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Biodiversity Decline as a Consequence of an Inappropriate Environmental Risk Assessment of Pesticides

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The widespread contamination of ecosystems with plant protection products (pesticides in this text) around the world is evident (Hoferkamp et al., 2010; Shunthirasingham et al., 2011; Stehle and Schulz, 2015a; Ferrario et al., 2017; Hvězdová et al., 2018; Silva et al., 2019). Pesticide effects on the physiology, activity and diversity of various aquatic and terrestrial non-target organisms is addressed by numerous studies, and many new aspects are also described in a recent Frontiers Research Topic.

We currently observe a deterioration of biodiversity in agricultural landscapes, and the dramatic losses are increasingly discussed by the public (European Commission, 2018a). Declines of insect biomass of more than 70% in the last few decades in Germany, the halving of farmland bird populations in Europe and effects on pollinators are widely known (Donald et al., 2001; Potts et al., 2010; Hallmann et al., 2017). Out of a set of recorded parameters of agricultural intensification (such as field size, fertilizer application, landscape heterogeneity) a unique, pan-European study identified pesticide application as the responsible factor for lower biodiversity of plants, ground beetles, and birds in wheat fields (Geiger et al., 2010). Recently, a review recognized chemical pollution including pesticides as the second most important driver for the worldwide decline in insect populations (Sánchez-Bayo and Wyckhuys, 2019). Other drivers were habitat loss and conversion to intensive agriculture, fertilizer inputs, introduced species, and climate change.

There is agreement in the scientific community that pesticides are a central responsible factor for the observed terrestrial biodiversity declines. However, pesticides are perceived also as the chemicals with the strictest regulation, requiring an in-depth Environmental Risk Assessment (ERA) for registration in the European Union (European Parliament, 2009). This procedure includes the performance of a set of toxicity studies and calculations using predicted exposure values to calculate a risk. If the risk is deemed acceptable pesticides can be placed on the market (for an overview see.g. Storck et al., 2017). Interestingly during this step of the authorization process the "acceptable risk" is leading to pesticides considered "safe" for the environment (EFSA, 2019). Farmers, assuming they are using "safe" pesticides, are currently confronted with the public, blaming them for the observed declines of biodiversity. It seems that the ERA for pesticide regulation as currently carried out is inappropriate since it cannot prevent that registered and commonly used pesticides have detrimental effects on our environment.

In the last decade we have seen an increasing complexity in ERA of pesticides. The European Food Safety Authority (EFSA), as the responsible authority for pesticide registration in Europe, published guidance documents describing the required studies for different groups of aquatic and terrestrial organisms and their implementation in risk calculations (EFSA, 2010, 2013a). For the terrestrial environment there are also specific documents for birds and mammals as well as for bees (EFSA, 2009, 2013b). Furthermore, EFSA also recently published scientific opinions on in-soil organisms, non-target arthropods, amphibians, and reptiles as well as non-target terrestrial plants calling for improvement of ERA for the respective groups (EFSA, 2014, 2015, 2017, 2018). In some instances, such as for the currently neglected amphibians and reptiles, standard toxicity studies to produce reliable endpoints are lacking and the entire ERA is not even outlined yet. Scientific opinions are documents that highlight steps in ERA that need to be improved. However, the ERA is still performed as before until a guidance document is issued.

The current scheme for ERA of pesticides was also recently addressed by the group of chief scientific advisors, recommending among others the setting of unambiguous and quantifiable protection goals and structural changes of the registration process in the EU (European Commission, 2018b). The majority of the members of the European parliament agreed on a motion for a resolution on the authorization procedure for pesticides that mentions concern regarding the widespread use of pesticides and a lack of public knowledge about hazard and risk of pesticide use (European Parliament, 2018). A few scientific assessments of the European ERA scheme and its shortcomings exist (e.g. Newman et al., 2006; Schäfer et al., 2011; Stehle and Schulz, 2015b; Storck et al., 2017). Main points that are often raised are the inclusion of new test or surrogate species, the extension of studies to more realistic scenarios, the validity of the used uncertainty (assessment) factors, the lack of including sublethal endpoints in risk assessments and the need to address ignored groups of organisms (e.g. Jänsch et al., 2006; Desneux et al., 2007; Stahlschmidt and Brühl, 2012; Brühl et al., 2013). The consideration of interactions of pesticide effects with additional stressors such as nutrients or climate change was also pointed out (Köhler and Triebskorn, 2013; Baier et al., 2016).

But instead of highlighting all the open questions on various stages of a complex ERA scheme we consider it necessary to step back and address its entire structure. The observed biodiversity declines in European agricultural landscapes are mostly discussed for terrestrial organisms and not for aquatic systems. We will therefore specifically focus on the terrestrial part of ERA.

APPLICATION SEQUENCES IN PESTICIDE USE

The existing ERA is performed for one active substance or pesticide product that is applied once or a few times in a specific crop. However, the current cropping systems do not only receive one application of a pesticide. Their seeds might be already treated with a mixture of multiple systemic pesticides and several further products are applied on the growing plants or fruits during the season. In Germany in 2016 on average there were 6 pesticides applied (treatment index) in wheat, 7 in oilseed rape, 14 in potatoes, 22 in vine orchards, and 32 in apple production orchards (JKI, 2019). In the UK even more pesticides were used for the same crops: 11 pesticides for wheat, 13 for oilseed rape, and 21 for potatoes (FERA, 2017). Outside the EU maximum pesticide inputs as in banana in Costa Rica, where aerial applications are conducted in conventional plantations every 4 days, result in volumes of over 75 kg of active molecules/ha/year. It is obvious to every ecotoxicologist and ecologist that multiple, sequential field applications of biologically active chemicals are likely to cause more severe effects on a population of organisms than a single application event. However, the current risk assessment assumes that populations only face a single impact from a specific pesticide, with sufficient time following after application to allow the population to recover to former levels. In reality the same population is facing multiple pesticide impacts during the growing season. This is a worrying underestimation of the actual risk for biodiversity in the agricultural landscape resulting from pesticide use. Similar concerns of an underestimation of effects of contamination with multiple pesticides and other chemicals are also raised for human health (Leu and Shiva, 2014).

INDIRECT EFFECTS

The current ERA scheme addresses the effects of a pesticide on each group of organisms separately. There are ERA sections on plants, on insects and spiders (arthropods) and birds. Field studies are sometimes performed for arthropods, where interactions between predatory insects and their prey is recorded. However, ERA does not include so-called indirect effects or interactions between trophic levels of *different* organism groups. An example can be seen in an herbicide that has no acute toxic effect on insects as well as birds and therefore passes the current risk assessment for both groups. However, the application of the herbicide leads to a reduction of "weeds" (as intended in the field) and of "non-target plants" (the same plant species growing outside the field), therefore reducing the amount of food for pollinators and herbivorous insects. This depletion can lead to further impacts on birds since herbivorous insect larvae, such as caterpillars, are smaller and less abundant after herbicide treatments (Hahn et al., 2014), reducing the insect biomass available to feed the birds offspring. Trophic interactions are fundamental features of ecosystems and therefore need to be considered in ERA.

IN-FIELD EFFECTS ON BIODIVERSITY

The European ERA focusses on environmental effects that can occur in semi-natural structures outside the agricultural fields. Currently no ERA for the in-field risk is mandated. However, the scientific opinion for non-target arthropods, mentions "biodiversity has to be supported *to a certain degree* in the in-field areas (...) in order to provide important ecosystem services (EFSA, 2015)." However, the respective guideline is not addressing this issue and negative effects on biodiversity are therefore deliberately accepted in the cropping area where pesticides are directly applied at biologically effective rates. The agricultural cropping area that receives pesticide inputs in Europe represents 22% of the total land area, reaching more than 30% for example in Germany and France (for 2015, Eurostat, 2019). Therefore, in countries with a high proportion of cropped area almost a third of the terrestrial land surface is not evaluated regarding negative effects of pesticides on its biodiversity. To explain the observed decline in insect biomass in the agricultural landscape of Germany (Hallmann et al., 2017) the most parsimonious explanation (Occam's razor) is the annual application of insecticides on more than 30% of Germanys land area, the entire cropping area, since the 1970s. No other factor such as the suggested light pollution or soil sealing needs to be invoked to explain the observed reductions (BMU, 2018).

The ERA required for pesticide regulation is in most cases not addressing the impact of pesticide use in agricultural fields and does not include food-web related ecosystem effects. This fundamental misconception leads to an ERA scheme and a resulting pesticide regulation that is not protective for biodiversity. If we remain working with the ERA scheme in place, in our opinion we will continue to observe further declines of many groups of organisms such as farmland birds and insects in the agricultural landscape. Neglecting the three described factors can have far-reaching consequences at the ecosystem level that are likely larger than an underestimation of risk due to a lower uncertainty factor or a flaw in the experimental design of a field study. The misconception can also not be compensated by additional studies including new surrogate species or groups of organisms. The banning of certain insecticides or broad-band herbicides will also hardly improve the situation. We therefore urgently need to rethink our basis for the regulation of these biologically active substances and develop a holistic approach to include indirect effects caused by multiple pesticides applied in the agricultural productive land area of Europe. Since the current ERA for the regulation of pesticides is not addressing the real-world situation we ought to accept that the current practice of pesticide use in European agriculture is not sufficiently protective and therefore not safe for the terrestrial environment.

RISK MANAGEMENT INSTEAD OF ASSESSMENT

The development of a new systemic approach for ERA will take considerable time and require substantial resources. We therefore also need to discuss other options to at least halt the negative effects of pesticides on biodiversity of the agricultural landscape. Risk management to mitigate negative pesticide effects might be a helpful alternative until we are able to assess the true environmental risk of pesticide usage. Reducing pesticides in agricultural practice is an obvious option. It was estimated that total pesticide use could be reduced by more than 40% in almost 60% of 946 evaluated farms in a French network without any negative effects on both productivity and profitability (Lechenet et al., 2017). Integrated pest management should focus on using natural enemies of pests and crop rotations and agree on pesticides as a last option instead of current practices, where pesticides are prophylactically implemented in farming practices (e.g., seed-treatments of cereals). We additionally could extend the proportion of semi-natural habitats without pesticide inputs in the agricultural landscape, increase agri-environmental schemes and enlarge the area of organic farming. Many options are on the table and a strengthening of the greening of the common agricultural policy (CAP) is currently discussed for the coming period of European policy (Erjavec and Erjavec, 2015; Solazzo et al., 2016; Alons, 2017). Risk mitigation of pesticides needs to be implemented effectively and at a large scale to bend the curve of biodiversity decline in agricultural landscapes now. If we delay to change agricultural practice and its current pesticide use our efforts to stop the current biodiversity decline and restore it to former levels need to be much larger at a later stage.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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