Exploring an ecosystem services framework for setting protection goals and the needs of chemical risk assessment: outcomes from 4 chemical sector case studies

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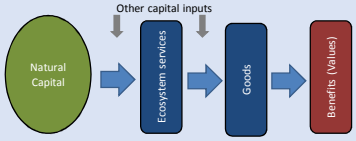
Introduction

- Environmental protection goals tend to be defined in general terms and are inconsistently applied across regions, leading to a lack of clarity on how to achieve such protection.
- There is a growing interest in using an ecosystem services approach to help define and communicate protection goals and this will inevitably influence chemical regulation.
- In September 2013 ECETOC initiated a Task Force to investigate a new risk assessment paradigm, developed by EFSA, based on a structured framework to identify ecosystem services that might be affected by (agro)chemicals [1], set protection goals and assess relevant risk assessment schemes.
- Using a series of case studies, including the example of down-the-drain chemicals presented, the intention was to develop the framework so that it is applicable to the wider chemical industry.
- We did not consider the need for valuation of ES in this work.

What are ecosystem services (ES)?



- Ecosystem Services are the benefits people get from nature. They are the flows from natural capital stocks [2]. Natural Capital includes ecosystems, species, freshwater, land, minerals, the air and oceans, as well as natural processes and functions [3].

5-step Ecosystem Service Approach

1. A habitat x ES matrix was constructed using published habitat and ES typologies [4-6]
2. Likely exposure and published information [7-10] was used to assign importance rankings to each habitat x ES combination (Table 1)
3. For each case study, exposure and effects information was used to rank potential impact for each habitat x ES combination and identify potentially impacted service providing units, SPU, (Table 2)
4. The importance x impact matrix (Table 3) was used to identify ES of high, medium, low & negligible concern for each habitat type (Table 4)
5. For each habitat prioritised in Step 4, specific protection goals (SPGs) were defined for each ES of high and medium concern (Table 5)

Case studies

- **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 waste water treatment/disposal infrastructure.
- **Oil refinery:** Exposure of aquatic habitats, including wetlands to the chemicals present in waste water from a single refinery in an estuarine location.
- **Oil dispersants:** Exposure from the use of dispersants in ocean, coastal and estuarine environments, not including the impact of spilled oil.
- **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.

Conclusions and Development Needs

In principle, the EFSA framework can be applied to a broad range of chemical exposure scenarios. With modifications, clarity on terminology/definitions and further development, the framework could provide a methodical approach to the identification and prioritisation of ecosystems and services which are most at risk. Prioritised habitats and service providing units, SPUs, could form the focus for subsequent risk assessment.

Development needs:

- a comprehensive compilation of habitat types indicating their importance for provision of services to help prioritise habitats at risk from exposure to chemicals
- Scientific, and ultimately policy, guidance on deriving specific protection goals from consideration of ecological entities, their attributes and the scale of impact that is considered acceptable
- methods and models to determine the magnitude of impacts of chemicals on SPUs
- More ecological knowledge is needed to define the acceptable magnitudes of impacts on sustainable delivery/production of ESs

References

1. EFSA (2010) Scientific Opinion on the development of specific protection goal options for environmental risk assessment of pesticides, in particular in relation to the revision of the Guidance Documents on Aquatic and Terrestrial Ecotoxicology (SANCO/3268/2001 and SANCO/10329/2002). *EFSA Journal*, **8(10)**:1821; 2.Costanza. R et al. (1997) The value of the world's ecosystem services and natural capital. *Nature*, **387**, 253-260; 3.Natural Capital Committee (2014) *Towards a Framework for Defining and Measuring Changes in Natural Capital*. Working Paper 1 http://www.naturalcapitalcommittee.org/working-papers.html, 4.European Commission (2013) *Mapping and Assessment of Ecosystems and their Services*. Brussels, 5. MEA 2005a Ecosystems and Human Well-being: Synthesis. Island Press, Washington DC., 6. MEA 2005b Ecosystems and Human Well-being: Biodiversity Synthesis. World Resources Institute, Washington DC., 7. Harrison PA et al. (2010) Identifying and prioritising services in European terrestrial and freshwater ecosystems. *Biodiversity and Conservation*, **19**, 2791–2821, 8. NEA (2011) *The UK National Ecosystem Assessment: Synthesis of the Key Findings*. UNEP-WCMC, Cambridge, 9. Young-Haines, R & Potschin, M (2008) England's Terrestrial Ecosystem Services and the Rationale for an Ecosystem Approach. Defra Project NR0107 , 10. Vandewalle, M; et al. (2008) Review paper on concepts of dynamic ecosystems and their services. http://www.rubicode.net/rubicode/RUBICODE_ES_Concepts_Summary.pdf

Application of framework

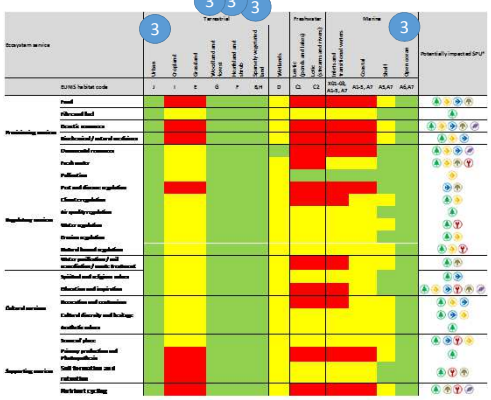
Table 1: ES x habitat matrix

Ecosystem service		Terrestrial: Urban	Cropland	Grassland	Woodland and forest	Heathland and shrub	Sparsely vegetated land	Wetlands	Freshwater: Rivers and lakes	Marine: Inland and transitional waters	Coastal	Shelf	Open ocean
EUNIS habitat code		J	I	E	G	F	B, H	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	++	+++	++	++	++	?	+++	++	++	+	+	+

Key - Relative importance for delivering ES: + small ++ intermediate +++ large ? not considered

Exposure scenario of chemicals

Table 2: Potentially impacted ES



Potential impact: severe moderate negligible

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

Table 3: Importance x impact matrix

Potential impact	Importance of Ecosystem Service: Small (+)	Intermediate (++)	Large (+++)
Low (green)	NEGLIGIBLE CONCERN	NEGLIGIBLE CONCERN	LOW CONCERN
Medium (amber)	NEGLIGIBLE CONCERN	LOW CONCERN	MEDIUM CONCERN
High (red)	LOW CONCERN	MEDIUM CONCERN	HIGH CONCERN

Table 4: ES of concern

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

Table 5: Illustration of possible SPGs: Example - provision of food from aquatic habitats

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)
Freshwater (lakes and rivers)	Secondary Consumers (SC) Game fish	Population / Metapopulation	Contaminant load	Tolerable intake limit for secondary consumers	Waterbody (<1km) to watershed (≥1km)	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	Waterbody (<1km) to watershed (≥1km)	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 Producers (PP) Saltmarsh plants, macroalgae	Population / Metapopulation	Contaminant load	Tolerable intake limit for primary consumers	Waterbody (<1km) to watershed (≥1km)	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	Waterbody (<1km) to watershed (≥1km)	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)

BPR: Biocidal Products Regulation; MPHU: Medicinal Products for Human Use Directive; CBD: Convention on Biological Diversity; FSR: Food Standards Regulations; HD: Habitats Directive; BD: Birds Directive; MPHU: Human Medicinal Products Regulations; MSFD: Marine Strategy Framework Directive; PPPR: Plant Protection Products Regulations; MPVU: Veterinary Medicinal Products Regulations; REACH: Regulation, evaluation, authorisation and restriction of chemicals Regulation

Comments

Table 1 General:

- Additional details added – EUNIS codes, proposed level of importance added (replacing "?" - not provided in refs 7-10) where supported by literature
- Only ES from biological resources assessed
- Photosynthesis & primary production combined
- Supporting services considered individually

Specific:

1. Habitat not considered (low exposure in most case studies and insufficient knowledge)
2. Lakes & rivers assessed separately in some case studies, e.g. down the drain chemicals. Level of resolution depends on exposure scenario

Table 2 General:

- Ranking of potential impact based on exposure with additional knowledge of hazard (if available) linked to chemicals in each case study
- Icons summarising potentially impacted SPUs useful in communication
- Listing of key SPUs providing specific ESs from specific habitats speeds up working through the framework

Specific:

3. All low priority potential impacts (completely green columns not considered further)

Table 4 General:

- Provides option to focus on high and medium priorities for risk assessment
- Higher resolution of SPUs required to feed into Table 5

Table 5 General:

- More ecological knowledge required to define magnitude/scale of impact that enables sustainable delivery of ES.
- Attributes for the same SPU depend on SPG
- Complex range of regulatory guidance to consider but lacks detail on SPG