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COMMON VOLE (*MICROTUS ARVALIS*) ECOLOGY AND MANAGEMENT: IMPLICATIONS FOR RISK ASSESSMENT OF PLANT PROTECTION PRODUCTS

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Running title: Common voles in the risk assessment of plant protection products

Abstract

Common voles (*Microtus arvalis*) are common small mammals in some European landscapes. They can be a major rodent pest in European agriculture and they are also a representative generic focal small herbivorous mammal species used in risk assessment for plant protection products.

In this manuscript, common vole population dynamics, habitat and food preferences, pest potential and use of the common vole as a model small wild mammal species in the risk assessment process are reviewed. Common voles are a component of agro-ecosystems in many parts of Europe, inhabiting agricultural areas (secondary habitats) when the carrying capacity of primary grassland habitats are exceeded. Colonization of secondary habitats occurs during multi-annual outbreaks, when population sizes can exceed 1,000 individuals per hectare. In such cases, in-crop common vole population control management has been practised to avoid significant crop damage.

The species' status as a crop pest, high fecundity, resilience to disturbance and intermittent colonisation of crop habitats are important characteristics that should be reflected in risk assessment. Based on the information provided in the scientific literature, it seems justified to modify elements of the current risk assessment scheme for plant protection products including the use of realistic food intake rates, reduced assessment factors or the use of alternate focal rodent species in particular European regions. Some of these adjustments are already applied in some EU Member States. Therefore it seems reasonable to consistently apply such pragmatic and realistic approaches in risk assessments for plant protection products across the EU.

Key words: agriculture, crop damage, small mammals, registration, regulation, plant protection products

1 INTRODUCTION

Agriculture provides food for more than six billion people globally [1], with agricultural production greatly increased due to intensification of farming practices such as increased fertiliser applications, improved plant breeding techniques, irrigation, mechanisation and an increased use of plant protection products [2, 3].

Plant protection products minimise pre- and post-harvest losses in many crops including grains, vegetables and corn but also in horticulture and forestry, by regulating plant disease and reducing the impact of invertebrates, weeds and occasionally vertebrates on crop yields.

The use of plant protection products and their active ingredients is regulated at European Union (EU) level and nationally at Member State (MS) level to ensure that products are effective in managing crop pests and safe for humans and the environment. In the regulatory process, pesticide risk is assessed for formulated products and their active ingredients based on scientific studies performed using recognised test procedures (e.g. OECD, EC, ISO) with resulting endpoints applied in risk assessment models [4, 5]. Only active ingredients and formulated products satisfying the requirements of the risk assessment to protect non-target organisms from effects associated with the application of the plant protection product can be registered for use.

Risk assessment approaches for wild mammals aim to evaluate the potential impact of a pesticide application on a model 'representative' species that is likely to be present in crop at the time of application. Typically a model species will have a high food intake rate (FIR), consume mostly a relevant type of food (i.e. a food type potentially carrying residues) and have a low body weight, all of which maximises the potential exposure to and risk from the pesticide. Under the current scheme of mammalian risk assessment [5], the common vole (*Microtus arvalis*) is such a model species representing herbivorous mammals. In agro-ecosystems, the common vole is an important component of the food web, providing ecosystem services such as soil aeration, fertilisation and its burrow system can provide shelter for many other species [6].

However, the common vole is also an important vertebrate pest species in many crops types across the European agricultural landscape. It consumes plant material (e.g., leaves, stems, seeds, roots, bark) from several agricultural, horticultural and forestry plants, which can result in significant crop damage. [7]. Outbreaks of common voles occur about every 2-5 years [8]. During outbreaks, farmers typically manage the associated damage by applying rodenticides directly to tunnel entrances. Where possible, farmers can use indirect control methods to manage common voles such as decreasing vegetation height and cover, which removes food and also reduces shelter from predation.

Within the framework of Commission Regulation 1107/2009 for placing of plant protection products on the market within the EU, mammalian environmental risk assessments are performed according to guidance presented in an EFSA (European Food Safety Authority) (2009) guidance document [5]. Within this guidance, the common vole is the representative generic focal small herbivorous mammal species used in acute and chronic risk assessments, considered relevant for almost all crop types. With a low body weight and a high food intake rate, the common vole has a high potential exposure in crops following product application.

The uncertainty on how to deal with common voles in risk assessment has remained a constant feature of small herbivorous mammal risk assessments under EFSA (2009) Guidance.

This article presents a review of common vole population dynamics, biology, behaviour including habitat preferences and crop damage potential relevant to risk assessment. In the review refined approaches to the use of common voles in the risk assessment of plant protection products within the EU regulatory framework based on realistic and scientifically-based information are discussed.

2 COMMON VOLES

2.1 Distribution

Common voles are the most abundant small mammal species in Europe [9] belonging to the family *Cricetidae*, subfamily *Arvicolinae* [10]. They have been present in Europe for at least 500,000 years according to the fossil record [11] Common voles are mainly folivorous and typically inhabit steppe habitats [9]. The species is considered to have expanded its range from the north-west to the south-east of Europe prior to the last glacial period persisting in multiple locations during the last glacial maximum[12, 13].

Today, common voles inhabit large areas of continental Europe ranging from Northern Spain to the Middle East and Central Russia [14, 15] at elevations from sea level to about 2,600 m [16]. Isolated populations are found in the Iberian Peninsula, in the Channel Islands in the English Channel and in the Orkney Islands off the west coast of Scotland [14, 17].

Other voles species such as field voles (*M. agrestis*) [18] are known to frequently inhabit at least some agricultural fields. However, consideration of other vole species is not in the scope of this publication.

2.2 Common vole biology and population dynamics

The bodyweight of adult common voles ranges between 25-30 g but under optimal conditions, body weights can exceed 50 g for males and 40 g for females [19]. They live in shallow burrows rarely more than about 30 cm deep [19] which are equipped with tunnel systems of low complexity [20]. Runways connect tunnel entrances and feeding areas at the surface. Common voles can be active day and night with activity synchronised at the population level by sunrise and sunset with further bouts of activity at approximately 3 hourly intervals [21]. Activity might be shifted mainly to daytime when weather conditions deteriorate.

Common vole populations are subject to seasonal highly variable fluctuations in size which mainly reflect seasonal breeding success. The highest population densities are usually achieved towards the end of the breeding period, typically in autumn. Winter breeding can occur when food availability is high and sufficient snow cover protects voles from predation and low temperature during winter [22]. Common voles can begin reproducing at an early age (14 days)[23, 24]. They can have 5-6 pups per litter, produced after a three week gestation period – although litter sizes can reach >10 pups [19] with on average 4.5 litters produced per breeding season [19, 25].

Where population densities are low, common voles of both sexes tend to be highly territorial. Where high population densities occur, e.g., several hundred individuals per hectare, territoriality is reduced and large colonies of closely related individuals can be established in close proximity [26, 27].

A high intrinsic rate of reproduction and a flexible territorial behaviour contribute to allowing common vole populations to increase rapidly to more than 2,000 individuals per hectare [28], which is an order of magnitude higher than in other vole species. This leads to the most impressive ecological feature of common voles, their multi-annual population outbreaks that occur in many parts of their European distribution more or less regularly every 2-5 years [29-32, 8]).

Common vole outbreaks are generally similar to population cycles of rodents in northern Fennoscandia such as Lemmings (e.g. *Lemmus* spec.) [29, 30] because they are considered to be associated with the same suite of demographic characteristics including summer population decline and density-dependent variation in body mass (Chitty effect; [33]) [31, 34]. The occurrence of multi-annual cycles in population density increases from Southern to Northern Europe and with increasing altitude moving from marine to continental conditions [31, 32, 35]. Some of the European common vole population outbreaks are cyclical [31, 32] while in other regions populations seem to fluctuate irregularly [7]. Numerous hypotheses have been developed to mechanistically explain the dramatic rise and fall in population numbers in European vole species, including population genetics (e.g., [36]), maternal effects [37], seasonality [38], dispersal mechanisms [39], stress [26], predation [40], food quality and quantity [41-43], pathogens [44] as well as landscape features, cropping and fragmentation [45, 46].

The various factors that can affect common vole population dynamics can act via multiple direct or indirect pathways such as weather conditions, which can lead to increased direct mortality [47]. Weather can also indirectly increase survival rates, if conditions promote plant growth resulting in increased food availability and increased cover from predators [48]. Certain specific weather scenarios can impact on common vole dynamics [49-51] suggesting that more than half of the long-term variation in the dynamics of common vole populations can be explained solely by weather scenarios.

Soil and terrain characteristics are closely linked to the general prevalence of common vole outbreaks [52], possibly because a low groundwater table is favorable for voles [53] as are light soils [54]. Regulation of vole dynamics through predators is plausible for Fennoscandian cycles but so far no common cause or combination of causes has been identified that regulates common vole population dynamics [31]. Nevertheless, weather-based predictions can be made to forecast the likelihood of common vole outbreaks several months in advance [49].

Population modeling approaches indicate that cycle amplitude can be related to variations in the length of the breeding season and movement patterns of common voles [55]. Individual-based models have been developed for risk assessment in wood mice (*Apodemus sylvaticus*) [56] and common voles [55] and agent-based models have been proposed [57]. Such models may be helpful tools for risk assessment if they are based on sound knowledge and successful validation for all required scenarios [58].

2.3 Feeding and habitat preferences

The common vole is primarily a grassland species that is well adapted to steppe habitats. Primary habitats are meadows, set-a-side land, flower strips, grassy field verges, alfalfa and clover fields [59]. It prefers to inhabit undisturbed short vegetation and can be found in grass leys in forests after clear cuts and other grassy habitats.

Common voles also occur in secondary habitats in substantial numbers normally only during population outbreaks. These include cropped areas such as grain cereals, oilseed rape, peas, beans and carrots, and occasionally sugar beet and potatoes [19].

Survival of voles in primary habitats where refuges are more abundant is greater than for secondary habitats. For instance, monthly survival rates in winter in set aside grasslands (primary habitat) are about 0.5-0.6 while they are close to zero on arable fields [60]. When population outbreaks occur, voles may invade secondary habitats if the carrying capacity (critical population density) of primary habitats is exceeded. The carrying capacity of high quality primary habitat may amount to several hundred common voles per hectare [27, 61].

The selected habitat needs to provide food to satisfy the energy budgets for maintaining essential body functions including reproduction as well as providing shelter from predators. Food uptake is dependent on ambient temperature and can vary between 4.4 g/day/adult vole (at 27°C) and 7.8 g/day/adult vole (at 0°C) [21]. For instance, twice as much alfalfa is consumed at 5°C versus 22°C (ca. 5 g versus 2.5 g) [62].

Common voles exist in diverse habitats resulting in a dietary composition that is also highly variable. Up to 79 different plant species have been identified in the diet of common voles [63].

However, little is known about the specific use of secondary (crop) habitats at specific plant growth stages (BBCH). Available information indicates that winter oilseed rape is an important secondary habitat for common voles [64]. From germination when the leaf rosette is produced until harvest, the fraction of rape leaves in the voles' diet decreases from >90% to about 50% [64].

Meadows (primary habitat) are extensively used by common voles with animals showing a clear preference for *Trifolium pratense* and *Taraxacum officinale* constituting ca. 55% of their diet by volume [65]. Similarly, sown wildflower strips are highly attractive to common voles, where they eat a variety of plants including grasses and herbaceous vegetation [66]. Selective feeding by common voles can change nutrient availability to and composition of plants in meadows [67].

Janova et al. (2008) [68] established that common vole populations in alfalfa reach greater population abundance and have a greater body mass than animals present in adjacent primary habitat e.g. set aside weedy habitat. Wheat fields can be populated by common voles starting approximately in June in non-outbreak conditions and reach their annual maximum there for a couple of months before harvest [60]. Both wheat and barley are consumed by common voles but there is little or no preference for one or the other in laboratory trials [69].

In food preference trials Balmelli et al. (1999) demonstrated that voles not only preferred certain plant species but also showed preference for particular plant organs [70]. Particularly leaves of the weeds *Achillea millefolium* and *Trifolium pratense* and leaves of cultivated plants such as *Hordeum vulgare* and *Brassica napus* as well as *Beta vulgaris altissima* roots are consumed. Feeding preference is unrelated to nutritional content of food [70]. Similar results were obtained by Lantova et al. (2009) [71]. They conclude that common voles in the field often feed on grasses because grasses are widely available but prefer to consume protein-rich herbaceous perennial plants when possible.

2.4 Impact of agriculture on common voles

The crops and crop connectivity (fragmentation) [45] as well as landscape factors [72] at least partly determine the spatial and temporal distribution of common voles. Farming practices considerably influence the life history and behavior of common voles, with intensive land use leading to a negative influence on common vole population dynamics, breeding and movement patterns [60]. Mean and peak densities as well as survival rates are higher and breeding period is longer on grassland habitats compared to arable fields (e.g. wheat) [60].

Farming practices causing heavy disturbance such as ploughing, reduce survival dramatically while other farming practices affect population dynamics only slightly (harvesting, mowing) or not at all (mulching) in short- and long-term [60, 73]. The effects observed on survival and population size can be caused directly by farming practices and indirectly by removing food and cover from predators, so reducing movements [74] and inducing risk-averse feeding patterns in common voles [75].

Severe impact on common voles in agro-ecosystems is exerted when rodenticides are used for population management in an outbreak situation to suppress population density below damage threshold levels. The use of rodenticides such as zinc phosphide to minimize damage is widespread during outbreaks. Products authorized in the EU to manage common voles differ among countries but are usually applied directly into tunnel entrances or used in bait containers to protect non-target wildlife.

Bait shyness can develop [76] and sooner or later immigration of individuals from untreated areas or reproduction of remaining survivors leads to re-colonization of treated areas but very little is known about the rate of recovery for common vole populations after the application of rodenticides.

In pocket gophers (*Thomomys* spec.) following use of rodenticides, re-colonisation is rapid leading to 86% re-occupied plots 6 months post-baiting [77]. Depending on timing of gopher removal, recovery ratios can be even 100% [78, 79]. Many rodent species such as *Rattus losea* [80], Mediterranean pine voles [81], montane voles (*Microtus montanus*) [82], *Microtus townsendii* [83], wood mice (*Apodemus sylvaticus*), and bank voles (*Myodes glareolus*) [84] also recover rapidly after rodenticide application. Similarly, deer mice (*Peromyscus maniculatus*) appear quickly if suitable clear cuts are created [85, 86] and re-appear rapidly after removal trapping [87].

Therefore, sustainable suppression of rodent populations with rodenticides requires synchronous large-scale action in infested crops and should include adjacent refuges and possibly reapplication. However, this approach to pest management does not come without significant non-target wildlife risk.

2.5 Impact of common voles in agro-ecosystems

Common voles as well as other small vertebrates provide important benefits to agro-ecosystems. They are an important food source for more than 75 predator species feeding on common voles in Northern and Central Europe [88]. Some predatory species are adapted to use cyclic pulses of vole availability for enhanced reproduction [89]. Common voles also contribute to plant dispersal, aeration of soil, soil turn-over and fertilisation. Moreover, their burrow and tunnel systems also provide refuge for other small mammals, reptiles, amphibians and arthropods [6].

Nevertheless, at times of high abundance, common voles can damage crops (reviewed in [7]), and transmit diseases to humans, livestock or companion animals including leptospirosis [90], tularaemia [91], borreliosis [92] and echinococcosis [93]. Predation of ground breeding bird nests by voles during population outbreaks is also a conservation issue [94]. Indirect effects can occur when predator populations that build up during a common vole outbreak need to search for dietary alternatives after the population collapse because these alternatives may include animal species of high conservation value [95].

When population density exceeds >200 voles per hectare the resulting damage to crops in agriculture, forestry and horticulture mostly in temperate regions becomes much more visible [96], especially in temperate regions at latitudes between 40°N and 60°N.

Rodents damage crops directly by feeding on shoots and leaves, which results in crop loss or decreased crop quality. In addition, secondary damage results in plants becoming more susceptible to attack by viral, bacterial and fungal diseases. This is particularly problematic in perennial crops such as fruit trees [97] and grapevine [98].

Livestock may be particularly susceptible to food competition with voles. During vole population outbreaks grazing livestock may have to be transferred early from pastures to stables, resulting in additional husbandry costs for fodder. Soil excavated by the burrowing activity of voles can contaminate silage, which in turn may disturb fermentation, reduce silage quality and lead to lower milk yields [99].

Moreover, indirect costs associated with rodent management can be substantial [7]. Where damage is extensive, fields may need to be ploughed and re-sown. This causes substantial cost not only from machinery operation, but also seeds and dwindling benefits from subsidies in designated ‘no-plough areas’. Gnawing can damage machinery and cables whilst burrowing can negatively affect road verges and dikes.

The control costs associated with rodent management can be substantial [7].

Owing to common voles’ habitat and food preferences, the crops that are mostly affected are perennial grasslands, clover, alfalfa, rape and winter cereals. However, during population outbreaks, other crops such as fruiting trees, sugar beets and leafy and fruiting vegetables may also be impacted [19].

During our history, common vole population outbreaks have substantially impacted food security in Europe. Vole control efforts continue to be substantial in crops throughout Europe especially during vole population outbreaks. For example in Hungary in 1965, 2.5 million people had to engage in common vole control on approximately one third of the nation's cropped land [18]. In Spain in 2007, common voles occupied >3 million ha of agricultural land, with tilling, rodenticide application being employed across >1 million ha resulting in management costs of €15 million with €9 million paid in compensation. (pers. comm., C. Caminero Saldaña, ITACyL, Castilla y León Government). In Germany in 2007/8, approximately 300,000 ha of farmland required treatment with rodenticides to control voles [100], leading to pre-harvest damage that accumulated to several hundreds of million Euro at the national level in wheat, grassland and horticulture [100, 101] (equivalent to €15 – 450 per hectare lost income [101]). In Poland crop damage accounts for about 0.2-6.4% of primary plant production due to consumption by common voles, equating to a financial loss of about 3.5% (range 0.5-16%) of the farmers' income [102].

Locally, damage can be dramatic, e.g. >80% of rape [96, 103], 100% of grasslands [104] and 100% of wheat (E. Tkadlec pers. comm.) can be lost. Damage in forestry is usually minor on a national scale but can be highly significant locally [105-107].

When considering benefits and damage caused by the common vole during periodic outbreaks, the associated crop losses and management cost suggest that this species is the most serious vertebrate pest in European agriculture.

2.6 Common vole management in European agriculture

Several methods for large scale common vole management are available to minimise extensive crop damage including the use of rodenticides, habitat management/manipulation of vegetation, farming practices and bio-control.

Population outbreaks of common voles are directly controlled using rodenticides applied in cropped areas, to minimise crop damage. Rodenticides can be applied on a large scale; they are inexpensive and widely available. For example, 1,679 t of rodenticide baits were applied on arable land in the UK in 2000 [108], with similar amounts (ca. 2,000 t) sold in Germany each year for plant protection and biocide use [109].

Non-target organisms may be exposed to bait intended for common voles. This includes primary poisoning when rodenticides are eaten directly and secondary poisoning when rodenticides are consumed indirectly via poisoned prey. The risk of non-target individuals consuming bait can be minimized by applying bait directly into tunnel entrances or in bait boxes. The risk of secondary poisoning is low if acute poison such as zinc phosphide is used but may be of concern when anticoagulant rodenticides are applied [110].

Rodenticide application for vole population control can be associated with wildlife risks but there are no practical large-scale alternatives for field use. Small scale methods are available for use in home gardens and for small valuable crops, including trapping, repellents and fencing. In large scale use, farming practices can mitigate in-field rodent problems e.g. ploughing will destroy nests and common voles present [73] but may have adverse effects on erosion, water retention of soil and other species in the agro-ecosystem. A reduction of vegetation height within cropped areas is also suitable to suppress vole numbers [111] but may lead to unwanted effects on other organisms reliant on the established vegetation. Where cut vegetation is not removed, common vole populations can persist [60, 73, 74]. Decreased cover can be achieved thermally (burning, hot steam, hot water treatment), mechanically through mowing and grazing in addition to chemical methods (herbicides).

There is no published information on the effects of herbicide use on common voles. Studies conducted with meadow voles (*Microtus pennsylvanicus*), deer mice (*Peromyscus maniculatus*), Oregon voles (*Microtus oregoni*) and Townsend chipmunks (*Eutamias* *townsendii*) indicate that herbicide use in forestry had little or no short-term effect on populations [112-116] or on small mammal diversity [117]. Long-term effects of herbicide use on red-backed vole (*Myodes gapperi*) abundance were observed but not on deer mice and meadow vole abundance or body mass and sex-ratio in the two former species [117]. The magnitude of such indirect positive and negative effects observed, were found to be within the range of natural biological variation for red-backed voles and deer mice [117].

In contrast, experimental application of a total herbicide to apple orchard floors, reduced the abundance of montane voles significantly, possibly through the lack of food [118]. Disappearing voles were replaced by deer mice and northwestern chipmunks (*Eutamias amoenus*) and as a result there was no difference in small mammal biomass between treated and untreated orchards [118].

Bio-control is frequently mentioned as an appropriate technique to manage common vole populations by supporting avian and terrestrial predators or using pathogens. However, there is limited evidence to support widespread use. Results in other small mammal species are equivocal (review in [119]). Fertility control agents could be applied at large scale and they have been shown to slow population growth in small mammals [120-123]. Side effects associated with some methods available are prohibitive for field use and it is difficult to achieve long-lasting effects via oral application [124].

2.7 Common voles in risk assessment

Does the common vole represent a good choice of herbivorous mammal in risk assessment? Wild mammal risk assessment is based on the context of EC Regulation No. 1107/2009 of the European Parliament and of the Council of 21 October 2009 1107/2009, concerning the placing of plant protection products on the market in the EU [5]. It aims to establish the risk of wild mammals being exposed to plant protection products, when applied to a crop in accordance with product label recommendations according to the General Agricultural Practices (GAP).

Under EC Regulation 1107/2009, environmental risk assessments must be conducted for all plant protection products and active ingredients in accordance with the respective data and testing requirements of EC Regulation No 545/2011 [125] and 544/2011 [126] for registration in the EU.

Within this framework, risk assessments for birds, wild mammals, aquatic organisms, bees, soil organisms, non-target terrestrial plants and aquatic plants must be presented. These assessments compare agreed toxicological endpoints (generated using small rodent and rabbit models) with active ingredient exposure estimates, to generate a ‘toxicity exposure ratio’ (TER value). This value in turn is evaluated against a trigger value (Annex VI of Uniform Principle as stated in the Regulation EC 1107/2009) to ensure that environmental protection goals are maintained. Where the toxicity exposure ratios exceeds the trigger value, the acute or reproductive (or both) dietary exposure risk in the field for that particular feeding guild of mammals is considered to be acceptable.

For wild mammals, acute dietary and reproductive dietary risk assessments are required. Acute and reproductive toxicological endpoints generated for the active ingredients are compared with the level of residues likely in the field following application of the product according to the GAP. The assessments follow a tiered approach according to the guidance document[5].

Within the guidance document, the common vole is considered to be a representative ‘generic focal’ herbivorous species with a high exposure potential given a high food intake rate (FIR), an herbivorous diet and a low body weight. For higher tier refinement of mammal risk assessments, additional data relevant to a particular focal species that is likely to be found in the field may be justified for use in risk assessment where its selection is supported by relevant investigations in field studies typically performed in crops relevant to the proposed GAP.

In the Tier 1 risk assessment for wild mammals, acute and reproductive dietary toxicity exposure ratio (TER) values, are calculated by dividing the acute or long-term toxicity endpoint by the exposure estimate. The exposure estimate expressed as daily dietary dose (DDD) is a function of the product application rate (kg active substance/ ha), application frequency, food intake rate by bodyweight (FIR/bw), proportion of different items found in the diet (PD) and the residues per unit dose (RUD) on those food items, the proportion of time spent feeding in a particular crop (PT) and the decline kinetics (DT50) of the active ingredient on the food items. The derived TER value is compared to the Annex VI trigger value and if the value is below the trigger value of 10 for acute or 5 for reproductive risk assessment a refined risk assessment is required. The trigger values were determined based on a selected level of protection and the standard assessment procedures to ensure that the surrogate protection goal of making any mortality or reproductive effects unlikely. If trigger values are not met, potential refinements to the risk assessment are put in place. In a refined risk assessment exposure parameters may be modified e.g. RUD value refined using crop specific residues data or by applying deposition factors according to food item, based on the BBCH growth stage, or using focal species data to justify another focal species as being more relevant to a particular crop exposure scenario. When derived TER values are greater than the established trigger values the assessment confirms that the level of protection is adequate to ensure the surrogate protection goal is achieved.

The risk assessment according to EFSA (2009) [5] is detailed and prescriptive. Herbivorous mammals are identified at the screening phase of the risk assessment with generic focal species such as the common vole, identified at the Tier 1 risk assessment phase and defined according to crop type and by BBCH growth stage [5, 127] (Table 1).

The evaluation of risk assessments comprising common voles differs among the regulatory authorities of different EU member states, most likely because some countries consider that common voles are recognised as a pest and it does not have any protection status. A pragmatic approach in some European member states includes the use of alternative focal species based on relevant distribution and / or modified trigger values to address the uncertainty associated with the use of the common vole in the risk assessment. For example, in Germany, use of a reduced TER trigger value for acute and chronic mammal risk assessments, is acceptable (5 and 2, respectively) [128]. The rationale for a reduced trigger value by UBA (Umweltbundesamt – Federal Environment Agency) in Germany is that the vole is closely related to the actual study species (laboratory rat, *R. norvegicus*) minimizing potential inter-species variability in sensitivity to the study compound. In the UK, the common vole is not considered a relevant focal species, given its absence from most of the UK. Instead the ‘field vole’ is relevant for crops where it occurs. In other countries, where the common vole is not relevant, using country-specific species in risk assessment can be problematic given a lack of field monitoring data for those species. Refinements in these countries can therefore be difficult.

In EFSA (2009) Guidance [5] the common vole appears in the majority of crop types compared to only grassland, cereals, orchards, hops and vines according to the previous SANCO/4145/2000 Guidance [4].

A comparison of the outcomes of risk assessments performed according to EFSA (2009) [5] and according to SANCO/4145/2000 [4] has been presented by Murfitt (2012) [129]. For mammals, the conservative definition of herbivorous mammal generic focal species provided in the Tier 1 risk assessment under EFSA (2009), triggers higher tier refinements to risk assessment more often than under SANCO (2000). In contrast, for birds higher tier refinements were less frequently triggered by Tier I of the EFSA [5] risk assessment compared to SANCO risk assessment [4, 129].

3 DISCUSSION

When considering voles in risk assessment, a realistic position on the importance of voles to the agro-ecosystem should be taken. Published information highlights opportunities to balance risk assessment with characteristics of common vole biology and ecology and pest status.

3.1 Habitat preferences

Common voles are essential food web components ensuring energy flow through the trophic levels as a significant primary consumer [6]. They are an important food source for predators within the food chain [88] e.g., raptor species adapt their abundance to coincide with outbreaks of small mammals [130]. This has obvious ecological benefits but can also result in conservation issues during times of common vole population decline when large predator populations search for alternative food [95].

Common voles are an important pest species in multiple crops, causing significant levels of damage [7]. Their distribution and damage potential is widespread across agricultural landscapes within Europe.

Common vole populations peak usually seasonally during autumn. Multi-annually, there is a long term pattern of vole population growth and decline that results in outbreaks occurring in about 2-5 year periods [29-32], which means that naturally occurring seasonal and multi-annual fluctuations are the rule for common vole populations.

The preferred primary habitat of common voles is steppe, which comprises grassland, pasture and meadow with mixed grassland, herbs and weeds that provide appropriate cover to avoid predation [59]. For common voles, many cropped areas are considered to be secondary habitats and significant invasion into them occurs when there is a population outbreak [19]. In contrast to primary habitats these secondary habitats cannot maintain common vole populations sustainably for long periods due to the seasonal nature of farming, where populations are regularly disrupted by harvest and tilling [60, 73].

Although the common vole is indicated as the representative generic focal species in screening and Tier 1 risk assessments under EFSA (2009), population dynamics and habitat preferences indicate that in the period between population outbreaks the likelihood of significant numbers of common voles being found in secondary habitats such as grain crops, vegetables and sugar beet, is low.

During vole population outbreaks, the density of voles in primary habitats is high, which is likely to provide a considerable buffer for potential adverse effects of plant protection products on common vole populations in secondary habitats such as cropped areas. Inclusion of different levels of comparative risk in primary and secondary habitats for a pest such as the common vole is considered to be appropriate to ensure a sufficient population density is maintained in the primary habitat. This contributes to maintaining the protection goal to avoid long term detrimental effects on common vole populations.

3.2 Managing Common Vole Populations

In Europe, few rodenticidal compounds are used regularly for direct control of common vole populations in crop habitats. The use of rodenticides and alternative methods can reduce crop damage. However, even with such extensive direct action during outbreaks, *Microtus* populations are seen to recover relatively quickly following rodenticide application [81, 82] although no data is available for common voles. These findings, along with the exceptional reproductive potential of common voles [23, 24], indicate that common voles are anticipated to overcome potential adverse effects of in-crop application of plant protection products at the landscape level.

3.3 Use of Common Vole in Risk Assessment

Based on pest status, population dynamics, habitat preference, resilience and the reproductive potential of the common vole, its relevance to environmental risk assessments must be practically established to ensure that at Tier I of the risk assessment process, [5] the risk to voles across multiple crops is realistically assessed.

Risk assessment parameters for default generic focal species as defined in the Appendix A of the EFSA (2009) [5] bird and mammal guidance document do not always appear to concur with results of scientific observations in field and laboratory studies. For example, EFSA (2009) [5] use of energy balance models indicates that a 25 g vole must consume 1.33 times its own bodyweight (the default food intake rate / bodyweight (FIR/bw)) to satisfy the theoretical daily energy expenditure (DEE). However, in laboratory studies, common voles have been found to only consume about a third of their body weight per day [19] and values as low as 10% based on the uptake of dry matter have been reported [131]. As shown in laboratory studies, even at low temperatures when food uptake is highest, an amount of food equivalent to about 50% of the body weight is eaten [21, 62], although this was not verified under field conditions.

Re-evaluating certain generic focal species food intake rates that are not in concordance with literature values is an area of future research that, coupled with additional research, could provide realistic food consumption data for use in risk assessment.

The common vole is a model species that exists in cropped areas and, given body weight and food intake rates, does represent a worst-case exposure model. It seems therefore reasonable to consider an adjustment in the Annex VI (trigger value) to account for reduced uncertainty, associated with the evaluation of derived TER values from acute and reproduction dietary risk assessments. This reduction could follow the model used in Germany where lower TER trigger values ≥ 5 in the acute and ≥ 2 in the chronic risk assessment being applied for common voles and wood mice.

German regulators consider these species as the worst case exposure models and not simply representatives of the worst case exposure model [128]. They also stress that mammalian toxicity endpoints are usually derived from studies with laboratory Norway rats (*Rattus norvegicus*) or house mice (*Mus musculus*) that have a close phylogenetic relationship to field rodent species, thereby reducing the inter-species uncertainty associated with extrapolating laboratory endpoints to wild mammals.

Thus, adjusting the acute and chronic TER trigger points (as is the case in Germany) would be a realistic and pragmatic approach appropriate across all EU member states. The use of alternate focal species within the same feeding guild (e.g. field vole) is a pragmatic approach to risk assessment proposed for the Northern zone where common voles are not widely distributed [132]. However, this position, although pragmatic, cannot be consistently applied across member states.

More information is necessary to better assess resilience and recovery in common vole populations and to further develop and validate modelling approaches that can be valuable in assisting decision-making in risk assessment. This information could be obtained from rodent control programmes and field monitoring data evaluating impacts on populations at the agro-ecosystem level. This information could be used to establish more accurate exposure estimates and to gain a better understanding of the differences in the dynamics of common vole populations when associated with different crop types.

4. CONCLUSIONS

Common voles are widely distributed in agro-ecosystems. The risk of side effects of plant protection products for common voles is limited to individuals present in crops during product application while (extensive) populations in off-crop primary habitat refuges remain unaffected. For many crops the occurrence of common voles is restricted to population outbreaks and is associated with voles becoming significant agricultural pests. Their pest status, highly fluctuating population dynamics, habitat preferences, resilience and high reproductive potential should reduce potential pesticide impact upon common vole populations but this is not fully reflected in the current risk assessment scheme [5].

Overall, based on the compelling evidence provided in this document it is proposed that it would be justified to modify elements of the current risk assessment, such as 1) refinement of consumption estimates based on expanded field collected data on common voles, 2) the application of reduced TER trigger values universally across all member states, and / or 3) to advocate alternate focal species where considered geographically appropriate. This will ensure that a more realistic and pragmatic approach to wild mammal risk assessment is taken in the assessment of plant protection products.

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Generic focal species	*BBCH	Crop	Diet
Common vole (small herbivorous mammal)	from BBCH ≥ 40 onwards	bulbs and onion like crops, cereals, cotton, hop, legume forage, oilseed rape, ornamentals and nursery, pulses, root and stem vegetables, strawberries, sugar beet, sunflower, leafy vegetables	grass and cereals
	from BBCH 10	bush and cane fruit, fruiting vegetables, maize	
	all season	grassland, orchards, vineyards	

*BBCH (**B**iologische **B**undesanstalt Bundessortenamt **Ch**emical Industry working group) is a uniform coding system of phenologically similar growth stages of all mono- and dicotyledonous plant species [127].

Table 1 Tier 1 crop scenarios for common vole (*Microtus arvalis*) risk assessment according to EFSA (2009) [5]

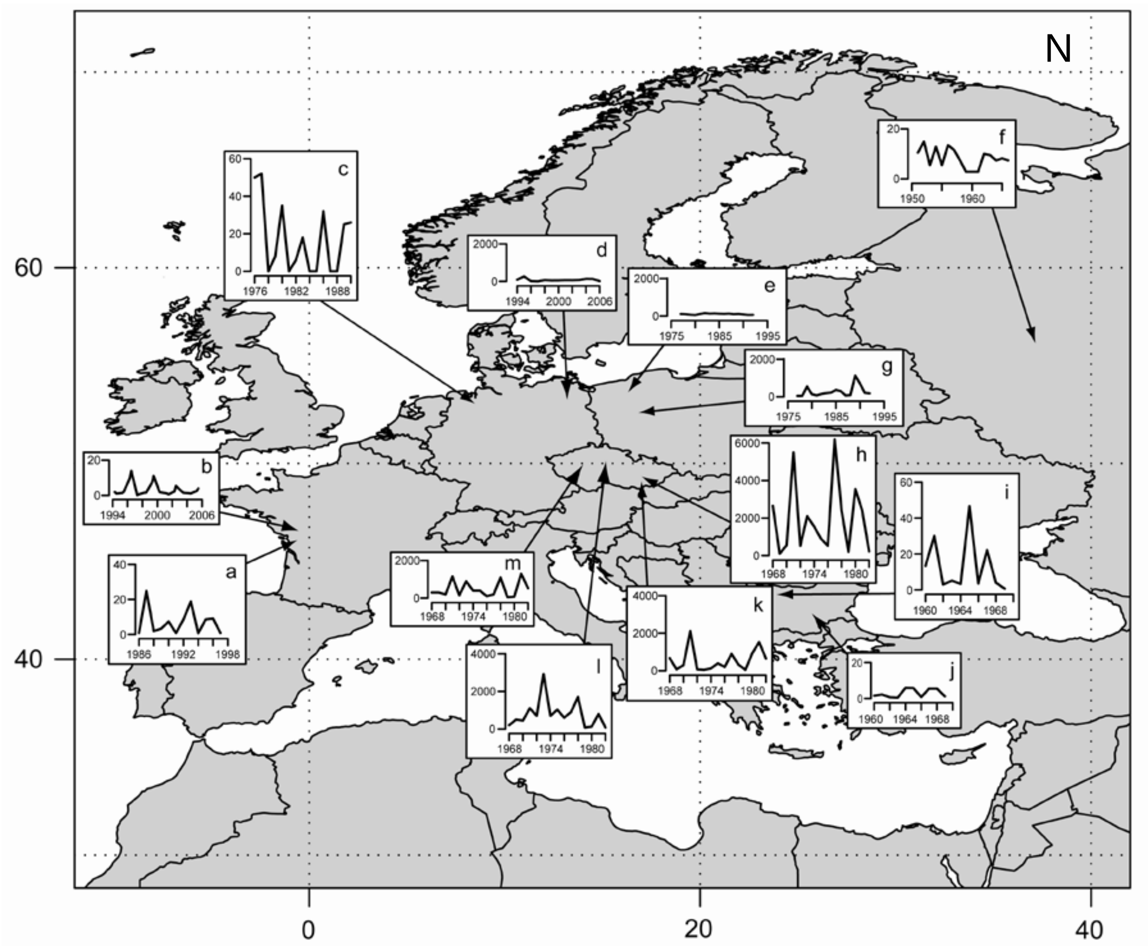

Figure 1 Multi-annual population dynamics of common voles in Europe (a) Rochefort, France; (b) Deux-Sèvres, France; (c) Weser-Ems region, Germany; (d) Mecklenburg-West Pomerania, Germany; (e) Koszalin, Poland; (f) Tula region, Russia; (g) Poznan, Poland; (h) Brno, Czech Republic; (i) Knezha, Bulgaria; (j) Chirpan, Bulgaria; (k) Břeclav, Czech Republic; (l) Kutná Hora, Czech Republic; (m) Příbram, Czech Republic. Population dynamics a-c, f, i, and j are based on percentage trapping index. Population size in d, e, g, h, and k-m was measured as the number of reopened burrow entrances per hectare. (Data compilation from [7] with kind permission of the International Rice Research Institute, Manila, Philippines).