+	+	+
	Genetic resources	++	++	+++	+++	+++	+++	+++	+++	+++	+++	+++
	Biochemical / natural medicines	?	++	+	++	++	+	+	++	+	+	
	Ornamental resources	+	+	+	+	+	+	+	+	+		
	Fresh water	++	++	+	+++	+++	+++	+++				
Regulatory services	Pollination	++	+++	+++	++	+++	++	+	++			
	Pest and disease regulation	++	+++	+	++	+	++	++	+	++	++	++
	Climate regulation	+++	+++	++	+++	++	+++	++	++	+++	+++	+++
	Air quality regulation	+++	++	++	+++	++	+	++	+	+++	+++	+++
	Water regulation	+++	++	++	+++	++	+++	+++	+++	+		
	Erosion regulation	+	++	++	++	+++	++	++	+	++		
	Natural hazard regulation	+	++	++	++	+++	++	++	+++	+++	++	++
	Water purification / soil remediation / waste treatment	+++	+++	+++	+++	+++	+++	+++	+++	++	++	++
Cultural services	Spiritual and religious values	++	+	++	++	++	++	++	+++	+		
	Education and inspiration	+	+	++	++	++	+++	++	+++	++	+	+
	Recreation and ecotourism	++	++	+++	+++	+++	+++	+++	+++	+++		
	Cultural diversity and heritage	+	++	++	+	++	++	++	++	++		
	Aesthetic values	+++	+++	+++	+++	+++	+++	+++	+++	++		
	Sense of place	+	+++	+++	++	+++	+++	+++	+++	++		
Supporting services	Primary production and photosynthesis	++	+++	++	+++	++	+++	++	+++	++	+	+
	Soil formation and retention	++	++	++	++	++	++	++	++			
	Nutrient cycling	++	+++	++	++	++	+++	++	++	+	+	+

2.4 Step 3: Rank potential impact for each habitat x ecosystem service combination using exposure and effects information

Information on the likely exposure of habitats in each case study was used to identify habitats potentially at risk. Knowledge of the level of redundancy among SPUs providing each ecosystem service, and the potential level of impact of chemicals versus regulatory protection goals for these services was used to identify ecosystem services potentially at risk. This information was combined to categorise ES x habitat combinations as either high potential impact (red) or medium potential impact (amber) or low potential impact (green).

2.4.1 Rationale for ranking potential impacts on habitats and ecosystem services

- This evaluation concerns the levels of exposure and likely impact of chemicals on ecosystem services. **No consideration** has been given to the **beneficial effects**, e.g. of applying nutrients in aqueous sewage and sewage sludge (biosolids) to agricultural land and pasture.
- The impact on SPUs is considered to be mainly driven by the **overall level of exposure** to the chemical(s).
- The chemical mode of action and characteristics, e.g. **complexity and variability** were considered when known, i.e. **existing knowledge of chemical fate and effects** were taken into account.
- **Direct linking** of specific chemical properties with impacts on SPUs (e.g. EDs potentially producing chronic effects on populations) will be possible only in **exceptional cases**.
- Chemical exposures are more problematic for **certain ecosystem services** due to:
  - secondary exposures e.g. via the food chain – chemical residues are more problematic in food (following non-lethal exposure) than in fibre and fuel,
  - lack of redundancy in the provision of some ecosystem services, e.g. less species are pollinators than are primary producers.

These factors were applied to two of the case studies (down the drain chemicals and oil dispersants) to illustrate the approach, see Tables 2.4 and 2.5. The outcome of this step for each of the 4 case studies is shown in Chapter 4, Tables 4.1 – 4.4. Explanatory comments on the potential impacts of chemicals on single ESs are provided in Appendix D.

Table 2.4: Analysis of factors determining the potential level of impact of chemicals on ecosystem services; Example: down the drain chemicals

Ecosystem services	Exposure level	Additional factors influencing the level of concern	Remarks / examples
Food	x	x	**Residues:** heavy metal accumulation, persistent compounds/PBTs **Biomass:** population decline due to toxicants interacting with the endocrine system (EDs)
Fibre and fuel	x		
Genetic resources	x		
Biochemical / natural medicines	x		
Ornamental resources	x		
Fresh water	x		
Pollination	x	x	Specific toxicants impacting plant reproductive parts (e.g. reduced flowering) can indirectly affect pollinators
Pest and disease regulation	x		
Climate regulation	x		
Air quality regulation	x		
Water regulation	x		
Erosion regulation	x		
Natural hazard regulation			
Water purification / soil remediation / waste treatment	x		
Spiritual and religious values	x		
Education and inspiration	x		
Recreation and ecotourism	x	x	**Residues:** heavy metals or other bioaccumulative substances in fish (recreational fishing) **Biomass:** population decline due to toxicants interacting with the endocrine system (EDs)
Cultural diversity and heritage	x		
Aesthetic values	x		
Sense of place	x		
Primary production	x		
Soil formation and retention	x		Microbial decomposition generally less sensitive + bioavailability in soil can be lower than in water
Nutrient cycling	x	x	Given microbial catabolic processes may be generally relatively tolerant, some nutrient cycling can require relatively sensitive species, e.g. nitrification

Table 2.5: Ecosystem services likely to be affected by increases in chemical exposure levels versus additional chemical or ES-related factors; Example: oil dispersants

Ecosystem service	Exposure level	Additional factors influencing the level of concern	Remarks / examples
Food	x	x	**Biomass:** population decline in the near surface mixing zone including primary producers **Seasonality:** reproduction and migration periods may be impacted resulting in effects on organisms dispersal and population growth
Fibre and fuel	x		
Genetic resources	x	x	Broad spectrum of marine and estuarine species (i.e. crustaceans, grasses, fishes, benthic organisms, marine mammals, birds), some stationary and others more mobile
Biochemical / natural medicines	x		
Ornamental resources	x	x	Similar to genetic resources in that a broad-spectrum of organisms / materials are utilised for ornamental purposes (i.e. shells, corals, aquarium fish, plants – grasses and drift wood, sand)
Fresh water	x		
Pollination	x		
Pest and disease regulation	x		
Climate regulation	x		
Air quality regulation	x		
Water regulation	x		
Erosion regulation	x		
Natural hazard regulation	x	x	Coral and oyster reefs provide measure of wave reduction and barriers to storm surges protecting coastal shorelines and vegetation
Water purification / soil remediation / waste treatment	x		
Spiritual and religious values	x		
Education and inspiration	x		
Recreation and ecotourism	x	x	Potential temporary closures of fisheries (recreational, subsistence, and commercial) **Biomass:** may observe a temporary decline in some populations, may also see an uptick in biomass due to increase of dispersant feeding bacteria into the food chain
Cultural diversity and heritage	x		
Aesthetic values	x		
Sense of place	x		
Primary production	x	x	Potential initial reduction of primary production at the surface water mixing zone
Soil formation and retention	x		
Nutrient cycling	x		

2.5 Step 4: Identify ecosystem services of high, medium, low and negligible concern for each habitat type within each case study

Ecosystem services are prioritised based on their relative importance (Step 2, Table 2.3) and the potential impact of chemical exposure on service delivery (Step 3). Ecosystem services are categorised as high, medium, low or negligible concern using Table 2.6. Of highest concern are those services that have large relative importance scores and the potential impact of chemical exposure is high.

Table 2.6: Prioritisation matrix based on relative importance of habitats for delivering specific ecosystem services and the potential impact of chemical exposure on service delivery

		Importance of Ecosystem Service		
		Small	**Intermediate**	**Large**
Potential impact	Low	NEGLIGIBLE CONCERN	NEGLIGIBLE CONCERN	LOW CONCERN
	Medium	NEGLIGIBLE CONCERN	LOW CONCERN	MEDIUM CONCERN
	High	LOW CONCERN	MEDIUM CONCERN	HIGH CONCERN

2.6 Step 5: Define SPGs for each ecosystem service of high and medium concern

Note: The following tables are organised by habitats with generally similar groups of SPUs. Each tabulation is then ordered into three trophic levels, primary producers, primary consumers (including decomposers, detritivores and ecosystem-engineers), secondary consumers.

Some taxa are included as specific examples of ecosystem-engineers. These taxa can also be listed under their general trophic level and so may appear more than once in each habitat table, e.g. ants and termites are listed as ecosystem-engineers as well as primary consumers in cropland and grassland. Taking a different perspective, there are several ecosystem-engineer taxa representing different trophic levels that could all influence ecosystem functions affecting a range of regulating and supporting ecosystem services (see Table 2.7: ants and termites (primary consumers), moles (secondary consumers)).

Examples given are illustrative of one or more habitats within each table, hence the tables contain much duplication but are not the same. Sparsely vegetated land is excluded because the level of importance this habitat represents for most ecosystem services is unknown.

Table 2.7: Cropland and grassland (terrestrial compartments)

Proposed SPU		Including [examples]	Taxa used in EFSA opinion on SPGs for Plant Protection Products (EFSA, 2010)
Trophic level	**Associated taxa**		
Primary producers	Terrestrial plants	Vascular plants, e.g. flowering plants, grasses, crop species incl. woody species such as fruit trees, willow	Non target plants (terrestrial)
Primary consumers	Bacteria, fungi, protists	Decomposers , e.g. aerobic and anaerobic bacteria; fungi incl. rusts, moulds, yeasts, mycorrhiza; protozoa	Microbes
	Terrestrial invertebrates	Detritivores e.g. woodlice, springtails; earthworms; dung beetles; slugs; millipedes Ecosystem-engineers e.g. ants; termites Insects e.g. beetles, bees, bugs, butterflies, flies, grasshoppers, ants, termites Arachnids (mites) Molluscs e.g. snails Nematodes	Detritivores Terrestrial non target arthropods including honeybees, terrestrial non arthropod invertebrates
	Terrestrial vertebrates	Birds; mammals (both incl. livestock and wild game); amphibians; reptiles	Vertebrates (terrestrial)
Secondary consumers	Terrestrial invertebrates	Insects, e.g. beetles, bugs, wasps Arachnids, e.g. spiders, mites Centipedes	Terrestrial non target arthropods including honeybees, terrestrial non arthropod invertebrates
	Terrestrial vertebrates	Birds; mammals; amphibians; reptiles Ecosystem-engineers , e.g. moles	

Table 2.8: Woodland and forest (terrestrial compartments)

Proposed SPU		Including [examples]	Taxa used in EFSA opinion on SPGs for Plant Protection Products (EFSA, 2010)
Trophic level	**Associated taxa**		
Primary producers	Lichens	Lichens	
	Terrestrial plants	Vascular plants, e.g. flowering plants; ferns, clubmoss, horsetails, incl. woody species such as conifers; non-vascular plants, e.g. mosses and liverworts	Non target plants (terrestrial)
Primary consumers	Bacteria and fungi	Decomposers, e.g. aerobic and anaerobic bacteria; mushrooms, rusts, moulds, yeasts, mycorrhiza	Microbes
	Terrestrial invertebrates	Detritivores, e.g. woodlice; earthworms Insects, e.g. beetles, bees, bugs, butterflies, flies, grasshoppers Arachnids (mites) Molluscs, e.g. snails Nematodes	Detritivores Terrestrial non target arthropods including honeybees, terrestrial non-arthropod invertebrates
	Terrestrial vertebrates	Birds, mammals (both incl. wild game); amphibians; reptiles	Vertebrates (terrestrial)
Secondary consumers	Terrestrial invertebrates	Insects, e.g. beetles, bugs, wasps, ants Arachnids, e.g. spiders, mites Centipedes	Terrestrial non target arthropods including honeybees, terrestrial non arthropod invertebrates
	Terrestrial vertebrates	Mammals; birds; amphibians; reptiles Ecosystem-engineers, e.g. moles	Vertebrates (terrestrial)

Table 2.9: Heathland and shrub including tundra

Proposed SPU		Including [examples]	Taxa used in EFSA opinion on SPGs for Plant Protection Products (EFSA, 2010)
Trophic level	**Associated taxa**		
Primary producers	Lichens	Lichens	
	Terrestrial plants	Vascular plants, e.g. flowering plants, ferns, clubmoss, horsetails, incl. woody species; non-vascular plants, e.g. mosses and liverworts	Non target plants (terrestrial)
Primary consumers	Bacteria and fungi	Decomposers, e.g. terrestrial; mushrooms, rusts, moulds, yeasts, mycorrhiza	Microbes
	Terrestrial invertebrates	Ecosystem-engineers, e.g. earthworms Detritivores, e.g. woodlouse Insects, e.g. beetles, bees, bugs, butterflies, flies, grasshoppers Arachnids (mites)	Terrestrial non target arthropods including honeybees, terrestrial non-arthropod invertebrates
	Terrestrial vertebrates	Birds; mammals (incl. livestock); amphibians; reptiles (reptiles not in tundra)	Vertebrates (terrestrial)
Secondary consumers	Terrestrial plants	Carnivorous plants, e.g. butterworts	
	Terrestrial invertebrates	Insects, e.g. beetles, wasps, ants Arachnids, e.g. spiders, mites	Terrestrial non target arthropods including honeybees, terrestrial non-arthropod invertebrates
	Terrestrial vertebrates	Birds; mammals; amphibians; reptiles Ecosystem-engineers, e.g. moles	Vertebrates (terrestrial)

Table 2.10: Wetlands

Proposed SPU		Including [examples]	Taxa used in EFSA opinion on SPGs for Plant Protection Products (EFSA, 2010)
Trophic level	**Associated taxa**		
Primary producers	Algae	Freshwater and terrestrial uni- to multicellular	Algae (freshwater)
	Aquatic plants	Vascular plants, e.g. flowering plants; non-vascular plants, e.g. mosses and liverworts, stoneworts	Non target plants (aquatic [macrophytes] and terrestrial)
	Terrestrial plants	Vascular plants, e.g. flowering plants, ferns, clubmoss, horsetails, incl. woody species; non-vascular plants, e.g. mosses and liverworts; peat bog, riparian and marsh / wetland species, e.g. reed	Non target plants (aquatic [macrophytes] and terrestrial)
Primary consumers	Bacteria and fungi	Decomposers, terrestrial and aquatic, aerobic and anaerobic bacteria, molds, yeasts	Microbes
	Aquatic invertebrates	Detritivores, amphipods; beetles Insects; amphipods; molluscs; worms	Aquatic invertebrates (freshwater)
	Terrestrial invertebrates	Detritivores, beetles; woodlouse Insects, e.g. beetles, bees, bugs, butterflies, flies, grasshoppers Arachnids (mites) Molluscs, e.g. snails Nematodes	Terrestrial non target arthropods including honeybees, terrestrial non-arthropod invertebrates
	Aquatic vertebrates	Amphibians	Vertebrates (aquatic and terrestrial)
	Terrestrial vertebrates	Birds; mammals; reptiles	Vertebrates (aquatic and terrestrial)
Secondary consumers	Aquatic invertebrates	Insects	Aquatic invertebrates (freshwater)
	Terrestrial invertebrates	Insects, e.g. beetles Arachnids, e.g. spiders, mites Leeches	Terrestrial non target arthropods including honeybees, terrestrial non-arthropod invertebrates
	Terrestrial vertebrates	Birds; mammals (including wild game); amphibians; reptiles	Vertebrates (aquatic and terrestrial)

Table 2.11: Rivers and lakes

Proposed SPU		Including [examples]	Taxa used in EFSA opinion on SPGs for Plant Protection Products (EFSA, 2010)
Trophic level	**Associated taxa**		
Primary producers	Bacteria	Cyanobacteria	
	Algae	Freshwater; uni- to multicellular (incl. phytoplankton and macro-algae)	Algae (freshwater)
	Aquatic plants	Vascular plants, e.g. flowering plants; non-vascular plants, e.g. mosses and liverworts, stoneworts	Non target plants (aquatic [macrophytes])
Primary consumers	Aquatic invertebrates	Decomposers, aquatic, aerobic and anaerobic bacteria, molds, yeasts Detritivores, e.g. amphipods Ecosystem-engineers, e.g. insects; crustaceans; molluscs; worms Insects; molluscs; crustaceans (including zooplankton); worms	Aquatic invertebrates (freshwater and marine)
	Aquatic vertebrates	Bony fish	Vertebrates (aquatic)
Secondary consumers	Aquatic plants	Carnivorous plants, e.g. bladderworts	
	Aquatic invertebrates	Insects; leeches; worms; jellyfish	Aquatic invertebrates (freshwater)
	Aquatic vertebrates	Predatory fish (bony and cartilaginous); amphibians; birds	Vertebrates (aquatic)

Table 2.12: Inlets and transitional waters, coastal, shelf and ocean

Proposed SPU		Including [examples]	Taxa used in EFSA opinion on SPGs for Plant Protection Products (EFSA, 2010)
Trophic level	**Associated taxa**		
Primary producers	Bacteria	Cyanobacteria	Microbes
	Algae	Marine uni- to multicellular (incl. phytoplankton, epiphyton and macro-algae, e.g. kelp)	Algae (marine)
	Aquatic plants	Vascular plants, e.g. flowering plants incl. woody plants; non-vascular plants, e.g. stoneworts	Non target plants (aquatic [macrophytes])
Primary consumers	Bacteria and fungi	Decomposers, aquatic, aerobic and anaerobic bacteria, molds, yeasts	Microbes
	Aquatic invertebrates	Detritivores, e.g. amphipods, molluscs, crabs Ecosystem-engineers, e.g. crustaceans; molluscs, e.g. mussel beds; corals; worms, e.g. tubeworms Molluscs and crustaceans (including zooplankton, e.g. krill); worms; corals; jellyfish; sponges; other filter feeders, e.g. tunicates	Detritivores Aquatic invertebrates (marine)
	Aquatic vertebrates	Fish (bony and cartilaginous); reptiles	Vertebrates (aquatic)
Secondary consumers	Aquatic invertebrates	Molluscs (including octopods); worms; jellyfish; starfish	Aquatic invertebrates (marine)
	Aquatic vertebrates	Predatory fish (bony and cartilaginous); mammals, e.g. cetaceans, seals; birds	Vertebrates (aquatic)

3. REGULATIONS

3.1 Introduction

3.1.1 Regulatory demands and challenges

The European chemical industry is highly regulated, both internally and externally, with a range of guidelines and legislative instruments requiring environmental testing and assessment of new products to ensure environmental (and human) safety prior to market authorisation in the European Union (EU) (Hommen *et al*, 2010). Whilst regulations are highly consistent across chemical sectors, environmental testing may be tailored for different classes of chemicals, according to their inherent risks to the environment. In each case a tiered environmental risk assessment (ERA) is performed, beginning with the estimation of exposure profiles based on chemical use, volumes and/or physico-chemical properties. Predicted or measured chemical exposure concentrations may then be compared to predicted or measured effects on environmentally relevant and/or sensitive test species, while also taking into account chemical mode of action and potency, including the potential for bioconcentration and secondary poisoning (Hommen *et al*, 2010).

Despite highly developed environmental principles (Table 3.1) and internationally standardised test methods (OECD, 2015), environmental protection goals for chemical registration remain vague, such as requiring prevention of 'unacceptable' or 'adverse' impacts on 'biodiversity' and 'ecosystems' or the 'environment as a whole'. Due to the complexity of ecosystems these high-level goals have not been adequately addressed by current regulations and ERA guidance documents, leading regulators to 'err on the side of caution'. The widespread adoption of this overarching 'precautionary principle' (UN Rio Declaration, 1992b) has led to the application of assessment (uncertainty) factors in order to extrapolate from the most sensitive test species to protect the theoretically most sensitive species in the field, with the intention of protecting 'ecosystems' and the 'environment as a whole'.

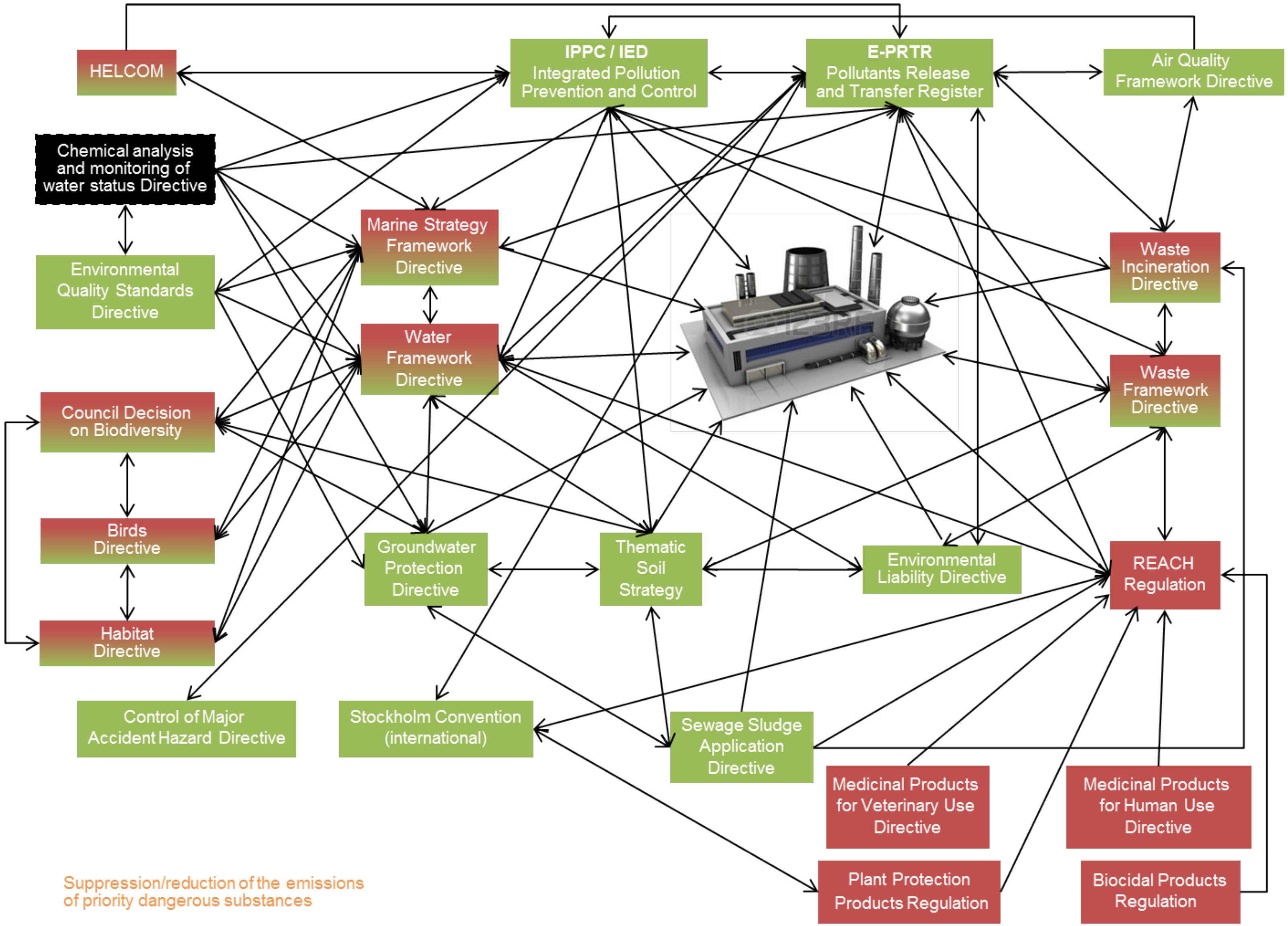
Uncertainties in ERA are attributable to: i) natural background variability in the environment; ii) representation of multiple chemical exposure profiles; iii) extrapolation of chemical effects from individual laboratory test organisms to wild populations; iv) failure to account for ecological factors, including interactions between species and between physical, chemical and biological stressors (Table 1.1, after Chapman, 2002; Hommen *et al*, 2010; SCHER/SCENIHR/SCCS, 2012).

Table 3.1: Environmental principles adopted in the prospective and retrospective ERA of chemicals - requiring environmental protection goals at different levels of biological organisational (underlined) (Adapted from Brock* et al*, 2006; Beder, 2006)

Environmental principle	Description	Definitive text / source
Prospective risk assessment		
Precautionary principle	Avoid any pollution of the environment and ecosystems - occurrence of damage is uncertain and cannot be predicted clearly	« Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation. » (UN Rio Declaration on Environment and Development (1992b), Principle 15).
Pollution prevention principle	Prevent pollution of the environment and ecosystems i.e. prevent pollution at source, minimise environmental damage, reduce risk of harm, avoid transboundary pollution - occurrence of damage is probable if no measure is taken to reduce pollutant load or concentration below a safe threshold	International – « States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction. » (UN Stockholm Declaration on the Human Environment (1972): Principle 21). National – « The principle of preventive and curative action, as a priority at source, of damage to the environment and this by using best available techniques at reasonable costs » (French Environmental Code: Article L 110-1 para. II).
Ecological threshold principle	Ecosystems can tolerate a certain degree of stress without adverse effects to their *structure and function*	« Ecological threshold is the point at which a relatively small change in external conditions causes a rapid change in an ecosystem. When an ecological threshold has been passed, the ecosystem may no longer be able to return to its state. » (Groffman *et al*, 2006).
Community recovery principle	The abundance and structure of natural populations and communities vary in space and time- reductions in population abundance are tolerable as long as they are within the natural range of variability, and the recovery of populations is likely, whereas long-term effects are unlikely.	« EU Member States shall ensure that use of plant protection products does not have any long-term repercussions for the abundance and diversity of non-target species. » Uniform principles for evaluation and authorisation of plant protection products (PPPs) (EU Regulation (546/2011) Annex Part 1 C).
Functional redundancy principle	A decrease in biodiversity might be tolerated for some situations or ecosystems, as long as the ecological function is maintained.	« Owing to ecological redundancy, ecosystem structural endpoints are generally more sensitive to PPP application than functional endpoints » (EFSA, 2014b). « Ecosystem functioning and resilience depends on ecosystem structure, dynamic relationships within species, among species and between species and their abiotic environment, as well as the physical and chemical interactions within the environment. The conservation and, where appropriate, restoration of these interactions and processes is of greater significance for the long-term maintenance of biological diversity than simply protection of species (biodiversity) » (UNEP, 1998: Malawi Principle 5).

Environmental principle	Description	Definitive text / source
Retrospective risk assessment		
Polluter pays principle	Environmental abatement, mitigation and/or clean-up costs for significant environmental pollution / damage must be met by the polluter.	« In the event of any incident or accident significantly affecting the environment, Member States shall take the necessary measures to ensure that … the operator immediately takes the measures to limit the environmental consequences and to prevent further possible incidents or accidents … take any appropriate complementary measures that the competent authority considers necessary to limit the environmental consequences and to prevent further possible incidents or accidents » (EU Industrial Emissions Directive [2010/75/EU]).

Figure 3.1: EU environmental legislation and conventions relating to chemicals relating to Appendix C Tables: C1.1 (red boxes); C1.2 (red/green boxes); C1.3 (green boxes)



3.1.2 Broader regulatory perspectives on regulatory protection goals

Here a broader range of regulatory instruments than those previously considered for prospective ERA prior to chemical product registration and retrospective assessment under the Water Framework Directive (Hommen *et al*, 2010) are reviewed. These broader instruments provide a 'catch-all' or environmental 'safety net' covering the life-cycle of chemicals from manufacture to use and disposal. They include environmental and nature conservation legislation and International Conventions, many of which require retrospective environmental surveillance, monitoring and impact assessment, instead of, or in addition to prospective risk assessment (Appendix C Tables C1.1 to C1.3, Figure 3.1). The complementary use of retrospective and prospective approaches is recognised as important for improving ERA (Ragas, 2011; Boxall *et al*, 2012; SCHER/SCENIHR/SCCS, 2012). The Task Force has identified existing examples of specific protection goals (SPGs) from consolidated regulatory texts and guidance documents, including historical and recent amendments, covering a wide range of ecological entities, from individual organisms to entire habitats or ecosystems, and key attributes reflecting ecosystem health (Section 3.3.1).

3.2 Adverse environmental effects

3.2.1 Qualitative definitions of adverse effects

EU regulations concerning prospective ERA of chemicals (Figure 3.1) require no 'unacceptable', 'undesirable', 'harmful' or 'adverse' effects on 'biodiversity', 'ecosystems' or 'the environment as a whole' (Tables C1.1 and C1.2). Definitions of these terms (here generally referred to as adverse) in environmental legislation and chemical sector-specific guidance (Table 3.2) tend to focus on individuals, which is at odds with stated high-level environmental protection goals aimed at ecological populations, communities and ecosystems (Table C1.1). For example, the WHO/UNEP/OECD/ILO International Programme for Chemical Safety (IPCS) definition of adverse effect (below) is adopted under the Registration Evaluation Authorisation and restriction of Chemicals (REACH) Regulation (EC 1907/2006), Plant Protection Products Regulation (PPPR) (EC 1107/2009) and Biocidal Products Regulation (BPR) (EU 528/2012), with the exclusion of the terms 'system' and '(sub)population' (Table 3.2). The context of the term 'system' may be considered ambiguous in the IPCS definition and could refer to *in vivo* system (e.g. endocrine system) or eco-system.

IPCS definition of adverse effect: "a change in the morphology, physiology, growth, development, reproduction, or life span of an organism, system, or (sub)population that results in *(i) an impairment of functional capacity, (ii) an impairment of the capacity to compensate for additional stress,* or *(iii) an increase in susceptibility to other influences*" (WHO/UNEP/OECD/ILO, 2004; after Bayne, 1975).

Notes:

(i) The *impairment of functional capacity* (at the ecosystem-level), is elaborated under the Environmental Liability Directive (ELD) (2004/35/CE) and the Control of Major Accident Hazard (COMAH) Directive (2012/18/EU), with supporting guidance (DETR, 1999; CDOIF, 2013). These documents refer to the "long-term maintenance of … the functions of habitats", including defined, statutory protected and undesignated land-based habitats and water bodies. In addition, some specific ecosystem functions e.g. biodegradation of animal dung and sewage effluents are protected in several chemical and environmental regulations (Tables C1.1 and C1.2).

(ii) With respect to *impairment of the compensatory capacity* of individuals, populations and ecosystems, guidance for the Convention on Biological Diversity (UN, 1992a; CBD SBSTTA, 2000) and Habitats Directive (HD) (92/43/EEC) specifically refers to the preservation of ecosystem integrity, including ‘the capacity for self-regulation’. Similarly, the PPPR (EC 1107/2009) and the ELD consider the potential for populations to ‘recover’ or ‘regenerate naturally’, following chemical exposures or spills (Tables C1.1 and C1.2).

(iii) In terms of *susceptibility to additional stress … or other influences*, the PPPR and BPR both require the consideration of possible cumulative and interactive (synergistic) effects of co-formulated chemical mixtures / products and relevant metabolites or transformation products on biodiversity and ecosystems. The potential ‘long-range’ or ‘transboundary’ transport of some chemicals is also acknowledged in PPPR, BPR, the Air Quality Framework Directive (AQFD) (2008/50/EC) and the UN Stockholm Declaration on the Human Environment (1972). Defining acceptable versus unacceptable limits of exposure for such chemicals inevitably requires the assessment of cumulative risks from multiple emission sources.

3.2.2 Quantitative definitions of adverse effects

Quantitative definitions of the terms ‘impairment’, ‘unacceptable’, ‘undesirable’, ‘harmful’ or ‘*adverse*’ are generally lacking in chemical regulations and supporting guidance documents (Table C1.1; Table 3.2). Furthermore, although prospective ERA places emphasis on assessing population-relevant effects in controlled exposure studies (often in the laboratory), their ‘significance’ is ultimately framed in statistical terms, and the ecological significance of effects on wild populations may be exaggerated, or worse still, overlooked (Forbes *et al*, 2008; 2011; Brown *et al*, 2014). Alternatively, the ERA of plant protection products also includes the option for appropriate assessments under field conditions of: the population density and viability of non-target species (including keystone and/or indicator species); biodiversity (e.g. overall species richness of ecological communities); and ecosystem services (including the provision of harvestable resources and aesthetic resources including species with ‘popular appeal’) (SANCO, 2002). However, there is still a lack of clarity in the definition and relevance of unacceptable impacts on each of these ecological entities, and hence their recovery, indicating the absence of long-term effects, may be used as an alternative decision criterion under PPPR (Hommen *et al*, 2010; Moe *et al*, 2013) and COMAH (CDOIF, 2013). It is important to recognise that “ecosystems change, including species composition and population abundance” and that environmental management should take account of such natural, background changes (Malawi Principle 9: CBD SBSTTA, 2000). Retrospective environmental assessments (Tables C1.2 and C1.3) have the advantage of historical baselines for established ‘reference’ sites, which are capable of quantifying such natural variability, including seasonal cycles and long-term climate change (Moe *et al*, 2013). Ecological baselines are fundamental to environmental quality assessment under the Water Framework Directive (WFD) (2000/60/EC), Oslo Paris Convention (OSPAR) (Table C1.3) and the Thematic Soil Strategy (TSS)

(COM/2006/0231/EU, COM/2006/0232/EU) (Table C1.2) and retrospective evaluation of chemical impacts under the ELD and COMAH (Table C1.2).

Table 3.2: Definitions of adverse (unacceptable, harmful) effects in international guidance and EU legislation concerning prospective ERA of chemicals

International guidance	**Organism-level definition**	**Population to ecosystem-level definition**
WHO/UNEP/ILO International Programme on Chemical Safety (IPCS) Glossary of terms on chemical safety: http://www.ilo.org/legacy/english/protection/safework/cis/products/safetytm/glossary.htm	"Abnormal, undesirable or harmful effect to an organism, indicated by some result such as mortality, altered food consumption, altered body and organ weights, altered enzyme levels or visible (pathological) change. An effect may be classed as adverse effect if it causes functional or anatomical damage, causes irreversible changes or increases the susceptibility of the organism to other chemical or biological stress. A non-adverse effect will usually be reversed when exposure to the chemical ceases."	
IPCS Risk Assessment Terminology Part 1: http://www.inchem.org/documents/harmproj/harmproj/harmproj1.pdf	"Change in the morphology, physiology, growth, development, reproduction, or life span of an organism, system, or (sub)population that results in an impairment of functional capacity, an impairment of the capacity to compensate for additional stress, or an increase in susceptibility to other influences."	
EU Technical Guidance Document (TGD) on Chemical Risk Assessment: https://echa.europa.eu/documents/10162/16960216/tgdpart2_2ed_en.pdf	Neurotoxicity, behavioural effects and endocrine disrupting effects.	
	Adverse effects on microbial activity in sewage treatment plants. Adverse effects on soil functions such as filtration, buffering capacity and metabolic capacity.	
EU legislation	**Organism-level definition**	**Population to ecosystem-level definition**
Registration Evaluation Authorisation and restriction of Chemicals (REACH) Regulation (EC 1907/2006) REACH Definitions and REACH Acronyms: http://www.reach-compliance.eu/english/REACH-ME/engine/sources/definitions.html	Change in morphology, physiology, growth, development or lifespan of an organism which results in impairment of its functional capacity or impairment of its capacity to compensate for additional stress or increased susceptibility to the harmful effects of other environmental influences.	
Plant Protection Products Regulation (PPPR) (EC 1107/2009) Article 4: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:309:0001:0050:EN:PDF	Impact on non-target species, including on the ongoing behaviour of those species. Impact on biodiversity and the ecosystem.	
Uniform principles for evaluation and authorisation of plant protection products PPPs Regulation (546/2011) Annex Part 1 C: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:155:0127:0175:EN:PDF	Member States shall ensure that use of plant protection products does not have any long-term repercussions for the abundance and diversity of non-target species.	
Criteria for identifying Endocrine Disruptors in the context of the implementation of the PPPR and BPR. EU ROADMAP 06/2014: http://ec.europa.eu/smart-regulation/impact/planned_ia/docs/2014_env_009_endocrine_disruptors_en.pdf	Change in morphology, physiology, growth, development or lifespan of an organism which results in impairment of its functional capacity or impairment of its capacity to compensate for additional stress or increased susceptibility to the harmful effects of other environmental influences.	

<table>
<tr><th>EU legislation</th><th>Organism-level definition</th><th>Population to ecosystem-level definition</th></tr>
<tr><td>Biocidal Products Regulation (BPR)
(EU 528/2012)
Guidance on the Biocidal Products Regulation Volume III, Part A Human health#:
http://echa.europa.eu/guidance-documents/guidance-on-biocides-legislation</td><td>Impairment of male and female reproductive functions or capacity, for example from effects on oestrus cycle, sexual behaviour, any aspect of spermatogenesis or oogenesis, or hormonal activity or physiological response which would interfere with the capacity to fertilise, fertilisation itself or development of the fertilised ovum up to and including implantation.
Adverse effects on the progeny, for example any effect interfering with normal development, both before and after birth. This includes morphological anomalies such as changes in anogenital index, nipple retention, and functional disturbances (such as reproductive and neurological effects).
Effects accentuated over generations.</td><td></td></tr>
<tr><td rowspan="2">Medicinal Products for Human Use Directive (MPHU)
(2001/83/EC)
Refers to the TGD (above)</td><td>Neurotoxicity, behavioural effects and endocrine disrupting effects.</td><td></td></tr>
<tr><td colspan="2">Adverse effects on microbial activity in municipal wastewater treatment plants.
Adverse effects on soil functions such as filtration, buffering capacity and metabolic capacity.</td></tr>
<tr><td rowspan="2">Medicinal Products for Veterinary Use Directive (MPVU) (2009/9/EC) Guideline on Environmental Impact Assessment for Veterinary Medicinal Products Phase II (CVMP/VICH/790/03-FINAL)
http://www.ema.europa.eu/docs/en_GB/document_library/Scientific_guideline/2009/10/WC500004393.pdf</td><td>Adverse effects / impacts - mortality and sub-lethal effects.</td><td></td></tr>
<tr><td colspan="2">Impacts of greatest potential concern are usually those at community and ecosystem function levels, with the aim being to protect most species. However, there may be a need to distinguish between local and landscape effects.</td></tr>
<tr><td>Classification Labelling and Packaging Regulations (CLPR)
(EC 1272/2008)
https://osha.europa.eu/en/topics/ds/clp-classification-labelling-and-packaging-of-substances-and-mixtures</td><td>Hazard classification groups:
Carcinogen, mutagen, or reprotoxicant (CMR), endocrine disrupting chemical (EDC).
Toxic or very toxic or harmful chemicals defined by the following hazard statements:
H351: Suspected of causing cancer
H373: May cause damage to organs through prolonged or repeated exposure
H350: May cause cancer
H340: May cause genetic defects
H360: May damage fertility or the unborn child</td><td></td></tr>
</table>

All URLs were accessed in March 2015

Guidance on the Biocidal Products Regulation Volume IV, Part B guidance for Environmental Health is currently under development.

3.3 Environmental protection goals

3.3.1 Examples of specific protection goals

For reasons already discussed, specific environmental protection goals are generally lacking in legislation and guidance concerning the prospective and retrospective ERA of chemicals (Table C1.1), including the following specific industry sectors:

- the plant protection products regulation (EC 1107/2009), which specifies the goal of "no unacceptable effects on the environment",
- the pharmaceuticals industry (Directive 2001/83/EC), which aims to prevent "any risk of undesirable effects on the environment",
- and the maritime transport industry (Directive 2012/33/EU), which aims to achieve "levels of air quality that do not give rise to significant negative impacts on and risks to human health and the environment".

Conversely, it may be argued that some environmental protection goals are too specific, such as the environmental protection goals for bees in the EFSA guidance for plant protection products (EFSA, 2013), which require measuring and linking PPP exposure to colony-relevant population changes (despite the potential influence of other causal factors). This apparent 'gulf' between the general and specific protection goals is also apparent for other groups of organisms / species that are covered in the prospective environmental risk assessment of plant protection and other chemical products. However, there are several examples of specific protection goals associated with environmental monitoring in retrospective ERA (Tables C1.2 and C1.3), and these generally fall into two categories. The first category contains population-level goals for indicator species, identified using a reductionist approach typified by OSPAR's Ecological Quality Objectives (e.g. focusing on priority chemicals and individual biomarkers or population trends for indicator species, Table C1.3). The second category contains more holistic community or ecosystem-level goals (e.g. protection of ecological communities reflecting biological quality status defined under the Water Framework Directive, or entire habitat features under the Habitats Directive, Table C1.3). These specific protection goals provide valuable working examples for guiding prospective ERA, helping to justify the selection of ecological entities (e.g. population, functional group or community) and their key attributes (e.g. biomass or function) as reliable indicators of ecosystem health. Quantifiable changes in these attributes, versus acceptable limits or reference values, should ideally be defined in terms of magnitude of change, spatial scale and temporal scale (EFSA, 2010). All three dimensions are considered in the setting of specific protection goals under OSPAR (e.g. "ecological quality objective" of <10% decline in recruitment (5 year rolling average) for defined sub-populations of 5 species of North Sea seals [OSPAR, 2010]), the Water Framework Directive ("biological water quality classification" based on species diversity, abundance, distribution and trends) and the Habitats Directive ("favourable conservation status" based on species population dynamics, long-term viability and natural range; habitat species richness, structure and function, extent and trends, necessary for their long-term maintenance [EC, 2011c; EC, 2012]). Critically, in each of these cases, the main focus is on magnitude of change, while spatial and temporal dimensions are constrained by pre-defined monitoring regions, water bodies or habitats and reporting cycles.

3.3.2 Towards ecosystem-level protection

Traditionally, a bottom-up approach is adopted in environmental risk assessment (ERA), whereby (eco)toxicity testing results for sensitive 'model' organisms are extrapolated using assessment factors in order to protect 'populations' representing various trophic levels and taxonomic groups potentially subjected to chemical exposure. Although populations are widely considered to be the 'operational taxonomic units' of choice for species protection (IUCN, 2012), they may not always be the most suitable for ecosystem-level protection. This is due to lack of consideration of species interactions (Slocombe, 1993) and other ecological interactions and selective pressures, which promote evolutionary divergence within and between species (Sneath and Sokal, 1973), including their differential susceptibilities to chemicals (Brown *et al*, 2009; 2014). Consequently, no single 'model' species or population will be most susceptible to all chemicals and therefore protective of all other species and populations. Furthermore, the operational taxonomic units of species and populations cannot be applied readily to micro-organisms (Koeppel and Wu, 2013), which provide an enormous pool of biological and genetic diversity and which support / provide numerous ecosystem services (e.g. nutrient cycling, climate regulation, soil formation, retention and remediation, water purification, and waste treatment [Millennium Ecosystem Assessment, 2005b]).

3.4 Ecosystem protection goals

3.4.1 Ecosystem-level protection goals

The importance of protecting ecosystem services (or amenities) from chemical exposure has been recognised for several decades. For instance, the UN's Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP, 1986) defined marine pollution as: "The introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries), which results in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities including fishing, impairment of quality for use of sea water and reduction of amenities". This definition is largely unchanged under the current EU Marine Strategy Framework Directive (MSFD) (2008/56/EC). A key point, which should be noted, is that chemicals only form part of these ecosystem service protection goals.

Despite the maturity of the ecosystem service concept and its relevance to environmental regulation, current definitions of ecosystem-level protection goals in ERA remain blurred. For example, the protection of ecosystem structure and function are both commonly referred to in EU environmental and chemical regulations (Figure 3.1, Table C1.1). Whilst ecosystem structure and function (and resilience / integrity) are intrinsically linked (Malawi Principle 5: CBD SBSTTA, 2000), protection of ecosystem function (underpinning ecosystem services) takes into account functional redundancies among similar species, whereas the explicit protection of ecosystem structure is more demanding (EFSA, 2014b). By focusing on functional groups or 'service-providing units' (SPUs), the derivation of ecosystem service protection goals is undoubtedly more transparent than attempting to protect all species' populations, everywhere, all of the time (as is the current paradigm, involving extrapolation from tests on model species to all species in the field (Section 3.1.1)).

The use of an ecosystem service approach also has the advantage that trade-offs, spatial scales and redundancies are considered collectively in ERAs (EFSA, 2010).

3.5 Conclusions

Regulations and guidelines for chemical environmental risk and impact assessment have consistent, high-level, aspirational goals for protecting the environment as a whole, including ecosystem structure and how to achieve ecosystem-level protection in the prospective ERA of chemicals. Despite generic ecosystem-level protection goals being common to all chemical sectors, specific protection goals are conspicuously lacking, which has engendered a high degree of conservatism in risk assessments and reliance on the precautionary principle (Table 3.1). All chemical sectors rely on generic predicted no-effect concentrations, PNECs, (or predicted no-adverse effect concentrations) to protect ecological populations *per se* in prospective ERA. Specific protection goals for ecosystems are generally limited to wider environmental / nature legislation requiring environmental monitoring and impact assessment and retrospective ERA. This is due mainly to the existence of tangible baselines or reference conditions, which help define acceptable versus unacceptable environmental effects. In some cases these specific protection goals are based on a reductionist approach and rely on population-based indicators of ecosystem health (e.g. OSPAR), while others are more holistic and therefore more in tune with the concept of the 'ecosystem approach' (e.g. protection of entire habitat features under the Habitats Directive, protection of aquatic ecological communities under the Water Framework Directive'). A promising yet not yet fully operational alternative is the spatially explicit, holistic and pragmatic 'ecosystem services approach' recently devised for plant protection products (EFSA, 2010; Nienstedt *et al*, 2012). We propose that better protection of 'the environment as a whole' will be facilitated by amalgamating this new approach with current best practices for defining 'specific protection goals', as identified during this review of current chemical and environmental regulations.

4. CASE STUDIES: STEP 3

In Chapter 2, the generic approach to steps 1 and 2 is described and we applied as such to the four case studies. Deviations to these two first steps were relatively few and are discussed in Chapter 7. In this section the third step in the EFSA framework is discussed for each case study, i.e. the ranking of potential impacts for each habitat x ES combination using chemical exposure and effects information.

In an attempt to describe and capture ecosystem services in relationship to chemical use and disposal in the environment, a series of scenarios have been developed as examples to better understand the potential risks to ecosystem services. Scenarios include: oil refinery emissions to an estuary, oil dispersant application at sea, down the drain chemicals, air dispersed persistent organic pollutants (POPs). Whilst the Task Force's application of the EFSA framework follows a prospective approach to informing risk assessment (generic or site specific), we recognise that the framework can also be applied retrospectively (site specific). For example, identifying relevant ecosystem services can follow a site-specific exercise dependent upon temporal and spatial aspects of the material release or application. Elements of ecosystem services may overlap between similarly described habitats and may be an ecological entity or a physical aspect. When conducting an ecosystem services evaluation it is often necessary to utilise local experts in the fields of environment and socio-economic issues, who are familiar with the local complexities and priorities. Nevertheless the following chemical case studies are intended to cover a broad range of generic cases. Note that we have identified and considered only negative effects of the chemicals represented in the case studies. Positive, impacts may arise, e.g. indirect effects following application of oil dispersants is usually tied to oil spills. As such dispersants enhance the opportunities for water purification through material breakdown enabling micro-organisms to better feed upon contaminants.

4.1 Case study 1: Oil refinery – discharge into estuarine environments

4.1.1 Rationale for level of impacts of oil refinery discharge

Oil refineries are often situated in coastal locations, typically on estuaries, allowing relatively easy transport links and access to water for cooling etc. during the refining process. In this case study, the discharge from a single refinery, situated on an estuary is considered. The emission routes and subsequent movement in the environment are shown in Figure 4.1.

Refinery effluents are complex mixtures of organic and non-organic chemicals, discharged directly into the environment. Much of the chemical components will be hydrocarbons, with a non-specific mode of action, causing baseline toxicity and untreated refinery effluents discharged into an estuary have the potential to impact a wide range of SPUs, across all taxonomic groups as shown in Table 4.1. Before discharge, refinery waste waters are subjected to a variety of different physical, chemical and/or biological treatment processes that significantly reduce total emissions and their potential to cause adverse environmental effects (Comber *et al, 2015*). However, for the purposes of this case study, it is assumed that the refinery effluent is not treated.

Figure 4.1: Refinery discharge into estuarine environment

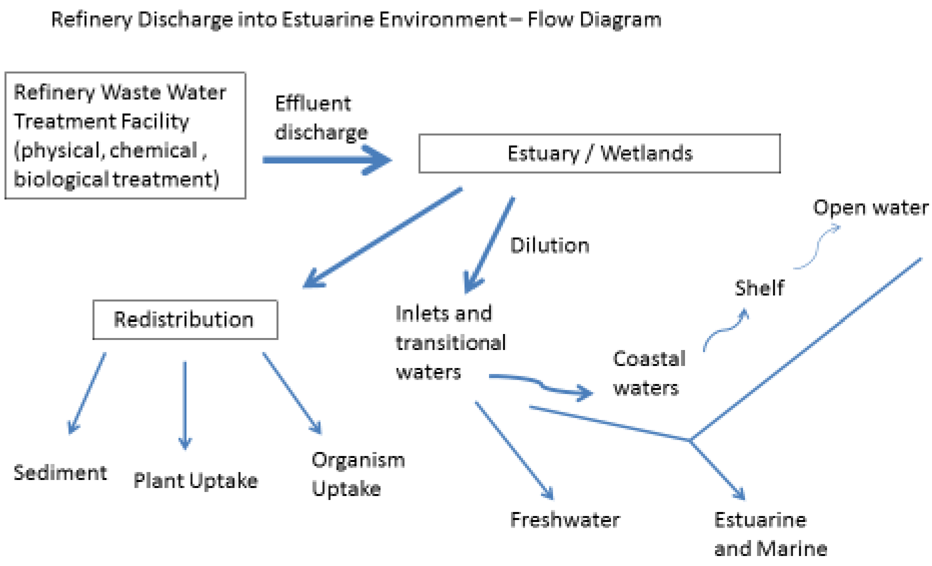


Table 4.1: Potential impact of an oil refinery discharge on specific ecosystem services (green: no impact; yellow: moderate impact; red: severe impact) and potentially impacted service-providing units (SPU)

	Ecosystem service	Terrestrial: Urban	Terrestrial: Cropland	Terrestrial: Grassland	Terrestrial: Woodland and forest	Terrestrial: Heathland and shrub	Terrestrial: Wetlands	FW: Rivers and Lakes	Marine: Inlets and transitional waters	Marine: Coastal	Marine: Shelf	Marine: Open ocean	Potentially impacted SPU*
	EUNIS habitat code	**J**	**I**	**E**	**G**	**F**	**D**	**C1, C2**	**X01-03, A1-5, A7**	**A1-5, A7**	**A5, A7**	**A6, A7**	
Provisioning services	Food	green	green	green	green	green	yellow	yellow	red	red	yellow	green	Primary producers; Primary consumers; Secondary consumers; Decomposers
	Fibre and fuel	green	green	green	green	green	yellow	yellow	yellow	yellow	green	green	Primary producers
	Genetic resources	green	green	green	green	green	yellow	yellow	red	red	yellow	green	Primary producers; Primary consumers; Secondary consumers; Decomposers; Detritivores
	Biochemical / natural medicines	green	green	green	green	green	yellow	yellow	yellow	yellow	yellow	green	Primary producers; Primary consumers; Secondary consumers
	Ornamental resources	green	green	green	green	green	green	yellow	yellow	yellow	green	green	Primary producers; Primary consumers; Secondary consumers; Eco-engineers
	Fresh water	green	green	green	green	green	green	yellow	yellow	green	green	green	Primary producers; Primary consumers; Decomposers; Eco-engineers
Regulatory services	Pollination	green	green	green	green	green	yellow	green	yellow	yellow	green	green	Primary consumers
	Pest and disease regulation	green	green	green	green	green	yellow	green	yellow	yellow	yellow	green	Secondary consumers; Decomposers
	Climate regulation	green	green	green	green	green	yellow	green	yellow	yellow	yellow	green	Primary producers; Primary consumers
	Air quality regulation	green	green	green	green	green	yellow	green	yellow	yellow	yellow	green	Primary producers
	Water regulation	green	green	green	green	green	yellow	green	yellow	yellow	yellow	green	Primary producers; Eco-engineers
	Erosion regulation	green	green	green	green	green	yellow	green	yellow	yellow	green	green	Primary producers; Primary consumers
	Natural hazard regulation	green	green	green	green	green	yellow	green	red	red	yellow	green	Primary producers; Primary consumers; Eco-engineers
	Water purification / soil remediation / waste treatment	green	green	green	green	green	yellow	yellow	red	red	yellow	green	Primary producers; Decomposers
Cultural services	Spiritual and religious values	green	green	green	green	green	yellow	green	red	red	yellow	green	Primary producers; Secondary consumers
	Education and inspiration	green	green	green	green	green	yellow	green	red	red	yellow	green	Primary producers; Primary consumers; Secondary consumers; Eco-engineers; Decomposers; Detritivores
	Recreation and ecotourism	green	green	green	green	green	yellow	green	red	red	yellow	green	Primary producers; Primary consumers; Secondary consumers
	Cultural diversity and heritage	green	green	green	green	green	yellow	green	red	red	green	green	Primary producers; Primary consumers; Secondary consumers
	Aesthetic values	green	green	green	green	green	yellow	green	red	red	yellow	green	Primary producers
	Sense of place	green	green	green	green	green	yellow	green	red	red	yellow	green	Primary producers; Primary consumers; Secondary consumers; Eco-engineers
Supporting services	Primary production and photosynthesis	green	green	green	green	green	yellow	green	yellow	yellow	yellow	green	Primary producers
	Soil formation and retention	green	green	green	green	green	green	green	green	green	green	green	
	Nutrient cycling	green	green	green	green	green	yellow	yellow	yellow	yellow	yellow	green	Primary producers; Decomposers; Eco-engineers; Detritivores

*SPU key: Primary producers; Primary consumers; Secondary consumers; Decomposers; Eco-engineers; Detritivores

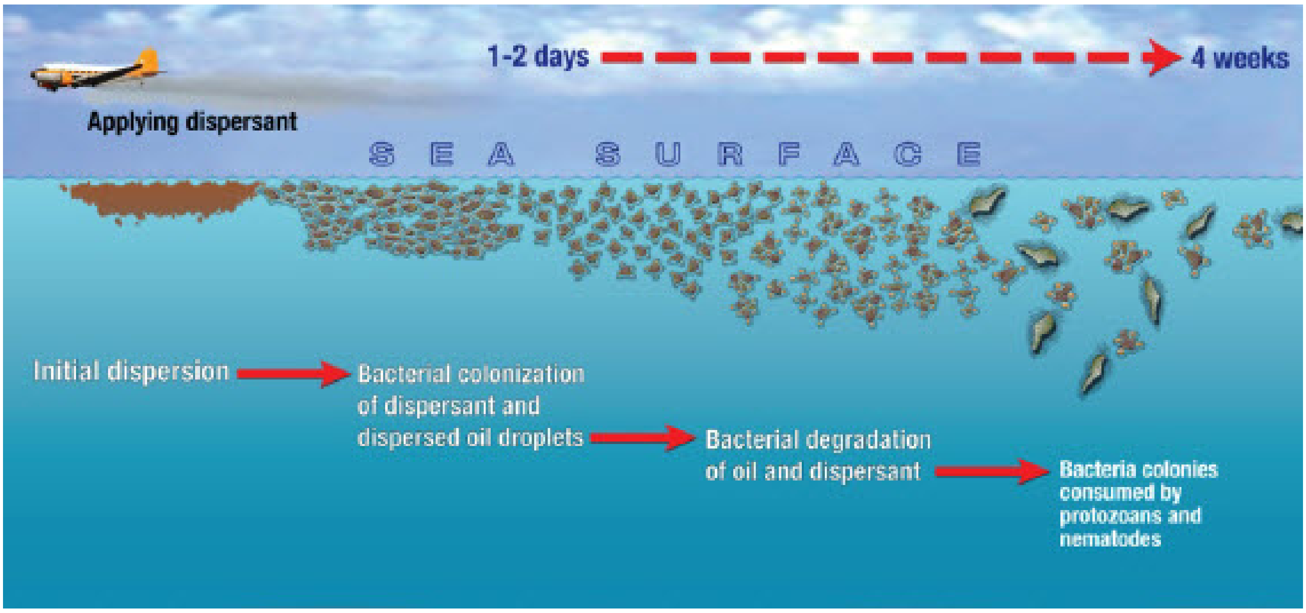
4.2 Case study 2: Oil dispersants

4.2.1 Rationale for level of impacts of dispersants in aquatic environments

Dispersants are primarily used in conjunction with an oil release into an aquatic environment and predominantly into a marine environment. Dispersants are usually applied to surface oil via spray (airplane, helicopter or boat). Based upon conditions and contact accuracy their use may result in either oil, oil and dispersant mixture, or dispersant only in the water. Under correct application, low concentrations of dispersant alone may be observed in the environment but these will only persist for a few minutes in the open environment. Measured low level concentrations and the transient nature of higher concentrations should be taken into consideration when comparing dispersant application with untreated oil in a net environmental benefit analysis.

Dispersants are a blend of several surfactants that reduce the oil-water interfacial tension and work by enhancing the natural dispersal of oil (which can occur naturally via wave action) into the water column as smaller particles with greater surface area. The increased surface area enables more rapid biodegradation by micro-organisms present in the water column.

Figure 4.2: Environmental exposure route for oil dispersants



For the purposes of this example, dispersants will be considered as a chemical application (dispersant that did not interact with oil when applied). Dispersants are primarily utilised at low levels in offshore water with minimal depth criteria (i.e. 300 meters), but may be used in near shore applications with appropriate approval. Dispersants rapidly dilute in the open ocean (<10 ppm in minutes) and like dispersed oil, may cause temporary impacts to sensitive marine species. These are limited to the immediate spill vicinity (upper layer of water column i.e. top 10 meters) and for a short period after dispersants are applied. These impacts are generally limited to non-motile organisms that have reproductive schemes that can readily recover from large losses.

This example will attempt to identify potential ecosystem services during dispersant use in a variety of water environments including off shore (open water), near shore (coastal) and the transition zones (inlets and rivers). This example does not explicitly condone nor dismiss the use of dispersants in shallow marine or freshwater, however for the purposes of identifying ecosystem services in these zones consistent with the other scenarios, an attempt will be made to capture potential ecosystem services that might be considered in an assessment.

4.2.2 Dispersant: rationale for colour coding in Table 4.2

- This evaluation focuses on the levels of exposure and probable impact of dispersants on ecosystem services. No consideration has been given to the beneficial effects of applying dispersants during an oil spill which would disperse the oil, enable more rapid biodegradation and limit potentially greater impacts to shorelines and organisms. These benefits should be considered in a Net Environmental Benefit Analysis.
- The impact on SPUs is proposed to be primarily driven by the overall level of exposure to the dispersant – considering concentration and short-term duration of exposure.
- Exposures are expected to be in the surface mixing zone of marine waters with potential exposure in estuarine waters.
- The exposure scenario consists of dispersant application in the water column separate from any interaction with spilt oil (i.e. off target dispersant spraying).

Table 4.2: Potential impact of dispersant use on specific ecosystem services (green: no impact; yellow: moderate impact; red: severe impact) and potentially impacted service-providing units (SPU)

Ecosystem service		Terrestrial						FW	Marine				Potentially impacted SPU*
		Urban	Cropland	Grassland	Woodland and forest	Heathland and shrub	Wetlands	Rivers and Lakes	Inlets and transitional waters	Coastal	Shelf	Open ocean	
EUNIS habitat code		J	I	E	G	F	D	C1, C2	X01-03, A1-5, A7	A1-5, A7	A5,A7	A6,A7	
Provisioning services	Food												
	Fibre and fuel												
	Genetic resources												
	Biochemical / natural medicines												
	Ornamental resources												
	Fresh water												
Regulatory services	Pollination												
	Pest and disease regulation												
	Climate regulation												
	Air quality regulation												
	Water regulation												
	Erosion regulation												
	Natural hazard regulation												
	Water purification / soil remediation / waste treatment												
Cultural services	Spiritual and religious values												
	Education and inspiration												
	Recreation and ecotourism												
	Cultural diversity and heritage												
	Aesthetic values												
	Sense of place												
Supporting services	Primary production and photosynthesis												
	Soil formation and retention												
	Nutrient cycling												

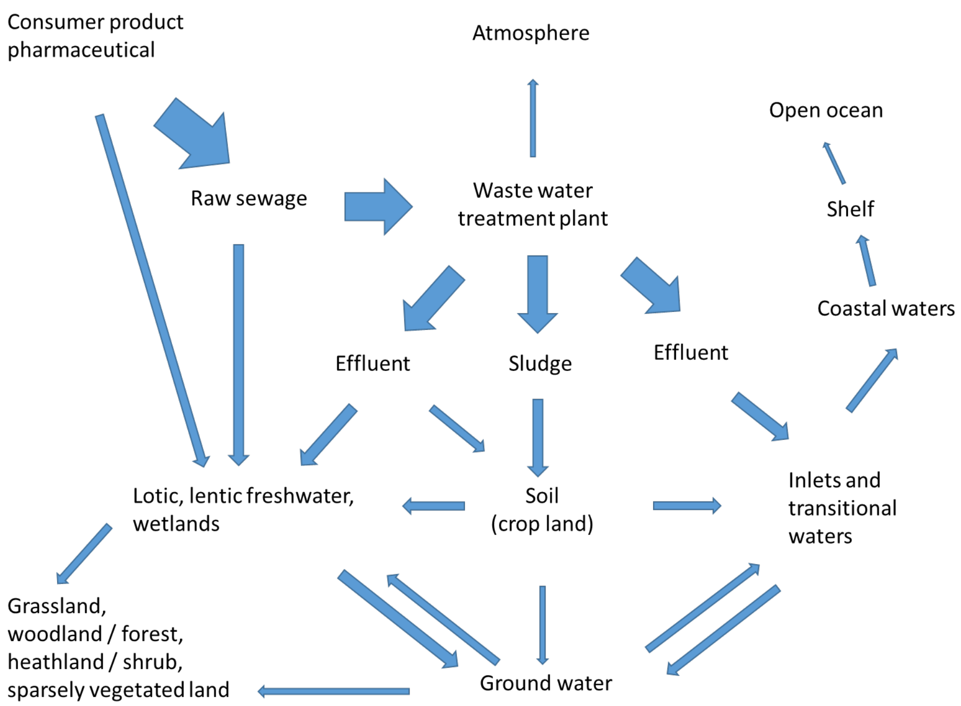
*SPU key: Primary producers; Primary consumers; Secondary consumers; Decomposers; Eco-engineers; Detritivores

4.3 Case study 3: Down the drain chemicals

4.3.1 Rationale for level of impacts of down the drain chemicals on habitats

Figure 4.3 indicates the key routes of environmental exposure to down the drain chemicals. By far the highest volumes of discharges result from end consumer use. In Europe most consumer emissions are into municipal sewerage systems which can lead to discharges of treated or untreated effluent into receiving waters or to soil as contaminants in aqueous sewage (as irrigation water) or sewage sludge (applied as fertiliser[1]). Therefore, habitats likely to experience highest exposures are those closest to the points of discharge, i.e. lotic freshwaters and transitional waters and cropland / grassland. Coastal waters can also be the primary receiving environment but, in general, may provide greater initial dilution of effluents than freshwater systems. Lentic systems are often by-passed to avoid discharging into slowly moving water but may be exposed via inflowing lotic water. As the distance from the point of discharge increases towards the open ocean, exposure is expected to rapidly reduce because of loss processes (biotic and abiotic degradation and partitioning to solids) and further dilution. Terrestrial habitats other than cropland / grassland are unlikely to receive direct applications of aqueous sewage and sludge, and so will only be exposed via indirect routes such as transport in ground water or irrigation water.

Figure 4.3: Emission routes of chemicals in consumer products and pharmaceuticals into the environment



[1] In this case study we focus on toxicants originating from dtdc and being dispersed with sewage sludge; it is assumed that dtdc do not significantly contribute to the nutrient content of sludge.

The chemicals present in consumer products and pharmaceuticals represent a wide range of chemistry in terms of physico-chemical properties and mode of toxic action. A proportion of the thousands of chemicals included in these categories are considered to have a non-specific mode of action and therefore, have potential to impact a wide range of SPUs. Others may be specific physiological targets and/or have higher potency for specific taxonomic groups, e.g. antimicrobial compounds, synthetic oestrogens, etc. However, for many chemicals the breadth of potentially affected species means that the lists of potentially impacted SPU will tend to be a comprehensive listing for each ecosystem service that they deliver.

Table 4.3: Potential impact of down the drain chemicals on specific ecosystem services (green: no impact; yellow: moderate impact; red: severe impact) and potentially impacted service-providing units (SPU)

	Ecosystem service	Terrestrial						Freshwater		Marine				Potentially impacted SPU*
		Urban	Cropland	Grassland	Woodland and forest	Heathland and shrub	Wetlands	Lentic (ponds and lakes)	Lotic (streams and rivers)	Inlets and transitional waters	Coastal	Shelf	Open ocean	
	EUNIS habitat code	**J**	**I**	**E**	**G**	**F**	**D**	**C1**	**C2**	**X01-03, A1-5, A7**	**A1-5, A7**	**A5, A7**	**A6, A7**	
Provisioning services	Food	green	red	red	green	green	yellow	red	red	red	red	yellow	green	Primary producers; Primary consumers; Secondary consumers; Decomposers
	Fibre and fuel	green	yellow	yellow	green	green	yellow	yellow	yellow	yellow	yellow	green	green	Primary producers
	Genetic resources	green	red	red	green	green	yellow	red	red	red	red	yellow	green	Primary producers; Primary consumers; Secondary consumers; Decomposers; Detritivores
	Biochemical / natural medicines	green	red	red	green	green	yellow	red	red	red	red	yellow	green	Primary producers; Primary consumers; Secondary consumers
	Ornamental resources	green	yellow	yellow	green	green	green	red	red	red	red	green	green	Primary producers; Primary consumers; Secondary consumers; Detritivores
	Fresh water	green	yellow	yellow	green	green	yellow	red	red	yellow	yellow	green	green	Primary producers; Primary consumers; Decomposers; Eco-engineers
Regulatory services	Pollination	green	yellow	yellow	green	green	yellow	green	green	green	green	green	green	Primary consumers
	Pest and disease regulation	green	red	red	green	green	yellow	red	red	red	red	green	green	Secondary consumers; Decomposers
	Climate regulation	green	yellow	yellow	green	green	yellow	red	red	red	yellow	yellow	green	Primary producers; Primary consumers
	Air quality regulation	green	yellow	yellow	green	green	yellow	yellow	yellow	yellow	yellow	green	green	Primary producers
	Water regulation	green	yellow	yellow	green	green	yellow	yellow	yellow	yellow	yellow	yellow	green	Primary producers; Eco-engineers
	Erosion regulation	green	yellow	yellow	green	green	yellow	yellow	yellow	yellow	yellow	green	green	Primary producers; Primary consumers
	Natural hazard regulation	green	yellow	yellow	green	green	yellow	yellow	yellow	yellow	yellow	yellow	green	Primary producers; Primary consumers; Eco-engineers
	Water purification / soil remediation / waste treatment	green	yellow	yellow	green	green	yellow	red	red	red	yellow	yellow	green	Primary producers; Decomposers
Cultural services	Spiritual and religious values	green	yellow	yellow	green	green	yellow	yellow	yellow	yellow	yellow	green	green	Primary producers; Secondary consumers
	Education and inspiration	green	yellow	yellow	green	green	yellow	red	red	red	yellow	green	green	Primary producers; Primary consumers; Secondary consumers; Eco-engineers; Decomposers; Detritivores
	Recreation and ecotourism	green	yellow	yellow	green	green	yellow	red	red	red	yellow	yellow	green	Primary producers; Primary consumers; Secondary consumers
	Cultural diversity and heritage	green	yellow	yellow	green	green	yellow	yellow	yellow	yellow	yellow	yellow	green	Primary producers; Secondary consumers; Primary consumers
	Aesthetic values	green	yellow	yellow	green	green	yellow	yellow	yellow	yellow	yellow	yellow	green	Primary producers
	Sense of place	green	yellow	yellow	green	green	yellow	yellow	yellow	yellow	yellow	yellow	green	Primary producers; Secondary consumers; Eco-engineers; Primary consumers
Supporting services	Primary production and photosynthesis	green	red	red	green	green	yellow	red	red	red	red	yellow	green	Primary producers
	Soil formation and retention	green	red	red	green	green	yellow	yellow	yellow	yellow	yellow	green	green	Primary producers; Eco-engineers; Decomposers
	Nutrient cycling	green	red	red	green	green	yellow	red	red	red	red	yellow	green	Primary producers; Decomposers; Eco-engineers; Detritivores

*SPU key: Primary producers; Primary consumers; Secondary consumers; Decomposers; Eco-engineers; Detritivores

4.4 Case study 4: Persistent organic pollutants (POP)

This study is based on the release of a POP-type chemical predicted to undergo long-range transport from undefined emission sources. POPs can be present in gaseous form in the atmosphere or bound to the surface of solid particles. Contamination of remote areas such as the Arctic environment can be via atmospheric, oceanic current and/or freshwater transport. POPs can undergo several cycles of transport, deposition and re-volatilisation. These processes are often strongly influenced by temperature.

The chemical is assumed to have generic characteristics, i.e. low abiotic and biotic degradation / transformation rates, a high vapour pressure and high hydrophobicity (potential to bioaccumulate). This allows for bioaccumulation in fatty tissues of living organisms and slow metabolism, which confers the compound's persistence and accumulation in food chains.

In the last 30 years international regulations (see Chapter 3) and voluntary phase-outs have significantly reduced exposure. Nevertheless new POP like substances are regularly developed which could cause new pressures on ecosystem services in Arctic regions (Vorkamp and Riget, 2014).

4.4.1 Exposure assessment

Assessment of historical emissions is outside the scope of this case study and the chemical is assumed not to be locally produced in Arctic regions. The chemical is expected to have low but ubiquitous concentrations in all Arctic habitats (see Figure 4.4). It is possible that larger dilution factors in the open ocean might result in lower concentrations than those found in coastal habitats. However, such differences are small and are not considered likely to affect the major concern associated with accumulation of POPs through food webs. Although lotic and lentic freshwater habitats have been considered separately in this case study, both habitat types could have been combined into a generic freshwater habitat since the potential for exposure and food chain accumulation is likely to apply to both. Differences in exposure concentrations would be addressed in any risk assessment of the POP chemical in prioritised SPUs.

The chemical would be expected to be detected in most habitats around the globe but notably in Arctic regions due to global fate and transport processes such as atmospheric advection and polar condensation. In this study the assessment of exposure is restricted to the Arctic environment. Local transport processes could also be important, e.g. terrestrial to aquatic systems.

Figure 4.4: Emissions of a POP-like chemical to Arctic regions

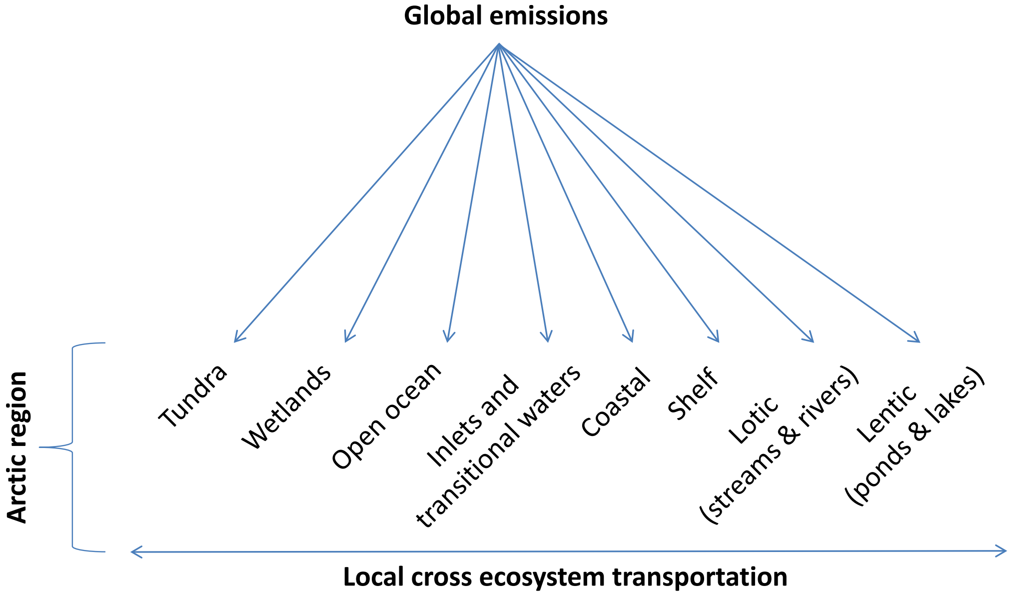


Table 4.4: Potential impact of Persistent Organic Pollutant (POP) on specific ecosystem services (green: no impact; yellow: moderate impact; red: severe impact) and potentially impacted service-providing units (SPU)

	Ecosystem service	**Arctic Terrestrial**			**Arctic Freshwater**		**Arctic Marine**				**Potentially impacted SPU***
		Urban	**Shrubs, heathland and tundra**	**Wetlands**	**Lentic (ponds and lakes)**	**Lotic (streams and rivers)**	**Inlets and transitional waters**	**Coastal**	**Shelf**	**Open ocean**	
	EUNIS habitat code	**J**	**B, H**	**D**	**C1**	**C2**	**X01-03, A1-5, A7**	**A1-5, A7**	**A5, A7**	**A6, A7**	
Provisioning services	Food	green	red	yellow	yellow	yellow	red	red	red	red	Primary consumers; Secondary consumers
	Fibre and fuel	green	green	green	green	green	green	green	green	green	
	Genetic resources	green	green	green	green	green	green	green	green	green	
	Biochemical / natural medicines	green	green	green	green	green	green	green	green	green	
	Ornamental resources	green	green	green	green	green	green	green	green	green	
	Fresh water	green	green	green	green	green	green	green	green	green	
	Pollination	green	green	green	green	green	green	green	green	green	
	Pest and disease regulation	green	green	green	green	green	green	green	green	green	
	Climate regulation	green	green	green	green	green	green	green	green	green	
	Air quality regulation	green	green	green	green	green	green	green	green	green	
	Water regulation	green	green	green	green	green	green	green	green	green	
	Erosion regulation	green	green	green	green	green	green	green	green	green	
	Natural hazard regulation	green	green	green	green	green	green	green	green	green	
	Water purification / soil remediation / waste treatment	green	green	green	green	green	green	green	green	green	
Cultural services	Spiritual and religious values	green	green	green	yellow	yellow	yellow	yellow	yellow	yellow	Primary consumers; Secondary consumers
	Education and inspiration	green	green	green	yellow	yellow	yellow	yellow	yellow	yellow	Primary producers; Primary consumers; Secondary consumers; Eco-engineers
	Recreation and ecotourism	green	green	green	yellow	yellow	yellow	yellow	yellow	yellow	Primary consumers; Secondary consumers
	Cultural diversity and heritage	green	green	green	yellow	yellow	yellow	yellow	yellow	yellow	Secondary consumers; Primary consumers
	Aesthetic values	green	green	green	green	green	green	green	green	green	
	Sense of place	green	green	green	green	green	green	green	green	green	
	Primary production and photosynthesis	green	green	green	green	green	green	green	green	green	
	Soil formation and retention	green	green	green	green	green	green	green	green	green	
	Nutrient cycling	green	green	green	green	green	green	green	green	green	

*SPU key: Primary producers; Primary consumers; Secondary consumers; Decomposers; Eco-engineers; Detritivores

5. CASE STUDIES: STEP 4

The tables presented in this chapter were derived by combining the importance rankings of all habitat x ecosystem service combinations relevant for a certain case study with the rankings of potential impacts. The underlying tables are provided in Section 2.3 (importance rankings, same for all case studies) and Chapter 4 (impact tables, differing between case studies), respectively. The importance x impact matrix shown in Section 2.5 has been applied to identify habitat x ecosystem service combinations with different levels of concern. Only those combinations for which medium or high concern has been found were addressed in more detail. Giving priority to the most critical areas was considered a reasonable approach. No SPU examples are given in the last column if, for all habitat types of a certain ecosystem services, only low or negligible concern was obtained. If medium or high concern has been revealed, SPUs involved in delivery of the critical ecosystem services were assigned.

A master table is presented at the end of the chapter (Section 5.5) which integrates maximum concerns derived from the four case studies.

5.1 Case study 1: Oil refinery – discharge into estuarine environments

In the oil refinery case study, high concern has been revealed particularly for inlets and transitional waters (Table 5.1). This finding can be explained by the importance of this habitat type for the provision of certain ecosystem services (e.g. natural hazard regulation, recreation and ecotourism) and its potentially close proximity to the point of discharge. Oil refineries are often located on estuaries (see Section 4.1.1) and are thus in direct contact with transitional waters, which potentially leads to high levels of exposure. Medium concern has been found for a number of habitat x ecosystem service combinations. Increased concern became less frequent in habitats at larger distance from the source, i.e. shelf and particularly in the open ocean.

Table 5.1: Oil refinery – ecosystem services of concern with examples of SPUs involved in the delivery of potentially threatened services. Black: high concern; dark grey: medium concern; light grey: low concern; white: negligible concern

Ecosystem service	**Wetlands**	**Rivers and lakes**	**Inlets and transitional waters**	**Coastal**	**Shelf**	**Open ocean**	**SPUs** Decomposers (Dc) Detritivores (Dt) Eco-engineers (Ee) Primary producers (PP) Primary consumers (PC) Secondary consumers (SC)
	1	**2**	**3**	**4**	**5**	**6**	**Superscripts indicate habitat locations of SPUs**
Food							PP = seaweed[3,4]; PC = fish and shellfish[3,4]; SC = wild game (birds mainly) and fish[3,4]
Fibre and fuel							
Genetic resources							All SPUs incl. PP = terrestrial and aquatic plants[1-5] (incl. algae); PC and SC = terrestrial[1] and aquatic[2-5] animals
Biochemical / natural medicines							PP = aquatic plants[3]; PC = sponges, leeches, snails[3]; SC = venomous animals[3]
Ornamental resources							
Fresh water							
Pollination							
Pest and disease regulation							
Climate regulation							PP = terrestrial[1] and aquatic plants[4,5] (incl. algae); PC = carbon / carbonate sequestering shellfish and corals[4,5]
Air quality regulation							PP = algae and aquatic plants[4-5]
Water regulation							Ee = dam builders e.g. beavers[2]; reef building corals and tubeworms[3]; PP = terrestrial and aquatic[1-3] plants (submerged, emergent and marginal vegetation)
Erosion regulation							
Natural hazard regulation							PP = aquatic plants[3,4] (marginal vegetation, pioneer and mature saltmarsh); Ee = reef building corals and tubeworms[3,4]; PC = mussel beds[3,4]
Water purification / soil remediation / waste treatment							Dc = fungi[1], bacteria[1-4]; PP = filtering terrestrial and aquatic[1-4] plants e.g. reeds, oxygenating aquatic plants
Spiritual and religious values							PC and SC = conspicuous aquatic vertebrates[3], e.g. seals, porpoise

Ecosystem service	**Wetlands**	**Rivers and lakes**	**Inlets and transitional waters**	**Coastal**	**Shelf**	**Open ocean**	**SPUs**	Decomposers (Dc)	Detritivores (Dt)	Eco-engineers (Ee)	Primary producers (PP)	Primary consumers (PC)	Secondary consumers (SC)
	1	**2**	**3**	**4**	**5**	**6**	**Superscripts indicate habitat locations of SPUs**						
Education and inspiration							Ee = dam builders[3] e.g. beavers; reef building corals[4]; PP = terrestrial[1] and aquatic[3,4] plants (submerged, emergent and marginal vegetation); PC and SC = terrestrial[1] and aquatic[3,4] animals						
Recreation and ecotourism							Ee = reef building corals[4]; PP = terrestrial and aquatic[1-4] plants in general; PC = aquatic invertebrates, fish[2-4]; SC = fish, birds[1-4]						
Cultural diversity and heritage							Ee = reef building corals[4]; SC = fish, birds[3,4]						
Aesthetic values							Ee = reef building corals[4]; PP = terrestrial and aquatic plants[1-4]; PC = aquatic invertebrates for pond netting[1-3], aquatic vertebrates e.g. coarse fish[2-4]; SC = coarse fish[2-4]						
Sense of place							PP = fragrant terrestrial and aquatic plants[1-4]; PC and SC = audible animals[1-4] invertebrates e.g. crickets and vertebrates e.g. birds, whales						
Primary production							PP = terrestrial[1] and aquatic[3,4] plants and cyanobacteria						
Soil formation and retention													
Nutrient cycling							Dc = aquatic fungi and bacteria[3]; Dt = aquatic detritivores[3], asellids, gammarids etc.; PP = terrestrial[1] and aquatic[3] plants						

5.2 Case study 2: Oil dispersants

The oil dispersant case study indicated high concern particularly for inlets, transitional waters and for coastal habitats (Table 5.2). This finding can be explained by the importance of these habitat types for the provision of certain ES (e.g. genetic resources, recreation and ecotourism) and the potentially short distance to the point of discharge. Oil dispersants may be applied to water environments like coastal and transitional (Section 4.2.1); thus a high level of potential exposure can be assumed. Overall, increased concern (medium + high) has been found for less habitat x ecosystem service combinations than in other case studies (e.g. oil refinery or down the drain chemicals). This is linked with the comparably lower impact of these types of chemicals on the considered ecosystem services and SPUs which provide them, respectively (cf. Table 4.2, Section 4.2). The potentially lower impact (Section 4.2.1) may be due to the limited temporal and spatial occurrence of oil dispersants in (mainly marine) water bodies.

Table 5.2: Oil dispersants – ecosystem services of concern with examples of SPUs involved in the delivery of potentially threatened services. Black: high concern; dark grey: medium concern; light grey: low concern; white: negligible concern

Ecosystem service	**Wetlands**	**Rivers and lakes**	**Inlets and transitional waters**	**Coastal**	**Shelf**	**Open ocean**	**SPUs**	Decomposers (Dc)	Detritivores (Dt)	Eco-engineers (Ee)	Primary producers (PP)	Primary consumers (PC)	Secondary consumers (SC)
	1	**2**	**3**	**4**	**5**	**6**	**Superscripts indicate habitat locations of SPUs**						
Food							PP = aquatic plants[3-5]; PC = shellfish and fish[3-6]; SC = fish[3-6]; Ee = shellfish[3-5]						
Fibre and fuel													
Genetic resources							All SPUs: Dc = aquatic bacteria[2-6]; Dt = aquatic dentivores[2-6]; Ee = reef building corals[3-5], benthic worms[2-4]; PP = aquatic plants, diatoms, plankton[2-6]; PC and SC = aquatic organisms[2-6]						
Biochemical / natural medicines													
Ornamental resources							PP = aquatic plants[3-5]; PC and SC = shell fish[3-5]; Ee = corals[3-5]						
Fresh water							Ee = soil and sediment builders[2]; Dc = aquatic bacteria[2]; PP = aquatic macrophytes, algae[2]; PC = mollusc[2]						
Pollination													
Pest and disease regulation													
Climate regulation							PP = aquatic plants[4]; PC = carbon seq. shellfish, corals[4]						
Air quality regulation													
Water regulation													
Erosion regulation													
Natural hazard regulation							Ee = reef building corals[3,4]; PP = coastal vegetation[3,4]; PC = mussel beds[3,4]						
Water purification / soil remediation / waste treatment													
Spiritual and religious values							Ee = reef building corals[3]; PC and SC = mollusc (i.e. shells), large vertebrates (i.e. seals, whales)[3]						
Education and inspiration							ALL SPUs						
Recreation and ecotourism							Ee = reef building corals[3,4]; PP = sea grass beds[3,4]; PC and SC = crustaceans, mollusc, fish and larger aquatic vertebrates, birds[3,4]						

Ecosystem service	**Wetlands**	**Rivers and lakes**	**Inlets and transitional waters**	**Coastal**	**Shelf**	**Open ocean**	**SPUs**	Decomposers (Dc)	Detritivores (Dt)	Eco-engineers (Ee)	Primary producers (PP)	Primary consumers (PC)	Secondary consumers (SC)
	1	**2**	**3**	**4**	**5**	**6**	**Superscripts indicate habitat locations of SPUs**						
Cultural diversity and heritage													
Aesthetic values							Ee = reef building corals[3]; PP = coastal vegetation[3]; PC and SC = fish, larger aquatic vertebrates, birds[3]						
Sense of place							Ee = reef building corals (waves crashing)[3]; PP = coastal vegetation and shoreline[3]; PC and SC = bird and animal sites and sounds (i.e. sea gulls, loons, dolphins)[3]						
Primary production							PP = aquatic micro and macrophytes, coastal plants[3,4]						
Soil formation and retention													
Nutrient cycling													

5.3 Case study 3: Down the drain chemicals

With down the drain chemicals, high concern has been revealed particularly for freshwater habitats (rivers and lakes) and for transitional waters (Table 5.3). High concern has also been detected for several cropland – ecosystem service combinations. These findings can be explained by the importance of those habitats for the provision of certain ecosystem services (e.g. cropland – food; rivers – freshwater) and their potentially short distance from the point of discharge, leading to a high level of exposure. Medium concern has been found for a number of habitat x ecosystem service combinations. It is only in habitats at longer distances from the source (i.e. shelf) and overall lower importance for the delivery of an ecosystem service that increased concern became less frequent. Combinations of medium or high concern were found for all (four) categories of ecosystem services without any clear focus on one of those groups.

Within a certain ecosystem service, medium or high concern has often been found for various habitats (e.g. genetic resources in terrestrial, freshwater and marine habitats). As a consequence, the number and diversity of involved SPU is usually high. For some ecosystem services in this case study, only negligible or low concern has been found over all considered habitats. On one hand this can be explained by the 'robustness' of the SPUs providing a certain service; on the other hand, the expected level of exposure has to be taken into account. To give an example, terrestrial plants are involved in erosion regulation in crop- and grassland habitats. However, the potential impact of sewage sludge or sewage for irrigation is not considered to be strong enough to significantly impair this service, i.e. the plant cover will most probably not be destroyed.

Table 5.3: Down the drain chemicals – ecosystem services of concern with examples of SPUs involved in the delivery of potentially threatened services.
Black: high concern; dark grey: medium concern; light grey: low concern; white: negligible concern

Ecosystem service	**Cropland**	**Grassland**	**Wetlands**	**Rivers and lakes**	**Inlets and transitional waters**	**Coastal**	**Shelf**	**SPUs** Decomposers (Dc) Detritivores (Dt) Eco-engineers (Ee) Primary producers (PP) Primary consumers (PC) Secondary consumers (SC)
	1	**2**	**3**	**4**	**5**	**6**	**7**	**Superscripts indicate habitat locations of SPUs**
Food								Dc = mushrooms[1,2]; PP = terrestrial plants[1,2] e.g. cereals, veg, fruit; PC = terrestrial grazing livestock[2], wild game[2], shellfish and fish[4-6]; SC = wild game[2] and fish[4-6]
Fibre and fuel								PP = crop plants[1] e.g. cereals, oil seed rape, sunflower
Genetic resources								All SPUs incl. PP = terrestrial[1-3] and aquatic[4-7] plants (incl. algae); PC and SC = terrestrial[2,3] and aquatic[4-7] animals
Biochemical / natural medicines								PP = medicinal plants[1]; PC = leeches[4], sponges[5], snails[1,4,5]; SC = venomous animals[4,5] (for neurological treatments)
Ornamental resources								
Fresh water								Ee = soil and sediment bioturbators[3,4] e.g. annelid worms; Dc = aquatic bacteria, cyanobacteria, fungi[3,4]; PP = aquatic macrophytes, reeds, algae[3,4]; PC = filter feeders, sponges, molluscs[3,4]
Pollination								PC = insects, bees[1,2]
Pest and disease regulation								Dc = saprophytic fungi[1]; SC = beneficial predatory insects[1] e.g. ladybirds, lacewings; predatory fish[4] e.g. mosquito fish; scavenging terrestrial and aquatic animals[1,4]
Climate regulation								PP = terrestrial and aquatic plants[1,3-6]; PC = carbon / carbonate sequestering shellfish and corals[4-7]
Air quality regulation								PP[6] = marine micro- and macro-algae
Water regulation								Ee = dam builders[3,4] e.g. beavers; reef building corals and tubeworms[5]; PP = aquatic plants – submerged, emergent and marginal vegetation[3-5]
Erosion regulation								
Natural hazard regulation								Ee = reef building corals and tubeworms[5,6]; PP = marginal vegetation, pioneer and mature saltmarsh[5,6]; PC = mussel beds[5,6] – stabilising banks for wave / flood protection
Water purification / soil remediation / waste treatment								Dc = fungi[1-4]; PP = soil cleansing terrestrial plants[1-3] e.g. sunflowers; filtering aquatic plants[4,5] e.g. reeds, oxygenating aquatic plants

Ecosystem service	**Cropland**	**Grassland**	**Wetlands**	**Rivers and lakes**	**Inlets and transitional waters**	**Coastal**	**Shelf**	**SPUs** Decomposers (Dc) Detritivores (Dt) Eco-engineers (Ee) Primary producers (PP) Primary consumers (PC) Secondary consumers (SC)
	1	**2**	**3**	**4**	**5**	**6**	**7**	**Superscripts indicate habitat locations of SPUs**
Spiritual and religious values								PC and SC = conspicuous aquatic vertebrates[5], e.g. seals, porpoise
Education and inspiration								Ee = dam builders[3,4] e.g. beavers; reef building corals[5]; PP = aquatic plants[3-5] – submerged, emergent and marginal vegetation; PC and SC = terrestrial and aquatic animals[3-5]
Recreation and ecotourism								PP = terrestrial and aquatic plants in general[2-6]; PC = aquatic invertebrates for pond netting[3-5]; aquatic vertebrates[3-7] e.g. coarse fish; SC = coarse fish
Cultural diversity and heritage								
Aesthetic values								PP = terrestrial and aquatic plants with visual appeal in the landscape and watershed[1-5]
Sense of place								PP = fragrant terrestrial and aquatic plants[1-5]; PC and SC = audible animals[1-5] invertebrates e.g. crickets; and vertebrates e.g. birds, whales
Primary production								PP = terrestrial and aquatic plants and cyanobacteria[1-6]
Soil formation and retention								Ee = bioturbating terrestrial invertebrates[1,2] e.g. annelid worms; Dt = terrestrial detritivores[1,2] e.g. woodlouse; PP = terrestrial plants[1,2]
Nutrient cycling								ALL SPUs, particularly Dc = terrestrial and aquatic fungi and bacteria[1-5]; Dt = terrestrial and aquatic detritivores[1-5] e.g. woodlouse, water hoglouse, gammarids etc.; PP = terrestrial and aquatic plants[1-5]

5.4 Case study 4: Persistent organic pollutants

In the POP case study, none of the habitats taken into account (Table 5.4) were identified as being of high concern; indeed medium concern was determined only for a low number of habitat x ecosystem service combinations. This can be explained by the assumed low impact of POP-type chemicals on most ecosystem services due to the expected low concentrations in pristine areas (cf. Table 4.4, Section 4.4). When severe impact on a certain ecosystem service was assumed (e.g. in the case of food provision), this resulted in only medium concern because the respective habitats were considered to be of no more than intermediate importance for delivery of this service.

Table 5.4: Persistent organic pollutants – ecosystem services of concern with examples of SPUs involved in the delivery of potentially threatened services. Dark grey: medium concern; light grey: low concern; white: negligible concern

Ecosystem service	**Urban**	**Heathland and shrub**	**Wetlands**	**Rivers and lakes**	**Inlets and transitional waters**	**Coastal**	**Shelf**	**Open ocean**	**SPUs**	Decomposers (Dc)	Detritivores (Dt)	Eco-engineers (Ee)	Primary producers (PP)	Primary consumers (PC)	Secondary consumers (SC)
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Superscripts indicate habitat locations of SPUs**						
Food									PC and SC = aquatic vertebrates like fish, seals and whales[5-8]; polar bears[2], birds[2,5,6]						
Fibre and fuel															
Genetic resources															
Biochemical / natural medicines															
Ornamental resources															
Fresh water															
Spiritual and religious values									SC = aquatic vertebrates, e.g. seals or whales[5]						
Education and inspiration									SC = terrestrial and aquatic vertebrates like birds[3,5] and seals[5]						
Recreation and ecotourism									PC and SC = aquatic vertebrates like seals and whales[4-6]; polar bears[2], birds[2-6]						
Cultural diversity and heritage															
Aesthetic values															
Sense of place															

5.5 Master Table: integration of maximum concerns from the four case studies

A master version of the case study Tables 5.1 to 5.4 was made by taking the highest level of concern for each habitat x ES cell. From the habitats perspective, the pattern in Table 5.5 shows that high concern was particularly apparent for habitats in the transition between freshwater and marine. This result is clearly driven by the selection of the case studies and the related proximity to the sources of pollution, combined with the 'sensitivity' of some services and the organisms which provide them. In contrast, in more remote habitats (e.g. shelf, open ocean), high concern regarding the delivery of different ecosystem services is the exception.

The integration of the different case studies produced high concern combinations in all (four) ecosystem services categories with no clear focus on any one category. The highest frequency of concern across habitats was found for the services 'genetic resources' and 'recreation and ecotourism', which are not habitat specific and are generally perceived to be particularly susceptible to negative impacts by chemicals. In this context it should be noted that the ecosystem service 'genetic resources' is treated inconsistently by different authorities. While the definition of this ecosystem service used in this report is rather strict with a clear focus on genetic information suitable for animal and plant breeding and biotechnology (cf. Millennium Ecosystem Assessment, 2005b), the term is sometimes used synonymously with biodiversity. As a consequence, all species would be considered to be potentially important sources of genetic information. This leads to the numerous habitats in which this ecosystem service is considered to be of high importance and to the relatively large number of high concern combinations (see Table 2.3 in Chapter 2). In 2015, EFSA published guidance to define protection goals for environmental risk assessment in relation to biodiversity and ecosystem services (EFSA 2015). This guidance outlines the relationship between biodiversity and ecosystem services and helps rectify the consideration of genetic resources in defining protection goals.

The provisioning service 'food' is also assumed to be sensitive to chemical pollutants; however, the prevailing medium concern in this example can be explained by the lower importance of exposed habitats in delivering this service (cf. Table 2.3, Chapter 2).

Table 5.5: Summary of potential concerns, obtained by integrating all case studies. Black: high concern; dark grey: medium concern; light grey: low concern; white: negligible concern

Ecosystem service	**Urban**	**Cropland**	**Grassland**	**Heathland and shrub**	**Wetlands**	**Rivers and lakes**	**Inlets and transitional waters**	**Coastal**	**Shelf**	**Open ocean**
Food										
Fibre and fuel										
Genetic resources										
Biochemical / natural medicines										
Ornamental resources										
Fresh water										
Pollination										
Pest and disease regulation										
Climate regulation										
Air quality regulation										
Water regulation										
Erosion regulation										
Natural hazard regulation										
Water purification / soil remediation / waste treatment										
Spiritual and religious values										
Education and inspiration										
Recreation and ecotourism										
Cultural diversity and heritage										
Aesthetic values										
Sense of place										
Primary production										
Soil formation and retention										
Nutrient cycling										

6. CASE STUDIES: STEP 5 DERIVING SPECIFIC PROTECTION GOALS

In this section, the derivation and description of SPGs for selected ecosystem services is presented based on the combined outcome for case studies in step 4 (Table 5.5). The ecosystem services selected to illustrate the approach represent those considered to be of potentially high concern (relatively more habitat x ecosystem service cells prioritised as high or medium concern of chemical impact) and include food provisioning, genetic resources, natural hazard regulation, water purification / soil remediation / waste treatment, recreation and ecotourism and nutrient cycling.

The order of the columns in Table 6 was changed from the original table proposed by EFSA (2010), in order to describe chronologically the derivation of SPGs for SPUs, prioritised in previous steps for each chemical case study (Section 4). Nevertheless SPGs are ultimately framed in five dimensions according to EFSA's guidance: ecological entity (individuals, (meta)populations, functional groups); attributes (process / behaviour, abundance / biomass); magnitude of impact; temporal and spatial scale of impact. The degree of certainty that the specified level of impact will not be exceeded was not addressed. The final column 'legal requirement' in Table 6 provides a reference against which the SPGs derived by using the EFSA framework can be checked. NB the listed legal requirements relate to the SPUs specified in each row.

The Task Force concluded that more ecological knowledge is required to define the maximum magnitude of impact that would still enable the sustainable delivery of an ecosystem service by an SPU. There is a need to define acceptable / sustainable levels of impact more explicitly than currently defined in EFSA's guidance (EFSA, 2010) and in environmental regulations (Section 3). There is some existing guidance for defining spatio-temporal scales of impact, for example in EFSA's aquatic ERA guidance document (EFSA, 2013). EFSA adopts two approaches: 'ecological threshold option' and the 'ecological recovery option'. The ecological threshold option focuses on the identifying the maximum tolerable impact on the entity/attribute of concern in order to protect the ecosystem service of interest. The scientific challenge here is to have sufficient knowledge to be able to link ecological changes to changes in ecosystem service delivery (i.e. ecological production functions) and to identify thresholds of ecological change at which ecosystem service delivery is affected. Given the uncertainties associated with identifying thresholds, a precautionary approach is to assume that 'maximum tolerable impact' is 'no/negligible impact'.

The recovery option considers some impacts at limited spatial and temporal scales to be acceptable assuming that full recovery occurs. The scientific challenge here, in addition to establishing ecological production functions, is understanding recovery processes within a landscape context and the spatio-temporal dynamics of ecosystem service delivery.

In addition, there are the risk managers to consider, who may, for non-scientific reasons, find certain risks acceptable or not acceptable. Examples here may be the focus on the individual-level for vertebrates and the more stringent controls on effects for GMOs.

The Task Force considered that the magnitude of an acceptable impact will differ between SPUs and would depend upon factors such as natural variation or fluctuations, which could be determined from retrospective analysis of control or reference data. The Task Force also suggested higher magnitudes of effect might be tolerable / sustainable for shorter periods and/or smaller areas of exposure according to the principle that all three dimensions of impact scale are inter-linked (EFSA, 2010; EFSA, 2013), but their relation to real world tolerance has yet to be proven.

As stated above, the magnitude and scale of acceptable impacts need to be defined by risk managers based on underpinning science, together with other considerations. One important consideration being that an acceptable impact needs to be measurable, to ensure protection goals are met. For illustrative purposes, an example of how this might be done is given in Table 6.1 and followed throughout Tables 6.2 – 6.7. The spatial scales of impact used are considered suitable for application at three different scales: i) local impacts within 0.1 km of the source / site of exposure, e.g. field margins, edge of field ditches, shore line, river mixing zones; ii) landscape impacts up to 1 km e.g. agricultural, urban or natural and iii) regional scale impacts ranging over distances exceeding 1 km. A linear measure is applied for each SPU/habitat combination which can represent a measure of length, e.g. in the case of flowing water bodies, or of area (as a measure of the radius from the central point of exposure), e.g. for static water bodies and terrestrial habitats. In both cases these metrics are intended to be indicative of scale and require case by case evaluation when used in the derivation of specific protection goals.

The following definitions of 'sustainable' levels of impact are based on the premise that effects would be unsustainable if any one of the three dimensions of effect are exceeded. As stated above these proposals are for illustrative purposes only. They are offered as a means of stimulating debate that requires both scientific underpinning and risk manager involvement to agree actual definitions.

Table 6.1: Potential definitions of sustainable (acceptable) impacts

	Magnitude of impact	Spatial scale of impact*	Temporal scale of impact
Chronic effect (small)	10% reduction in SPU (population abundance or function etc.)	Landscape (>10 km)	Months (<12 months)
Chronic effect (medium)	25% reduction in SPU (population abundance or function etc.)	Local to landscape (1 km to 10 km)	Weeks (<4 weeks)
Acute effect (large)	50% reduction in SPU (population abundance or function etc.)	Point of emission to local (<1 km)	Days (<1 week)

* Some level of impact may be sustainable beyond the conventionally accepted mixing zone i.e. >100 m depending on magnitude and duration of impact and also functional redundancy amongst SPUs.

Rules of thumb for designating <u>spatial scale</u> of impact:

- If legal requirement includes EC Regulation 1107/2009 – consider field to edge of field (at least initially).
- If legal requirement includes Habitats Directive – consider specific 'interest feature' protected under the Directive.
- If legal requirement includes WFD – consider water body level.
- If ecosystem service is a cultural service – consider landscape or water body level.

Rules of thumb for designating <u>temporal scale</u> of impact:

- If ecosystem service is a cultural service – consider weeks to months (visible growing seasonal).
- If ecosystem service is a supporting service – consider all year round importance and how temporal scale is applicable.
- If attribute includes taxonomic richness or genetic diversity – consider all year round importance, therefore temporal scale may not be applicable, unless some contributing species are migratory.

Table 6.2: Ecosystem Service – Food provisioning

Habitat group	Key SPUs	Ecological entity	Attribute (measurement endpoint)	Scale: Magnitude of impact	Scale: Spatial scale of impact	Scale: Temporal scale of impact	Specific protection goal	Legal requirement (legal instrument)
Terrestrial (crop / grassland)	**Primary producers** • Terrestrial plants	Population / Metapopulation	Contaminant load / residue concentration	Tolerable intake limit for primary consumers	Local field (<1 km) to landscape (≥10 km) scale	Short-term (days to weeks)	No local exceedance of max tolerable residue levels in field crops / grasses for >days to weeks	Limits for chemical body burdens/ residue concentrations (PPPR, BPR, MPVU, SSAD)
		Population	Production/ biomass	Small to medium effects in crop/grassland	Local field scale (<1 km)	Growing season (weeks to months)	No more than small local biomass reductions in field crops / grasses	Protection of non-target organism populations / metapopulations (BPR, MPHU, PPPR, REACH, MPVU)
		Metapopulation	Production/ biomass	Negligible effect across landscape	Landscape scale (≥ 10 km)	Growing season (weeks to months)	No more than negligible biomass reductions in field crops / grasses across landscape for >weeks to months	
Terrestrial (crop / grassland)	**Primary consumers** • Terrestrial livestock and game	Population / Metapopulation	Contaminant load	Tolerable intake limit for primary consumers	Landscape scale (≥ 10km)	Short-term (days to weeks)	No exceedance of max tolerable residue levels in livestock / game for >days to weeks	Limits for chemical body burdens / residue concentrations (PPPR, BPR, MPVU)
		Population / Metapopulation	Abundance, biomass/ production	Negligible to small effects on biomass	Landscape scale (≥ 10 km)	Season (weeks to months)	No more than negligible biomass reductions with domestic and wild animals for >weeks to months	Protection of non-target organism populations (BPR, MPHU, PPPR, REACH, MPVU), key species populations (BD), communities (HD)
Freshwater (lakes and rivers)	**Secondary consumers** • Game fish	Population / Metapopulation	Contaminant load	Tolerable intake limit for secondary consumers	watershed (≥10 km)	Short-term (days to weeks)	No exceedance of max tolerable residue levels in livestock / game for >days to weeks	Limits for chemical body burdens/ residue concentrations (FSR)
		Population / Metapopulation	Abundance, biomass/ production	Negligible to small effects on biomass	watershed (≥10 km)	Season (weeks to months)	No more than negligible reductions in population numbers and biomass for >weeks to months	Protection of non-target organism populations (BPR, MPHU, PPPR, REACH, MPVU), key species populations (BD), communities (HD)

Habitat group	Key SPUs	Ecological entity	Attribute (measurement endpoint)	Scale: Magnitude of impact	Scale: Spatial scale of impact	Scale: Temporal scale of impact	Specific protection goal	Legal requirement (legal instrument)
Transitional / Marine (estuaries / inlets, coastal waters)	**Primary producers** • Saltmarsh plants, macroalgae	Population / Metapopulation	Contaminant load	Tolerable intake limit for primary consumers	watershed (≥10 km)	Short-term (days to weeks)	No exceedance of max tolerable residue levels in plants for >days to weeks levels	Limits for chemical body burdens (FSR, MSFD)
		Population / Metapopulation	Abundance, biomass/ production	Negligible to small effects on biomass	watershed (≥10 km)	Season (weeks to months)	No more than negligible reductions in population numbers and biomass for >weeks to months	Protection of non-target organism populations (BPR, MPHU, PPPR, REACH, MPVU), key species populations (BD), communities (HD)
Transitional / Marine (estuaries / inlets, coastal waters)	**Primary consumers** • Shellfish	Population / Metapopulation	Contaminant load	Tolerable intake limit for secondary consumers	watershed (≥10 km)	Short-term (days to weeks)	No exceedance of max tolerable residue levels in plants for >days to weeks levels	Limits for chemical body burdens (FSR, MSFD)
		Population / Metapopulation	Abundance, biomass/ production	Negligible to small effects on biomass	watershed (≥10 km)	Season (weeks to months)	No more than negligible reductions in population numbers and biomass for >weeks to months	Protection of non-target organism populations (BPR, MPHU, PPPR, REACH, MPVU), key species populations (BD), communities (HD)

Table 6.3: Ecosystem Service – Genetic resources

Habitat group	Key SPUs	Ecological entity	Attribute	Scale			Specific protection goal	Legal requirement (legal instrument)
			(measurement endpoint)	Magnitude of impact	Spatial scale of impact	Temporal scale of impact		
Terrestrial (crop / grassland)	**Primary producers** • Terrestrial plants	Population / Metapopulation	Seed production (for propagation and/or hybridisation of genetic strains / varieties)	Small to medium effects in crop / grassland	Local field scale (<1 km)	Growing season (weeks to months)	No more than small local reductions in seed production in field crops / grasses	Protection of non-target organism populations / metapopulations (BPR, MPHU, MPVU PPPR, REACH, HD)
				Negligible effect across landscape	Landscape scale (≥10 km)	Growing season (weeks to months)	No more than negligible reductions in seed production in field crops / grasses across landscape for >weeks to months	
Terrestrial (crop / grassland)	**Primary consumers** • Terrestrial livestock and beneficial wild fauna	Population / Metapopulation	Abundance and genetic diversity (for domestic animal breeding and maintenance of wild populations)	Negligible to small effects on abundance and genetic diversity	Landscape scale (≥10 km)	Season (weeks to months)	No more than negligible reductions in abundance and genetic diversity with domestic and wild animal (meta)populations for >weeks to months	Protection of non-target organism populations (BPR, MPHU, PPPR, REACH, MPVU), key species populations (BD), communities (HD)
Freshwater (lakes and rivers)	**Secondary consumers** • Aquaculture fish and shellfish	Population / Metapopulation	Abundance and genetic diversity (for maintenance of populations)	Negligible to small effects on abundance and genetic diversity	watershed (≥10 km)	Season (weeks to months)	No more than negligible reductions in population numbers and genetic diversity for >weeks to months	Protection of non-target organism populations (BPR, MPHU, PPPR, REACH, MPVU), key species populations (HD)
Transitional / Marine (estuaries / inlets, coastal waters)	**Primary producers** • Microalgae / cyanobacteria, macroalgae	Population / Metapopulation	Abundance, propagule / spore production	Negligible to small effects on abundance, propagule / spore production	watershed (≥10 km)	Season (weeks to months)	No more than negligible reductions in population numbers and propagule / spore production for >weeks to months	Protection of non-target organism populations (BPR, MPHU, PPPR, REACH, MPVU), key species populations (HD)
Transitional / Marine (estuaries / inlets, coastal waters)	**Primary consumers** • Shellfish	Population / Metapopulation	Abundance, genetic diversity	Negligible to small effects on abundance and genetic diversity	watershed (≥10 km)	Season (weeks to months)	No more than negligible reductions in population numbers and genetic diversity for >weeks to months	Protection of non-target organism populations (BPR, MPHU, PPPR, REACH, MPVU), key species populations (HD)

Table 6.4: Ecosystem Service – Natural hazard regulation

Habitat group	Key SPUs	Ecological entity	Attribute (measurement endpoint)	Scale: Magnitude of impact	Scale: Spatial scale of impact	Scale: Temporal scale of impact	Specific protection goal	Legal requirement (legal instrument)
Marine (inlets and transitional waters, coastal)	**Primary producers** • Marginal and saltmarsh plants, macro algae	Functional groups*	Function	Medium effects	Point of emission (<100 m)	Weeks to months	Only negligible larger scale effects on functional groups providing protection from physical damage by waves etc.	Protection of non-target organism populations (BPR, MPHU, MPVU, OSPAR, PPPR, REACH), communities (HD, MSFD)
		Functional groups*	Function	Negligible to small effects	Local (<1 km)	Weeks to months		
Marine (inlets and transitional waters, coastal)	**Eco-engineers** • Molluscs, corals, worms	Functional groups*	Function	Medium effects	Point of emission (<100 m)	Weeks to months	Only negligible larger scale effects on functional groups providing protection from physical damage by waves etc.	Protection of non-target organism populations (BPR, MPHU, MPVU, OSPAR, PPPR, REACH,), communities (HD, MSFD)
		Functional groups*	Function	Negligible to small effects	Local (<1 km)	Weeks to months		

* Limited functional redundancy, i.e. only a few highly specialised species are expected to provide this service (example: *Spartina* in saltmarshes); thus, although functional aspects are in focus, the ecological entity may therefore be the population

Table 6.5: Ecosystem Service – Water purification / soil remediation / waste treatment

Habitat group	Key SPUs	Ecological entity	Attribute (measurement endpoint)	Scale of sustainable impact: Magnitude of impact	Scale of sustainable impact: Spatial scale of impact*	Scale of sustainable impact: Temporal scale of impact	Specific protection goal	Legal requirement (legal instrument)
Terrestrial (crop / grassland / wetlands)	**Primary producers** • Terrestrial and semi-terrestrial plants	Functional groups	Function	Medium effects	Point of emission to local (≤1 km)	Weeks to months	Only negligible larger scale effects on functional groups providing assimilation and detoxification of compounds	Protection of non-target organism populations / metapopulations (BPR, MPHU, PPPR, REACH, MPVU), communities (HD)
		Functional groups	Function	Negligible to small effects	Landscape (≤10 km)	Weeks to months		
Terrestrial (crop / grassland / wetlands)	**Decomposers** • Soil bacteria and fungi	Functional groups	Function	Medium effects	Point of emission to local (<1 km)	Weeks to months	Only negligible larger scale effects on functional groups decomposing compounds	Protection of non-target organism populations / metapopulations (BPR, MPHU, PPPR, REACH, MPVU)
		Functional groups	Function	Negligible to small effects	Landscape (≥10 km)	Weeks to months		

Habitat group	Key SPUs	Ecological entity	Attribute (measurement endpoint)	Scale of sustainable impact			Specific protection goal	Legal requirement (legal instrument)
				Magnitude of impact	Spatial scale of impact*	Temporal scale of impact		
Freshwater (rivers and lakes)	**Primary producers** • Freshwater algae and plants	Functional groups	Function	Medium effects	Point of emission (≥100 m)	Weeks to months	Only negligible larger scale effects on functional groups providing assimilation and detoxification of compounds	Protection of non-target organism populations (BPR, MPHU, PPPR, REACH, MPVU), key species populations (BD), communities (HD)
		Functional groups	Function	Negligible to small effects	Local (<1 km)	Weeks to months		
Freshwater (rivers and lakes)	**Decomposers** • Aerobic and anaerobic bacteria	Functional groups	Function	Medium effects	Point of emission (≥100 m)	Weeks to months	Only negligible larger scale effects on functional groups decomposing compounds	No unacceptable effects on microbiological activity of sewage treatment plants (REACH, MPHU); no specific requirements for decomposing bacteria in natural habitats
		Functional groups	Function	Negligible to small effects	Local (<1 km)	Weeks to months		
Marine (inlets and transitional waters)	**Primary producers** • Marine micro and macro algae	Functional groups	Function	Medium effects	Point of emission (≥100 m)	Weeks to months	Only negligible larger scale effects on functional groups providing assimilation and detoxification of compounds	Protection of non-target organism populations (BPR, MPHU, PPPR, REACH, MPVU), key species populations (BD), communities (HD)
		Functional groups	Function	Negligible to small effects	Local (<1 km)	Weeks to months		
Marine (inlets and transitional waters)	**Decomposers** • Aerobic and anaerobic bacteria	Functional groups	Function	Medium effects	Point of emission (≥100 m)	Weeks to months	Only negligible larger scale effects on functional groups decomposing compounds	No specific requirements for decomposing bacteria in natural habitats
		Functional groups	Function	Negligible to small effects	Local (<1 km)	Weeks to months		

* Some level of impact may be sustainable beyond the conventionally accepted mixing zone i.e. >100 m depending on magnitude and duration of impact and also functional redundancy amongst SPUs

Table 6.6: Ecosystem Service – Nutrient cycling

Habitat group	Key SPUs	Ecological entity	Attribute (measurement endpoint)	Scale: Magnitude of impact	Scale: Spatial scale of impact	Scale: Temporal scale of impact	Specific protection goal	Legal requirement (legal instrument)
Terrestrial (crop / grassland / wetland)	**Decomposers** • Mycorrhizae	Functional group	Function (nutrient uptake)	Medium to large effects in-field, small effects off-field	Point of emission to local (<1 km)	Season (weeks to months)	Only negligible larger scale effects on functional groups	PPPR, EFSA guidance
Terrestrial / freshwater / marine (all habitats)	**Decomposers** • Bacteria and fungi	Functional group	Function (nutrient uptake, CNP ratio)	Medium to large effects in-field, small effects off-field	Point of emission to local (<1 km)	Weeks to months	Only negligible larger scale effects on functional groups	PPPR, MPVU
Terrestrial / freshwater (all habitats)	**Detritivores** • Woodlouse, gammarids, earthworms	Functional group	Function (leaf shredding / nutrient release)	Small to medium effects on populations	Point of emission to local (<1 km)	Months to a year	Only negligible larger scale effects on functional groups	PPPR, MPVU
Freshwater / marine (freshwater / inlets and transitional waters / coastal / shelf / ocean)	**Primary producers** • Oxygenating aquatic plants, reed beds, cyanobacteria, phytoplankton	Functional group	Function (nutrient uptake, N fixation, oxygenation)	Locally small to medium effects but negligible effects on watershed	Point of emission to local (<1 km)	Months to a year	Only negligible larger scale effects on functional groups	MSFD, OSPAR, WFD

Table 6.7: Ecosystem Service – Recreation and eco-tourism

Habitat group	Key SPUs	Ecological entity	Attribute (measurement endpoint)	Scale: Magnitude of impact	Scale: Spatial scale of impact	Scale: Temporal scale of impact	Specific protection goal	Legal requirement (legal instrument)
Terrestrial / freshwater	**Primary producers** • Terrestrial and aquatic plants	Population / metapopulation / community	Abundance / taxa richness / area / biomass	Locally small to medium effects but negligible effects on watershed / landscape level	Point of emission (<1 km)	Weeks to months (growing season)	Only small scale effects on populations / metapopulations	HD, WFD
Freshwater	**Primary consumers** • Wild coarse fish	Population / metapopulation / community	Abundance / taxa richness / area (mortality, fecundity)	Negligible to small effects from local to watershed level	Point of emission (<1 km)	Weeks to months (breeding, growing season)	Only small scale effects on populations / metapopulations	HD, WFD
Freshwater / marine	**Primary consumers** • Coarse fish / non-edible shellfish	Population / metapopulation / community	Abundance / taxa richness / area (mortality, fecundity)		Point of emission (<1 km)	Weeks to months (breeding, growing season)	Only small scale effects on populations / metapopulations	HD, MSFD, OSPAR, WFD

7. DISCUSSION AND CONCLUSIONS

7.1 Discussion

In considering the EFSA framework developed for pesticides in a broader chemical context and in applying the framework to several case studies, the Task Force found the approach to be conceptually straightforward and logical. However, there were many points in the framework where additional information and more detailed guidance will be required for general applicability to all chemical sectors, including pesticides. A strong theme throughout the Task Force application of the framework was the importance of prioritising at each step in order to manage the time and effort required. This discussion outlines the key development needs that the Task Force identified at each step.

Steps 1 and 2: Construct a habitat x ecosystem service matrix and assign importance rankings

The first two steps can be considered as i) the development of a reference table of habitats and ii) their importance for ecosystem service provision. This is essential information for the framework approach and although these two steps were considered in that order for the case studies, identification of which habitats would be expected to be exposed to specific chemicals would also be an initial step in applying the framework.

The habitat x ecosystem service matrix provides a flexible method for selecting relevant habitats and then drawing on expert assessments of the importance these habitats can be in providing ESs. The Task Force considered the EUNIS habitat typology a good, multi-level hierarchical classification. Although the case studies developed by the Task Force generally applied habitat classifications at a similar hierarchical level across all habitats, in principle, the hierarchy could effectively use different levels of resolution as required. It is clear that the matrix presented in Table 2.3 requires further work to extend the assessment to all combinations of habitats and ecosystem services. Levels of importance (+ to +++) were collated from key publications that compared multiple ecosystem services across multiple habitats. Additional information was added by the Task Force where supporting knowledge was available to enable the case studies to better assess specific habitat importance. These were mostly the marine habitats (i.e marine inlets and transitional waters; coastal areas; shelf; open ocean). Sparsely vegetated land was not generally considered in the Task Force case studies, because of low exposure in most case studies and insufficient knowledge.

The matrix can be used with various levels of habitat resolution, for example, all fresh water habitats could be considered as one generic habitat or could be sub-divided into lotic and lentic habitats. Further differentiation of lotic or lentic habitats might also be appropriate for specific chemical emissions, although this level of information would require further development. The down the drain chemicals case study assessed lotic and lentic fresh water habitats separately since exposure of lotic systems was expected to be higher than lentic systems in most cases.

The use of all types of ecosystem services in the initial steps of the framework, as recommended by Maes *et al* (2014) and EFSA (2010), was considered important in identifying the key SPUs. The Task Force did not consider the completeness of the list but did not identify any gaps arising from the four case studies. Deviations from the EFSA approach included the combining of primary production with photosynthesis where the Task Force considered the SPUs to be essentially similar and the exclusion of abiotic ecosystem services such as oil (for fuel) and flowing water (for power generation), since these were not provided via biotic SPUs. Explicitly including SPUs that provide supporting and other intermediate services was considered a more explicit and informed approach to deriving key groups of SPUs and, therefore, in any subsequent identification of testing strategies for risk assessing the potential impacts on SPGs.

The treatment of biodiversity in the habitat x ecosystem service matrix was identified as a topic requiring further discussion. The Task Force recognised the importance of addressing biodiversity in relation to ecosystem services and adopted the position that biodiversity underpins the delivery of all ecosystem services that are dependent on biotic processes and specific components of biodiversity are explicitly addressed in many individual ecosystem services (e.g. genetic resources, ornamental resources, pollination, pest control, aesthetic value, etc). Biodiversity, as defined by the Convention on Biological Diversity, was considered part of natural capital and not an ecosystem service *per se* as its inclusion as an ecosystem service would lead to the protection of 'everything, everywhere', which is too generic and vague to be useful for scientific risk assessment. Therefore, the TF did not consider biodiversity as a discrete ecosystem service. The Task Force identified potential confusion between genetic resources and biodiversity, i.e. both terms could be interpreted as meaning the same ecosystem service. These are defined as completely different ecosystem services and misinterpreting genetic diversity with biodiversity also adds to the issue outlined above. Familiarity with the definitions of ecosystem services and other terms is an important requirement if the EFSA framework is to be applied correctly and efficiently.

Step 3: Ranking potential impact for habitat x ecosystem service combinations using exposure and effects information

The Task Force found the preparation of schematic diagrams of potential routes of exposure helpful in assessing the relative level of exposure each of the habitats could experience from specific chemicals in the case studies. Inclusion of such schematic figures provides a simple and effective communication of exposure. The use of a three coloured traffic light approach proved adequate in ranking and differentiating levels of concern. However, the Task Force observed that different individuals scored (coloured) some cells differently in different case studies, i.e. there were differences in judgement of level of concern. Additional experience and guidance would help minimise such differences. In those case studies where chemical exposure or importance of the habitat for specific ecosystem service provision was negligible for a habitat or a specific ecosystem service, then that row or column in the matrix was dropped from further consideration, e.g. urban, woodland and forest, heathland and shrub, sparsely vegetated land, open ocean. Note that forest habitats could potentially be impacted by POPs, particularly in high altitude Alpine areas, in which atmospheric distillation takes place. Again, the use of a simple traffic light approach helps identify these cases.

The Task Force initially aimed to only use the relative level of exposure to rank the level of concern for each habitat x ecosystem service combination. Although exposure was indeed acknowledged as the main driver along with importance of habitats for ecosystem service provision, additional chemical-related factors were also identified and applied. These refinements are described in Chapter 4 and include use of prior knowledge of chemical fate, behaviour and toxicity such as contamination of the (human) food chain, the range of potentially impacted species (more species exposed may lead to broader potential impacts, unless there is scope for compensation via functional redundancy) and the potential for both direct and indirect chemical impacts. There was also potential for additional factors to lead to reduced ranking, for example, due to the lower sensitivity of micro-organisms compared to higher organisms.

Assessing the level of potential impact due to chemical exposure was difficult for some ecosystem services. This was particularly pertinent for cultural services, for example education and inspiration could be considered likely to be always potentially impacted if the relevant habitats are exposed. Also, there can be differences in how different cultures perceive and value ecosystem services. Additional research to document and reference such differences would reduce uncertainties and inaccuracies in assessing levels of concern for impacts on cultural ecosystem services.

Although the identification of SPUs in this step is needed, the use of icons representative of the main taxonomic and functional groups was considered an appropriate level of resolution and a helpful summary at this step in the framework.

Step 4: Categorising the level of concern for exposed ecosystem services

In order to streamline the assessment of exposed habitat x ecosystem service combinations, the Task Force devised a prioritisation matrix (Chapter 2, Table 2.6). Only those combinations assessed as medium or high concern were investigated further in the case studies. This was simply to focus the Task Force resources on the combinations of higher concern, although including prioritising steps into the framework in general use is an important option to help align resources to the required level of assessment. Those combinations considered to be of low concern may still be important depending on the requirements of the specific protection goal description, i.e. how comprehensive it needs to be in informing subsequent risk assessment.

At this step, the Task Force ensured that potentially impacted service providing units in habitat and ecosystem service combinations identified as medium and high concern were identified at a suitable level of resolution for subsequent specific protection goal description. Access to reference tables of the key service providing units likely to occur in specific habitats helps complete this task and aids consistency. Since each habitat x ecosystem service cell requires relevant service providing units to be listed, the Task Force adopted a numerical superscript to simplify presentation of this information.

Step 5: Defining SPGs for ecosystem services of high and medium concern

Population and application of the tables reported in Chapter 6 was made with a high degree of uncertainty. This was because of the lack of detailed guidance and knowledge in deciding ecological entities, attributes and especially scale of potential impact. The Task Force considered that the six dimensions in EFSA’s guidance (ecological entity, attributes, magnitude of effect, temporal and spatial scale of effect and the degree of certainty required) provide a good basis for describing specific protection goals. However, more ecological knowledge is required in order for risk managers to define the acceptable magnitude and scale of impact based on underpinning science, together with other considerations. The Task Force did not assess the level of uncertainty required because of insufficient experience and guidance.

There is clearly a complex range of regulatory guidance to consider (see Chapter 3) but there remains a general lack of detail on specific protection goals in all but a few legal instruments. One notable exception is the derivation of ecological quality objectives under OSPAR, which clearly defines acceptable magnitudes, spatial and temporal scales of impact for key indicators or ecological populations in the North Sea (Table C1.3). For the most effective use of the ecosystem service approach, i.e. to utilise a habitat focus for setting specific protection goals, guidance on application of the various chemical sector specific regulations to land use scenarios is required. The Task Force considered that the use of legal requirement information should be made explicit, i.e. whether it is used to inform the specific protection goal or to use as additional information to ensure that a subsequent risk assessment is appropriately scoped.

The scope of the Task Force objectives effectively concluded with the derivation of specific protection goals for selected case studies. How these specific protection goals might be used in subsequent chemical risk assessment (prospective and retrospective) was not considered, but this is a key next step in practical application of the EFSA framework. In addition to the development of testing and modelling approaches needed to assess impacts on the service providing units that underpin specific protection goals, there is a need to define acceptable effects from unacceptable 'adverse' environmental effects, e.g. using retrospective or diagnostic methods.

7.2 Conclusions

Applying the ecosystem services concept to derive environmental specific protection goals brings the potential for greater spatial resolution in chemical risk assessment, i.e. specific protection goals can be derived for specific land-uses or landscape typologies. It, therefore, can be considered as one approach that could facilitate increasing the environmental relevance of risk assessments, a need identified by several scientific advisory groups, e.g. EC Scientific Committees. Whilst increasing environmental relevance in this way has scientific merit, the practical outcome of defining spatially explicit protection goals to inform risk assessment for a range of chemical sectors requires further investigation and evaluation. The Task Force recommends that such further work is initiated to more fully determine the practical application of the ecosystem services approach. One such activity is the CEFIC LRi project, ECO 27, Chemicals: Assessment of Risks
to Ecosystem Services (CARES), which was initiated in 2015 to gain a consensus between regulatory, academic and industrial stakeholders for a road map for implementing an ecosystem services approach to informing chemical risk assessment. The project will be completed early 2017.

The EFSA framework represents a top-down approach for deriving specific protection goals for habitats expected to be exposed to specified anthropogenic chemicals. In principle, the framework can be applied to a broad range of chemicals and exposure scenarios. With modifications, clarity on terminology / definitions and further development and guidance, the framework could provide a methodical approach for the identification and prioritisation of ecosystems and services which are most at risk. Prioritised habitats and key service providing units could form the focus for subsequent risk assessment.

GLOSSARY

Biodiversity	*"The variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems"* (UN Convention of Biological Diversity (CBD), Article 2, 1992a).
Ecosystem	*"The system composed of physical-chemical-biological processes active within a space-time unit of any magnitude"* (Lindeman, 1942). *"A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit"* (UN, 1992a).
Ecosystem approach	*"Environmental management based on our best understanding of the ecological interactions and processes necessary to sustain ecosystem composition, structure and function"* (Christensen *et al*, 1996).
Ecosystem services (ES)	Direct and indirect contribution of ecosystems to human well-being (TEEB, 2010a). *"The benefits people derive from ecosystems – the support of sustainable human well-being that ecosystems provide"* (Costanza *et al*, 1997; Millennium Ecosystem Assessment, 2005b) … *"arising from the interaction of society, the built economy, and ecosystems (social, built and natural capital)"* (Costanza *et al*, 2014).
Ecosystem services approach	Establishing *"the linkages between ecosystem structures and process functioning … which are understood to … lead directly or indirectly to valued human welfare benefits"* (Turner and Daily, 2008).
Final services	Those components of nature that are enjoyed, consumed or used to yield human well-being (Boyd and Banzhaf, 2007).
Intermediate services	Those components of nature that are not enjoyed, consumed or used directly to yield human well-being (Boyd and Banzhaf, 2007).
Natural Capital	The elements of nature that directly or indirectly produce value or benefits to people, including ecosystems, species, freshwater, land, minerals, the air and oceans, as well as natural processes and functions (UK NCC, 2014). *"The biophysical components of ecosystems – land, water, air, minerals, biodiversity"* (Costanza, 2008).

Service-providing units (SPU)	Biological components that provide, or might provide in the future, a recognised ecosystem service at some temporal or spatial scale (Luck *et al*, 2003).

ABBREVIATIONS

AEL	Associated Emission Level
AQFD	Air Quality Framework Directive
BAP	Biodiversity Action Plan
BAT	Best Available Techniques
BD	Birds Directive
BPR	Biocidal Products Regulation
CAP	Common Agricultural Policy
CBD	Convention on Biological Diversity
CICES	Common International Classification of Ecosystem Services
CLPR	Classification, Labelling and Packaging Regulation
CMS	Convention on Migratory Species
CNP	Carbon:Nitrogen:Phosphorus
COD	Chemical Oxygen Demand
COMAH	Control of Major Accident Hazard
DDT	Dichlorodiphenyltrichloroethane
EC	European Commission
EcoQO	Ecological Quality Objective
ED	Endocrine Disruptor
Ee	Eco-engineers
EEZ	Exclusive Economic Zone
EFSA	European Food Safety Authority
ELD	Environmental Liability Directive
ELVs	Emission Limit Values
E-PRTR	European Pollutant Release and Transfer Register
EQSD	Environmental Quality Standards Directive
EQSs	Environmental Quality Standards
ERA	Environmental Risk Assessment
EU	European Union
EUNIS	European Nature Information System
FCS	Favourable Conservation Status
FSA	Food Standards Agency
FSR	Food Standards Regulations
GES	Good Environmental Status
GPD	Groundwater Protection Directive
HD	Habitats Directive
IED	Industrial Emissions Directive
IPCS	International Programme for Chemical Safety
MA	Millennium Ecosystem Assessment
MAES	Mapping and Assessment of Ecosystems and their Services
MPHU	Medicinal Products for Human Use
MPVU	Medicinal Products for Veterinary Use
MS	Member State
MSFD	Marine Strategy Framework Directive
OSPAR	Oslo Paris Commission

PBT	Persistent, Bioaccumulative and Toxic
PEC	Predicted Environmental Concentration
PNEC	Predicted No-Effect Concentration
POP	Persistent organic pollutants
PPP	Plant Protection Products
PPPR	Plant Protection Products Regulations
QSR	Quality Status Report
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
SAICM	Strategic Approach to International Chemicals Management
SC	Stockholm Convention
SCCS	Scientific Committee on Consumer Safety
SCENIHR	Scientific Committee on Emerging and Newly Identified Health Risks
SCHER	Scientific Committee on Health and Environmental Risks
SPA	Special Protection Area
SPGs	Specific Protection Goals
SPU	Service-providing units
SSAD	Sewage Sludge Application Directive
TAG	Technical Advisory Group
TBT	Tributyltin
TEEB	The Economics for Ecosystems and Biodiversity
TGD	Technical Guidance Document
TSS	Thematic Soil Strategy
UN	United Nations
UNEP	United Nations Environment Programme
US EPA	US Environmental Protection Agency
WFD	Water Framework Directive
WTP	Willingness to pay
WWTP	Wastewater Treatment Plant

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APPENDIX A: CROSS TABULATION OF MA, TEEB AND CICES CLASSIFICATION SYSTEMS

Source: http://biodiversity.europa.eu/maes/ecosystem-services-categories-in-millennium-ecosystem-assessment-ma-the-economics-of-ecosystem-and-biodiversity-teeb-and-common-international-classification-of-ecosystem-services-cices

Millennium Ecosystem Assessment (MA) categories	TEEB categories	CICES v4.3 group
Food (fodder)	Food	Biomass [Nutrition]
		Biomass (Materials from plants, algae and animals for agricultural use)
Fresh water	Water	Water (for drinking purposes) [Nutrition]
		Water (for non-drinking purposes) [Materials]
Fibre, timber	Raw Materials	Biomass (fibres and other materials from plants, algae and animals for direct use and processing)
Genetic resources	Genetic resources	Biomass (genetic materials from all biota)
Biochemicals	Medicinal resources	Biomass (fibres and other materials from plants, algae and animals for direct use and processing)
Ornamental resources	Ornamental resources	Biomass (fibres and other materials from plants, algae and animals for direct use and processing)
		Biomass based energy sources
		Mechanical energy (animal based)
Air quality regulation	Air quality regulation	[Mediation of] gaseous/air flows
Water purification and water treatment	Waste treatment (water purification)	Mediation [of waste, toxics and other nuisances] by biota
		Mediation [of waste, toxics and other nuisances] by ecosystems
Water regulation	Regulation of water flows	[Mediation of] liquid flows
	Moderation of extreme events	
Erosion regulation	Erosion prevention	[Mediation of] mass flows
Climate regulation	Climate regulation	Atmospheric composition and climate regulation
Soil formation (supporting service)	Maintenance of soil fertility	Soil formation and composition
Pollination	Pollination	Lifecycle maintenance, habitat and gene pool protection
Pest regulation	Biological control	Pest and disease control
Disease regulation		
Primary production Nutrient cycling (supporting services)	Maintenance of life cycles of migratory species (incl. nursery service)	Lifecycle maintenance, habitat and gene pool protection
		Soil formation and composition
		[Maintenance of] water conditions
	Maintenance of genetic diversity (especially in gene pool protection)	Lifecycle maintenance, habitat and gene pool protection
Spiritual and religious values	Spiritual experience	Spiritual and/or emblematic

Millennium Ecosystem Assessment (MA) categories	**TEEB categories**	**CICES v4.3 group**
Aesthetic values	Aesthetic information	Intellectual and representational interactions
Cultural diversity	Inspiration for culture, art and design	Intellectual and representational interactions
		Spiritual and/or emblematic
Recreation and ecotourism	Recreation and tourism	Physical and experiential interactions
Knowledge systems and educational values	Information for cognitive development	Intellectual and representational interactions
		Other cultural outputs (existence, bequest)
MA provides a classification that is globally recognised and used in sub global assessments.	*TEEB provides an updated classification, based on the MA, which is used in on-going national TEEB studies across Europe.*	*CICES provides a hierarchical system, building on the MA and TEEB classifications but tailored to accounting.*

APPENDIX B: EUNIS HABITAT CODE DESCRIPTIONS

Descriptions of EUNIS habitat codes used in Table 2.2. A complete list of EUNIS habitat codes and descriptions are available via the European Environment Agency web site (http://eunis.eea.europa.eu/habitats-code-browser.jsp)

Habitat code	Habitat name	Description
A1	Littoral rock and other hard substrata	Littoral rock includes habitats of bedrock, boulders and cobbles which occur in the intertidal zone (the area of the shore between high and low tides) and the splash zone. The upper limit is marked by the top of the lichen zone and the lower limit by the top of the laminarian kelp zone. Exposed shores tend to support faunal-dominated communities of barnacles and mussels and some robust seaweeds. Sheltered shores are most notable for their dense cover of fucoid seaweeds, with distinctive zones occurring down the shore. In between these extremes of wave exposure, on moderately exposed shores, mosaics of seaweeds and barnacles are more typical.
A2	Littoral sediment	Littoral sediment includes habitats of shingle (mobile cobbles and pebbles), gravel, sand and mud or any combination of these which occur in the intertidal zone. Some intertidal sediments are dominated by angiosperms, e.g. eelgrass beds on the mid and upper shore of muddy sand flats, or saltmarshes and saline reedbeds (A2.5) which develop on the extreme upper shore of sheltered fine sediment flats. Littoral sediments are found across the entire intertidal zone, including the strandline. Sediment biotopes can extend further landwards (dune systems, marshes) and further seawards (sublittoral sediments). Sediment shores are generally found along relatively more sheltered stretches of coast compared to rocky shores. Muddy shores or muddy sand shores occur mainly in very sheltered inlets and along estuaries, where wave exposure is low enough to allow fine sediments to settle. Sandy shores and coarser sediment (gravel, pebbles, cobbles) shores are found in areas subject to higher wave exposures.
A3	Infralittoral rock and other hard substrata	Infralittoral rock includes habitats of bedrock, boulders and cobbles which occur in the shallow subtidal zone and typically support seaweed communities. The upper limit is marked by the top of the kelp zone whilst the lower limit is marked by the lower limit of kelp growth or the lower limit of dense seaweed growth. Infralittoral rock typically has an upper zone of dense kelp (forest) and a lower zone of sparse kelp (park), both with an understorey of erect seaweeds. On the extreme lower shore and in the very shallow subtidal (sublittoral fringe) there is usually a narrow band of dabberlocks [*Alaria esculenta*] (exposed coasts) or kelps. Areas of mixed ground, lacking stable rock, may lack kelps but support seaweed communities. In estuaries and other turbid-water areas the shallow subtidal may be dominated by animal communities, with only poorly developed seaweed communities.
A4	Circalittoral rock and other hard substrata	Circalittoral rock is characterised by animal dominated communities. The circalittoral zone can itself be split into two sub-zones; upper circalittoral (foliose red algae present but not dominant) and lower circalittoral (foliose red algae absent). The depth at which the circalittoral zone begins is directly dependent on the intensity of light reaching the seabed; in highly turbid conditions, the circalittoral zone may begin just below water level at mean low water springs (MLWS). The character of the fauna varies enormously and is affected mainly by wave action, tidal stream strength, salinity, turbidity, the degree of scouring and rock topography. It is typical for the community not to be dominated by single species, as is common in shore and infralittoral habitats, but rather comprise a mosaic of species. This, coupled with the range of influencing factors, makes circalittoral rock a difficult area to satisfactorily classify; particular care should therefore be taken in matching species and habitat data to the classification.
A5	Sublittoral sediment	Sediment habitats in the sublittoral near shore zone (i.e. covering the infralittoral and circalittoral zones), typically extending from the extreme lower shore down to the edge of the bathyal zone (200 m). Sediment ranges from boulders and cobbles, through pebbles and shingle, coarse sands, sands, fine sands, muds, and mixed sediments. Those communities found in or on sediment are described within this broad habitat type.
A6	Deep-sea bed	The sea bed beyond the continental shelf break. The shelf break occurs at variable depth, but is generally over 200 m. The upper limit of the deep-sea zone is marked by the edge of the shelf. Includes areas of the Mediterranean Sea which are deeper than 200 m but not of the Baltic Sea which is a shelf sea.
A7	Pelagic water column	The water column of shallow or deep sea, or enclosed coastal waters.

Habitat code	Habitat name	Description
B	Coastal habitats	Coastal habitats are those above spring high tide limit (or above mean water level in non-tidal waters) occupying coastal features and characterised by their proximity to the sea, including coastal dunes and wooded coastal dunes, beaches and cliffs. Includes free-draining supralittoral habitats adjacent to marine habitats which are normally only affected by spray or splash, strandlines characterised by terrestrial invertebrates and moist and wet coastal dune slacks and dune-slack pools. Excludes supralittoral rock pools and habitats adjacent to the sea which are not characterised by salt spray, wave or sea-ice erosion.
C	Inland surface waters	Inland surface waters are non-coastal above-ground open fresh or brackish waterbodies (e.g. lakes and pools (C1), rivers, streams and springs (C2)), including their littoral zones. Includes constructed inland freshwater, brackish or saline waterbodies (such as canals, ponds, etc.) which support a semi-natural community of both plants and animals; seasonal waterbodies which may dry out for part of the year (temporary or intermittent rivers and lakes and their littoral zones). Freshwater littoral zones (C3) include those parts of banks or shores that are sufficiently frequently inundated to prevent the formation of closed terrestrial vegetation. Excludes permanent snow and ice.
D	Mires, bogs and fens	Wetlands, with the water table at or above ground level for at least half of the year, dominated by herbaceous or ericoid vegetation. Includes inland saltmarshes and waterlogged habitats where the groundwater is frozen. Excludes the water body and rock structure of springs (C2) and waterlogged habitats dominated by trees or large shrubs (F, G). Note that habitats that intimately combine waterlogged mires and vegetation rafts with pools of open water are considered as complexes.
E	Grasslands and lands dominated by forbs, mosses or lichens	Non-coastal land which is dry or only seasonally wet (with the water table at or above ground level for less than half of the year) with greater than 30% vegetation cover. The vegetation is dominated by grasses and other non-woody plants, including mosses, macrolichens, ferns, sedges and herbs. Includes semiarid steppes, successional weedy vegetation and managed grasslands such as recreation fields and lawns. Excludes regularly tilled habitats (I) dominated by cultivated herbaceous vegetation such as arable fields.
F	Heathland, scrub and tundra	Non-coastal land which is dry or only seasonally inundated (with the water table at or above ground level for less than half of the year) with greater than 30% vegetation cover. Tundra is characterised by the presence of permafrost. Heathland and scrub are defined as vegetation dominated by shrubs or dwarf shrubs of species that typically do not exceed 5 m maximum height. Includes shrub orchards, vineyards, hedges (which may have occasional tall trees). Also includes stands of climatically-limited dwarf trees < 3 m high, such as occur in extreme alpine conditions. Includes *Salix* and *Frangula* carrs but excludes coppice and *Alnus* and *Populus* swamp woodland (G).
G	Woodland, forest and other wooded land	Woodland and recently cleared or burnt land where the dominant vegetation is, or was until very recently, trees with a canopy cover of at least 10%. Trees are defined as woody plants, typically single-stemmed, that can reach a height of 5 m at maturity unless stunted by poor climate or soil. Includes lines of trees, coppices, regularly tilled tree nurseries, tree-crop plantations and fruit and nut tree orchards. Includes *Alnus* and *Populus* swamp woodland and riverine *Salix* woodland. Excludes *Corylus avellana* scrub and *Salix* and *Frangula* carrs. Excludes stands of climatically-limited dwarf trees < 3m high, such as occur at the Arctic or alpine tree limit. Excludes parkland with canopy less than 10%, which are listed under sparsely wooded grasslands (E).
H	Inland unvegetated or sparsely vegetated habitats	Non-coastal habitats with less than 30% vegetation cover (other than in crevices of rocks, screes or cliffs) which are dry or only seasonally wet (with the water table at or above ground level for less than half of the year). Subterranean non-marine caves and passages including underground waters and disused underground mines. Habitats characterised by the presence of permanent snow and surface ice other than marine ice bodies.
I	Regularly or recently cultivated agricultural, horticultural and domestic habitats	Habitats maintained solely by frequent tilling or arising from recent abandonment of previously tilled ground such as arable land (I1) and gardens (I2). Includes tilled ground subject to inundation. Excludes lawns and sports fields (E), shrub orchards (F), tree nurseries and tree-crop plantations (G).
J	Constructed, industrial and other artificial habitats	Primarily human settlements, buildings, industrial developments, the transport network, waste dump sites. Includes highly artificial saline and non-saline waters with wholly constructed beds or heavily contaminated water (such as industrial lagoons and saltworks) which are virtually devoid of plant and animal life. Excludes disused underground mines (H1.7).

Habitat code	Habitat name	Description
X01	Estuaries	Downstream part of a river valley, subject to the tide and extending from the limit of brackish waters. River estuaries are coastal inlets where there is generally a substantial freshwater influence. The mixing of freshwater and sea water and the reduced current flows in the shelter of the estuary lead to deposition of fine sediments, often forming extensive intertidal sand and mud flats. Where the tidal currents are faster than flood tides, most sediments deposit to form a delta at the mouth of the estuary. Baltic river mouths, considered as an estuary subtype, have brackish water and no tide, with helophytic wetland vegetation and luxurious aquatic vegetation in shallow water areas. Littoral and sublittoral habitat types typical of estuaries are included in A2 and A5, although many other habitat types including tidal rivers may occur in estuaries.
X02	Saline coastal lagoons	Lagoons are expanses of shallow coastal salt water, of varying salinity and water volume, wholly or partially separated from the sea by sand banks or shingle, or, less frequently, by rocks. Salinity may vary from brackish water to hypersalinity depending on rainfall, evaporation and through the addition of fresh seawater from storms, temporary flooding of the sea in winter or tidal exchange. With or without vegetation of seagrasses or charophytes. Habitat types typical of lagoons are included in A5, although many other habitat types may also occur in lagoons.
X03	Brackish coastal lagoons	Flads and gloes, considered a Baltic variety of lagoons, are small, usually shallow, more or less delimited water bodies still connected to the sea or cut off from the sea very recently by land upheaval. Characterised by well-developed reedbeds and luxuriant submerged vegetation and having several morphological and botanical development stages in the process whereby sea becomes land. Mediterranean lagoons may host the *Ruppietum* community with halophytic vegetation, while at sites with a fresh water supply, plant communities of *Juncetum* and *Phragmitetum* can develop.

APPENDIX C: SUMMARY OF EU ENVIRONMENTAL LEGISLATION AND CONVENTIONS WITH ECOLOGICAL PROTECTION GOALS RELATING TO CHEMICALS

Table C1.1: Legislation and conventions focusing on chemicals and requiring prospective environmental risk assessment (ERA)

	European Legislation					**International Agreement**
	Registration Evaluation Authorisation and restriction of Chemicals (REACH) Regulation (EC 1907/2006)	**Plant Protection Products Regulation (PPPR) (EC 1107/2009)**	**Biocidal Products Regulation (BPR) (EU 528/2012)**	**Medicinal Products for Human Use Directive (MPHU) (2001/83/EC)**	**Medicinal Products for Veterinary Use Directive (MPVU) (2009/9/EC)**	**Strategic Approach to International Chemicals Management (SAICM, 2006)**
High-level protection goals	Protect human (and animal [PPPR, BPR]) health and the environment via the Precautionary Principle			- Prevent undesirable environmental effects due to the use and/or disposal of human (MPHU) / veterinary (MPVU) medicinal products - Assess environmental impacts for all new marketing authorisations, indications and extensions		Manage chemicals to minimise significant adverse human health and environmental effects by 2020
	No significant adverse effects in any environmental compartment	No unacceptable environmental effects, including impacts on **biodiversity and the ecosystem**				
Chemical protection goals (incl. chemical contamination in biota / food chains)	*Chemical hazard*: (a) human; (b) physicochemical; (c) environmental; d) Persistent, bioaccumulative and toxic (PBT) and very persistent and very bioaccumulative (vPvB) - Apply restrictions - Substitute higher risk substances with lower risk alternatives			*Chemical hazard*: - Screen active pharmaceutical ingredients (APIs) with Log K_{ow} >4.5 for PBT	*Chemical hazard*: (see MPHU) - (see PPPR, BPR) - Extra requirements for products containing genetically modified organisms	- Prevent use of high risk chemicals by 2020 - Minimise release of high risk chemicals by 2020 - Reduce hazardous waste generation, and ensure green hazardous waste management - Substitute high risk chemicals with lower risk alternatives
	- *Risk assessment and exposure mitigation* of active substances (incl. micro-organisms [BPR]), relevant major metabolites (≥10% of parent and/or with comparable toxicity to parent compound), formulated products - Maximum residue limits set for food (treated animals and excreta [MPVU]), soil and groundwater					
Ecological protection goals	No significant adverse effects on ecological populations, food chains and communities	No unacceptable effects in non-target species (PPPR, MPVU) / any compartment (BPR, MPHU); surface waters, groundwater, soil, air (PPPR, MPVU), sewage treatment plants (BPR, MPHU), excreta (MPVU)				Protect vulnerable ecosystems in decision making

	European Legislation					**International Agreement**
	Registration Evaluation Authorisation and restriction of Chemicals (REACH) Regulation (EC 1907/2006)	**Plant Protection Products Regulation (PPPR) (EC 1107/2009)**	**Biocidal Products Regulation (BPR) (EU 528/2012)**	**Medicinal Products for Human Use Directive (MPHU) (2001/83/EC)**	**Medicinal Products for Veterinary Use Directive (MPVU) (2009/9/EC)**	**Strategic Approach to International Chemicals Management (SAICM, 2006)**
Ecological entities considered	*Non target organisms* (aquatic and terrestrial); plants, invertebrates (incl. dung organisms [MPVU]), vertebrates, soil micro-organisms (PPPR, BPR, MPVU), microbiological activity of sewage treatment plants (REACH, MPHU)					
	Represents relevant exposed compartments	Target organisms (plant products)	Target organisms	(see REACH column)	Target organisms (animals)	(see REACH column)
Assessment criteria (critical attributes) identified for ecological entities	*Direct effects*: - Survival, growth, development, reproductive success, function (microbial activity, respiration, biodegradability)	*Direct effects*: Non-target species acute or chronic effects, incl. - survival and development - harmful effects on animal health - behavioural effects		*Direct effects*: (see REACH column)		
	Indirect effects: Secondary poisoning via the food chain (all); evolution of resistance incl. anti-microbial resistance (BPR, MPHU, MPVU)					
Assessment endpoints / indicators (measured / monitored)	Risk Characterisation Ratio compares predicted environmental concentration (PEC) with generic, multi -species and -trophic level predicted no effect concentration (PNEC) (see EU TGD)	Toxicity Exposure Ratios compare predicted exposure concentration with effect concentrations for a range specific endpoints spanning microbe function (e.g. nitrogen cycling) to individual health parameters (e.g. bird's egg shell thickness)	Risk Characterisation Ratio compares predicted environmental concentration (PEC) with generic, multi -species and -trophic level predicted no effect concentration (PNEC) (see EU TGD)			
	Assessment endpoints are stipulated in approved test guidelines referred to in the EU Technical Guidance Document (TGD) and sector-specific guidance					
Indicator targets / thresholds for acceptable versus unacceptable effects or status	Adopt ecological threshold principle in EU Technical Guidance - use PEC/PNEC <1					
		Community recovery principle	Retrospective risk assessment via: information on adverse environmental effects (BPR); eco-pharmacovigilance (MPHU) (see Pharmacovigilance Regulation EU 1235/2010)			

Table C1.2: Legislation and conventions focusing on chemicals and requiring prospective ERA and/or retrospective environmental surveillance, monitoring and impact assessment

	European Legislation									**International Convention**
	Environmental Liability Directive (ELD) (2004/35/CE)	**Control of Major Accident Hazard Directive (COMAH) (2012/18/EU)**	**Sewage Sludge Application Directive (SSAD) (86/278/EEC)**	**Air Quality Framework Directive (AQFD) (2008/50/EC)**	**Groundwater Protection Directive (GPD) (2006/118/EC)**	**Environmental Quality Standards Directive (EQSD) (2008/105/EC)**	**Industrial Emissions Directive (IED) (2010/75/EU)**	**European Pollutant Release and Transfer Register (E-PRTR) Regulation (EC 166/2006)**	**Thematic Soil Strategy (TSS) COM/2006/0231 COM/2006/0232**	**Stockholm Convention (SC, 2001)**
High-level protection goals	*Prevent (and remedy)*: Environmental damage ('Polluter pays' principle) (ELD); major accidents ('Precautionary principle') (COMAH); human health and environmental hazards associated with sewage sludge; soil and agricultural product quality impairment (SSAD)			Protect human health and the environment as a whole		- Reduce priority substance pollution	- Protect human health and the environment as a whole - Remedy environmental damage	- Provide public access to information on pollutant releases and off-site transfers, and track trends	- Protect soil and sustainable use - Preserve soil functions - Manage soil use and risks	- Protect human health and the environment from Persistent Organic Pollutants (POPs)
				- Combat atmospheric emissions at source - Set ambient air quality objectives						
					Prevent, reduce and/or remediate (via the 'Precautionary' and 'Polluter pays' principles): Deterioration and chemical pollution of groundwater (GPD); environmental damage at source from priority hazardous substance emissions (EQSD); industrial pollution (IED); pollution and human health impacts (E-PRTR), soil degradation (TSS), harmful impacts of POPs, including transboundary impacts requiring international cooperation, conciliation and funding (SC)					
Chemical protection goals (focusing on chemical contamination in biota / food chains)	Prevent and/or remedy release of Classification Labelling and Packaging Regulation (CLPR) (EC 1272/2008) and COMAH listed dangerous substances		Set limit values for listed substances		Maintain good groundwater chemical status via: - Limiting pollutant input - Preventing listed (WFD, CLPR, PPPR, BPR) hazardous substance input	- Set Environmental Quality Standards (EQSs) for priority substances and priority hazardous substances	*Integrated approach*: - Set industry emission limit values (ELVs) - Adopt best available techniques (BAT)	Threshold pollutant release values (loads) for reporting	- Address soil contamination at source - Identify, monitor and remediate historically contaminated sites (via ELD)	- Eliminate production / use and properly dispose / remediate POPs listed in Annex A - Minimise (using BAT) exposure from production and use of POPs in Annex B & C
	Prevent and/or remedy release of: listed (WFD, CLPR, PPPR, BPR) hazardous substances		Minimum periods following sludge application before use of pasture or harvesting of crops	Set critical values which may directly affect some receptors, but not humans						

<table>
<tr><th rowspan="2"></th><th colspan="9">European Legislation</th><th>International Convention</th></tr>
<tr><th>Environmental Liability Directive (ELD) (2004/35/CE)</th><th>Control of Major Accident Hazard Directive (COMAH) (2012/18/EU)</th><th>Sewage Sludge Application Directive (SSAD) (86/278/EEC)</th><th>Air Quality Framework Directive (AQFD) (2008/50/EC)</th><th>Groundwater Protection Directive (GPD) (2006/118/EC)</th><th>Environmental Quality Standards Directive (EQSD) (2008/105/EC)</th><th>Industrial Emissions Directive (IED) (2010/75/EU)</th><th>European Pollutant Release and Transfer Register (E-PRTR) Regulation (EC 166/2006)</th><th>Thematic Soil Strategy (TSS) COM/2006/0231 COM/2006/0232</th><th>Stockholm Convention (SC, 2001)</th></tr>
<tr><td>Ecological protection goals</td><td>No adverse impact of:
- <u>Biodiversity</u>: Natural habitats and protected species
- <u>Water</u>: <u>Ecological quality or potential</u>.
- <u>Land</u>: <u>natural resources and services</u> affecting human health</td><td>Avoid permanent or long-term damage to:
- Terrestrial habitats
- Freshwater habitats
- Marine habitats
- Groundwater</td><td>Prevent contamination of:
- Agricultural crops
- Livestock</td><td>Avoid, prevent or reduce harmful effects on:
- Vegetation
- Natural ecosystems</td><td>Conserve groundwater quantity, chemical quality, and dependent ecosystems</td><td>Prevent chemicals from causing:
- Acute and chronic aquatic toxicity
- Accumulation in the ecosystem
- Habitat and biodiversity loss
- Threats to human health</td><td>Report:
Direct emissions into:
- Air
- Water
Indirect emissions into land</td><td>Report releases into:
- Air
- Water
- Land</td><td>- Protect soil structure and function (incl. ecosystem services)</td><td>Prevent adverse effects to human health and the environment, incl. from toxicological interactions involving multiple chemicals</td></tr>
<tr><td rowspan="3">Ecological entities considered</td><td colspan="2">Listed protected species and natural habitats (ELD: <u>biodiversity</u>; COMAH: <u>terrestrial</u>)</td><td rowspan="3">- Agricultural crops
- Livestock</td><td rowspan="3">- Vegetation
- Natural ecosystems</td><td rowspan="3">Groundwater:
- As a resource
- Ecosystems
- Dependent ecosystems
- River basin management plans limited to WFD</td><td rowspan="3">Aquatic biota</td><td rowspan="3">None specified</td><td rowspan="3">None specified</td><td rowspan="3">Soil associated ecosystem services</td><td rowspan="3">Humans: Arctic indigenous communities, pregnant women.
Arctic eco-systems: incl. top predators (due to biomagnification)</td></tr>
<tr><td colspan="2">WFD (Annex V) listed biological quality elements</td></tr>
<tr><td><u>Land</u>: resources and services unspecified</td><td>Agricultural habitats</td></tr>
</table>

<table>
<tr><th rowspan="2"></th><th colspan="9">European Legislation</th><th>International Convention</th></tr>
<tr><th>Environmental Liability Directive (ELD) (2004/35/CE)</th><th>Control of Major Accident Hazard Directive (COMAH) (2012/18/EU)</th><th>Sewage Sludge Application Directive (SSAD) (86/278/EEC)</th><th>Air Quality Framework Directive (AQFD) (2008/50/EC)</th><th>Groundwater Protection Directive (GPD) (2006/118/EC)</th><th>Environmental Quality Standards Directive (EQSD) (2008/105/EC)</th><th>Industrial Emissions Directive (IED) (2010/75/EU)</th><th>European Pollutant Release and Transfer Register (E-PRTR) Regulation (EC 166/2006)</th><th>Thematic Soil Strategy (TSS) COM/2006/0231 COM/2006/0232</th><th>Stockholm Convention (SC, 2001)</th></tr>
<tr><td rowspan="2">Assessment criteria (critical attributes) identified for ecological entities</td><td rowspan="2">Biodiversity
Long-term maintenance of:
- Distribution/area
- Structure
- Habitat function
- Survival
- Species density
Water: See WFD Annex V
Land: See ELD Annex 1</td><td rowspan="2">- (See ELD column)
- See domestic guidance within Member States (MSs)</td><td colspan="3">Chemical concentrations and loads in; soil (SSAD), air (AQFD), groundwater (GPD)</td><td rowspan="2">Chemical criteria in:
- Water (primarily)
- Sediment
- Biota</td><td rowspan="2">- ELVs for water and air
- Baselines for monitoring
- Soil and
- Groundwater contamination</td><td rowspan="2">Chemical (loads) for releases to:
- Air
- Water
- Land</td><td rowspan="2">Long-term maintenance of soil:
- Structure
- Function</td><td rowspan="2">- Bioconcentration / accumulation factors (measured or predicted using Log K_{ow})
- Reproductive health</td></tr>
<tr><td colspan="2"></td><td>Groundwater quantity criteria</td></tr>
<tr><td rowspan="2">Assessment indicators measured / monitored</td><td colspan="2" rowspan="2">- Number of individuals
- Density / area
- Roles of natural resources affected
- Species / habitat rarity (local to regional level)
- Population dynamics
- Human health impacts</td><td colspan="2" rowspan="2">Chemicals only (see Annexes 1A, 1B and 1C [SSAD]; Annexes II & XIII [AQFD])</td><td colspan="2">Chemicals and conductivity in groundwater (GPD), water (EQSD) (see Annexes I & II)</td><td colspan="2" rowspan="2">Chemicals only (polluting substances listed in Annex II)</td><td rowspan="2">Indicators likely linked to main threats</td><td rowspan="2">- Presence, levels and trends in humans and environment
- Transport, fate transformation
- Effects on human health and environment (including reproductive health)</td></tr>
<tr><td></td><td>- Chemicals in biota (see Article 3)</td></tr>
<tr><td>Indicator targets / thresholds for acceptable vs unacceptable effects or status</td><td>Effects assessed against ‘baseline condition’, considering:
- ‘Favourable Condition Status’ for habitats (HD Article 1)
- Natural species and habitat fluctuations
- Recovery potential</td><td>- Significant damage defined in ELD Annex 1
- Area and duration of major accidents (COMAH Annex VI)</td><td colspan="2">Chemicals only (see Annexes 1A, 1B and 1C [SSAD]; Annexes II & XIII [AQFD])</td><td>Chemicals and conductivity in groundwater (see Annexes I & II)</td><td>EQSs represent:
- Annual averages for long-term exposure protection
- Maximum allowable concentrations for short-term exposure protection</td><td colspan="2">Chemicals only (see ELVs in Annexes V-VIII [IED]; Annex II [E-PRTR])</td><td>Thresholds and scope still under development</td><td>- Persistence threshold (half-life in months) water 2, soil 6, sediment
- Bioconcentration / accumulation factor 5000 (or Log K_{ow} 5)</td></tr>
</table>

Table C1.3: Legislation and conventions also affecting chemicals and requiring prospective ERA and/or retrospective environmental surveillance, monitoring and impact assessment

	European Legislation				**International Conventions**			
	Marine Strategy Framework Directive (MSFD) (2008/56/EC)	**Habitats Directive (HD) (92/43/EEC)**	**Birds Directive (BD) (79/409/EEC)**	**Water Framework Directive (WFD) (2000/60/EC)**	**Convention on Biological Diversity (CBD) (UN, 1992a)**	**OSPAR Convention (OSPAR, 1992)**	**Bonn Convention on Migratory Species (CMS, 1979)**	**Convention on the Law of the Sea (UNCLOS, 1982)**
High-level protection goals	Achieve Good Environmental Status (GES) in marine waters by 2020 (biodiversity descriptors: 1, 2, 4, 6)	Maintain / restore natural habitats and species of Community interest to 'Favourable Conservation Status' (FCS) Establish Natura 2000 Special Areas of Conservation network	Conserve, protect and manage all wild birds species, and set rules for their exploitation Establish Special Protection Areas (SPAs)	Protect, enhance and restore all surface water bodies Achieve good surface water status by 2015 and 2027	Conserve biological diversity, ensure sustainable use and fair and equitable sharing of benefits of genetic resources	Prevent and eliminate pollution, protect the OSPAR maritime area against adverse effects of human activities	Conserve migratory species and their habitats Agreements between Range States to conserve species listed in Appendix II	Provide law and order in the world's oceans and seas Protect and preserve the marine environment and exploit resources in accordance with this Prevent, reduce and control marine pollution
Chemical protection goals (focusing on chemical contamination in biota / food chains)	Action at source to avoid pollution Define safe levels for human consumption Prevent and reduce marine environment inputs	Not defined	Not defined	Achieve good chemical status by 2015 and 2027 (see Sections 1.2 and 2.3)	Not defined	Reduce environmental inputs and concentrations of Priority Hazardous Substances. Prevent pollution by continuous reduction of discharges.	Not defined	Prevent, reduce and control marine pollution
Ecological protection goals	Prevent significant impacts / risks to marine biodiversity, ecosystems, human health or legitimate uses of the sea	See HD FCS assessment criteria targets (see Annex E and EU Guidance [EC, 2011c])	Maintain species population levels at ecological, scientific, cultural and economic requirements	Achieve good ecological status by 2015 and 2027 (see Annex V and Section 1.2)	2011-2020 Strategic Plan: 20 'Aichi' Biodiversity Targets for 2015 or 2020 Contracting Parties may set individual targets	Regional Assessment defines % targets for criteria used in the QSR regional assessment process (see Tables A2.1 and A3.1 of OSPAR [2009])	Long-term species viability No range reduction Sufficient habitat for long-term population maintenance	Not defined

	European Legislation				International Conventions			
	Marine Strategy Framework Directive (MSFD) (2008/56/EC)	**Habitats Directive (HD) (92/43/EEC)**	**Birds Directive (BD) (79/409/EEC)**	**Water Framework Directive (WFD) (2000/60/EC)**	**Convention on Biological Diversity (CBD) (UN, 1992a)**	**OSPAR Convention (OSPAR, 1992)**	**Bonn Convention on Migratory Species (CMS, 1979)**	**Convention on the Law of the Sea (UNCLOS, 1982)**
Ecological status classes	GES Sub-GES	Favourable Unfavourable (inadequate/bad)	Not defined	*Ecological status*: High, Good, Moderate, Poor, Bad	Not defined	Good Moderate Poor	Not defined	Not defined
Ecological entities considered	All EU marine biodiversity (see Annex III, Table 1)	HD listed Natural habitats and species (see Annexes I, II, IV & V)	All naturally occurring wild birds species (see Annexes I, II & III)	Biological quality elements (see Section 1.2.1)	All biological diversity	All North-East Atlantic maritime habitats and species	CMS listed migratory species (see Appendix I and II)	Vulnerable, rare or declining marine habitats and species (globally) Migratory species
Assessment criteria (critical attributes) identified for ecological entities	See descriptors: 1, 2, 4 and 6 of 2010/477/EU	*Habitat*: - Range, area, structure and function *Species*: - Range, habitat, population size and condition	- Population size and trends - Breeding distribution and range size / trends - Main pressures and threats - SPA coverage and conservation	Biological quality elements (see Section 1.1)	2011-2020 Strategic Plan describes five strategic goals	*Habitat*: - Range, extent, condition *Species*: - Range, population size and condition	Population dynamics and viability *Species*: - Range, habitat, distribution and abundance	Not defined
Assessment indicators measured / monitored	See commission decision (2010/477/EU) Common indicators under discussion at OSPAR level	No EU-level indicators UK: Common Standards Monitoring for protected sites and FCS indicators.	Not defined	Indicators determined via intercalibration across MSs (see WFD-TAG UK classification tools [WFD-TAG, 2014])	Indicators under development likely to include: - Breeding bird populations - Priority species and habitats - Protected areas - Sustainable fisheries - Invasive species - Marine ecosystem integrity	Seal population trends Harbour porpoise by-catch Fisheries spawning stock biomass and size Eutrophication Imposex Oiled sea birds Hazardous substance levels in seabird eggs Plastic particle levels in fulmar stomachs	Not defined	Not defined

	European Legislation				International Conventions			
	Marine Strategy Framework Directive (MSFD) (2008/56/EC)	**Habitats Directive (HD) (92/43/EEC)**	**Birds Directive (BD) (79/409/EEC)**	**Water Framework Directive (WFD) (2000/60/EC)**	**Convention on Biological Diversity (CBD) (UN, 1992a)**	**OSPAR Convention (OSPAR, 1992)**	**Bonn Convention on Migratory Species (CMS, 1979)**	**Convention on the Law of the Sea (UNCLOS, 1982)**
Indicator targets / thresholds for acceptable vs unacceptable effects or status	Not defined	Not defined	Not defined	Class thresholds determined via inter-calibration across MSs within Geographic Inter-calibration Groups	Not defined	Each indicator (Ecological Quality Objective - EcoQO) has an associated target value for the North Sea Region only	Not defined	Not defined
Geographic scope	Member State waters from baseline (excluding transitional waters) to Exclusive Economic Zone (EEZ), including extended continental shelf and WFD coastal waters	Designated habitats within MSs. Marine waters out to EEZs, including continental shelf, and WFD transitional and coastal waters	EU MS territory	All EU MS territory water bodies in river basins, including transitional and coastal waters one nautical mile from baseline	Within national jurisdiction limits of 193 Contracting Parties globally	North-East Atlantic maritime area	Any State that exercises jurisdiction over any part of the range of that migratory species	Territorial seas of coastal states out to 12 nautical miles from the baseline of 157 Contracting Parties
Baseline conditions	*OSPAR Guidance* Conditions in line with prevailing physiographic, geographic and climatic conditions	*EC Guidance* Favourable reference values Range and area viability (habitats), or range and population size (species) Can use a 1994 baseline (UK) or historical data, where appropriate	Agreed baseline of 1979 for all MSs	*Directive text* Conditions that are not/minimally anthropogenically impacted (i.e. conditions specified for each water body / habitat type)	Varied baselines used and must be articulated for several targets within the 2011-2020 Strategic Plan for Biodiversity	EcoQOs use varied baselines Threatened or declining habitats / species use historic, recent or current baseline QSR assessment uses former natural conditions as baseline	Not defined within CMS. UK has used HD baselines for species also listed on that Directive	Not defined

APPENDIX D: COMMENTS ON POTENTIAL IMPACTS OF CASE STUDY CHEMICALS ON SINGLE ESS

Case study 1: Oil refinery discharge

The potential impacts shown in Table 4.1 could only be manifested if appropriate controls are not in place. Oil refineries are complex and may therefore have more than one discharge. The main waste stream(s) where petroleum products may enter the discharge would be related to the main process area and, even if diffuser systems are used, this discharge would be considered as a point source entry into an estuary. Once discharged the refinery effluents (and components thereof) will undergo redistribution and dilution into many aquatic habitats. For example, there can be distribution via tidal flow into freshwater lotic environments, freshwater and coastal wetlands and especially into estuarine and marine coastal waters and beyond. Site specific circumstances such as geography, hydrography and complexity of the refinery will influence both the types of environments and degree of impacts of refinery effluent discharges. The potential for impacts to occur is mitigated by prospective controls based on permissible levels of contaminants as defined by EU and local regulations. For example, in the EU refinery effluent discharges come under the auspices of the Industrial Emissions Directive (IED) (2010/75/EU). The legislative framework for regulating emissions from industrial sites to the air, water and soil in which Best Available Techniques (BATs) are applied with Associated Emission Levels (BAT-AELs). There are specific requirements for a range of sectors and controls and BAT-AELs for a range of contaminants present in refinery effluents are stipulated in the refinery best available techniques reference document (Refinery BREF).

Food: Potential contamination affecting food quality of fish / shellfish stocks or aquaculture in estuarine coastal areas. Dilution will reduce potential impacts on shelf areas. This can be a concern because of the perception that petroleum hydrocarbons can affect the taste (taint) fish and shellfish.

Fibre and fuel: Potential impacts on wetlands supporting natural fibre and fuel plants. Although hydrocarbons can adversely affect plants and wetlands major (i.e. catastrophic) impacts are usually associated with oil spills and there have been controls on ‘free oil’ being discharged for many years.

Genetic resources: Covers whole biota – biodiversity.

Biochemical / natural medicines Products (derivatives) from the biota used as medicines etc., rather than the potential, which differentiates it from genetic resources.

Ornamental resources (flowers, aquarium plants and fish etc.): Potential for direct impacts on aquatic plants, fish, invertebrates (molluscs, corals, crustacea).

Freshwater: Limited potential for contamination of freshwater bodies and associated wetlands.

Pollination: Limited, indirect effects on pollinating insects that may breed along coastal and wetland areas.

Pest and disease regulation: Potential to effect organisms responsible for pest and disease regulation, similar to genetic resources.

Climate regulation: Potential for direct effects on marine algae and invertebrates (e.g. corals) acting as CO2 sink.

Air quality regulation: Potential for effects on primary producers.

Water regulation: Potential impact on reef builders.

Erosion regulation: Direct effects on aquatic plants and algae and on marine algae and marsh grass which stabilise sediments; effects on marine molluscs and corals that build reefs.

Natural hazard regulation: Similar to 'erosion regulation'; all SPUs involved in maintenance of ecosystem resilience towards stressors like storms, waves, floods etc.

Invasion resistance: Effects on plants and algae and on aquatic invertebrates and vertebrates which form stable communities in which alien species cannot easily establish ('weakening'), zebra mussels, lamprey, snails, etc.

Water purification / soil remediation / waste treatment: May impact semi-aquatic (wetland, marginal) and aquatic plants in freshwater ecosystems and transitional waters, the latter eliminating pollutants from water and increasing oxygen concentrations which improves overall biological activity.

Cultural Services as a whole area this is difficult to define for refinery effluents. The presence of a large manufacturing site is likely to have a negative impact on how these are evaluated. There are often negative perceptions because even low levels of oil contamination are visible (oil sheens) and in many areas natural hydrocarbon sheens (e.g. originating from vegetation) can be mistaken for those originating from a refinery. Odour of any discharges (more likely from the manufacturing sites themselves rather than discharges) can enhance negative perceptions.

Spiritual and religious values: Perceptions see above.

Education and inspiration: Potential effects on aquatic organisms and possibly birds If discharges are properly controlled should not occur. There are many sites operating and discharging without any adverse impacts on wetlands, RAMSAR sites etc.

Recreation and ecotourism: Direct and indirect effects on various organisms perceived as having recreational value (hunting, fishing, bird and other wildlife watching). Could potentially occur in the event of poorly controlled discharges but mainly likely to be perception.

Cultural diversity and heritage: Perceptions.

Aesthetic values: Similar to education, inspiration and recreation in that visible loss of particular species, will have impact. Mainly likely to be perception but odour could influence aesthetic value.

Sense of place:

Primary production and photosynthesis: Direct effects on macrophytes and algae. For refinery effluents this can be both a positive and negative impact. Refinery effluents can provide a source of nutrients (nitrogen and phosphorous) and food for bacteria which can help stimulate productivity.

Soil formation and retention: n/a

Nutrient cycling: Effects on micro-organisms, plants and algae involved in nutrient cycling.

Case study 2: Oil dispersants

Food: Direct and indirect effects on palatable organisms in aquatic ecosystems near shore and off shore, magnitude of effects expected to decrease with distance from source / application due to depth, dispersion (dilution and wave action).

Fibre and fuel: Limited impact on biological fibre and fuel.

Genetic resources: Direct and indirect effects on organisms in aquatic ecosystems, magnitude of effects expected to decrease with distance from source / application due to depth, dilution, and dispersion. Lower potential impact on mobile organisms. Potential impact on those organisms in the near surface zone, which are typically those organisms that have an ability to reproduce effectively.

Biochemical / natural medicines: Potential for temporary effects on marine organisms used in biochemistry and as medicinal research (fish, algae, corals).

Ornamental resources: Potential for temporary effects on aquatic invertebrates used for ornamental purposes (e.g. corals, molluscs, aquarium fish).

Fresh water: Direct potential if applied in freshwater river scenario (i.e. drinking water), otherwise limited impact.

Pollination: Negligible impact

Pest and disease regulation: Potential for temporary exposure to marine species resulting in possible short term lowering of immune system (i.e. added stress).

Climate regulation: Potential for direct effects on marine algae and invertebrates (e.g. corals) acting as CO2 sink.

Air quality regulation: Potential for localised temporary impacts to air quality.

Water regulation: Limited potential for water regulation effects.

Erosion regulation: Limited direct impact on soil erosion may have impact on vegetation which in turn stabilises soil / sediment along coastal areas.

Natural hazard regulation: Potential impact on coastal vegetation and coral reefs which provide protection from natural hazards such as storms, waves and tidal impacts.

Water purification / soil remediation / waste treatment: May impact semi-aquatic (wetland, marginal) and aquatic plants in freshwater ecosystems and transitional waters.

Spiritual and religious values: Potential for direct effects on wetlands (coastal marshes) and aquatic plants; potential for direct and indirect effects on water birds and marine mammals valued in different religion expression.

Education and inspiration (education includes research): Potential for direct effects on aquatic organisms in various ecosystems, as well as coastal landscape dynamics.

Recreation and ecotourism: Potential for temporary effects with ability to access resources during application period, short-term population fluctuations, indirect effects on presumption of long term injury and stigma to region.

Cultural diversity and heritage: Potential for temporary indirect effect to 'way of life'.

Aesthetic values: Similar to temporary visual effects to coastal environment (i.e. beaches, marshes).

Sense of place: cf. aesthetic values, even open water has a sense of place 'aquatic wilderness' for sailing.

Primary production: Potential for temporary direct and localised effects on plankton, marine algae and coastal plants communities.

Soil formation and retention: Potential for direct effect on coast marsh grass which in turn may affect soil and sediment retention.

Nutrient cycling: Temporary direct effects on plankton and algae (wetlands, margins) which transform nutrients.

Case study 3: Down the drain chemicals

Two principal emission routes: 1) land application of sewage sludge and aqueous sewage effluent in order to fertilise and irrigate agricultural crops and grassland (pasture for grazing by livestock and wild game); 2) discharge of sewage effluent[2] to surface waters (lotic and lentic freshwaters, inlets, transitional and coastal waters) are considered when assessing the likely exposure and impact of down the drain chemicals on habitats and ecosystem services:

Food: 1) Potential negative impact of chemical contamination contravening food quality standards or safe intake limits for humans. There may be occasional direct negative impacts on crop growth although such impacts would probably be rapidly identified. 2) Aqueous discharges to surface waters can directly affect surface water bodies (inland to coastal) potentially contaminating edible fish and shellfish stocks and/or

[2] The majority of aqueous sewage effluents are treated before discharge in the EU, but this may not necessarily be the case in other countries / regions.

impacting aquaculture yields. Despite higher dilution in coastal areas, local fisheries may be impacted via contamination of nursery grounds in inlets and transitional waters. Discharges may disperse causing less severe impacts on adjacent wetlands and shelf sea areas.

Fibre and fuel: 1) Fibre and fuel product quality and yield may be reduced. 2) Aqueous discharges impact on surface water bodies and, to a lesser extent, associated wetlands potentially reducing the quality and yield of natural fibre and fuel plants (e.g. reeds, willow, peat, macroalgae / alginates). *NB: quality standards for chemical contaminants in fibre and fuel products are less stringent compared to food products therefore exposure related impacts are perceived to be less.*

Genetic resources[3]**:** 1) Occasional direct impacts on species representing genetic resources, although such impacts would likely be rapidly identified. 2) Aqueous discharges impact upon plant and animal species representing genetic resources and being sensitive to chemical contaminants.

Biochemical / natural medicines (proteins, peptides or other products / derivatives of genetic resources)**:** 1) and 2) Impact risks on these ecosystem services / products are the same as for genetic resources.

Ornamental resources (flowers, aquarium plants and fish etc.)**:** 1) Occasional direct impacts on wild flowers or other decorative plant species (and associated fauna). 2) Aqueous discharges impact on species which are sensitive to chemical contaminants. In each case, tolerant species increase in abundance, but the range of species is likely to decline.

Freshwater: 1) Cropland / grassland exposure to dtdc can impact primary producers, eco-engineers and decomposers involved in filtration and purification of water, which are key for the recharge of aquifers and surface freshwater bodies. Exposure / impact is expected to be moderate due to limited application in terms of land area and season, i.e. irrigation water is applied in the dry season when uptake and transpiration by plants is greatest. 2) Aqueous discharges can impact on freshwater communities (e.g. primary producers, detritivores) involved in the provision of freshwater.

Pollination: 1) Fertilising / irrigation of crop / grassland leads to moderate chemical exposure and direct impact on pollinators. Seasonal application of irrigation water (during the dry, summer season) coincides with plant flowering and pollination periods. However, exposure and impact is expected to be moderate due to limited application in terms of land area. Another potential impact of toxicants in sewage / sewage sludge is on plant reproductive parts (e.g. reduced flowering) which may indirectly affect pollinators. 2) Aqueous discharges can impact indirectly upon adjacent wetlands and associated pollinators, but again exposure and impact are expected to be moderate only.

Pest and disease regulation: 1) Fertilising / irrigation of crop / grassland potentially leads to major chemical exposure and impact on saprophytic fungi and predatory insects. This ecosystem service is linked very closely with genetic diversity and food web / ecosystem complexity. 2) Aqueous discharges containing down the drain chemicals can impact upon predatory fish feeding on pests and vectors for diseases.

Climate regulation: 1) Fertilising / irrigation of crop / grassland is expected to lead to negligible impact on climate regulation due to CO_2 consumption by photosynthesising plants, since application is limited in terms

[3] Genes and genetic information for example used for animal and plant breeding and biotechnology (UN, 1992a; Millennium Ecosystem Assessment, 2005a).

of land area and impacts will be counterbalanced by increased crop growth and productivity due to nutrient additions. 2) Aqueous discharges containing down the drain chemicals can disperse impacting more widely and significantly upon aquatic plants (microalgae and macrophytes), which contribute to climate regulation.

Air quality regulation: 1) Fertilising / irrigation of crop / grassland is expected to lead to negligible impact on vegetation acting as a sink for airborne pollutants (e.g. dust). 2) Aqueous discharges containing down the drain chemicals can disperse impacting upon aquatic plants (micro-, macroalgae and macrophytes), which contribute to air quality regulation.

Water regulation: 1) Fertilising / irrigation of crop / grassland with sewage sludge / sewage water is likely to impact soil organisms (e.g. earthworms, voles) which ensure favourable physical soil conditions (infiltration rates, water holding capacity). 2) Aqueous discharges containing down the drain chemicals may negatively affect semi-aquatic and aquatic plants in freshwater ecosystems which retard water flow. Effluents reaching marine habitats may impact reef builders which protect coastal areas from flooding from extreme tidal flows.

Erosion regulation: cf. Natural hazard regulation.

Natural hazard regulation: 1) Fertilising / irrigation of crop / grassland is likely to have negligible negative impacts on plant growth and coverage, the latter reducing erosion and denudation of fertile soils. 2) Aqueous discharges containing down the drain chemicals may negatively affect semi-aquatic (marginal, pioneer, saltmarsh) and aquatic plants which stabilise soils and sediments. In marine habitats, effluents may impact reef builders and mussel banks which stabilise coastlines and offer protection from wave action and storm surges.

Water purification / soil remediation / waste treatment: 1) Fertilising / irrigation of crop / grassland could negatively affect soil micro-organisms involved in water purification. 2) Aqueous discharges containing down the drain chemicals may impact semi-aquatic (wetland, marginal) and aquatic plants in freshwater ecosystems and transitional waters, capable of removing pollutants from water and increasing oxygen concentrations, which improves overall biological activity.

Spiritual and religious values: 1) Occasional direct impacts on wild flowers or other decorative plant species (and associated fauna). 2) Aqueous discharges may impact organisms of different trophic levels in wetlands, freshwater ecosystems and transitional waters. Mainly conspicuous and attractive organisms are expected to provide this service.

Education and inspiration: 1) Occasional direct impacts on wild flowers or other decorative and fascinating plant species (and associated fauna). 2) Aqueous discharges may impact organisms of different trophic levels in wetlands, freshwater ecosystems and transitional waters. Education and inspiration will mainly be provided by conspicuous and attractive organisms, e.g. wetland and marginal flowering plants, birds in marshland and corals and fish in reefs.

Recreation and ecotourism: In Europe, ecotourism may be impacted to a minor extent because sewage sludge / irrigation water is unlikely to be applied in landscapes managed for their conservation value, although lotic or lentic water bodies in such areas could be exposed via wastewater discharges. 1) Direct and indirect effects on various organisms perceived as having recreational value (painting, hunting, walking, bird watching). 2) Effects on recreational fishing, e.g. contaminated fish, reduced fish population sizes. Reduced water quality, affecting recreational swimming.

Cultural diversity and heritage: 1) Occasional direct minor impacts on wild flowers or other decorative plant species (and associated fauna), whilst major effects overtly impacting on the appearance of a landscape are expected to be rare. 2) Aqueous discharges may impact organisms of different trophic levels in wetlands, freshwater ecosystems and transitional waters. Cultural diversity and heritage will mainly be provided by conspicuous and attractive organisms, e.g. wetland and marginal flowering plants, birds in marshland and corals and fish in reefs.

Aesthetic values: Similar to cultural diversity, i.e. only major effects that really change the appearance of a landscape are expected to play a role and these are expected to be rare. 1) Direct effects on cropland and grassland plants. 2) Direct effects on aquatic and marginal plants.

Sense of place: cf. Aesthetic values.

Primary production: 1) Direct effects on plants, that produce biological material used in ecosystem functioning and maintenance in cropland and grassland. 2) Direct effects on macrophytes, freshwater and marine algae and blue-green algae.

Soil formation and retention: 1) Effects on cropland and grassland decomposers and eco-engineers such as invertebrates (e.g. earthworms) and vertebrates (e.g. moles); effects on terrestrial plants which retain soil via physical mechanisms, e.g. root structure. 2) Effects on decomposers and eco-engineers in semi-terrestrial habitats (e.g. floodplains, margins of rivers and lakes); contact to contaminated water either directly (flooding) or via high groundwater table.

Nutrient cycling: 1) Direct effects on cropland, grassland decomposers (soil microbes, earthworms, gastropod snails) that directly or indirectly increase availability of nutrients for growth. 2) Equivalent effects on aquatic taxa, e.g. micro-organisms, algae, macro-invertebrates, molluscs.nutrients

Case study 4: POPs

Whilst exposure across the environment can be considered to be similar, the same cannot be said when it comes to human exposure (it is assumed that humans will not eat food (SPU) from urban environments). Additionally, urban environments are not seen as pristine environments. This explains our rationale to allocate a "no impact" level of concern to the urban environment for food and also the cultural services such as sense of place.

Shrubs, heathland and tundra.

Cropland has been removed as croplands are of little relevance for Arctic regions.

Food: In the Arctic environment, food web structure is often characterised by short food chains with highly specialised top predators at the highest trophic levels. Thus, top predators representing high trophic levels may be at risk from elevated levels of POPs in their prey. Many biological factors favour the accumulation of POPs in the Arctic environment. Usually, Arctic fauna have slower growth rates and store more lipids than those at lower latitude. This feature favours higher concentration of POPs and therefore, food is expected to be the most impacted provisioning service.

Spiritual and religious values: Concern for contamination of wildlife present in a range of Arctic habitats where the pristine status of the environment may be expected.

Education and inspiration: POPs may accumulate in organisms of different trophic levels in wetlands, freshwater ecosystems, transitional waters and marine habitats. Education and inspiration may be provided by conspicuous and attractive organisms, e.g. marine and terrestrial mammals, birds and fish.

Recreation and ecotourism: Concern largely associated with potential for reduced abundance of higher vertebrates (birds and mammals) and some fish.

Cultural diversity and heritage: Concern for contamination of wildlife present in a range of Arctic habitats where the pristine status of the environment may be expected.

Aesthetic values: Might potentially be affected by bioaccumulation as the status of the pristine environment has been influenced.

Sense of place: Might potentially be affected by bioaccumulation as the status of the pristine environment has been influenced.

In general cultural services are expected to be at risk of being highly impacted by the presence of POPs. There is growing worldwide public awareness due to the fact that POPs can be detected at relatively high concentrations in an environment considered as pristine. In addition the bioaccumulative properties of POPs make secondary consumer species such as polar bears, cetaceans and seals particularly vulnerable. These concerns have led to international initiatives such as Stockholm convention, to prohibit the dispersion of POPs. In this context, cultural services are significantly impacted by POPs.

Other ecosystem services are expected to be marginally impacted by POPs, if at all.

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