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POLLUTION

Science Brief for Target 7 of the Post-2020 Global Biodiversity Framework

TARGET 7 – POLLUTION

SCIENCE BRIEFS ON TARGETS, GOALS AND MONITORING IN SUPPORT OF THE POST-2020 GLOBAL BIODIVERSITY FRAMEWORK NEGOTIATIONS

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TARGET 7 – POLLUTION

Background on the science briefs

The bioDISCOVERY programme of Future Earth and the Secretariat of the Group on Earth Observations Biodiversity Observation Network (GEO BON), convened a group of experts to prepare six briefs to provide scientific support for the negotiations of the post-2020 global biodiversity framework (GBF) at the fourth meeting of the Working Group on the Post-2020 Global Biodiversity Framework in Nairobi, from 21 to 26 June 2022. This includes four briefs on individual Targets 1, 3, 7, 8 and 10; a brief on the GBF monitoring framework; and a brief on the ecosystem area and integrity objectives of the GBF that also addresses Targets 1 and 2 in detail.

This science brief addresses reducing nutrient and pesticide pollution components of Target 7

The analysis in this brief focuses on the wording and quantitative elements of Target 7, definitions of key terminology, and assessment of the adequacy and availability of indicators for tracking achievement this target.

This analysis is based on the text of the first draft of the post-2020 global biodiversity framework, CBD/WG2020/3/3 and subsequent negotiations of this text:

Target 7. Reduce pollution from all sources to levels that are not harmful to biodiversity and ecosystem functions and human health, including by reducing nutrients lost to the environment by at least half, and pesticides by at least two thirds and eliminating the discharge of plastic waste.

This analysis focuses on the nutrient and pesticide pollution. It also briefly summarizes the importance of treating plastic pollution in this target. This does not mean that other sources of pollution, including plastics are not important for the GBF.

Structure of this brief

- Key messages (1 page summary)
- Background

1) Relevance for biodiversity, nature's contributions to people and good quality of life
2) Target formulation, numerical objectives, indicators and impacts on SDGs
3) Indicators
4) Linkages to other relevant international policies
5) References

- Appendix – Graphics, tables and short texts in support of the background material

KEY MESSAGES CONCERNING THE NUTRIENT AND PESTICIDE POLLUTION OBJECTIVES OF TARGET 7

- Nutrient (nitrogen and phosphorus) and pesticide pollution are widespread and have well-documented negative impacts on nature, nature's contributions to people, agricultural sustainability and human health.
- Agriculture is the primary source of nutrient and pesticide pollution. Large reductions in nutrient and pesticide pollution from agriculture by 2030 would have significant benefits for nature and people, and can be achieved without compromising food security or livelihoods.
- The level of ambition for reductions in nutrient and pesticide pollution should seek a middle ground between the very deep cuts needed to achieve low risk for nature and what is feasible by 2030 without compromising food security.
- Reductions in fertilizer and pesticide use, in cases where they lead to reduced agricultural productivity, could lead to loss of natural habitats through land use change, a major driver of biodiversity loss. Systemic approaches to food production, distribution and consumption could avoid this.
- Looking towards 2050, transformative changes in food systems and other sources of nutrient and pesticide pollution should be initiated now because these provide opportunities for deep, long-term reductions in pollution, and provide many other benefits for nature and people.
- Measures to reduce pollution should be adapted to national contexts because sources, levels and impacts of pollution; effects on food production; and feasibility of reductions vary greatly.

Nutrients

- Based on the best available scientific evidence, the Target 7 objectives for nutrients are technically feasible and coherent with other international policies.
- Agriculture is the dominant source of nutrient pollution globally and in most countries; other important sources include wastewater, industry and biomass burning.
- Nutrient <u>losses</u> from agriculture can be reduced by up to 50% at local, national and global scales by 2030 without compromising food security, using existing farm-level practices and technologies as well as through landscape management.
- Available cost-effective mitigation technologies can reduce nutrient pollution from non-agricultural sources such as wastewater and fossil fuel combustion by far more than 50%.
- The current set of indicators for monitoring nutrient pollution under the GBF is not well adapted to assessing achievement of this objective, and should be complemented by other currently available indicators such as nutrient surplus.

Pesticides

- It is important to frame pesticide policies in terms of risk instead of quantity, because very toxic pesticides can pose high risks to certain groups of species even if they are used in low quantities. This could be reflected in the wording of Target 7 by replacing "...pesticides by at least two thirds" with "...risks associated with pesticide use by at least X%".
- Reductions of 20-50% in <u>pesticide risk</u> are achievable now without compromising food security by increasing efficiency and through substitution. Systemic changes and innovation in agriculture and food systems would allow considerably larger reductions.
- The headline indicator of total pesticide use per hectare, should be replaced with environmental risk-based indicators. Risk-based indicators can be calculated using currently available data—more precise risk-based indicators will require efforts to collect better data on pesticide use, exposure per active ingredient and toxicity.

BACKGROUND ON THE NUTRIENT AND PESTICIDE POLLUTION OBJECTIVES OF TARGET 7

1) Relevance for biodiversity, nature's contributions to people and good quality of life

The IPBES Global Assessment (IPBES 2019) ranked pollution as one of the five main drivers of biodiversity loss, accounting for about 12%, 17% and 15% of biodiversity loss in terrestrial, freshwater and marine ecosystems. Pollutants of concern affecting biodiversity and nature's contributions to people include nutrients, pesticides, plastics, industrial chemicals, heavy metals, light and noise. We provide background below on why nutrient (nitrogen and phosphorus) and pesticide pollution are of particular concern and are the focus of this brief. Because agriculture is the most important source of nitrogen, phosphorus and pesticide pollution, it is also the most important leverage point for reducing these forms of pollution.

Nutrient pollution refers to nitrogen (N) and phosphorus (P) pollution, which is one of the "planetary boundaries" most seriously transgressed (Steffen et al. 2015). It has been the focus of numerous global, regional and national policy targets (see section 4), including Aichi Target 8. Excessive nutrient losses to the environment can lead to detrimental impacts on biodiversity through a wide range of mechanisms (Lu and Tian 2017, Wang et al. 2016, Beasley 2020, Hernández et al. 2016, Sutton et al. 2021, Appendix-Table 1). Nutrient pollution in water causes eutrophication and dead zones—extremely low-oxygen environments which kill most aquatic life (Breitburg et al. 2018). Controlling this nutrient pollution can successfully reduce the eutrophication (Schindler et al. 2016). Emissions of reactive nitrogen gases, such as nitrogen oxides from car exhaust and ammonia from synthetic fertilizer and manure application, cause atmospheric N deposition onto natural terrestrial ecosystems that disrupts ecological balances and threatens biodiversity (Stevens et al. 2010). Nitrogen's substantial contributions to air pollution (e.g., NO_x directly and as a precursor of tropospheric ozone pollution), acid rain, greenhouse gas emissions (N_2O is the third most important greenhouse gas behind CO_2 and methane) and stratospheric ozone depletion also lead to well-documented contributions to climate change as well as damage to biodiversity, agricultural productivity and human health (Stevens et al. 2020, de Vries 2021, Appendix-Table 1). Critical thresholds for nitrogen and phosphorus have been established for many terrestrial and aquatic ecosystems and are highly context dependent (Bobbink et al. 2010, de Vries et al. 2015, Poikane et al. 2019, Appendix-Table 1). These critical thresholds are greatly exceeded in large areas of the globe (Bleeker et al. 2011, Chang et al. 2021, De Vries et al. 2021). In addition, significant impacts on biodiversity occur in some ecosystems even below current critical thresholds (Stevens et al. 2010). The take-home message is that **reducing nutrient pollution is a key to preserving and restoring biodiversity, achieving ambitious climate targets and protecting human health.**

Pesticide pollution in Target 7 primarily refers to pollution by plant protection products used for crop production since agriculture contributes to more than 80% of total pesticide used (Maggi et al. 2019). Agricultural use of pesticides has been shown to pose higher risks than urban use (Stehle et al. 2019). Pesticide use in other settings such as aquaculture and livestock production has not been well quantified. Globally, about two thirds of agricultural land is at risk of pesticide pollution by more than one active ingredient, and about a third is at high risk (Tang et al. 2021, see Appendix-Figure 1). Pesticide pollution threatens global terrestrial, freshwater and marine biodiversity (Geiger et al. 2010, Stehle & Schulz 2015, IPBES 2016, Sánchez-Bayoa and Wyckhuys 2019, Li et al. 2020), and their use expressed in terms of total applied toxicity is increasing for invertebrates and plants (Schulz et al. 2021). Pesticides also reduce ecosystem services that are essential for agricultural production such as pollination, natural pest control, beneficial soil organisms, and nutrient cycling (Köhler & Triebskorn 2013, Chagnon et al. 2015, Onwona-Kwakye 2020), and may threaten agricultural productivity over the long term rather than ensuring it (Mader et al. 2002). Pesticides also have important adverse effects on human health (Landrigan et al. 2018, Maggi et al. 2021, Appendix-Figure 4). The take-home message is that **reducing pesticide pollution is a key to preserving and restoring biodiversity, and also has substantial benefits for agricultural productivity, nature's contributions to people and human health.**

The focus on nutrients and pesticides in this brief does not mean that other sources of pollution are not important for the GBF. Plastic pollution is of particular concern because globally more than 25 million tonnes of plastics were emitted to aquatic and terrestrial environments every year (Lau et al.

2020, MacLeod et al. 2021). A recent analysis shows that more than 900 marine megafaunal species (including seabirds, marine mammals, sea turtles, fishes) were affected by entanglement and/or ingestion of plastics (Kühn & Van Franeker 2020). Ingestion of microplastics by animals and humans can cause physical injury, changes in physiology, and impaired feeding, growth and reproduction rates (Prinz & Korez 2020). These concerns recently led the UN Environment Assembly to establish a process to set international goals for halting plastic pollution. The current draft of the GBF monitoring framework recognizes the multiple forms of pollution that are important to mitigation and includes indicators for plastics, municipal solid waste, underwater noise pollution and hazardous waste generation, which could be supplemented with additional indicators. A 2021 policy brief from UNEP and the Basel, Rotterdam, Stockholm Conventions (BRS), and the Minamata Convention on Mercury (MC), concerning the relationships between biodiversity and chemical pollution can be found at this link (Interlinkages between the chemicals and waste multilateral environmental agreements and biodiversity: Key insights).

2) Target formulation, numerical objectives, indicators and impacts on SDGs

Target 7 was analyzed in this brief by breaking it down into its individual components. This is similar to the approach used for the Aichi Target analyses in the fourth and fifth editions of the *Global Biodiversity Outlooks*, as well as the "one-pager" summaries of the GBF goals, milestones and targets (CBD/WG2020/3/INF/3). Note that we did not address the plastic pollution component of this target.

➢ ***"Reduce pollution from all sources to levels that are not harmful to biodiversity and ecosystem functions and human health"***

This first component of Target 7 addresses all a wide range of pollutants and should logically be pursued as essential for protecting biodiversity and as a follow-up to Aichi Target 8. However, this target covers a very wide spectrum of pollutants, making progress difficult to evaluate. In addition, levels that are "not harmful to biodiversity and ecosystem functions and human health" are not well defined for most pollutants and are context-dependent (see Appendix-Tables 1&2). As such this component of Target 7 provides a broad statement of high ambition, but progress towards attaining the objective will be more difficult to assess than for individual classes of pollutants.

➢ ***"including by reducing nutrients lost to the environment by at least half"***

Anthropogenic nitrogen and phosphorus losses have several sources, but the major source is agriculture (Appendix-Figure 2). Nutrients are one of the main agricultural inputs for the production of food, feed, fiber, and biofuels, but oversupply of synthetic fertilizers and manure to agricultural land contributes over 60% of global N and P losses to the environment (MacDonald et al. 2016, Chowdhury et al. 2017, Withers et al. 2018, Kanter & Brownlie 2019, see Appendix-Figure 2). Human waste and food waste are other important sources of N and P pollution (approximately 10%-20%). Significant sources that are unique to N include industry (notably NO_x and N_2O emissions from nitric and adipic acid production), fossil fuel combustion (for both energy production and transport) and biomass burning. Together these sources are responsible for approximately 25% of anthropogenic N losses to the environment.

Target formulation **-** Given the multiple sources of pollution an important question is whether to focus exclusively on agriculture or include all sources of nutrient pollution. A focus on agriculture would enable a narrowly defined spotlight on the dominant source of nutrient pollution, with a limited set of indicators (fertilizer use, nutrient use efficiency, nutrient surplus…) creating a simpler approach to measuring progress towards Target 7. **A broad approach to nutrient pollution mitigation is more scientifically and economically sound than strictly focusing on agriculture**. First, excluding non-agricultural sources would omit significant and growing sources of nutrient pollution, limiting the potential benefits for biodiversity of achieving Target 7. Second, several of the measures to address non-agricultural sources, such as pollution from wastewater, are considerably cheaper and/or easier to implement because they rely on using market-ready technologies and can reduce emissions considerably more than most agricultural measures (Winiwarter et al. 2018). Finally, agriculture's contribution to nutrient pollution relative to other sectors varies significantly across countries, and therefore limiting Target 7's focus to agriculture would mean that countries with significant non-agricultural sources would not experience as much of a benefit to biodiversity from such a narrow focus (Sutton et al. 2013).

Numerical objectives, indicators and relationship to SDGs - **Halving nutrient losses to the environment by 2030 can be justified from environmental, agronomic and technical perspectives.** From an environmental standpoint, halving nutrient losses is in line with the planetary boundaries literature, which suggests that humanity needs to halve the amount of N and P introduced into the Earth System to return to a safe operating space (Steffen et al. 2015, De Vries et al. 2013). From an agronomic standpoint, Zhang et al. (2015) have estimated that to meet the 2050 food demand and bring N pollution back to the planetary boundary, total annual N surplus from the world's croplands needs to be reduced by about 50% (from 100 million tonnes N per year to 52 million tonnes N per year). Such reduction could be achieved by ambitious yet realistic and regionally tailored increases in N use efficiency (NUE, the proportion of N applied that is harvested vs. lost to the environment).

The possibility to significantly reduce nutrient losses without compromising agricultural productivity is supported by field experiments across multiple agricultural systems. For example, a recent study in China showed that a combination of improved management practices, enhanced efficiency fertilizers, mechanization and manure management could increase wheat, maize and rice yields by approximately 10% and NUE by almost 30% while reducing cropland nitrous oxide emissions and nitrate leaching by 50% and 40%, respectively, as well as livestock N losses by 20% and greenhouse gas emissions due to N fertilizer production, transport and application by over 15% compared to a 2012 baseline scenario (Guo et al. 2020). A global study that assessed the mitigation potential of improved management, reductions in food loss and waste and shifts towards more plant-based diets showed a decrease in N and P application by a half and two thirds, respectively, in 2050 relative to a baseline scenario that does not include any specific mitigation measures and a middle-of-the-road development pathway (Springmann et al. 2018). About 50% or even more reduction in N and P losses have been reported by fertilizer management strategies like band placement, deep placement, use of controlled release fertilizers (Yao et al. 2018, Zeng et al. 2008, Irfan et al. 2018, Wang and Huang 2021).

For non-agricultural sectors, several technologies are available to reduce industrial emissions by over 90% and transport emissions by over 50% and possibly more for the latter with a significant transition towards electric vehicles powered by low carbon electricity sources (Kanter et al. 2017). For wastewater, technologies exist to recover 75% of N and 20%-50% of P for reuse in agriculture, while wastewater treatment technologies can reduce the concentration of N and P in wastewater by up to 80% and 96%, respectively (Kanter & Brownlie, 2019).

One critical issue is the choice of baseline, i.e. halving nutrient losses to the environment compared to what? While some studies compare mitigation efforts to a counterfactual "no-action" trajectory, these trajectories are based on a variety of assumptions on economic and population growth, technological innovation and education levels amongst other variables that may not come to pass (Kanter et al. 2020). Consequently, baselines based on past years of recorded nutrient losses (possibly even an average across several years to account for interannual variability) is a much more scientifically defensible and measurable approach, using data on nutrient use efficiency and nutrient surpluses from sources such as Zhang et al. (2015) and Zhang et al. (2021a).

Adapting objectives to national contexts - **The goal of halving nutrient losses to the environment is a feasible global objective, but its implementation should be adapted to national circumstances.** Some countries have very high nutrient surpluses and low nutrient use efficiency, leaving ample opportunity for reducing nutrient losses from agriculture. Other countries have close to zero nutrient surpluses and high nutrient use efficiency, and in this case agricultural soils are being depleted of nutrients due to insufficient nutrient inputs, causing low yields as in the case of much of Sub-Saharan Africa. In these cases, nutrient inputs should be increased to improve productivity even if this is accompanied by small increases in nutrient losses to the environment (Zhang et al. 2015, UNEP 2022a). The analysis by Zhang et al. (2015) provides an example of how halving N surplus globally can take these regional differences into account while maintaining food security. For example, their proposed target for China is a reduction in annual N surplus by over 70% (from 38 million tonnes N in 2015 to 11 million tonnes N in 2050) combined with an increase in food production by over 20%, whereas the target for Sub-Saharan Africa allows for a doubling of N surplus (from 2 million tonnes N to 4 million tonnes N) while also doubling food production.

While increasing food production in countries with low nutrient use is critical, every effort should be made to avoid the trajectory followed by most OECD countries: a significant drop in nutrient use efficiency (and thus increase in nutrient losses) as nutrient application rates increase, followed by an increase in nutrient use efficiency as a blend of management practices, fertilizer technologies and crop breeding advancements become broadly adopted (Zhang et al. 2015). As fertilizer use and its use efficiency vary significantly among countries based on factors like climate, cropping patterns, economies etc., a thorough assessment of nutrient balances should be made such as those in the European N assessment (Sutton et al. 2011), Indian N assessment (Abrol 2017) and Pakistan N assessment (Aziz 2021). The livestock sector is the least efficient sector in terms of nutrient use, contributing greatly to nutrient pollution. The UN Economic Commission for Europe (UNECE) has adopted a guidance document on integrated sustainable N management providing a number of strategies to increase N use efficiency (UNECE 2021). Such guidance documents should also be prepared for phosphorus.

➢ ***including by reducing…" pesticides by at least two thirds"***

Global pesticide use and risks are increasing (Bernhardt et al. 2017, Schulz et al. 2021), with agriculture having by far the largest share (Maggi et al. 2019). Pest management in agriculture is essential to avoid potentially high yield losses from pests (Savary et al. 2019). Synthetic pesticides are just one of the solutions in the pest management toolbox, but most agricultural systems currently rely heavily on synthetic pesticides. Alternatives include biological solutions (e.g., biocontrol, bio-pesticides), agronomic solutions (e.g., adapted crop rotations, field hygiene), technical solutions (e.g., tools for precision application, mechanical weed control, smart farming), breeding solutions (e.g., resistant and adapted varieties) and system redesign (e.g., systems that favor natural solutions for pest control, see Möhring et al. 2020a for an overview). In principle, pesticides applied in agriculture follow registration procedures that ensure concentrations present in the non-target environment or reaching humans remain below those considered harmful, based on threshold values defined in ecotoxicological and toxicological testing programmes for each single pesticide. However, monitoring data for certain types of pesticides show that the concentrations regularly present in the environment greatly exceed the ecotoxicological thresholds determined in the regulatory pesticide risk assessment (Stehle & Schulz, 2015; Wolfram et al. 2018). These data are however largely restricted to surface waters, since we lack comprehensive monitoring for many terrestrial ecosystem components including biota.

<u>Target formulation</u> - The toxicity of pesticides varies greatly, and for example spans more than 12 orders of magnitude across insecticides and classes of aquatic invertebrates (Schulz et al. 2021). This means that some pesticides are highly toxic even at extremely low application rates, so pesticide quantity is not indicative of its risks. Highly toxic neonicotinoid insecticides for example only require application rates of a few grams per hectare, while older organophosphate insecticides are applied at rates of up to two kilograms per hectare. Toxicity to non-target organisms greatly depends on the type of pesticides and species group; insecticides are more relevant for pollinators and aquatic invertebrates, and herbicides are more relevant for plants (Schulz et al. 2021). **Any pesticide target based only on total pesticide mass applied in agriculture ignores the large range in toxicity**. For example, insecticide risk for aquatic invertebrates (driven by pyrethroids) or pollinators (driven by neonicotinoids) increased up to a factor of four in the USA between 1992 and 2016, while the applied insecticide amount decreased by about 40% (Schulz et al. 2021). Policies based on purely quantitative indicators (e.g., pesticide mass used) might therefore have unintended effects on risk reduction and might even result in incentives to use pesticides in lower quantities but with higher toxicity (Möhring et al. 2019). **It is of utmost importance to base pesticide policies and indicators on the toxicity of pesticides applied, or more generally on the risk associated with their application.**

Indicators for pesticide risk reduction should generally be applied at the level of pesticide sales or use to include all adverse impacts. Adverse impacts of pesticides include large field-level effects on non-target organisms such as pollinators and soil organisms, as well as effects of pesticides in non-target ecosystems that occur for example through spray drift or edge-of-field runoff (Beketov et al. 2013, Liess et al. 2021, Wolfram et al. 2021). Therefore, **the objective Target 7 should not be interpreted as being restricted to "pesticides lost to the environment".**

Numerical objectives, indicators and relationship to SDGs - Pest management plays an essential role in maintaining food security and agricultural incomes. Reducing pesticide risk can be achieved by 1) increasing the efficiency of current pesticide use, 2) substituting high risk with low risk pesticides and other pest management tools and 3) redesigning production systems (e.g. Pretty, 2018). **Literature and experiences from case studies show that increasing efficiency and substitution can achieve risk reduction of 20-50%, without redesign of production systems** (e.g., Lechenet et al. 2017, Kudsk et al. 2018, Möhring et al. 2020). Denmark, for example, was able to substantially reduce pesticide risks through the application of a risk based indicator in policies, even though quantitative indicators for total pesticide use increased (see Kudsk et al. 2018 for a description of relevant governmental sources).

Redesign of agricultural systems as well as novel pesticide-free production systems can greatly reduce pesticide use while increasing farmer's incomes and reducing trade-offs with yield losses compared to organic agriculture (Möhring and Finger 2022). The globally heterogeneous and context-dependent production potential of organic agriculture, i.e., using zero synthetic pesticides, shows that redesigning production systems might only lead to small yield losses for some production contexts and regions, but can be substantial for other regions and cropping systems (Seufert & Ramankutty 2017).

Transformation of pest management systems should therefore aim to reduce trade-offs and increase synergies with biodiversity to support pest control and productivity. For example, the trade-offs between increased mechanical weed control and soil erosion, or between reductions in agricultural productivity and the expansion of agricultural land or reductions in food security. Enhancing biodiversity in agricultural systems can help to greatly reduce pesticide inputs and should play an important role in redesign (Gurr 2016, Pretty 2018, Sattler 2021). Widespread adoption of sustainable pest management practices that are drastically reducing pesticide use or are pesticide-free will therefore require novel technologies, techniques and programs, as well as changes in food diets and food waste to compensate for potential yield reductions (Muller et al. 2017, Pretty 2018). Long-term and stable planning horizons for such changes will enable food-value chain actors to adapt and reduce trade-offs (Möhring et al. 2020). Further, food-value chain actors will play an important role in supporting this transformation to provide pathways for reducing potential trade-offs with food production, farmers incomes, soil conservation and greenhouse gas emissions (Möhring et al. 2020).

Adapting objectives to national contexts - Some countries have extremely high pesticide use and risks, others currently use very little pesticides (Tang et al. 2021, Appendix-Figure 1 and Maggi et al. 2021, Appendix-Figure 4). As such, **global numerical objectives for reduction of pesticide risk should not be applied directly to national levels, and should instead be based on evaluations of current pesticide use and risk, capacity for reducing risk and short- and long-term trade-offs.** Moreover, the entry routes into non-target ecosystems and in consequence the type of pesticides causing the main problems will differ between countries. Herbicide use has often the largest share of pesticide use and likely poses risks to terrestrial non-target plants, while insecticides are used in much smaller quantities, yet pose risks to many non-target invertebrates due to their tremendous toxicity (Schulz et al. 2021). Risk mitigation measures to account for the different entry routes have been proposed (Stehle et al. 2011).

1) Indicators

- ➢ **Indicators in GBF monitoring framework** - pre-SBSTTA 24, notes from SBSTTA-24 in {}

Headline in bold, component indicator in plain and *complementary indicator in italics*

7.0.1 Index of coastal eutrophication potential (excess nitrogen and phosphate loading, exported from national boundaries) / Disaggregation by water body type {or by basin}

7.1.1 Fertilizer use (FAO {SDG 14.1.1a})

7.1.2 Proportion of domestic and industrial wastewater flow safely treated (SDG 6.3.1)

{7.4.1 Municipal solid waste collected and managed (SDG 11.6.1)}

t7.1 Trends in Loss of Reactive Nitrogen to the Environment

7.0.3 Pesticide use per area of cropland / Disaggregation by broad pesticide use classes

➢ **Comments on nutrient indicators**

Measuring progress on reducing nutrient pollution requires numerous indicators given the multiple sources and impacts of nutrient pollution (Appendix-Figure 3). In general, sets of **indicators that focus on the point of use or loss (e.g., nutrient use efficiency; nutrient surplus; NO_x emissions from agriculture, transport and industry) are more helpful for informing policies to reduce pollution than sink-specific indicators such as N and P export to coastal areas from rivers, which is the current headline indicator** (Kanter et al. 2020, Quan et al. 2021, Raza et al. 2018). Moreover, a focus on one specific nutrient compound can increase the risk of pollution swapping, where actions to mitigate losses of one form of nutrient pollution leads to increases of another form (Stevens & Quinton 2009, Bouraoui & Grizzetti 2014).

The current GBF monitoring framework covers a small and piecemeal range of relevant nutrient pollution indicators, and the headline indicator covers only one part of important N and P pollution sinks (Appendix-Figure 3). This can only partially be improved because readily available indicators covering key sources and sinks of pollution with global coverage are lacking. It is, however, strongly recommended that the GBF complement the current set of indicators focusing on fertilizer use, coastal eutrophication potential and wastewater treatment, which capture only a narrow range of nutrient pollution impacts or potential implications of different policy actions. In particular, **indicators focusing on agricultural N and P surplus (= total N or P input minus the amount taken up by crops or pasture grasses) are available and more relevant than fertilizer use for assessing progress on agricultural sources of N and P pollution.** National-level data on N and P surpluses are documented in Zhang et al. (2021b) and Zou et al. (2020), respectively, and can be calculated from FAO data. Transdisciplinary and transnational collaboration is needed to improve the basic data (such as the quantification of nutrient budgets) for these indicators (Zhang et al 2021a).

There are several other indicators that might be considered including: N footprint (Shibata et al. 2017, Galloway et al. 2014) and the Sustainable Nitrogen Management Index (SNMI, used in the SDG Dashboard and the Environmental Performance Index; Zhang and Davidson 2019), which is defined based on two efficiency terms in crop production, namely Nitrogen Use Efficiency (NUE) and land use efficiency (crop yield).

➢ **Comments on pesticide indicators**

Several indicators of risk-based pesticide use have recently become available. These indicators provide different and complementary insights into pesticide risks for biodiversity and associated risks for the environment and human health, and should be used in combination to evaluate progress on Target 7.

Generally the basic requirement to compute aggregated risk indicators is data on pesticide sales or use on a product or active substance level, combined with data bases containing information on risk per product or active substance. Data for pesticide sales at a product level are available in almost every country through taxation or customs data (import/export). Data on risk per product or active substance is for example compiled in the Pesticide Properties Database and regularly updated (Lewis et al. 2016). More precise assessments of impacts require more detailed data on pesticide use and exposure on a product level, which is still very scarce even in regions with explicit pesticide risk reduction targets (e.g., Mesnage et al. 2021). For example, Denmark is using an indicator of potential pesticide risks, the Pesticide Load Indicator, on a national level with low administrative burdens and costs since 10 years (Kudsk et al. 2018).

Pesticide risk specifically focusing on biodiversity can be estimated for a wide range of species groups including aquatic and terrestrial plants, invertebrates and vertebrates based on toxicity data (Total Applied Toxicity, Appendix-Box 1, Schulze et al. 2021). The input data needed are substance-specific pesticide use data based on sales at the country level as well as pesticide toxicity data which are publicly available for a large number of compounds (>380) and eight species groups (Schulz et al. 2021). This can be accompanied by an indicator of human health risk.

Pesticide risk evaluation of environmental risk using toxicity measurements on model organisms (fish, earthworms and rats) can be quantified by the Risk Score (RS, Tang et al. 2021, Appendix-Figure 1 and

Box 1). This can be accompanied by an indicator of human health risk reduction using the Pesticide Health Risk Index of Countries (PHRIC, Maggi et al. 2021). Definitions and details can be found in Appendix-Box 1. RS and PHRIC require knowledge of the applied mass of and toxicity of individual active ingredients, crop type and several environmental parameters. Countries that do not collect this data may rely on to use estimates from FAOSTAT or other publicly accessible (peer reviewed) sources such as PEST-CHEMGRIDS (Maggi et al. 2019). An additional indicator, the surface area of agricultural land that is at risk of pesticide pollution, might also be considered and is based on the same methodology (Tang et al. 2021).

3) Linkages to other relevant international policies

The nutrient and pesticide pollution objectives of the GBF are broadly coherent with other international policies. There are thousands of nutrient and pesticide policies in place at local, national and supra-national levels that vary greatly in their objectives, so striving for greater coherency across policies is vital (Kanter et al. 2020, Möhring et al. 2020). Unfortunately, only a few of the many policies aimed at reducing nutrient and pesticide pollution have reached their objectives and globally nutrient and pesticide pollution are rising (SCBD 2020). Kanter et al. (2020, nutrients) and Möhring et al. (2020, pesticides) provide analyses of the reasons for failure and success of policies, and find that setting clear goals, choosing appropriate performance indicators and systemic approaches involving all actors are common denominators to help ensure success.

Nutrients

- Colombo Declaration (2019): Develop national roadmaps for sustainable nitrogen management, with an ambition to halve nitrogen waste by 2030;
- UNEA-4 and UNEA-5, Resolution on Sustainable Nitrogen Management (2019, 2021): ambition to significantly reduce nitrogen pollution by 2030 by covering all the spheres of the nitrogen cycle, potentially supported through the establishment of an inter-convention or intergovernmental nitrogen coordination mechanism. The ambition is to reduce nitrogen waste to combat pollution, climate change and biodiversity loss, while ensuring food security and offering the potential to save billions of United States dollars annually.
- See Kanter et al. (2020) for global database of N policies (mostly national) revealing a clear tension between policies that facilitate and/or directly encourage N use with a view towards food security, and policies that put constraints on N use and/or losses to the environment.

Pesticides

- UNEA Resolution ¾: Environmental and Health Impacts of Pesticides and Fertilizers and ways to Minimize Them. Synthesis Report (2021).
- Basel, Rotterdam, Stockholm Conventions (BRS), and the Minamata Convention on Mercury (MC): The 1998 Rotterdam Convention on the Prior Informed Consent Procedure for certain Hazardous Chemicals and Pesticides in International Trade is particularly pertinent for the pesticide objective. A 2021 policy brief on the relationships of this convention and the Basel and Stockholm Conventions to the GBF can be found at this link Interlinkages between the chemicals and waste multilateral environmental agreements and biodiversity: Key insights
- Example from the European Union of two policies covering pesticides: the Farm to Fork—to reduce by 50% the use and risk of chemical pesticides by 2030—and Biodiversity Strategies—reduce by 50% the use of more hazardous pesticides by 2030.

<u>4) References</u>

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TARGET 7–POLLUTION - APPENDIX

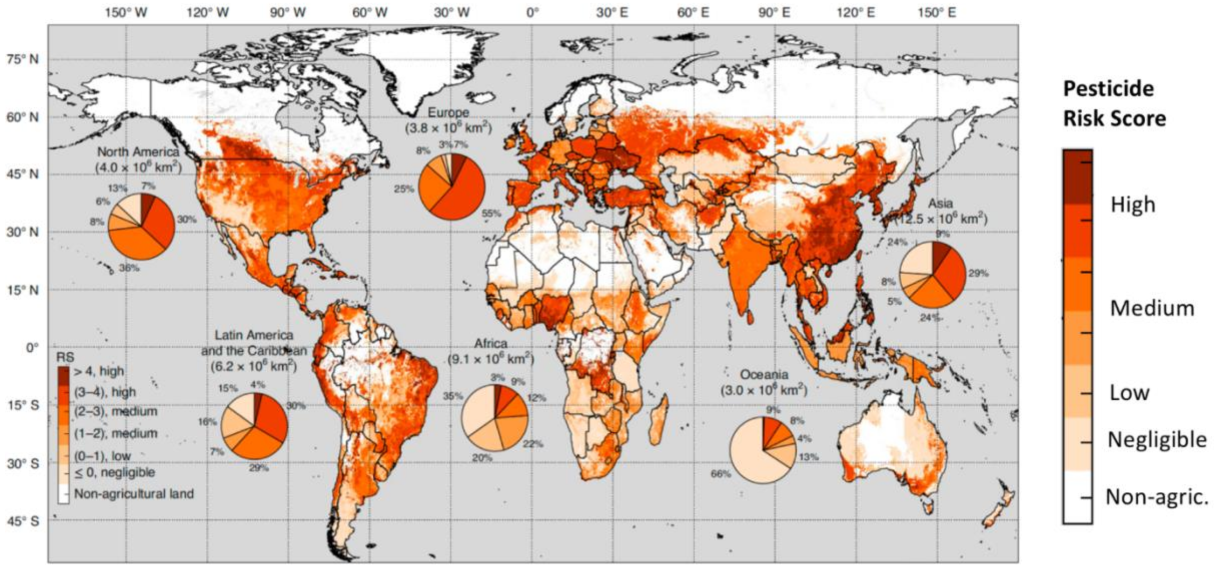


Figure 1. Global scale map of pesticide risk. "64% of global agricultural land is at risk of pesticide pollution by more than one active ingredient, and 31% is at high risk. Among the high-risk areas, about 34% are in high-biodiversity regions." Tang et al. (2021, see also description below in Box 1)

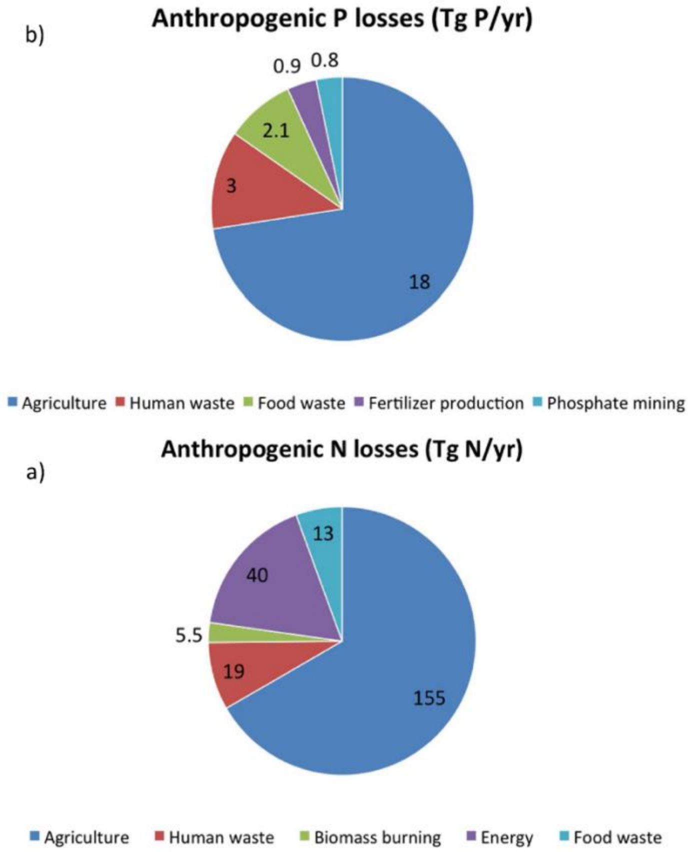


Figure 2. Sources of nitrogen (N) and phosphorus (P) losses to the environment at the global scale. from Kanter & Brownlie (2019)

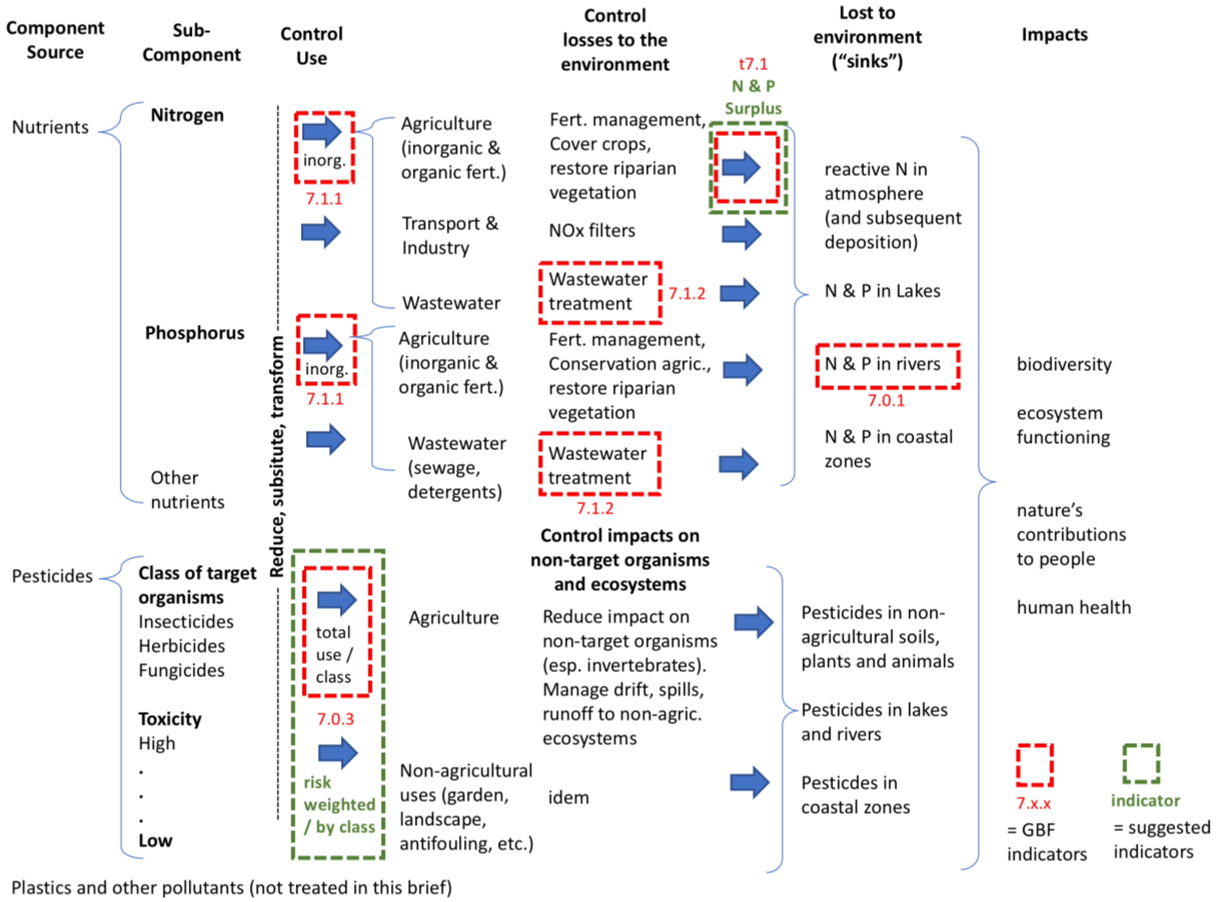


Figure 3. Summary of sources of nutrient and pesticide pollution; means of reducing pollution by controlling use or losses to the environment; proposed indicators for the GBF; and impacts. Indicators currently in the GBF are in red boxes. The headline indicator for nutrients is N and P in rivers lost to coastal areas (7.0.1). The only indicator for pesticides is total pesticide use (7.0.3). This brief suggests using N and P surplus as the headline indicator for nutrient pollution and risk based pesticide use as the primary indicator for pesticides (green boxes).

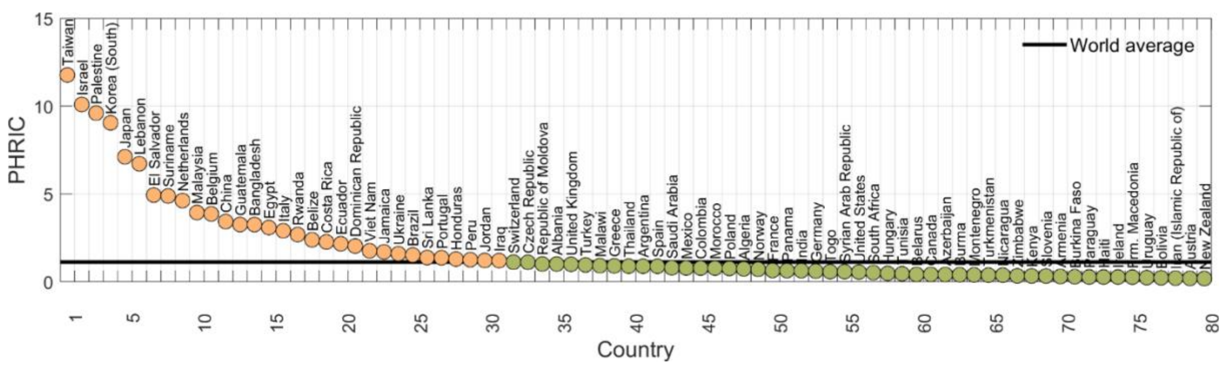


Figure 4. Pesticide health risk index of countries (PHRIC). 31 countries worldwide have PHRIC higher than the world average, where PHRIC aggregates the pesticide load (toxicity and mass), people exposure, and potential intake via inhalation and drinking water (Maggi et al. 2021).

Table 1. Summary of most important impacts of nutrient (nitrogen and phosphorus) pollution on biodiversity

Impact	Caused by	Indicators	Safe limits[1]
Freshwater eutrophication	- Increased and N and P discharge to surface water (from point sources, surface- and subsurface runoff) - Reduced streamflow	- N / P concentration in rivers, lakes and streams	- Nitrogen: 1-4 mg N l-1 - Phosphorus: 0.05-0.1 mg P l–1 - Variation across water bodies which nutrient is most limiting
Coastal eutrophication	- Increased and N and P delivery to coastal waters	- N & P concentrations in river discharge to coastal waters - ICEP - Chlorophyll a concentrations	
N enrichment impacts on terrestrial ecosystems (including acidification, micronutrient deficiencies, shifts in species composition	- Increased air emissions of reactive N (NH3+NOx) and consequent re-deposition onto terrestrial ecosystems	- Total N deposition in relation to an ecosystem's carrying capacity (critical load) - NO3- in soil solution	- Ecosystem-dependent critical loads (10-30 kg N ha-1 yr-1) - The duration of exceedances is also relevant
Direct damage to plants from NH3, NO2 or O3 exposure	- Increased air emissions of reactive N (NH3+NO)	Exposure to increased NH3 / NO2 / O3 concentrations	- NH3 in air: 1-3 µg NH3 m-3 - NO2 in air: 15-30 µg m-3 - Ozone: Growing-season AOT40 of 10 ppm/hour

Other N and P impacts not included in table:

- N contribution to particulate matter (PM2.5 + PM10) formation (relevant for human health, but impact on ES less well known)
- N contribution to stratospheric ozone depletion via N2O (relevant for human health, but impact on ES less well known)
- Nitrate pollution of groundwater (mainly relevant for human health)
- N contribution to climate change (climate change important driver of BD loss but N plays minor role and climate considered in other targets)

[1] Freshwater eutrophication: Poikane et al. 2019, Camargo & Alonso / Coastal eutrophication: Brooks et al. 2016, Garnier et al. 2010 / Terrestrial N enrichment: Bleeker et al. 2011, Bobbink et al. 2010, Payne et al. 2017 / Air pollution: Cape et al. 2009, Krupa 2003

Table 2. Summary of most important impacts of pesticide pollution on biodiversity. Reductions in applied pesticide toxicity are not well defined (see Box 1); however, the scarce data available indicate that strong reduction in applied toxicity is needed to ensure environmental and human health. It is however of utmost importance that an overall reduction in the applied toxicity for all relevant species groups is ensured, and current-use toxic pesticides are not just simply replaced by others that are toxic to another species group. (Jactel et al. 2019)

Impact	**Caused by**	**Indicators**	**Safe limits**
Surface water [and marine] biodiversity (structure and function)	- Point and nonpoint source entry - Direct exposure - Accidents - Main focus on insecticides: Pyrethroids, some OPs for aquatic invertebrates and fish	- Toxicity of pesticides applied (separated for species and compound groups) - Pesticide concentration in rivers, lakes, streams, [and coastal areas] (water, sediment, and biota)	- Critical limits not well defined from the standpoint of biodiversity (see Table legend, Box 1). - Concentrations of individual active ingredients or their breakdown compounds should not exceed regulatory threshold levels
Terrestrial biodiversity (structure and function)	- Direct exposure - Point and nonpoint source entry - Accidents - Main focus on insecticides and herbicides: Neonicotinoids for pollinators; Amino Acid synthesis inhibitors and cell membrane disruptors for terrestrial plants	- Toxicity of pesticides applied (separated for species and compound groups) - Pesticide concentration in terrestrial non-target ecosystems (plants, insects, vertebrates, other biota)	- Critical limits not well defined from the standpoint of biodiversity (see Table legend, Box 1). - Concentrations should not exceed regulatory threshold levels
Soil biodiversity (structure and function)	- Direct exposure - Point and nonpoint source entry - Accidents - Main focus on fungicides and insecticides: Azole fungicides and specific insecticides	- Toxicity of pesticides applied (separated for compound groups) - Pesticide concentration in terrestrial non-target ecosystems (plants, insects, vertebrates, other biota)	- Critical limits not well defined from the standpoint of biodiversity (see Table legend, Box 1). - Concentrations should not exceed regulatory threshold levels

Other pesticide impacts not included in table: effects on human health

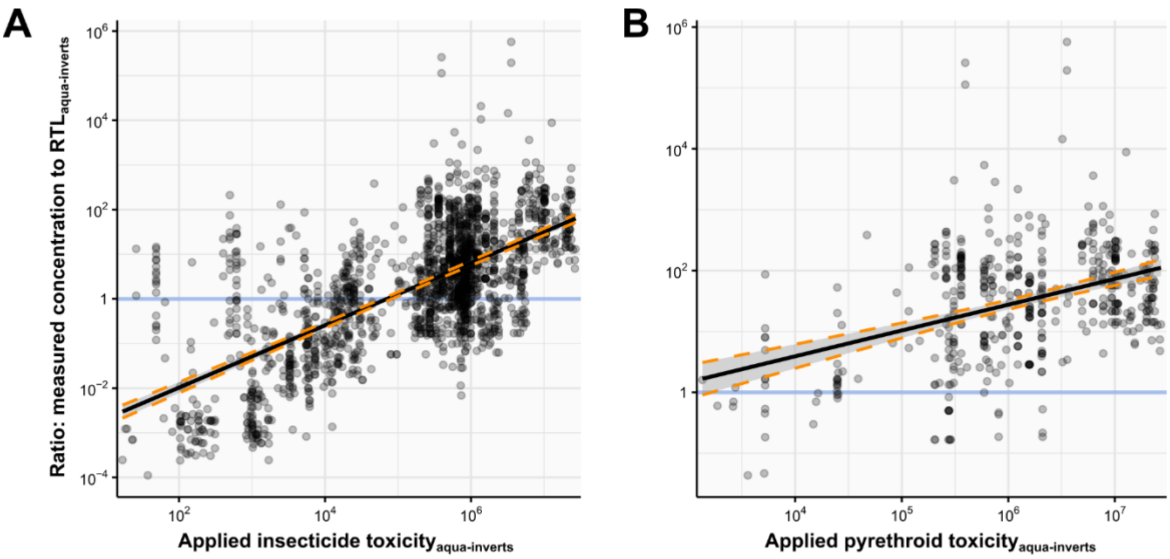
------------------------------ Box 1. Risk based indicators for pesticides —-----------------------

Environmental and human risk indicators - The Risk Score (RS) defined in Tang et al. (2021, see Appendix Figure 1) considers pesticide contamination of soil, surface water, ground water and air with an explicit accounting for environmental toxicity and degradation half-time. The Pesticide Health Risk Index of Countries (PHRIC) defined in Maggi et al. (2021) is a composite index including the applied mass of pesticides, their toxicity load, and human exposure and intake. RS and PHRIC require knowledge of the applied mass of individual active ingredients and the crop type. It is therefore critical that countries take initiatives to monitor and keep records of applied mass, timing and location (at least at the level of administrative units) for the purpose of quantifying the risk and analyze trends to achieve reduction of risk. Countries that do not collect data or are not in the position to do so may need to use estimates from FAOSTAT or other publicly accessible (peer reviewed) sources such as PEST-CHEMGRIDS (Maggi et al. 2019). Data quality of inputs and risk analyses may be improved when data have finer granularity (administrative units) in contrast to country totals. Countries may also monitor detrimental effects of not using or using in substantially lower amounts pesticides for food/fiber production.

Biodiversity-oriented risk indicators – Any pesticide risk indicator must, in order to help to reduce risks, at the end of the day lead to reduced concentrations of those types of pesticides most relevant, i.e. most toxic, to the different groups of species. It is therefore important to evaluate whether a lower risk indicator indeed leads to a lower exposure and thus risk in those ecosystems to be considered. The Total Applied Toxicity, TAT (Schulz et al. 2021) has up to now been calculated for eight groups of non-target organisms (aquatic invertebrates, fish, aquatic plants, terrestrial invertebrates, pollinators, birds, terrestrial mammals, and terrestrial plants). TAT simply multiplies the total use of pesticide active ingredients with the reciprocal of toxicity thresholds from the regulatory pesticide toxicity testing (RTL = Regulatory Threshold Levels; Stehle & Schulz 2015). In other words, the only thing TAT does, is to express pesticide use instead of amounts applied in terms of toxicity applied, separated for groups of pesticides and species. TAT does, in contrast to other risk indicators, such as the Risk Score (RS) defined in Tang et al. (2021) or the SYNOPS risk calculator used in the German National Action Plan (Strassemeyer et al. 2017), not attempt to estimate the transport of pesticides into the non-target environment.

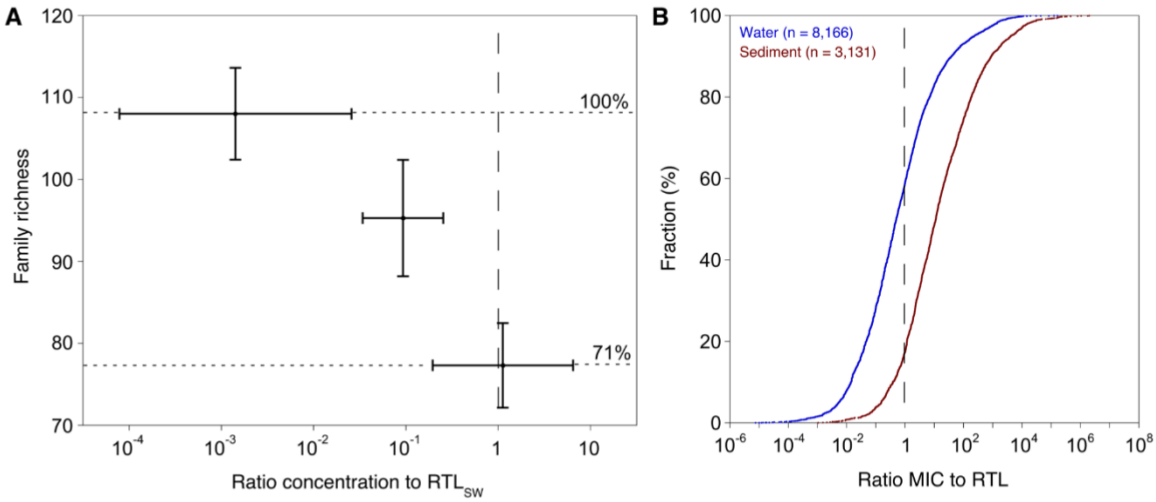
Although studies have shown that toxicity-weighted use is the strongest predictor of the potential impact of a pesticide on the environment, TAT relies on the assumption that pesticide use and its effects on organisms are robustly connected to each other at large scales (Schulz et al. 2021). This assumption is, however, been supported by data from the USA, even in the crucial case of pesticide and pyrethroid risks to aquatic invertebrates. The rate at which measured insecticide or pyrethroid concentrations exceed the RTL for aquatic invertebrates is significantly correlated with the applied toxicity (see figure below). This kind of analysis can, however, up to now only be made for surface waters, since the relevant data are lacking for all other ecosystems.

Both pesticide use and toxicity can then be computed very simply to come up with Total Applied Toxicity estimates, separated for pesticide type, organism group, ecosystem type, or cropping system. Calculations of, as a toxicity based indicator, can be done in any standard table calculation software and the low complexity of the input data eases transparency, understanding and interpretation of any risk-related outcomes.



Relationship between the aquatic invertebrate threshold level exceedance of insecticide (A) or pyrethroid (B) concentrations measured in U.S. surface waters and the total applied insecticide toxicity (Schulz et al. 2021).

Other studies have shown RTL-exceedances of pesticides in surface waters to be indicative of negative effects on aquatic biodiversity (Stehle & Schulz, 2015). The family richness of aquatic invertebrates is reduced by ~30% when the RTL is exceeded (see figure below). The RTL is exceeded in more than 40% of the insecticide concentrations quantified in the water phase and in more than 80% of those quantified in sediments (Stehle & Schulz 2015), illustrating how widespread the problem is (see also Tang et al. 2021).



(A) Observed ecological effects of insecticide exposure on regional surface water biodiversity and (B) distribution curves for global reported measured insecticide concentrations (MICs) in water and sediment relative to regulatory threshold levels (RTLs). The vertical dashed line indicates the RTL (Stehle & Schulz 2015).

It is important to note that only very few groups of pesticides or even very few individual pesticides drive large proportions of the TAT. In the case of aquatic invertebrates, only four pyrethroid compounds explain >80% of the TAT increase observed for this species group in the USA (Schulz et al. 2021). This fact comes along with the advantage that regulating only few compounds or pesticide groups may reduce the risks considerably, yet only under the assumption that the reduced use is not compensated by other pesticides, which then will increase the TAT again.