Developing indicators to measure biodiversity risk exposure of Natura2000 parks to industrial pollution

E-mail: szilard.erhart@ec.europa.eu
Via E. Fermi, 2749, 21027 Ispra VA, Italy

E-mail: balint.menyhert@ec.europa.eu
Via E. Fermi, 2749, 21027 Ispra VA, Italy

E-mail: kornel.erhart@gmail.com

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Abstract. While every protected natural park can be exposed to pollution, some may suffer more. We develop methods to analyze their biodiversity risks from industrial sites around Europe. This study is novel as it is the first attempt at linking the European Pollutant Release and Transfer database to the geographic data of Natura 2000 parks. Furthermore, we applied the improved characterization factors in the Environmental Footprint database published by the European Commission. The proximity of largest industrial facilities to Natura 2000 parks, which is the largest network of protected areas in the world, can affect biodiversity risks in Europe and globally. We quantify hazards in the recent past and at the Natura 2000 park level. We find that natural parks in Benelux states, Ruhr area of Germany, in Northern Italy and in countries in Central and Eastern Europe have been strongly exposed to eutrophication and biodiversity risks and about 2% of facilities are located in Natura 200 parks and 4% less than 100 meters away. All this calls for improved monitoring and respective prevention measures in some key regions of Europe along with international biodiversity loss mitigation efforts.

Keywords — Chemical footprint, Sustainability, E-PRTR, Eco-toxicity, Life-cycle-assessment, Water ecotoxicity, Natura 2000 parks, Biodiversity

1. Introduction

Pollutant releases are known for their ecological and human toxicity effects; for instance, they are reflected in a higher share of potentially affected species and human mortality rates, Fantke et al. [2015], García-Pérez et al. [2020], Fernández-Navarro et al. [2017], Nguyen et al. [2021]. There are well-known benefits of chemical use, however, the inadequate use or excess release of chemicals may not only cause harmful side effects on humans but can also negatively affect the ecosystem too, Nordborg et al. [2017], Sala and Goralczyk [2013]. In many regions, human pressures on the environment exceed levels that natural systems can sustain, Bjorn et al. [2020]

The European Union (EU) committed to halt the loss of biodiversity in its 2020 Biodiversity Strategy and in the Sustainable Finance Taxonomy regulation (EU) 2020/852 set biodiversity protection objectives and the 'Do No Significant Harm'(DNSH) criteria for activities that can be marketed as sustainable activities.

In a macroscopic study on Europe it was found that biodiversity loss is strongly associated with human development, Gatiso et al. [2022]. Buchanan et al. [2020] suggested improved biodiversity monitoring, which would facilitate more effective assessment of progress toward biodiversity targets and enable more insightful policy responses.

In this paper we develop methodologies and indicators for the assessment of a specific environmental objective in the EU Taxonomy Regulation, the *Protection and restoration of biodiversity and ecosystems*. We use the the European Pollutant Release and Transfer Register (E-PRTR), which covers the largest industrial facilities in Europe. We analyze the direct impact potentials of pollutant releases into freshwater on local biodiversity in terms of ecotoxicity and eutrophication.

Our study has two important methodological novelties. First, we investigated the location of E-PRTR facilities and their proximity to Natura 2000 parks. To the best of our knowledge, this is the first study to calculate the proximity of industrial facilities and the associated biodiversity risk. Earlier research papers focused on the estimation of freshwater ecotoxicity; however, they did not consider the proximity of protected natural areas, Nordborg et al. [2017], Sörme et al. [2016], Erhart and Erhart [2023].

Second, we used the recently released 3.1 Environmental Footprint package published by the Joint Research Centre, which provides improved characterization factors for metals into freshwater releases, Saouter et al. [2020].

Natura 2000 is the largest coordinated network of protected areas in the world offering living space to Europe's most valuable and threatened species and habitats. Protected areas can not be designed and managed with an isolated 'island' approach. By developing indicators to measure biodiversity risk exposure to industrial pollution, we aim to take into consideration the complexities of the socio-ecological system in which Natura 2000 parks in Europe are established Palomo et al. [2014].

Our methodology helps to broaden the coverage of Environmental Social and Governance risk assessments to the major industrial polluters (about 10 thousand companies in Europe) and allows a desegregated facility and regional-level thematic investigation of their biodiversity risks, which is not possible when using the consolidated company-level sustainability reports. Crenna et al. [2020] showed that sound ecological indicators and metrics need to be integrated in order to better assess the impacts of value chains on biodiversity on a global, regional, and local scale. Our analysis can also help the assessment of well-being levels of communities living near Protected Areas (PAs), which is a key factor for meeting biodiversity conservation targets Jones et al. [2020].

2. Methods and data

Here, we present a novel methodology to analyze the possible impacts of E-PRTR industrial facilities on Natura 2000 parks in an integrated way using the Environmental Footprint methodology developed by the contributors of the Joint Research Centre (Sala et al. [2022], Crenna et al. [2020], Zampori and Pant [2019], Saouter et al. [2020]).

Pollutants released by industrial facilities have a significant impact on the ecosystem at large. The seriousness of ecological consequences can be underestimated if only the quantity of pollutants is used Edwards and Walker [2020].

In Life Cycle Impact Assessment (LCA) the "elementary flows" to the environment without further human transformations are translated via a characterization step and aggregated to environmental impact indicator results related to human health, the natural environment and resource depletion Laurent et al. [2010].

2.1. Data

Our analysis is based on three datasets from the European Environmental Agency (EEA) and the European Commission Joint Research Centre (JRC): (1) on the EEA's European Pollutant Release and Transfer Register (E-PRTR), (2) on the EEA's dataset of Natura 2000 parks and (3) the JRC's Environmental Footprint (EF) 3.1 package.

The E-PRTR dataset contains information on industrial facilities (facility and parent company names, geographic coordinates) and their releases (pollutant name and Chemical Abstract Service Number–CAS, release media: AIR/WATER/SOIL, reporting year, etc.). The register covers 91 pollutants as listed in Annex II of the E-PRTR Regulation (EC) No 166/2006, which are classified as greenhouse gases, heavy metals, pesticides, and chlorinated organic substances. E-PRTR thresholds were calibrated and set to capture 90% of all European industrial point-source releases.

The Natura 2000 dataset includes geographic vector files and descriptive data for each Natura 2000 park (country, NUTS region code, park name, park code, park area, etc.) and information on species in the park (species name, whether it is protected, etc.)

The EU environmental footprint (EF) is a life-cycle-assessment (LCA) method which aims at assessing the environmental impacts of products and organisations through 16 mid-point impact categories, Sala et al. [2022]. The JRC EF dataset (url:

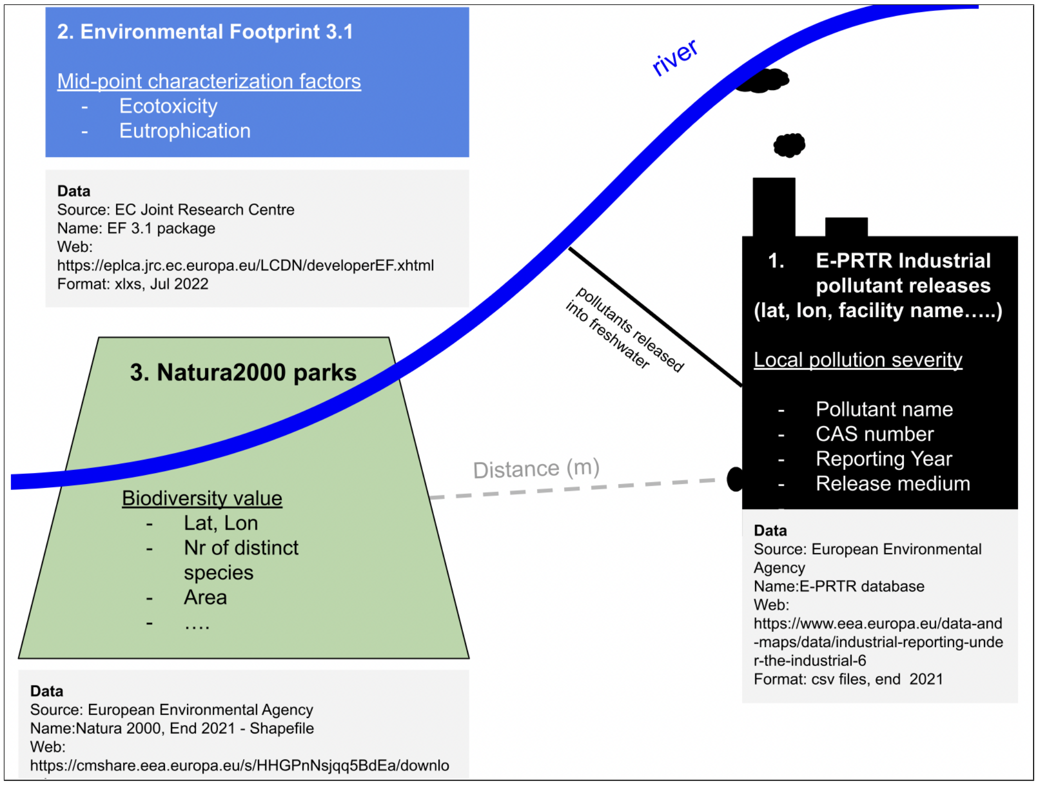


Figure 1: Simplified design of the applied research method

`https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtm`) contains updates of mid-point characterization factors in the life-cycle-assessment impact categories including eutrophication and freshwater ecotoxicity used for our analysis. Further environmental footprint categories such as acidification or climate change potential could also have biodiversity impacts, but usually on a global scale and not just on a regional scale; hence they cannot be assessed at the Natura 2000 park level in our study. The environmental footprint methods developed by the JRC to measure the life cycle environmental performances for Organization Environmental Footprint (OEF) have been included in the Commission Recommendation 2021/2279 published in December 2021.

This database also contains relevant information on pollutants and release types which is necessary to match the E-PRTR data with the Environmental Footprint calculation.

The graphs and figures in the study will be publicly available as supplementary materials in the Mendeley repository upon publication of the study. Erhart, Szilárd (2023), Mendeley Data, V1, doi: 10.17632/bvncmx7vvb.1

2.2. Methods

Our analysis of the potential risks from pollutant releases nearby Natura 2000 parks involves three consecutive steps (Figure 1).

First, the E-PRTR industrial facility level pollutant release data were matched with the mid-point characterization factors in the JRC EF 3.1 package (downloaded in Jul 2022) to calculate the environmental footprint of each pollutant release in the E-PRTR. The pollutants' Chemical Abstract Service numbers (CAS) were used to match two datasets under the condition that the life-cycle impact assessment (LCIA) method name was 'Ecotoxicity, freshwater' or 'Eutrophication, freshwater' , the FLOW class1 was "Emissions to water", and in the lack of precise knowledge on the subject the FLOW class2 was "Emissions to water, unspecified". In the same vein only observations in the E-PRTR database were used where the release medium was 'WATER'.

Second, the distance of each E-PRTR facility to the closest Natura 2000 park was calculated. For this calculation the geographic coordinates of the E-PRTR facilities are used and the GIS polygons of Natura 2000 parks. For the join of geographic layers we used the widely used QGIS 3.28 (url: `https://qgis.org/en/site/`), a free and open-source geographic information system application software. The join operation is based on nearest neighbour relationships. The result of the join is a new vector layer with the same geometry type and coordinate reference system as the input layers.

Third, we aggregated the environmental footprint in terms of freshwater ecotoxicity and eutrophication at the facility level, ranked and mapped facilities according to their footprint. Furthermore, building on the first two steps, we calculated the impacts for every Natura 2000 park by aggregating the environmental footprint of the E-PRTR facilities in the proximity of each park. As a technical rule in this study we aggregated the impacts of facilities in this last step for which the distance to the closest Natura 2000 parks is less than 500 m.

For the the implementation of the first step, we applied the same general method described in earlier research studies in the field by Sörme et al. [2016], Nordborg et al. [2017], Erhart and Erhart [2022] and calculated the ecotoxicity impact potentials and eutrophication impact potentials associated with emissions from point sources in the European Union and in other countries that report to the E-PRTR. The emissions in kilograms (E_{ij}) of each substance (i) in the E-PRTR were multiplied by their JRC EF 3.1 mid-point characterisation factors (CF_{ij}) and aggregated across all substances, facilities (j), Eq (1).

$$ImpactPotential = \sum_{ij} E_{ij} \times CF_{ij} \tag{1}$$

CF_{ij} is the characterization factor for the potential impacts of substances (i) from facility (j) in terms of either ecotoxicity or eutrophication released by facility (j) to freshwater.

Ecotoxicity refers to impacts on the ecosystem, particulary the damage to individual species and the function of the ecosystem Fantke et al. [2015], Zampori and Pant [2019]. Ecotoxicity is the result of a variety of different toxicological mechanisms caused by the release of substances with a direct effect on the health of the ecosystem. The characterization factor for aquatic ecotoxicity impacts is expressed at mid-point level (ecotoxicity potential) in comparative toxic units (CTUe) and provides an estimate of the potentially affected fraction of species (PAF) integrated over time and volume per unit mass of a chemical emitted. Its unit: CTUe per kg emitted = [PAF m^3 d per kg emitted].

Eutrophication occurs when nutrients (mainly nitrogen and phosphorus) are released, which accelerates the growth of algae and other vegetation in water, Zampori and Pant [2019]. The degradation of organic material consumes oxygen resulting in oxygen deficiency and, in some cases, fish death. Eutrophication translates the quantity of substances emitted into a common measure expressed as the oxygen required for the degradation of dead biomass. Its unit: Phosphor equivalents per kg emitted = [P eq per kg emitted].

The pollutants covered in our research are based on an extended list of pollutants in earlier studies on Sweden by Nordborg et al. [2017], and on Europe by Erhart and Erhart [2023]. The highest CFs, e.g. the CFs of the most toxic pollutant types were used when the E-PRTR does not provide information on the chemical types of a compound. This assumption is also relevant for Cr and As. In addition, AOX (Halogenated Organic Compounds) were assumed to be represented by 1,4 di-chlorobenzene, NMVOC by Benzene and PAH (Polyaromatic Hydrocarbons) by Benzo-(a)pyrene. These were chosen as a conservative risk management approach, because they have high CFs and are representative for the group. Furthermore, the most common sulphur oxide is sulphur dioxide, OECD [2021], hence we used SO2 as a representative for the E-PRTR pollutant category 'Sulphur oxides'. For the E-PRTR group 'Chlorine and inorganic compounds (as HCl)' we used the hydrogen chloride (CAS: 7647-01-0) as suggested by the Hungarian LAIR database. 'Total phosphorus' in the E-PRTR was characterized as phosphorus (CAS number: 7723-14-0). 'PCDD + PCDF (dioxins + furans) (as Teq)' was matched with 2,3,7,8-tetrachlorodibenzo-p-dioxin (CAS number: 1746-01-06). All pairs of pollutants and compounds in the E-PRTR and EF 3.1 used for our analysis are listed in the Annex Tables A1 and A2.

3. Results

3.1. Descriptive analysis of Natura 2000 parks and E-PRTR facilities

Natura 2000 parks cover almost 1 million km^2 in Europe and stretch over 23% of the EU's land area. There are, however, differences at the EU Member State level, with Croatia having the largest share, 59% of its land covered by Natura 2000 parks (Table 1). We used the Natura 2000 CSV files published by the European Environmental Agency (EEA) ‡ for the calculations.

There are 887 protected species in the EU, which are listed in the Birds Directive and in the Habitats Directive. Italy and Spain have the largest number of protected species 359 and 384, respectively. Approximately 3 percent of industrial facilities reporting to the E-PRTR are closer to foreign national parks than to the closest national park in the country where they are located. There are EU Member States, where the share of facilities in the proximity of foreign parks is higher, the Netherlands and Luxembourg are two examples, where approximately roughly 10 percent of industrial sites are closer to foreign Natura 2000 parks. This highlights the importance of managing biodiversity risks at the supranational level.

The number of E-PRTR reporting facilities depends on the size and industrial structure of EU Member States. The largest number of facilities are located in the largest EU Member States, France (15130) and Germany (12006) and there have been approximately 76000 facilities in the European Union taking into account all reporting years in our sample from 2001.

Figure 2 shows different layers of the geographic dataset. The top-left panel (Figure 2a) presents the polygons of Natura parks coloured according to the number of protected species listed in the annexes of the Bird Directive and Habitats Directives. The map shows that there are some Natura 2000 parks, which are home to only 1-3 protected species (parks coloured red on the map), and at the other end there are parks with many more protected species (27-151, coloured blue on the map). The top-right panel (Figure 2b) combines the layers of Natura 2000 polygons and all E-PRTR facility points, while (Figure 2c) shows only E-PRTR facilities based on a technical rule for the proximity of Natura 2000 parks, e.g. their distance to the parks is less than 500 meters. These figures reveal that the geographic density of E-PRTR facilities nearby Natura 2000 parks is higher in Central-Europe. The bottom-right panel (Figure 2d) is an example of a high-resolution segment of our combined map zoomed-in on the E-PRTR facilities in the proximity of 'Valls del Sió-Llobregós' park with information on the calculated distance to the closest Natura 2000 park. This map shows that there are several facilities, which are located right in Natura 2000 parks, some of which do not even report the name of the facility. Our high-resolution map reveals that the contours of Natura 2000 parks are sometimes drawn around the industrial sites. Careful and continuous monitoring of such derogation zones could

‡ The Natura 2000 park GIS and statistical data were downloaded in December 2022 from: https://www.eea.europa.eu/data-and-maps/data/natura-14

Table 1: Descriptive statistics of Natura 2000 parks and E-PRTR facilities by countries and the number of distinct protected species [a]

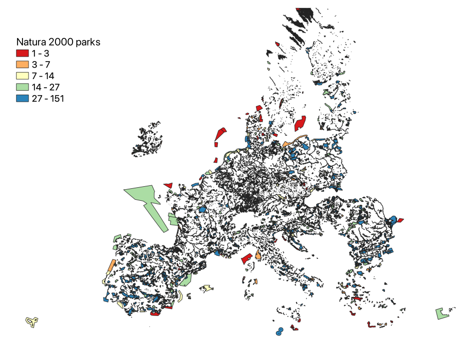
ISO	**A. Area (km2)**	**B. N2000 area (km2)**	**C. = B / A**	**D. Nr of protected species**	**E. EPRTR sites close to foreign Natura2000 parks (%)**	**F. Nr of EPRTR facilities in the country**
HR	56594	33527	59%	188	2%	504
SI	20273	11706	58%	167	4%	349
BG	110996	56164	51%	272	8%	676
SK	49035	19067	39%	132	na	63
GR	131694	48449	37%	134	0%	565
ES	498502	168748	34%	384	0%	8669
LU	2595	835	32%	83	9%	72
HU	93012	26275	28%	216	4%	1262
PT	89103	24418	27%	288	0%	1161
RO	238398	65209	27%	298	1%	1662
CY	9253	2383	26%	141	0%	206
PL	311929	79305	25%	237	1%	4329
IT	302073	72796	24%	359	1%	8093
EE	45336	10363	23%	122	0%	176
NL	37377	8313	22%	109	14%	7152
DE	357569	72408	20%	218	2%	12006
CZ	78871	14991	19%	120	4%	3745
AT	83878	15294	18%	257	8%	724
LT	65284	11796	18%	117	1%	313
DK	42925	7569	18%	112	2%	2817
FR	549060	93807	17%	288	3%	15130
MT	316	52	16%	19	2%	41
IE	69947	11252	16%	88	0%	1679
BE	30666	4478	15%	123	2%	2356
SE	447424	58428	13%	164	0%	1140
FI	338411	43109	13%	124	0%	998
LV	64586	7448	12%	139	1%	149
EU	4125107	968190	23%	887	3%	76037

[a] **Notes:** Source: European Environmental Agency (Natura 2000 park area and species statistics), EUROSTAT (country area statistics), author calculations. Only terrestrial Natura 2000 parks are showed. Number of species listed in ANNEX II-III of the Birds Directive and in ANNEX IV-V of the Habitats Directive.

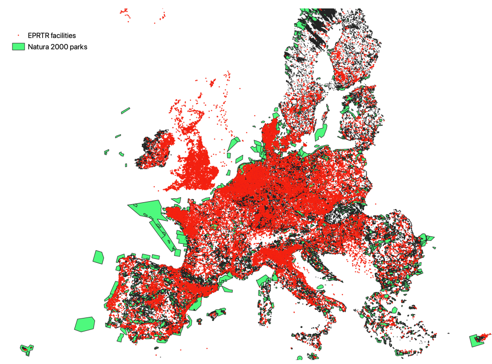
be an important supervisory task in the future.

Figure 2: Combined map layers of E-PRTR facilities and Natura 2000 parks

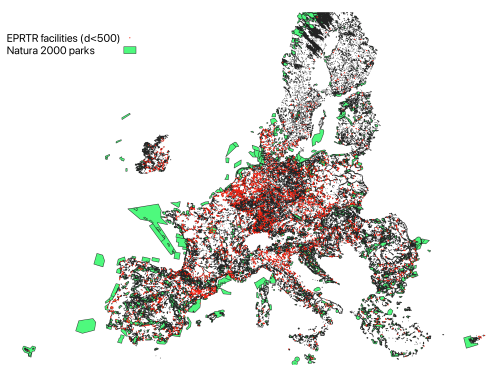
(a) Nr of protected species in Natura 2000 parks



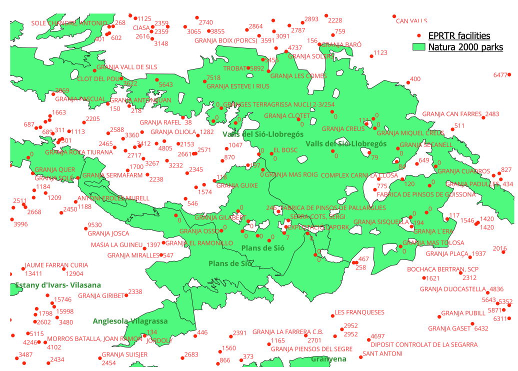
(b) E-PRTR facilities and Natura 2000 parks



(c) EPRTR facilities and Natura 2000 parks (where the distance is less than 500m)



(d) High-resolution map of E-PRTR facilities in the proximity of 'Valls del Sió-Llobregós' park[a]



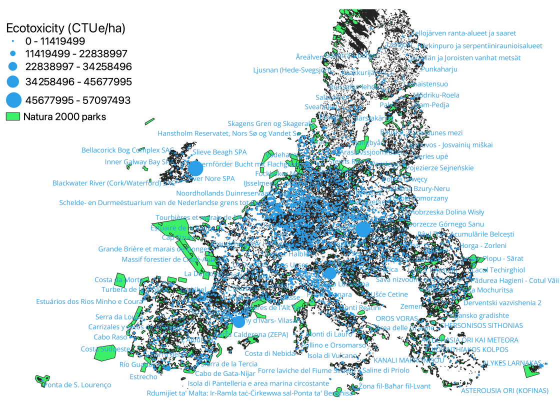
[a] Distance of each E-PRTR facilities to the nearest Natura parks are shown on the map in meters next to the location point of the facility.

3.2. Natura 2000 parks exposures to industrial ecotoxicity and eutrophication risks

Figure 3 depicts the geographic distribution and value of the calculated ecotoxicity and eutrophication risks in Natura 2000 parks. European protected natural areas are exposed to more risks in the most industrialised regions in the Benelux states, Ruhr area of Germany, in Northern Italy and in countries in Central and Eastern

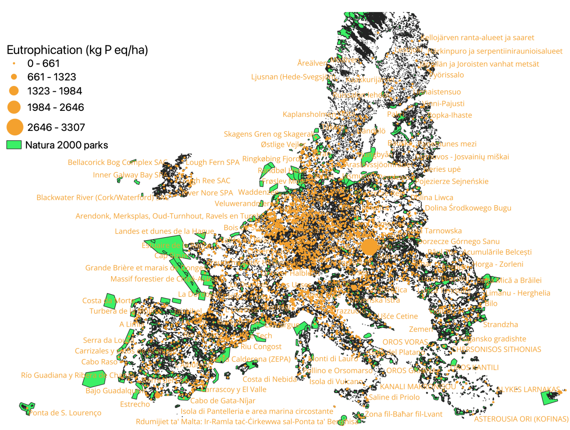
Figure 3: Natura 2000 parks in the proximity of industrial facilities with the largest freshwater ecotoxicity and eutrophication impact potentials per unit Natura 2000 area [a]

(a) Ecotoxicity per area (CTUe/ha)



SITENAME	ISO	CTUe/ha
S-Dublin Bay	IE	57097493
Modřické ram	CZ	48529754
Fiume Sile	IT	44461476
Delta Llob.	ES	36240899
Río Fuengir	ES	15361881
Untere Lavant	AT	10259693
Riu de Tordera	ES	9636534
Ljubljanica-G.	SI	8300029

(b) Eutrophication per area (P eq/ha)



SITENAME	ISO	P eq/ha
Modřické ram	CZ	3307
Río Guadalma	ES	677
Ljubljanica - G.	SI	674
Delta del Llob.	ES	348
S-Dublin Bay	IE	301
Inghiaie	IT	259
Nedre Møll.l	DK	190
Río Fuengir.	ES	149

[a] The bubbles on the maps were sized as a function of the impact potentials calculated with the EF 3.1 characterization factors for the reporting year 2019. Bubbles were placed at the centroids of the Natura 2000 park polygons.

Europe.

Ordering the Natura 2000 sites by the ecotoxicity and eutrophication per unit area resulted in simple rankings of their environmental pressures (Figure 3). The 'South Dublin Bay and River Tolka Estuary SPA' (sitecode¿ IE0004024), Modřické rameno (sitecode: CZ0620010), Fiume Sile (sitecode: IT3240019) and the Delta del Llobregat (sitecode: ES0000146) were estimated to have the largest exposure to ecotoxicity risks per area.

There is an overlap in the ranking of parks with regards to ecotoxicity and eutrophication risks (Figure 3), and there is relatively strong association in general between these variables (0.6 correlation coefficient).

Our results corroborate the findings of Erhart and Erhart [2023] who showed with the USEtox model that facilities in the sewerage sector have the largest contribution to ecotoxicity in general. Our new calculations with the EF 3.1 package, however better take account of the uncertainty of calculations, especially for metals. We also provide evidence that the sewerage and water treatment sectors contribute the most to eutrophication risks.

The facility with the largest contribution to ecotoxicity and to eutrophication impact potential in the proximity of Natura 2000 parks was Ringsend - Irish Water in 2019, (Table 2 and 3). Wastewater from Dublin has been treated at Ringsend since 1906. Built in 2005, the current plant is the largest in Ireland and was designed to cater for an equivalent of 1.64 million people. The Ringsend Wastewater Treatment Plant (WWTP), which provides over 40% of Ireland's wastewater treatment capacity, is currently overloaded and does not comply with the EU's Urban Wastewater Treatment Directive. The average daily load received at Ringsend Wastewater Treatment Plant in 2019 was 1.98 million population equivalent with peaks well in excess of this. The major upgrade underway to the Ringsend Wastewater Treatment plant is expected to enable it to treat the increasing volumes of wastewater arriving at the plant to the required standard, enabling future housing and commercial development. Other large sewerage companies are also ranked high based on our calculations. For example EYATH S.A. provides daily water supply and sewerage services to more than 1.2 million citizens in the greater Thessaloniki Urban Area. The Prat Llobregat treatment plant is one of the largest and most modern wastewater treatment plants in Europe. It can treat 420 million liters per day, which is equivalent to the water use of two million inhabitants and the associated economic activities (equivalent inhabitants).

It should be added, however, that wastewater treatment service is a major input to other economic sectors' production and therefore impact potentials are indirectly caused by the water treatment demand from companies in other sectors. In the same vein, the climate change impact of the electricity sector is dependent on activities in other industrial sectors Erhart and Erhart [2023]. Hence, the GHG emissions accounting approach could also be recommended for other environmental footprints, for example drawing a distinction of SCOPE1 direct emissions, SCOPE2-3 indirect emissions from indirect water treatment inputs and and from value-chain, could be an option.

4. Discussion

There are numerous barriers to precise toxicity analysis based on the E-PRTR, Nordborg et al. [2017]. A key barrier is that the number of substances in the E-PRTR is limited compared to chemical products listed in other chemical registers, Persson et al. [2019]. The E-PRTR database does not register emissions below reporting thresholds. Data reliability could be adversely affected by self-reporting and inappropriate estimations by facilities, and there may be gaps and inconsistencies in reporting across countries Leclerc et al. [2019].

A further obstacle to the punctual calculations is related to the grouping of pollutants in the E-PRTR reporting. If more detailed information of the released pollutants was available for the pollutant groups, the precision of the characterization in our study could be further improved.

In the absence of information our calculations did not consider several further important factors that could have influenced how Natura 2000 parks are impacted by industrial pollutant releases in their proximity. For example, the chemical structure and ecological conditions of the freshwater into which the pollutants are released can be important factors.

Our technical rule of proximity (less than 500 m) is a parameter that could be also the target of future studies.

5. Policy recommendations

We showed that in areas where groups of smaller European countries are located, an increased share of industrial facilities is located closer to foreign Natura 2000 parks than to the closest park in their own country. This calls for the importance of supranational management of the biodiversity risks from industrial activities.

Table 2: Industrial facilities with the largest estimated contribution to ecotoxicity in the proximity of Natura 2000 parks

Nr	Facility name	Country	NACE	Ecotoxicity (2019, CTUe)
1	Ringsend - Irish Water.	IE	Sewerage	1.25E+11
2	EDAR EL PRAT DE LLOBREGAT - Bacelona	ES	Sewerage	3.39E+10
3	Impianto di depurazione di Treviso	IT	Sewerage	2.39E+10
4	EYATH S.A. – SINDOS WASTEWATER TREATMENT PLANT	GR	Sewerage	2.17E+10
5	SOLVAY CHIMICA ITALIA S.P.A. ROSIGNANO	IT	Manuf. inorganic basic chem.	6.08E+09
6	Publiacqua S.p. A. - sito San Colombano	IT	Sewerage	5.42E+09
7	RAYONIER A.M. TARTAS	FR	Manuf. of pulp	4.86E+09
8	SIA Rīgas ūdens Bioloģiskās attīrīšanas stacija "Daugavgrīva""	LV	Water coll., treatm. and supply	4.41E+09
9	EDAR DE CÁDIZ - SAN FERNANDO	ES	Water coll., treatm. and supply	4.28E+09
10	FIBRE EXCELLENCE SAINT-GAUDENS	FR	Manuf. of pulp	4.01E+09

Table 3: Industrial facilities with the largest estimated contribution to eutrophication in the proximity of Natura 2000 parks

Nr	Facility name	Country	NACE	Eutrophication (2019, P e)
1	Ringsend - Irish Water.	IE	Sewerage	6.60E+05
2	VIO-HRUŠČICA	HR	Water coll., treatm. and supply	3.48E+05
3	EDAR EL PRAT DE LLOBREGAT - Bacelona	ES	Sewerage	3.26E+05
4	EYATH S.A. – SINDOS WASTEWATER TREATMENT PLANT	GR	Sewerage	2.23E+05
5	JP VOKA SNAGA, Centralna čistilna naprava Ljubljana	SI	Water coll., treatm. and supply	1.26E+05
6	Cork City - Irish Water	IE	Sewerage	9.75E+04
7	GRAMABASA-2 - Santa Pola	ES	Marine aquaculture	8.76E+04
8	ESTACIÓN DEPURADORA DE AGUAS RESIDUALES MURCIA ESTE	ES	Water coll., treatm. and supply	7.03E+04
9	SOLVAY CHIMICA ITALIA S.P.A. ROSIGNANO	IT	Manuf. inorganic basic chem.	6.84E+04
10	Publiacqua S.p. A. - sito San Colombano	IT	Sewerage	5.56E+04

The current E-PRTR regulation allows Member States to keep their information confidential. Better understanding and strict limitations of the reasons for confidentiality claims, to the types and reasons of information that has been withheld could help better investigate and manage related biodiversity risks.

Our geographic analysis also revealed that approximately 2% of E-PRTR facilities are located in Natura 2000 parks and 4% of facilities at sites less than 100 m away from the nearest park. Reassessment of the reasons and justification for overlaps in the industrial activities and protected areas could be an important step for understanding and managing biodiversity risks in Europe. The combination of proximity and not reporting to the E-PRTR with confidentiality claims can be considered as a factor that can increase the likelihood that the two are not independent. Our high-resolution map reveals that the contours of Natura 2000 parks are sometimes drawn around the industrial sites. The careful and continuous monitoring of such derogation zones could be an important supervisory task in the future.

6. Conclusions

The European Union (EU) committed to halting the biodiversity loss. We developed methods to analyze the biodiversity risks of Natura 2000 parks, the world's largest network of protected areas, from industrial sites around Europe.

In this paper we develop methodologies and indicators for the assessment of biodiversity risks. We used the the European Pollutant Release and Transfer Register (E-PRTR), which covers the largest industrial facilities around Europe and analyzed the direct impact potentials of pollutant releases into freshwater on local biodiversity in terms of ecotoxicity and eutrophication.

Our analysis is based on three datasets: (1) on the EEA's European Pollutant Release and Transfer Register (E-PRTR), (2) on the EEA's dataset of Natura 2000 parks and (3) the JRC's Environmental Footprint (EF) 3.1 package. The E-PRTR industrial facility level pollutant release data were matched with the mid-point characterization factors in the JRC EF 3.1 package to calculate the environmental footprint of each pollutant release in the E-PRTR. We also calculated the distance of each E-PRTR facility to the closest Natura 2000 park to create a useful indicator of biodiversity vulnerabilities.

We show that 2% of the E-PRTR facilities are located right in Natura 2000 parks, some of which do not even report the name of the facility. European protected natural areas are exposed to more risks in the most industrialized regions of Europe and in countries in Central and Eastern Europe

Ordering the Natura 2000 sites by the ecotoxicity and eutrophication per area resulted in simple rankings of their environmental pressures. The 'South Dublin Bay and River Tolka Estuary SPA' is estimated to have the largest exposure to ecotoxicity risks per area. There is an overlap in the ranking of parks with regards to ecotoxicity and eutrophication risks, and there is a relatively strong association in general between these variables.

We showed that in areas where groups of smaller European countries are located, an increased share of industrial facilities is located closer to foreign Natura 2000 parks than to the closest park in their own country. This calls for and strengthen the high importance of the supranational management of the biodiversity risks from industrial activities in Europe.

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Data access statement

The study is based on three publicly available data sources: (1) on the EEA's European Pollutant Release and Transfer Register (E-PRTR) (url: https://www.eea.europa.eu/data-and-maps/data/industrial-reporting-under-the-industrial-6), (2) on the EEA's dataset of Natura 2000 parks (url: https://cmshare.eea.europa.eu/s/HHGPnNsjqq5BdEa/download) and (3) the JRC's Environmental Footprint (EF) 3.1 package (url: https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xht).

Furthermore, the graphs and figures in the study will be publicly available in the Mendeley repository upon publication of the study.

Erhart, Szilárd (2023), Mendeley Data, V1, doi: 10.17632/bvncmx7vvb.1

Author contributions statement

All persons who meet authorship criteria are listed as authors.

B.M. participated in the conceptualization of research and contributed to reviewing the manuscript. S.E. conceptualized and formulated the research, analyzed and visualized results and wrote the main manuscript text. All authors discussed the results and reviewed the manuscript.

Ethics declaration

The authors declare that they have no competing interests.

Funding statement

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Appendix A. Additional graphs and tables

Table A1: Matching of the E-PRTR pollutants with the EF 3.1 chemicals

EF 3.1 FLOW_name	FLOW_casnumber	EPRTR pollutantName
lasso	15972-60-8	Alachlor
endosulfan	115-29-7	Endosulphan
(1,4,4a,5,88a)-1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4:5,8-dimethanonaphthalene	465-73-6	Isodrin
toxaphene	8001-35-2	Toxaphene
chlorfenvinfos	470-90-6	Chlorfenvinphos
endrin	72-20-8	Endrin
aldrin	309-00-2	Aldrin
mirex	2385-85-5	Mirex
dieldrin	60-57-1	Dieldrin
kepone	143-50-0	Chlordecone
1,1,2,2-tetrachloroethane	79-34-5	1,1,2,2-tetrachloroethane
chlordane , pur	57-74-9	Chlordane
heptachlor	76-44-8	Heptachlor
chloroform	67-66-3	Trichloromethane
benzo[a]pyrene	50-32-8	Polycyclic aromatic hydrocarbons
pentachlorobenzene	608-93-5	Pentachlorobenzene
hexachlorocyclohexane	608-73-1	1,2,3,4,5,6-hexachlorocyclohexane
lindane	58-89-9	Lindane
cyanide	57-12-5	Cyanides (as total CN)
cfc-10	56-23-5	Tetrachloromethane
isoproturon	34123-59-6	Isoproturon
benzene	71-43-2	Benzene
hydrocyanic acid	74-90-8	Hydrogen cyanide
vinyl chloride	75-01-4	Vinyl chloride
dichloromethane	75-09-2	Dichloromethane
ethylene oxide	75-21-8	Ethylene oxide
hydrogen chloride	7647-01-0	Chlorine and inorganic compounds (as HCl)
hydrogen fluoride	7664-39-3	Fluorides (as total F)
phosphorus	7723-14-0	Total phosphorus
trichloroethene	79-01-6	Trichloroethylene
hexachlorobutadiene	87-68-3	Hexachlorobutadiene
pentachlorophenol	87-86-5	Pentachlorophenol

Table A2: Continoued - Matching of the E-PRTR pollutants with the EF 3.1 chemicals

EF 3.1 FLOW_name	FLOW_casnumber	EPRTR pollutantName
naphthalene	91-20-3	Naphthalene
1,2-dichlorobenzene	95-50-1	Halogenated organic compounds (as AOX)
nickel (ii)	14701-22-5	Nickel and compounds (as Ni)
toluene	108-88-3	Toluene
phenol	108-95-2	Phenols (as total C)
di-sec-octyl phthalate	117-81-7	Di-(2-ethyl hexyl) phthalate
hexachlorobenzene	118-74-1	Hexachlorobenzene
trichlorobenzene	12002-48-1	Trichlorobenzenes (all isomers)
anthracene	0120-12-7	Anthracene
simazine	122-34-9	Simazine
tetrachloroethene	127-18-4	Tetrachloroethylene
xylene (all isomers)	1330-20-7	Xylenes
polychlorinated biphenyls	1336-36-3	Polychlorinated biphenyls
lead (ii)	14280-50-3	Lead and compounds (as Pb)
mercury (ii)	14302-87-5	Mercury and compounds (as Hg)
ddt	50-29-3	DDT
copper (ii)	15158-11-9	Copper and compounds (as Cu)
2,3,7,8-tetrachlorodibenzo-p-dioxin	1746-01-06	PCDD + PCDF (dioxins + furans) (as Teq)
chromium (vi)	18540-29-9	Chromium and compounds (as Cr)
atrazine	1912-24-9	Atrazine
fluoranthene	206-44-0	Fluoranthene
cadmium (ii)	22537-48-0	Cadmium and compounds (as Cd)
arsenic (iii)	22541-54-4	Arsenic and compounds (as As)
zinc (ii)	23713-49-7	Zinc and compounds (as Zn)
nonylphenol	25154-52-3	Nonylphenol and Nonylphenol ethoxylates
chlorpyrifos	2921-88-2	Chlorpyrifos
diuron	330-54-1	Diuron
ethyl benzene	100-41-4	Ethyl benzene