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Keystone, focal and target species in Ecology, Nature Conservation and Risk Assessment, a sometimes confusing matter of definition

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ABSTRACT

Communicating the results of research to policymakers and the general public becomes more and more important. To this end appealing titles, phrases and terms are used. However, when terms such as keystone, focal and target species are not precisely defined, or can be differently interpreted depending on the societal angle of approach, misinterpretation and confusion can result. This paper discusses the various interpretations and definitions of keystone, umbrella and flagship species in ecology, of target species in nature conservation and biocide assessment, of focal species in ecological risk assessment of pesticides and of threatened species in ecological risk assessment. The type of problems arising are described and a number of improvements are suggested, the most important being: phrase terms as neutral and functional as possible, because catchy terms cause confusion. A proper terminology is also part of scientific integrity. Too overdone or pertinent conclusions could even result in official complaints and social implementation.

Key words : *Focal species, Target species, Nature conservation, Risk assessment, Definitions*

Introduction

Communication has become essential in present-day ecology, nature management, and ecological risk assessment. Bringing the outcomes of research, policy and assessments across to the general public ask for clear language and easily understandable terminology. This poses a risk, however, that the use of catchy terms causes misinterpretation, in particular when organisations from different perspectives for policy and different aims for communication use the same term. This is relevant for Ecological Risk Assessment (ERA) which combines ecology and environmental toxicology. Especially in the field of risk assessment of pesticides result these different angles of approach now sometimes in the framing of problems and using terms that emphasize emotional instead of cognitive perspectives and do not reflect the true problem. This paper discusses several terms of which different interpretations may cause confusion and unnecessary debate: keystone, umbrella and flagship species in ecology, target species in nature conservation and biocide assessment, focal species in ecological risk assessment of pesticides, and threatened species in ecological risk assessment. The type of problems arising are shortly described and a number of improvements are suggested.

Keystone Species in Ecology

The term keystone is coined by Paine (1966) who observed that the removal of a top predator in an estuarine ecosystem caused a series of subsequent changes in the food chain feeding that predator. Shortly after there were comments that a keystone species does not need to be a food-related predator. Power *et al.* (1996) defined a keystone species in a more general way as *"a species that has a disproportionately large effect on its natural environment relative to its abundance. Such species are described as playing a critical role in maintaining the structure of an ecological community, affecting many other organisms in an ecosystem, and helping to determine the types and numbers of various other species in the community. A keystone species is a plant or animal that plays a unique and crucial role in the way an ecosystem functions"*. An ecosystem may experience a dramatic shift if a keystone species is removed, even though that species was a small part of the ecosystem by measures of biomass or productivity. Other authors relate keynote species to "*their size or specified activity...(e.g. the sole fruit disperser of many species of a tree*" (Mace *et al*., 2007) or their role as ecological engineers (Jones *et al*., 1994). According to Moore and de Ruiter (2012), the intensity of energy transfer is normative for the importance of a species (group) in food web interactions and for the stability of the interactions between groups and the structure and stability of the system.

The term umbrella species is defined by Krebs (2001) as, "*an indicator species with large area requirements and used in conservation to bring many other species under protection*" ..."*and is used by land managers who have to take decisions in the absence of detailed information*". It is questionable whether the grizzly bear mentioned as an example is a proper one; will protection of the grizzly also protect other species occurring in the same area? Krebs (2001) describes flagship species as, "*popular charismatic species that score as conservation symbols and rallying points for the protection of areas*". There is no clear ecological underpinning of these terms, which is illustrated by the fact that for the panda, mentioned as a clear example of a flagship species, there is in fact only one relation that counts *viz.* the provision of sufficient bamboo forest as a food source.

The term keystone species in conservation biology, alongside flagship and umbrella species as coined terms, undoubtedly improved awareness by policy and the general public. But it (over) simplified the complex and dynamically changing interactions between species groups, given the various interpretations and descriptions of what keystone species are and what their importance is. For umbrella and flagship species this is even more poignant. The operationalization of these terms in an ecologically relevant and quantitative way is needed to prevent misinterpretation and confusion.

Target Species in Nature Conservation and Biocide Assessment

During the turn of the century in the year 2000 a new policy and management system was initiated by Dutch Nature Conservation based on Nature-target types (Bal *et al*., 2001). These target-ecosystems and target species were described as "*particular endangered and deserve special protection and management*". The Netherlands Environmental Data Compendium (2019) formulates:" *Target species use these ecosystems as their living areas and are dependent on it for their permanent and sustainable persistence. As a policy target, the number (percentage) of target species is defined that has to be present on a specific location in order to reach the defined policy goal for that target type*".

In the ECHA guidelines, a target species is the target of a biocide application, i.e. a group of species to be eradicated, irrespective of their ecological function. Useful species like isopods and ants can become targets of biocide treatment (ECHA product type18) when experienced or expected to be a nuisance by the manufacturer or public, irrespective of their ecologically useful function.

Consequently, a species like an ant or a vole could be the target for nature conservation management plans in The Netherlands and at the same time a target for eradication when their numbers were too high. Because the Dutch authorities changed the name target species to "*priority*"species recently, the risk of confusion has minimized, although "*priority*" is still undefined.

Focal Species in Nature Management and Risk Assessment

The term"*focal*" suggests focused on, a species with a special position and meaning, a keystone in ecology or a target in nature conservancy. Lambeck (1997) suggests the term as a multi-species umbrella for nature conservation. He combines it with a schematic procedure to identify focal species, including area, dispersal or resource limitation. But it is also linked to environmental threats as being most sensitive in a changing environment. "*Focal species can be used to identify the appropriate spatial and functional parameters that must be present in an environment if it is to retain the biota that occurs there*" (Coral Reef Information System, 2020).

In the EFSA guidance on birds and mammals (EFSA, 2009) the first tier risk assessment of potential food chain transfer uses a "*generic focal species*". It is a representation (surrogate) of a range of species that could be at risk based on ecological characteristics and with a high food intake of mixed composition. Only a limited number of larger food type groups have been defined. These are considered to be a representative of the types of birds or mammals that occur across Member States.

For a second and third tier assessment, a "*focal species*" is selected. This is a real species that has to be present in the crop in which the assessed pesticide is intended to be used, has to occur in the crop when the pesticide is being applied. This species is representative of all other species of that type in the crop at that time. Because different food chain transfer routes are being assessed there could be selected insectivorous, omnivorous and granivorous focal species per crop application.

So, it represents a feeding group or a food chain link. A footnote of the Guidance Document reads: An '*indicator species' is not a real species but, by virtue of its size and feeding habits, is considered to have higher exposure than (i.e. to be protective of) other species that occur in the particular crop at a particular time. It has a high food intake rate, and consumes one type of food which in turn has high residues on/in it*'. Unfortunately, a proper definition is not always given in the Scientific Opinions of the EFSA-Scientific Committee, but the elaborated Opinions always contain a glossary: "*Focal Species are usually selected based on their ecological relevance, their likely exposure to the potential stressor under field conditions, their susceptibility to the potential stressor and their testability* (Hilbeck *et al.*, 2014; Romeis *et al.*, 2013). Ideally, focal species should have equal or greater sensitivity to the potential stressor than do the species they represent in the ERA and this knowledge of the effects on these species provides reliable predictions about effects on many other species (Raybould *et al*., 2011). The Glossary of the advice on 'Specific protection goals in relation to biodiversity and ecosystem services' (EFSA, 2016) has the same text on Focal Species. Hence, the focal species is selected, based on the ecological relevance, plus exposure to and sensitivity to a pesticide as a potential stressor.

The Glossary of the opinion on "*Recovery*"(EFSA, 2016) reads for Focal species, taxa, process and landscape: "*Those species, taxa, processes and landscapes focused on in ERA. Focal species/taxa are indicative for specific habitats as well as vulnerable to the potential stressor of concern and in this way represent a larger group of other species/taxa to be protected. A focal process is indicative for an essential ecological process vulnerable to the potential stressor of concern. A focal landscape concerns the type of landscape that has to be considered in the environmental scenario in order to allow a realistic worst-case ERA for the focal species/taxa of concern*".

Here focal species also have an indicative value for specific habitats, but what kind of indication is not described. Because "*recovery*" is an important element in the risk assessment procedure, it is defined as "*Ecological recovery is the return of the perturbed ecological endpoint (e.g. species composition, population density) to its normal operating range*". It aims not on a habitat but on the characteristics of a specific species or group of species, specifically on its normal functioning and operating.

This set of descriptions on focal species is related to food chain transfer. This includes the impact of bioaccumulation in a prey species or bioconcentration when transferred through the food chain. It also relates to decreasing food supply, causing indirect adverse impacts on the consumer or predator. When these terms are used with this interpretation within EFSA ERA procedures the chances for misinterpretation are limited and correctable. However, in discussions on the renewal of a particular pesticide this food chain aspect is now interpreted as being representative for impacts on ecosystem structure in general and as such on biodiversity at large!

Threatened and Endangered Species in Nature Conservation and ERA

For the position of endangered species in ERA, the EFSA Scientific Committee has produced an Opinion *viz.*"*Coverage of endangered species in environmental risk assessments at EFSA*"(EFSA, 2016). The Glossary contains no term for 'Endangered' or 'Threatened', but has a section on "What is meant by 'endangered species". The EFSA panel uses the term vulnerable to select species for ERA, it has "*a relatively high sensitivity to a specific stressor, a high chance of exposure and/or risk of indirect effects, plus a poor potential for population recovery*". In section 3 of the Opinion,this is worked out according to the type of threats of red list species, either on a European or global scale, as drafted by the IUCN.

The IUCN (IUCN, 2019) classifies red list species into nine groups, according to the rate of decline, population size, area of geographic distribution, and degree of population and distribution fragmentation. A vulnerable species should at least meet one of these criteria (see table 1 for all class descriptions).

For smaller local scales that do not meet the characteristics of red lists, the EFSA uses a classification by Rabinowitz (1981), based on a wide or narrow geographic distribution, a broad or narrow habitat specificity and a localized large or dispersed small population size.

How to bring the approaches by IUCN (2019) and Rabinowitz (1981), based on population distribution and temporal change, in line with the EFSA SC Opinion on endangered species in environmental risk assessment (EFSA, 2016) which focuses on sensitivity, exposure and recovery potential? Are those species that are sensitive to a specific toxic compound, are (likely) exposed and have a limited recovery potential, by definition to be placed on a red list? And a red list species not necessarily will be 'endangered' according to the EFSA characteristics, as a compound for which that species is sensitive does not need to be present or applied in the places where the species occurs.

What Problems can Arise from Misunderstanding About Terminology

Due to these different approaches different problems arise:

1. A species representative for a feeding group might be rare in one country – and deserves special protection – but occurs in large even pest-like numbers in other countries and will be eradicated. The common vole, for instance, is absent in the UK, a conservation target species in The Netherlands (but with incidentally very high local peaks) and a common species leading to pest outbreaks in Central Europe.
2. Quite some rare species according to nature protection policy have very specific food relations and are not representative for certain feeding groups. Vice versa it is not possible to define a focal species that is representative for that specific food relation. This can only be approached by a species-specific assessment. Examples are various butterfly species that specifically and exclusively feed on one plant species and do occur in and around agricultural areas.
3. In order to show a relation between pesticide application and species numbers decline, spatial patterns of pesticide applications or pesticide contents in surface waters in regional areas are correlated with spatial monitoring data of species numbers (Hallmann *et al.*, 2014). Or pesticide usage figures over a period of time are correlated with the declining numbers of insects in the same (large) area (Schuch *et al.*, 2012; van Klink *et al.*, 2020). Irrespective whether the monitoring grids are comparable, this correlation cannot be confirmed by causal dose-effect research.
4. Testing with rare species is unacceptable from a policy point of view, as testing will diminish their numbers. Examples are ample for invertebrates (butterflies) as well as vertebrates (birds of prey).
5. A rare and sensitive species might be part of the 5% falling outside the 95% protection limit of an SSD-curve and not be protected at all. Stoneflies for instance are sensitive for neonicotinoids (Roessink *et al.*, 2013), and regulations have been adapted and standards lowered so that this species group is protected. Research with related tropical species revealed that these are

Table 1. Description of different classes of species endangerement (IUCN, 2019)

- *Extinct* (EX) – beyond reasonable doubt that the species is no longer extant.
- *Extinct in the wild* (EW) – survives only in captivity, cultivation and/or outside native range, as presumed after exhaustive surveys.
- *Critically endangered* (CR) – in a particularly and extremely critical state.
- *Endangered* (EN) – very high risk of extinction in the wild, meets any of criteria A to E for Endangered.
- *Vulnerable* (VU) – meets one of the 5 red list criteria and thus considered to be at high risk of unnatural (human-caused) extinction without further human intervention.
- *Near threatened* (NT) – close to being at high risk of extinction in the near future.
- *Least concern* (LC) – unlikely to become extinct in the near future.
- *Data deficient* (DD)
- *Not evaluated* (NE)

still more sensitive (Sumon *et al*., 2018). In general, the variability in the tail ends is much higher than in the middle parts of the curve, consequently are the ranges much greater there.

6. Common and useful species groups can become 'nominated' target species, purely on the basis of marketing strategies of the manufacturer of a biocide. Examples are biocides offered for official approval to eradicate isopod and ant species.

Discussion and Further Outreach

Focal species

The term focal species in the EFSA guidance on birds and mammals starts from the presumption that ecosystem effects of pesticides are related by direct effects and by food chain transfer. For the direct effects, a large and diverse array of test species is available. The assessment of food chain transfer is based on feeding patterns (feeding guilds) and primarily exposure oriented. Risk assessment of these feeding groups or guilds will protect all members of these groups and the ecosystem-connections related to it.

In Netherlands Nature Protection policy, it is assumed that protecting the most sensitive species – formerly target species, now priority species - in an ecosystem will improve and ensure the protection of the whole ecosystem of which that species is part. This is not based on dose-effect experiments but because this species is rare, shows considerably declining numbers in The Netherlands or because a majority of the total population occurs in The Netherlands. Temporal or spatial differences in numbers are correlated with temporal or spatial developments in different environmental factors like eutrophication, desiccation, acidification, fragmentation, toxification (including pesticide application). There is, however, no attention for interaction between species like in ecosystems or the transfer of toxic compounds by bioaccumulation and bioconcentration.

When selecting a focal species these aspects have to be taken into consideration more seriously.

Endangered, threatened, vulnerable species

For this type of species, a proper and structural tuning between the various perspectives of this status is even more important.

EFSA-SC in its opinion on endangered species concludes about the status of endangered species from an ecotoxicological perspective: "*Examples show that endangered species can be more vulnerable due to particular characteristics related to exposure, recovery and/or sensitivity*", but the supporting database is very limited. Further they conclude "*In general endangered species are considered more vulnerable in view of general characteristics such as life-history traits and general distribution*" and "*With regard to exposure to potential stressors, no convincing evidence was found indicating that endangered species have in general a higher exposure than other species, with the exception of top predators due to biomagnification*"and *"the SSD examples and the Toxicokinetic/toxicodynamic considerations do not provide conclusive evidence that endangered species are per se more sensitive than other"*.

The IUCN (2019) mentions in his red lists a series of 11 possible threats to species, two being relevant for ecotoxicological assessment: agriculture/aquaculture and pollution. Missing, is a precise analysis of what activities or compounds are responsible or derive further study.

Comparative analyses of decline in insect numbers like Hallmann *et al.* (2014) and van Klink *et al*. (2020) mention various causes. Hallmann *et al.* (2014) suggest a relation between neonicotinoids and insectivorous birds, although their study area is an urbanised glasshouse area where these type of birds are not common. van Klink *et al.* (2020) compared a large series of very diverse studies and concluded in a more nuanced way that changes in land-use patterns could be a main driving force. Therefore, the rareness of a species has to be further specified: is it because it occurs at the border of its distribution area and as such is sensitive for all sorts of negative environmental impacts or because there is a specific threat in part of that area. Only then specific cause-effect studies can be designed. IUCN could help to select a small set of species that are rare and representative for the group of species threatened by agricultural or horticultural pollution to check whether there is a difference in sensitivity with the standard used test species.

Ecotoxicological Species Sensitivity Distribution analysis starts from the assumption that by protecting the majority of all species (95% confidence interval all species will be protected). The 5% of the species outside of the confidence interval might become harmed: the most sensitive species for that particular compound. Determining factors are specific toxic compounds whether or not in interaction with environmental factors like temperature or Relative Humidity or Organic C-levels. Impacts of mixtures of compounds have been assessed only to a limited extent. Species are handled as individual entities, without attention for the relations between species or for species that are rare or have a very specific food pattern.

There is a generally recognized need for more testing with non-standard species and non-standard test methodologies. This is more important as for other parts of the world than EU and US, where the SSD analysis was developed, there is insufficient knowledge about the distribution of sensitivities. In southern Africa for instance a fair to a major percentage of soil species groups are endemic (Janion-Scheepers *et al.*, 2016). It is unknown if sensitivities are differing from standard test species from European origin (Eijsackers *et al.*, 2017).

For a broad analysis of improvements of interaction between research and policy for regulatory assessment of chemicals see Ågerstrand *et al.* (2017). For ecological and ecotoxicological aspects the following could be useful:

1. Bring ecological and risk assessment arguments together for selecting a species as representative. Define the correlation between temporal variations in numbers of a selected set of functional feeding groups and the temporal variations in the amounts of a number of functional pesticide groups in soil and water.
2. Do the same for spatial distributions of selected species and amounts of selected pesticides in specified geographical areas or areas with specific crop types like fruit or vine growing areas, grain fields, horticultural areas.
3. When there is a positive correlation, investigate the sensitivity of some representatives of those feeding groups for a few selected compounds and compare these to the SSD of these compounds.
4. Assess to what extent these representatives need a special protection status based on their sensitivity for certain compounds, their ecological position in the community or ecosystem, their rare (local, regional, global) or declining numbers.
5. Select a small set of endangered species with a likely relation with a particular toxic compound (group) and test these for their sensitivity.

Communication in general

For impacts of pesticides or pollution in general precise terminology and conclusions are important to prevent unintended misinterpretation and implementation. Too often non-scientific arguments are used in societal discussions about potential or supposed negative impacts. It has to be realized that proper terminology is part of scientific integrity. Too overdone or pertinent conclusions could result in official complaints and social consequences. Therefore, the following suggestions may be helpful:

6. Be more concise and precise in coining terms. A focal species in EFSA guidelines is not the focal point of a community but just a mean representative of a community or a functional feeding group. A target species is only in the ECHA regulation a real target. Find agreement to use one definition and term for species that are used as representatives for a larger group, irrespective of the purpose for that (nature protection status or foodchain intoxication or biocide application).
7. Use functional terms instead of coining terms: so 'food chain representatives' and 'conservation representatives'. The most important is to explain by which arguments a species is selected: because of its special position or because its 'middle-of-the-road' representativeness.
8. Find agreement on one definition/term for species used as representatives, irrespective of its purpose (nature protection status, food chain intoxication, biocide application).
9. Integrate ecological and risk assessment arguments for selecting a species as representative.

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