Assessing Pressure Levels of a Wetland using the LUPLES concept: Data sources and policy objectives perspective

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Abstract

The degradation of wetland ecosystems and accelerating biodiversity loss demand evidence-based management to guide policy and restoration. Land-use classification systems such as Corine Land Cover (CLC) and European Nature Information System (EUNIS) offer essential frameworks for quantifying anthropogenic pressures but differ in thematic and spatial resolution, directly influencing outputs of pressure-assessment models like LUPLES – Land Use, Pressures Level, Ecological Status. Using a costal lagoon and the Water Framework Directive as reference, this study examines how choosing between CLC and EUNIS affects the reliability and applicability of LUPLES when assessing pressures on wetlands and surrounding catchments, linking pressure estimates to ecological status indicators. Comparing scenarios from both schemes highlights the importance of aligning input data with policy objectives. While the Nature Restoration Regulation introduces new EU-wide ecosystem classification, crosswalks with CLC and EUNIS remain unclear. Integrating multiple systems within adaptive management supports land-use planning, mitigation, and wetland restoration.

Keywords

Nature Restoration Regulation; ecosystem restoration; ecosystem classification; ecosystem management; wetlands; Corine Land Cover; European Nature Information System

1. Introduction

Earth is experiencing a biodiversity crisis, with species disappearing at rates 10 to 10 000 times, depending on the taxonomic group, faster than the natural background extinction rate, suggesting that approximately 1.2 million plant and animal species face extinction threats (IPBES, 2019). Human activities have been identified as the primary driver for the loss of biodiversity, with habitat loss, fragmentation and degradation, intensification of land-use changes, pollution, over exploitation of resources, invasive alien species, and climate change being the most impactful factors (Cowie et al., 2022).

Wetlands host approximately 40% of the Earth's biodiversity and provide essential services to human societies valued at more than INT$47 trillion annually (Davidson et al., 2019). These complex socio-ecological systems are very sensitive to human-induced pressures, namely resulting from land-use change, and to extreme weather events resulting from climate change, and the synergetic effect of these two factors can be critical for wetland conservation (Leberger et al., 2020). The loss of wetlands area has been long-term and widespread globally, with an estimated loss of 3.4 million km^2 of inland wetlands since 1700, corresponding to a net loss of 21% of global wetland area (Fluet-Chouinard et al., 2023). Even though the rate of loss of inland wetlands slowed since the 1980s, the loss of natural coastal wetlands remains generically high (Davidson, 2014). Coastal wetlands provide important ecosystem regulating services, such as hydrological cycle regulation, including protection against floods and coastal erosion; carbon biogeochemical cycle regulation, including carbon sequestration; habitats, namely areas for shelter, nursery and feeding, and genetic pools (Camacho et al., 2019). As well, coastal wetlands deliver provisioning services, e.g. commercial fisheries, and cultural services like recreation opportunities that can result from physical or intellectual experiences (Lillebø et al., 2019). The loss and fragmentation of coastal wetlands significantly impairs their capacity to deliver essential ecosystem services, thereby adversely affecting biodiversity, environmental health status (e.g. water quality, climate regulation, air quality) and human wellness, including human health and economic activities (Li et al., 2018). The conservation and restoration of wetlands are paramount for sustaining the diverse ecological, social, and economic benefits these ecosystems provide, to halt the loss of biodiversity and to mitigate the impact of climate change. The Ramsar Convention on Wetlands, adopted in 1971, has established the most comprehensive global framework for wetland conservation and wise use, now encompassing over 2 400 Wetlands of International Importance ("Ramsar Sites") across 172 Contracting Parties. The Convention's guiding principle of "wise use", referring to the maintenance of wetland ecological character through ecosystem-based approaches, has driven both policy and practical restoration efforts worldwide. Despite this progress, the 2021 Global Wetland Outlook underscores that wetlands continue to be lost and degraded at an alarming rate: natural wetlands have declined by 35% since 1970, and more than half of Ramsar Sites are negatively impacted by agriculture, pollution, water abstraction, and other pressures. While the Convention's implementation has led to improvements in some regions, analyses reveal that only about half of the Strategic Plan actions are being fully implemented by Contracting Parties, and many Ramsar Sites lack up-to-date assessments of their ecological status or measurable conservation and/or restoration actions (Convention on Wetlands, 2021).

The European Union has established a robust legislative framework to address wetland degradation, combining habitat protection, water quality management, and binding restoration targets. Central to this framework is the European Habitats Directive, which mandates the conservation of over 200 habitat types, including coastal wetlands, particularly for habitat types of community interest of group 1 of Annex 1 (saltmarshes, coastal lagoons, etc). By requiring member states to designate Special Areas of Conservation (SACs) under the Natura 2000 network, the directive has facilitated the protection of 18% of the EU's terrestrial and freshwater areas, with wetlands comprising a significant proportion (The Council of the European Union, 1992). However, assessments reveal that only 15% of wetland habitats in the EU currently meet "favourable conservation status" criteria, underscoring the need for active restoration.

Complementing this, the Water Framework Directive (WFD) requires achieving "good ecological status" for inland, transitional, and coastal waters by 2027, including biological quality elements such as angiosperms (seagrasses, helophytes, halophytes, and hydrophytes) in coastal and transitional waters (European Parliament and the Council, 2000; Annex V). WFD operationalizes integrated river basin management, addressing hydrological connectivity, pollution, and morphological alterations, including habitat fragmentation. In coastal areas where the WFD and the Marine Strategy Framework Directive (MSFD) overlap, the WFD assessment stands for elements it covers, while the MSFD applies only to aspects not foreseen under the WFD (e.g., underwater noise, marine litter, certain biodiversity components) (European Parliament and the Council, 2008; Article 3). The MSFD aims to achieve “good environmental status” of marine waters through a broader set of descriptors, complementing WFD measures without duplication.

A landmark development is the EU Nature Restoration Regulation (NRR), adopted in 2024, which sets legally binding targets to restore 30% of degraded terrestrial, freshwater, and marine ecosystems by 2030, scaling to 90% by 2050 (European Parliament and Council of the European Union, 2024). These targets align with the EU Biodiversity Strategy for 2030, which emphasizes wetland restoration as a cost-effective method to simultaneously address biodiversity loss, climate change, and disaster risk reduction. The strategy’s focus on "ecosystem-specific restoration actions" acknowledges that outcomes depend on factors such as degradation drivers (e.g., drainage, pollution) and local ecological conditions (European Commission, 2020). The EU NRR targets, among others, restoration obligations specific to terrestrial, coastal and freshwater habitat types and habitats of species in these areas, as well as marine habitats and habitats of marine species.

When effectively implemented, wetland restoration has been shown to significantly enhance ecosystem functions, supporting the providing services, and, to its end, biodiversity. For example, a comprehensive meta-analysis by Meli et al. (2014) found that restored wetlands exhibited a 36% increase in provisioning, regulating, and supporting ecosystem services compared to degraded sites, with biodiversity metrics demonstrating robust recovery trajectories. These findings underscore the value of strategic restoration efforts in reversing ecological degradation and securing long-term benefits for both wildlife and human wellness. Despite routine implementation of wetland restoration projects globally, systematic, evidence-based assessments of their effectiveness in recovering biodiversity and ecosystem services remain limited. Factors such as ecosystem traits, i.e., measurable characteristics of organisms or ecological components that influence how ecosystems function and respond to environmental changes, the primary drivers and pressures leading to degradation, specific restoration actions and its characteristics (e.g., time frame, spatial coverage) can significantly influence post-restoration biodiversity and ecosystem service outcomes (Meli et al., 2014a).

Ecological restoration projects frequently encounter data limitations that can hinder effective decision-making, including a scarce historical record, poor spatial and temporal monitoring, limited taxonomic details, and overall inconsistent preservation of ecological data. Additionally, recorded data can be subjective or ambiguous due to social norms and values dictating what types of information on which species were recorded and preserved (Atkinson et al., 2022; Barak et al., 2016). Smaller and locally led restoration projects are particularly affected by data limitations as they often lack the necessary technical equipment and training possibilities needed for complex data recording and analysis. These challenges can lead to fragmented monitoring approaches that negatively affect project outcomes by making it difficult to identify successful practices and make necessary adjustments to ongoing activities. Further, the way data are compiled and the information is noticed hardly follows metadata standardization and the FAIR (Findable, Accessible, Interoperable, and Reusable) principles (Wilkinson et al., 2016). Adding to this, the inherent dynamic complexity of ecosystems makes it practically impossible to collect complete data across all spatial and temporal scales. These limitations underscore the need for restoration strategies that operate beyond specific sites and adopt a basin-level perspective. Integrated river basin management, as mandated by the WFD, provides a framework to address hydrological connectivity, cumulative pressures, and upstream–downstream interactions (Lillebø et al., 2015). Basin-scale integration enables harmonized monitoring, data sharing, and coordinated interventions across multiple ecosystems, reducing fragmentation and improving the identification of successful practices. Tools and products, such as the CORINE Land Cover maps and related products, whose last generation products are based on the European Land Observation Systems, such as Copernicus, are useful to provide information about the type of land uses and that information can be used for establishing the level of pressures (Morant et al., 2021). The response of any particular site to a standard management intervention is highly context-dependent, which challenges restoration practitioners. Community dynamics in any ecosystem are very sensitive to stochastic processes, including priority effects, unpredictable disturbances, and climatic fluctuations. This complexity is further compounded by the fact that ecological restoration projects often have variable and unpredictable outcomes, limiting their overall impact on biodiversity. The heterogeneity among the effects of restoration is high in all models, indicating that despite significant overall effect sizes, there are large inconsistencies in the effect of restoration on both mean and variability of biodiversity variables (Atkinson et al., 2022). Despite these uncertainties, EU policy emphasizes that incomplete data should not delay restoration efforts. The Nature Restoration Regulation explicitly applies the precautionary principle, stating that "the lack of complete scientific data shall not be a reason for postponing or failing to take restoration measures" (European Parliament and Council of the European Union, 2024; Article 4). This approach reflects the urgent need to act in the face of accelerating ecosystem degradation, prioritizing interventions while continuing to improve monitoring and adaptive management. By acknowledging uncertainty yet mandating action, the EU framework seeks to balance scientific accuracy with timely responses to ecological crises. In this context, modelling can be powerful to test scenarios and evaluate the trade-offs of alternative land use changes and evaluate the outcomes and/or assess the long-term consequences of land use policies (Rahimi et al., 2020). Simple models offer several advantages for ecological restoration decision-making when complex data are limited. They can provide a conceptual framework for understanding ecosystem dynamics and guiding specific restoration practices. A key advantage of simple models is their ability to identify optimal strategies with minimal data requirements (Waring, 2023). Simple models can help identify and prioritize restoration strategies and sites, and assess trade-offs considering conflicting interests and ecosystem services with minimal data requirements. While simple models have limitations and may not capture all the complexities of socio-ecological systems, they can provide valuable science-based guidance for restoration practitioners facing data limitations and uncertainty (Atkinson et al., 2022).

A modelling tool that can achieve this end is the LUPLES: Land Uses for estimating Pressure Levels to approach the Ecological Status method (Morant et al., 2021). The LUPLES method provides a robust framework for quantifying anthropogenic pressures on wetlands by integrating land use dynamics (for pollution pressures in the catchment) with basin and/or wetland scale hydro-morphological alterations. By analysing catchment-area land uses and direct basin modifications, LUPLES calculates pressure indices that correlate with ecological status metrics defined by the Water Framework Directive. This approach captures both diffuse pressures (e.g., agricultural runoff, urban expansion) and direct habitat alterations (e.g., hydrological modifications), enabling the identification of critical pressures (Morant et al., 2021). Such integrated frameworks outperform single-factor models in coastal ecosystems, where synergistic pressures disproportionately impact wetland resilience (Simpson et al., 2024). The LUPLES compatibility with Ramsar's wetland monitoring frameworks makes it uniquely suited for implementing wetland restoration plans since the CORINE Land Cover (CLC)-based land use classification system used in the model allows targeted assessment of pollution sources and habitat fragmentation risks. The output of the model can inform adaptive management strategies through scenario testing of land use policies and restoration interventions.

Classification systems, such as the CLC (European Environment Agency (EEA), 2024a) and the European Nature Information System (EUNIS) (European Environment Agency (EEA), 2024a, 2024b), provide standardized information for habitat assessment, facilitating comparisons across regions over time. While the EUNIS classification aims specifically at categorizing wetland habitats based on ecological characteristics and species composition, offering insights into biodiversity and nature conservation (Moss, 2008), the CLC offers a broader classification based on land-use and human influence, essential to identify large-scale trends in wetland transformation (Barbara Kosztra et al., 2019). Some potential advantages of considering both classification systems when modelling wetlands are the identification of areas where one might lack relevant details or accuracy, increase in ecological understanding, and optimize the connection between specific habitats and the surrounding land use. For instance, research on Mediterranean wetlands demonstrated that land cover changes assessed through CLC can highlight broad-scale habitat loss, while EUNIS provides finer details on habitat structure and ecological function. By using both nomenclatures, scientists can better understand the driving forces behind wetland degradation, as well as the effectiveness of conservation strategies in mitigating habitat loss (Tomaselli et al., 2023). This approach is particularly relevant for wetland conservation policies, where accurate classification informs decision-making processes related to land management and biodiversity protection (Meli et al., 2014b), for instance, relating the pressures altering the ecological integrity with the ecological or conservation status indicators.

Having the WFD as a reference policy (assessing wetlands water bodies ecological status from catchment to coastal waters) and the Ria de Aveiro Natura 2000 area as showcase for coastal wetlands, the objective of this study was to assess the influence of considering different landscape units on the performance and applicability of the LUPLES concept in assessing anthropogenic pressures on wetlands. Specifically, the model concept was adapted to the Ria de Aveiro and its catchment area, integrating expert-based assessment to refine pressure estimation. The underlying hypothesis was that the use of two distinct classification systems, CLC and EUNIS, might lead to different representations of habitat patterns and land use thereby resulting in varying assessment results on pressure intensity levels and influencing the overall assessment outcomes. By comparing these results and linking them to ecological status indicators, this approach aims to enhance understanding of how input data variability can impact the reliability of pressure assessment, with implications for environmental decision-making, regulatory implementation, namely WFD, and the development of more robust wetland management strategies. Results will also be discussed framed in the Nature Restoration Regulation, which is introducing a new EU-wide ecosystem classification for reporting.

2. Materials and Methods

2.1. Characterization of the study area

The Vouga River basin (Figure 1) is located in Portugal-Center Region, flowing approximately 148 km before reaching the Ria de Aveiro Natura 2000 area, a coastal lagoon, through which Vouga estuary connects (Lillebø et al., 2015). The study area is mainly located at the Mediterranean bio-geographical region, but it is also influence by the North-Western European bio-geographical (Atlantic) (European Environment Agency (EEA), 2024c), with a temperate maritime climate classified as Csb (Peel et al., 2007). The Vouga River has episodic flood events during autumn/winter seasons that inundate lands at the confluence with Ria de Aveiro, a region known as Baixo Vouga (Martínez-López et al., 2019). Thus, three water realms can be found in the study area: freshwater, transitional and coastal waters. The status of the water bodies (chemical and ecological) is characterized in the River Basin Management Plan according to the Water Framework (Portuguese Environment Agency, 2023), and the reported total nitrogen (N total) and total phosphorus (P total) for the second monitoring period (2016-2021) were used as ecological indicators.

The CLC 2018 and EUNIS 2021/2022 habitats of the Ria de Aveiro Natura 2000 area are extensively characterized in the database RESTORE4Cs consortium (2025a, 2025b) and mapped in Figure 2

2.2. Weighing factors for pressure type

To assess the influence of various pressures on the ecological status of intertidal habitats in the Rede Ria de Aveiro Natura 2000 area an expert elicitation approach was employed. A panel of 13 experts with specialized knowledge in marine biology, economy, chemistry, communication and other relevant disciplines (Figure 5) was invited to independently and anonymously evaluate whether different categories of pressures – biological, physical, chemical, energy-related, and connectivity-related – exerted on the different habitats contribute to changes in the ecological status of the intertidal habitats. The pressures groups were defined to characterise the main implications of the land uses on the socio-ecological system, differing from the pressures used in the LUPLES concept, more focused on water quality alterations. The experts classified each pressure as either 1 (affects) or 0 (does not affect) based on their expertise and understanding of ecosystem interactions. This binary classification ensures a structured and objective assessment, thereby providing a clear distinction between pressures perceived as relevant and those considered negligible. The final weighting factors for pressure type for each habitat type were derived from the proportion of experts who assigned a value of 1. This approach, as modification of the original LUPLES concept (Morant et al., 2021) offers a transparent and reproducible method for identifying key induced pressures on wetlands.

2.3. Data analysis

Correlation analyses were performed between pressure values generated by the LUPLES concept adapted to Ria de Aveiro—based on CLC and EUNIS landscape units —and ecological indicators from Water Framework Directive (WFD) reports. The analysis, performed in Excel, aimed to quantify the relationship between land use-derived pressures and ecological status, and to assess the sensitivity of model outputs to the classification system used.

All maps were generated in ArcGIS Pro (version 3.5.3, Esri, Redlands, CA) using WGS 1984 geographic coordinate system. The input data were either acquired in this CRS or were projected/transformed to WGS 1984 prior to analysis to ensure consistency and accuracy across the dataset. The shapefiles with the Natura 2000 area, delineation of water bodies and river basin were obtained from the Portuguese Environment Agency (Portuguese Environment Agency, 2025).

3. Results

The ecological status of the Ria de Aveiro Natura 2000 water bodies was assessed and reported by the Portuguese Environment Agency according to the standards of the WFD. The reported results for the periods 2009-2015 and 2016-2021, as well as the projection for the period 2022-2027 are represented in Figure 3 and summarized in Table 1 (data derived from: Portuguese Environment Agency, 2023).

Table 1: Number of water bodies and their total occupied area [km^2] according to each category of the WFD global status classification

	1st period		2nd period		3rd period	
Classification	Water Bodies	Area [km^2]	Water Bodies	Area [km^2]	Water Bodies	Area [km^2]
Good and very good	3	77.1 (10%)	4	107.9 (13%)	2	147.1 (18%)
Less than good	11	733.7	10	702.9	12	663.7

The relative area with global status classification "Good and very good" increased from the first cycle to the second by 3%, it is expected to increase further to 8% in the third period. However, the number of water bodies with "Good and very good" classification is expected to decrease in the third period in relation to the second.

To assess the pressure levels on the Ria de Aveiro Natura 2000 area, landscape units were categorized (Figure 4; groups H1 to H8) considering EUNIS Level 1 as baseline and matching the CLC classes to those using the crosswalks provided by the European Environment Agency (EEA). This approach ensures a structured classification that balances ecological specificity with analytical clarity, allowing for effective pressure assessment. Using EUNIS Level 1 was a strategic choice, as it provides a manageable number of eight broad categories, enabling meaningful analysis of wetland pressures without excessive fragmentation. More detailed levels within EUNIS (e.g., Levels 2 and 3) offer refined distinctions, but complexity introduced may hinder large-scale comparative assessments. By working at Level 1, enough differentiation is retained to capture key landscape units while ensuring the classification remains interpretable and actionable for monitoring and restoration planning.

Table 2 presents a comparative analysis of the relative occupation of each group of landscape units in the Ria de Aveiro Natura 2000 area, using both CLC and EUNIS. The discrepancies observed in relative occupation between the two nomenclatures highlight the methodological and definitional differences in classifying land cover and habitat types. A key observation is the significant difference in the Marine habitat group (H1), where EUNIS estimates 45% occupation, whereas CLC reports only 23%, suggesting that EUNIS may categorize larger areas under marine habitat based on hydrological and biological factors, whereas CLC may emphasize distinctions related to anthropogenic influence or land-sea boundaries. In opposition, Habitat complexes (H9) have 21% in CLC and only 6% in EUNIS, suggesting that the broader land-use approach of CLC groups multiple mixed-use or mosaic-like landscapes into this category, while EUNIS may distribute these areas across more specific ecological types as having a sounder inspiration on biological components. Woodlands (H5) and Grasslands (H4) also display disparities, with CLC estimating a higher coverage for both categories (11% vs. 6% for woodlands and 4% vs. 0% for grasslands). This may be due to CLC's inclusion of more fragmented or human-influenced landscapes under these categories, whereas EUNIS applies stricter ecological criteria. Cultivated land (H6) and Artificial/constructed areas (H7) show near-identical values in both systems, indicating that these human-modified landscapes are consistently classified regardless of the system used.

Table 2: Groups of landscape units and their relative occupation in the study area

	Habitat	**CLC**	**EUNIS**	**Relative occupation [%]**	
Group	**description**	**Code**	**level 1**	**CLC**	**EUNIS**
H1	Marine	421; 423	A	23	45
H2	Coastal	311; 312; 322; 331	B	8	12
H3	Inland surface water	241; 411; 511; 512	C	2	3
H4	Grasslands	231; 242; 321	E	4	0
H5	Woodlands	241; 311; 312; 313; 324	G	11	6
H6	Cultivated land	141; 211; 212; 213; 241	I	23	20
H7	Constructed, industrial, and other artificial	111; 112; 121; 122; 123; 124; 131; 422	J	8	8
H8	Habitat complexes	243; 521; 523	X	21	6

The evaluation of pressure levels in the Ria de Aveiro Natura 2000 area was conducted based on expert assessments, as summarized in Table 2. The group of experts, representing different fields of knowledge (Figure 4), established the weighting factors used to quantify the intensity of each pressure category within the LUPLES framework. Regarding this assessment of pressure levels (Table 3), Marine (H1) and Coastal (H2) landscape units experience high biological (0.8–0.9), chemical (0.8), and energy-related pressures (0.8), largely due to fishing, aquaculture, and marine traffic. The high connectivity pressures (0.8–0.9) reflect disruptions caused by coastal development, erosion, and sea-level rise, which impact sediment transport and hydrodynamic processes. Inland surface water (H3) landscape units show elevated biological (0.9) and chemical pressures (0.9), likely due to the perceive influence of agricultural runoff, nutrient loading, and contamination, that contribute to eutrophication and biodiversity loss. Grasslands (H4), woodlands (H5), and cultivated land (H6) are under overall lower pressures, remain vulnerable to habitat fragmentation and reduced ecological connectivity. The high chemical pressure in constructed/artificial landscapes (H7) can be linked to industrial pollutants, and urban waste. Habitat complexes (H8) show a balanced pressure distribution, with notable biological (0.8) and chemical (0.8) influences, reflecting the mix of natural and human-altered environments. Physical and connectivity pressures (0.5–0.6) in H8 suggest that these areas act as transition zones between ecosystems, often facing multiple stressors simultaneously. Important to notice that the energy pressures are mostly affecting H1 and H2, the landscape units closer to the Atlantic Ocean and therefore more vulnerable to storms.

Table 3: Weighting factors for pressure type as assessed for the Ria de Aveiro Natura 2000 area, using the EUNIS basemap

Landscape code	Pressure type				
	biological	**chemical**	**energy**	**physical**	**connectivity**
H1	0.8	0.8	0.8	0.4	0.8
H2	0.9	0.8	0.8	0.9	0.9
H3	0.9	0.9	0.3	0.5	0.7
H4	0.7	0.6	0.2	0.5	0.7
H5	0.5	0.6	0.5	0.6	0.6
H6	0.5	0.6	0.4	0.5	0.2
H7	0.5	0.9	0.6	0.5	0.3
H8	0.8	0.8	0.5	0.5	0.6

The pressure levels were projected on the Ria de Aveiro Natura 2000 area, considering both CLC (Figure 6) and EUNIS (Figure 7) classification systems to evaluate how the choice of land cover typology influences the spatial distribution of pressures.

The area-weighted pressure analysis reveals that EUNIS-based assessments yield systematically higher-pressure estimates for most pressure types compared to CLC classifications. Energy pressure demonstrates the most substantial divergence (16.2% higher in EUNIS), followed by connectivity pressure (11.6% higher) and biological pressure (4.3% higher). Physical pressure represents the only exception, with EUNIS estimates 2.1% lower than CLC values. The overall pressure index increases by 6.5%

when using EUNIS compared to CLC, translating to an absolute difference of 0.04 in weighted pressure scores.

The classification systems produce markedly different spatial distributions of landscape units, fundamentally reshaping where management interventions would be prioritized. Marine (H1) habitats occupy 23% of the study area under CLC but expand to 45% under EUNIS – nearly doubling their spatial extent. This dramatic reclassification redistributes pressure calculations, as H1 carries high weighting factors across biological (0.8), chemical (0.8), energy (0.8), and connectivity (0.8) pressures. Conversely, H9 landscapes contract from 21% (CLC) to 6% (EUNIS), while woodlands (H5) virtually disappear, declining from 4% to less than 1% of the study area.

Correlation and regression analyses between pressure values (obtained based on the LUPLES concept) and ecological indicators (N total, P total) showed no statistically significant relationships overall (Table 4). For EUNIS-based data, no consistent trends were observed, as it describes habitat and ecological structures, which do not directly reflect anthropogenic sources of nutrients. In contrast, CLC-based pressure estimates revealed a weak negative trend with total nitrogen, suggesting that increased pressure values in certain landscape units may be associated with reduced water quality. CLC maps land uses linked to human activities, such as agriculture and urban areas, that are known drivers of nitrogen loading. Results showed a positive correlation between physical pressure and N total ($r = 0.94$, $p < 0.01$). These findings suggest that the choice of land cover classification system can influence the sensitivity and ecological relevance of pressure assessments. Meaning that the underlying hypothesis is confirmed, i.e., the use of CLC and EUNIS (two distinct classification systems) lead to different representations of land use and habitat patterns, thereby resulting in varying pressure intensity levels and influencing the overall assessment outcomes.

Table 4: Correlation and regression analyses between pressure values (obtained based on the LUPLES concept) and ecological indicators

EUNIS pressure	Indicator	Corr Coef	R^2 Adjusted	*F*	*P-value*	N
MEAN_WF_EU	Ntot_kg_y	-0.13	-0.15	0.10	0.76	8
MEAN_WF__1	Ntot_kg_y	-0.50	0.13	2.05	0.20	8
MEAN_WF__2	Ntot_kg_y	-0.71	0.43	6.22	0.05	8
MEAN_WF__3	Ntot_kg_y	-0.33	-0.04	0.73	0.43	8
MEAN_WF__4	Ntot_kg_y	-0.02	-0.17	0.00	0.97	8
MEAN_WF_EU	Ptot_kg_y	-0.16	-0.14	0.15	0.71	8
MEAN_WF__1	Ptot_kg_y	-0.51	0.14	2.11	0.20	8
MEAN_WF__2	Ptot_kg_y	-0.75	0.48	7.50	0.03	8
MEAN_WF__3	Ptot_kg_y	-0.29	-0.07	0.57	0.48	8
MEAN_WF__4	Ptot_kg_y	-0.05	-0.16	0.01	0.91	8

CLC pressure	Indicator	Corr Coef	R^2 Adjusted	*F*	*P-value*	n
MEAN_WF_bi	Ntot_kg_y	**0.37**	0.00	0.97	0.36	8
MEAN_WF_ch	Ntot_kg_y	**0.22**	-0.11	0.29	0.61	8

MEAN_WF_ph	**Ntot_kg_y**	**0.94**	**0.85**	**42.23**	**0.00**	**8**
MEAN_WF_en	Ntot_kg_y	**0.38**	0.01	1.04	0.35	8
MEAN_WF_co	Ntot_kg_y	**0.51**	0.14	2.10	0.20	8
MEAN_WF_bi	Ptot_kg_y	-0.07	-0.16	0.03	0.87	8
MEAN_WF_ch	Ptot_kg_y	-0.01	-0.17	0.00	0.98	8
MEAN_WF_ph	Ptot_kg_y	-0.22	-0.11	0.32	0.59	8
MEAN_WF_en	Ptot_kg_y	-0.69	0.39	5.56	0.06	8
MEAN_WF_co	Ptot_kg_y	-0.18	-0.13	0.20	0.67	8

4. Discussion

Applying the LUPLES concept to Ria the Aveiro Natura 2000 area showcases that sensitivity and ecological relevance of pressure assessments might be influenced by the land cover classification applied, specifically when comparing CLC and EUNIS. This evidence the potential implications for monitoring and reporting under legally bound obligations (e.g., Birds Directive, Habitats Directive, WFD, MSFD) including the most recent NRR, which is foreseeing a new classification for EU wide reporting.

Considering WFD as a policy of reference that integrates wetlands from catchment to coast, that is into force for 25 years, and that is considered by non-EU Member States to follow, it will structure the discussion of the results. The WFD status classification system provides a standardized approach for evaluating aquatic ecosystem health across European water bodies. The assessment integrates multiple biological quality elements complementing chemical and hydromorphological indicators, to assess the overall ecological status. This holistic integrative approach recognizes that aquatic ecosystems function as integrated systems where biological communities respond to both natural variability and anthropogenic pressures (European Parliament and the Council, 2000). In more detail, when considering the Ria de Aveiro Natura 2000 area, the status distribution reveals significant spatial heterogeneity in ecosystem health, with 71.4% of water bodies classified as "less than good" during the 2016-2021 period, corresponding to 87% of surface extent of the system (Portuguese Environment Agency, 2023). This pattern aligns with broader European trends where approximately half of all water bodies fail to achieve good ecological status (Lemm et al., 2021). The number of water bodies achieving “Good and very good” status in Ria de Aveiro Natura 2000 area is expected to decrease in the upcoming cycle, according to the Portuguese Environmental Agency reports (Portuguese Environment Agency, 2023). When these outcomes are interpreted together with the pressure analysis (Table 3), it becomes evident that the observed changes in ecological status are not associated with a consistent reduction of pressures within the catchment. Instead, the persistence of moderate to high pressure levels across key landscape units suggests that no coordinated or strategic restoration measures have been implemented at the catchment scale. This lack of integrated landscape management likely contributes to the maintenance, or even deterioration, of ecological conditions in certain areas, moving away from the WFD objective of achieving good ecological status for all water bodies. The decrease in the number of water bodies achieving “Good and very good” in the third cycle is also foreseen in other EU regions, with the stricter assessment criteria and increased monitoring, increase in anthropogenic pressures and climate and hydrological changes being pointed as main contributing factors (European Environment Agency, 2024).

The classification shown in the results demonstrates therefore the systematic vulnerability of transitional waters, reflecting the complex interplay of marine and freshwater influences combined with intensive anthropogenic pressures (Borgwardt et al., 2019a). The pressure analysis reveals a complex matrix of anthropogenic impacts that collectively compromise ecosystem integrity. In the Ria de Aveiro Natura 2000 area diffuse sources of pollution (total N and total P equivalents) merge as the dominant stressor, affecting 64% of assessed water bodies, followed by point source contamination and urban pressures each impacting 50% of water bodies (Portuguese Environment Agency, 2023)The temporal analysis reveals concerning trends in management effectiveness, with expected deterioration in three water bodies between 2016-2021 and 2022-2027 periods, while only one water body shows expected improvement. This pattern suggests that current management measures may be insufficient to address the cumulative pressures affecting these systems. The persistence of "less than good" status across multiple planning cycles indicates that achievement of WFD environmental objectives requires fundamental changes in management approach rather than incremental adjustments. The extensive list of planned measures documented in the River Basin Management Plan (Portuguese Environment Agency, 2023) reflects the comprehensive intervention strategy required for ecological status improvement. These measures span wastewater treatment upgrades, ecological restoration, invasive alien species management, and drainage system improvements, demonstrating the multi-sectoral coordination necessary for effective WFD implementation. The detailed characterization of the River Basin presented in the River Basin Management Plan enables pressure-specific management targeting, moving beyond generic improvement measures towards tailored interventions that address specific pollution sources and pathways. This precision approach is particularly relevant for transitional waters where multiple pressures interact in complex ways (Tagliapietra et al., 2020). While the WFD provides a comprehensive assessment methodology that enables systematic evaluation of aquatic ecosystem health, the persistence of poor status across multiple planning cycles indicates that technical assessment alone is not useful for environmental improvement when it does not lead to improvement actions.

Table 5: Highlights of CLC vs EUNIS in agreement with the findings of this study

Aspect	***CLC***	***EUNIS***
Primary Focus	Land-use and human influence patterns	Ecological habitat types based on species composition, habitat structure, and naturalness; hierarchical biodiversity classification
Thematic Resolution	44 standardized land-use categories at three hierarchical levels	Hierarchical classification (Level 1–Level 3+) with 199+ formally defined habitats at Level 3

Applicability for Pressure Assessment	Better linkage to anthropogenic pressures (agriculture intensification, urbanization, infrastructure, soil sealing) through direct land-use categorization	Focuses on habitat condition and ecological status; indirectly reflects pressure through habitat degradation indicators; fragmentation assessment relevant
Strengths	Captures broad-scale habitat loss, land-use change trends, and landscape-scale spatial patterns; actionable for regulatory intervention; directly identifies diffuse pollution sources (agricultural runoff, urban nutrient loading); supports basin-scale integrated management and LULUCF carbon accounting	Provides fine-scale ecological detail on habitat structure and function; essential for biodiversity assessment and conservation status determination; supports habitat-specific restoration targeting; detects subtle ecological shifts and species compositional changes
Policy Alignment	Directly aligned with WFD Article 5 for catchment-scale land-use assessment and pollution source tracking; integrated into LULUCF reporting under EU climate regulation; foundational for basin management plans	Aligned with biological quality elements of WFD; core basis for Habitats Directive (Annex I) assessments; integral to Natura 2000 network design and protected area management; mandatory for NRR compliance and habitat-specific restoration targets
Ecological Relevance	Directly reflects human-driven processes affecting water quality and hydrological function (nutrient loading from agriculture, stormwater from urban areas, channel modifications)	Reflects ecological integrity, functional habitat connectivity, and ecosystem services provision; captures fragmentation status and recovery potential; essential for assessing biodiversity value and ecosystem resilience
Restoration Planning	Identifies landscape-scale priorities for pollution abatement, land-use conflict zones, and broad restoration opportunities; supports prioritization at basin and regional scales; cost-effective for targeting large areas requiring intervention	Supports diagnosis of habitat-specific degradation mechanisms; enables design of tailored restoration measures addressing particular ecological threats; guides habitat-specific restoration targets mandated under NRR; tracks post-restoration habitat recovery and connectivity improvements
Integration Potential	Essential for basin-scale integrated management (WFD compliance); LULUCF carbon accounting; climate and land-use planning; landscape-level biodiversity baseline; multi-sector land management strategies	Critical for NRR compliance (30% habitat restoration by 2030); WFD biological indicator monitoring; Natura 2000 management; habitat-specific biodiversity tracking; carbon storage and sequestration potential assessment for priority habitats
Complementary Use	CLC provides spatial context for where pressures originate and where broad landscape intervention is needed; establishes catchment-scale baseline for pollution and land-use change assessment	EUNIS refines restoration targeting within CLC-identified priority areas; verifies restoration success through habitat quality and connectivity metrics; monitors compliance with species conservation and habitat condition targets under EU directives

The CLC and EUNIS frameworks for wetland mapping and assessment are two important classification systems towards the assessment of management priorities. While EUNIS provides ecologically detailed habitat classifications, CLC captures broader land-use patterns, and the two combined enable robust, multi-objective management frameworks, aligning with EU priorities for integrated coastal zone management and biodiversity conservation (Perissi, 2025). From a wetland management perspective, the choice of classification system has practical implications. Habitat-based systems like EUNIS are more suitable for conservation planning and biodiversity assessments, while land use-based systems like CLC offer better insight into anthropogenic pressures and are more actionable for regulatory and mitigation strategies. Therefore, depending on the classification used, pressure estimates—and consequently, management decisions—can vary significantly, highlighting the need for careful selection of input data in pressure assessment models to ensure alignment with the intended management objectives (Table 5; Kallimanis et al., 2013; Tomaselli et al., 2021).

The analysis of pressures in the wetland area underscores the importance of integrating multiple pressure indicators in wetland management strategies. Biological and chemical pressures are dominant in aquatic and intensively managed landscapes, whereas connectivity and physical pressures are key in terrestrial and transition habitats. This was also previously reported in the literature, reinforcing that spatially-explicit monitoring combined with pressure-specific interventions can reverse degradation trends and even improve the ecological status (Albulescu et al., 2023; Borgwardt et al., 2019b; Pasvisheh et al., 2021; Zhao et al., 2024).

For the Ria de Aveiro Natura 2000 area, under CLC-based prioritization, interventions would be distributed more broadly across landscape units, allocating substantial resources to H9 (21% of area), H7 (23%), and terrestrial systems. This approach would emphasize agricultural best management practices, urban stormwater control, and terrestrial habitat restoration alongside coastal interventions. Under EUNIS classifications, management priorities would concentrate on marine and coastal zones (H1–H2), which collectively represent 57% of the study area and exhibit cumulative pressure indices exceeding 0.42. This focus would emphasize marine spatial planning, fisheries management, aquaculture regulation, and coastal erosion mitigation. Energy and connectivity pressures receive heightened attention due to their elevated weighting in EUNIS assessments. The divergence between classification systems introduces structural uncertainty into environmental decision-making processes, distinct from uncertainties arising from data limitations or model errors. This classification-driven uncertainty affects both the identification and representation of landscape characteristics and boundaries.

The LUPLES concept adapted to the Ria de Aveiro Natura 2000 correlates estimated pressure levels with ecological status indicators derived from the WFD (Morant et al., 2021). When different classification systems (CLC versus EUNIS) are used as inputs to the LUPLES model, the outputs can be compared to evaluate how classification choice affects estimates. On one hand, our *ad-hoc* application of the LUPLES concept results using EUNIS-based pressure estimates in Ria de Aveiro Natura 2000 showed no consistent trends with ecological indicators, likely due to their ecological rather than anthropogenic focus. On the other hand, the results of our *ad-hoc* LUPLES results using CLC-based data revealed a positive correlation between physical pressure and total nitrogen, suggesting that land use types captured by CLC—such as intensive agriculture or urban development—are more indicative of nutrient loading and other stressors affecting water quality, as seen in (Morant et al., 2021). The differences in correlation outcomes between EUNIS and CLC classifications reflect fundamental distinctions in their design and ecological relevance. EUNIS is a hierarchical habitat classification system that emphasizes ecological structure and function. It includes detailed habitat types such as *coastal lagoons*, *salt marshes*, and *reed beds*, which are valuable for conservation but may not directly reflect anthropogenic pressures. In contrast, CLC focuses on land use categories such as *agricultural areas*, *pastures*, *urban fabric*, and *industrial zones*, which are more closely tied to human activities and their environmental impacts (Tomaselli et al., 2021).

As a result, in the Ria de Aveiro Natura 2000 area, as an example to showcase for other systems CLC-based mapping enables a clearer delineation of pressure gradients and a more consistent linkage between human activities and ecological responses within the catchment. Nevertheless, the relative suitability of each classification system depends on the analytical objective. As shown in the results, when assessing anthropogenic pressures, the ability to distinguish land-use types and their landscape-scale implications is critical, favoring the use of CLC. Conversely, EUNIS provides higher ecological specificity, making it more appropriate for habitat quality assessments and conservation planning. Integrating both frameworks may therefore enhance the robustness of pressure–response analyses and support more targeted management actions.

Despite these findings with CLC classification capturing spatial patterns of anthropogenic pressures more effectively than EUNIS, the overall lack of strong correlations between pressures and ecological indicators may be attributed to the complex nature of the Ria de Aveiro Natura 2000 area. As a tidal system, it is influenced by dynamic hydrological processes, salinity fluctuations, and marine inputs, which can mask or dilute the effects of land-based pressures (Lillebø et al., 2019). These factors bring another layer of complexity disabling the direct linkage between landscape-derived pressures and ecological status indicators.

The implementation of the European Nature Restoration Regulation (NRR) (European Parliament and Council of the European Union, 2024) mandates that European Union (EU) member states put in place restoration measures to restore at least 20% of its land and sea by 2030. The NRR's requirement for member states to develop National Restoration Plans that quantify restoration areas and prioritize measures, relies on robust habitat classification and monitoring frameworks to track ecological changes and assess restoration progress. The effectiveness of these plans depends on their alignment with other major EU policies, namely the nature and ecological status related ones (e.g., Birds Directive, Habitats Directive, WFD, MSFD) but also the Common Agricultural Policy (CAP) and National Energy and Climate Plans (NECPs), ensuring that restoration efforts support broader climate and biodiversity objectives (International Union for Conservation of Nature, 2025).

A critical component of this alignment is the use of standardized classification systems, such as CLC and EUNIS, to ensure consistency in habitat assessments and land-use planning across Member States, enabling a multi-scale analysis of landscape transformations (Perissi, 2025). Such integration is particularly valuable for detecting habitat degradation, resolving land-use conflicts, and identifying restoration opportunities. For instance, wetland restoration requires precise monitoring of hydrological changes, land use, and biodiversity shifts, which can be effectively assessed using these classification systems. The NRR's objectives also intersect with the EU's climate and decarbonization strategies, particularly under the Land Use, Land Use Change, and Forestry (LULUCF) Regulation (European Parliament and Council of the European Union, 2023). Member States must account for emissions and removals from land use and forestry, incorporating carbon sink enhancements into their restoration plans. However, there are disparities in how NECPs integrate nature-based solutions and climate adaptation measures, needing better coordination to avoid conflicting goals and overlapping efforts. The CAP's eco-schemes, which promote sustainable agriculture and high-diversity landscapes, provide additional tools for habitat restoration, especially in agricultural regions. Furthermore, policy coherence between NRR, NECPs, and CAP Plans is essential for achieving measurable outcomes in biodiversity conservation and climate resilience (Perissi, 2025).

Ultimately, standardized classification systems such as CLC and EUNIS play a crucial role in harmonizing data collection and reporting, ensuring that restoration efforts align with broader EU environmental policies. Crosswalks among classifications are therefore necessary. The NRR introduces its own EU-wide ecosystem classification to standardize restoration targets and reporting. While it does not replace existing systems such as CLC or EUNIS, the Regulation foresees implementing acts and technical guidance to ensure harmonization and facilitate the use of existing monitoring data. The translation of this into crosswalks between classification methos, similarly to what exists for Ecosystem Services classification systems (e.g., MA, TEEB, MAES, IPBES) would support Member States to build on established frameworks while meeting new legal requirements for restoration planning. Integrating these frameworks into the National Restoration Plans reporting structure will enhance policy coherence, facilitate habitat monitoring, and optimize resource allocation, making it possible to track the success of restoration measures across multiple landscapes and ecosystems (Perissi, 2025). The alignment of classification systems, facilitated with existing crosswalks (Carré et al., n.d.), allows for a multi-scale analysis of landscape transformations, making it possible to detect habitat degradation, land-use conflicts, and restoration opportunities across Member States. In this context, EUNIS offers detailed habitat typologies, while CLC provides broad land cover classes; together, they form the basis for large-scale screening and fine-scale habitat mapping. By aligning these systems with the NRR framework, Member States can leverage established monitoring infrastructures, avoid duplication, and ensure continuity with previous EU directives.

EUNIS Level 1 provides a manageable classification, avoiding the complexity of finer hierarchical levels, which require high-resolution data and risk inconsistencies across regions. Its generalized structure enhances interpretability, reduces computational demands, and aligns with EU initiatives (Chhetri et al., 2024a) such as Mapping and Assessment of Ecosystems and their Services (MAES), supporting large-scale environmental assessments. While EUNIS Level 1 captures dominant pressures (e.g., land-use changes, hydrological modifications), it lacks the resolution to detect subtle habitat shifts but remains a pragmatic framework for balancing ecological detail with operational feasibility in large-scale wetland management (Chhetri et al., 2024b).

The integration of cost-benefit analysis (CBA) into wetland restoration planning is the next critical step when optimizing resource allocation under EU policies such as the WFD and NRR (Martínez-Paz et al., 2013; van Zanten et al., 2025). Hydro-morphological rehabilitation (e.g., riparian zone restoration) often has costs 5 to 10 times higher than point-source pollution controls per hectare, primarily due to land acquisition and engineering complexity. For example, coastal lagoon restoration programs in Spain achieved 10% economic return rates only when combining physical habitat rehabilitation with nutrient reduction measures, as isolated hydro-morphological projects showed negative net present values (Martínez-Paz et al., 2013). Similarly, mangrove restoration in Indonesia revealed benefit-cost ratios of 2.1 to 3.4 when integrating carbon sequestration and fisheries enhancement, compared to 0.8 to 1.2 for purely structural rehabilitation (van Zanten et al., 2025). Here, it must be considered that both, carbon sequestration (e.g. through carbon credits) and fisheries enhancement (through fishing benefits) can be easily transformed in well monetized value, whereas other ecosystem services such as biodiversity support are not currently being accounted on monetary terms

Methodological challenges arise in reconciling temporal discounting effects—where short-term political incentives conflict with long-term ecological payoffs—and in valuing intangible benefits. Studies demonstrate that public preferences disproportionately favor policies with immediate returns, even when long-term benefits outweigh costs, a bias exacerbated by uncertainty in ecological outcomes (Barnfield, 2024). Standardized CBA frameworks incorporating EUNIS and CLC data layers address these constraints by spatially explicit discount rate adjustments. Such approach aligns with the WFD emphasis on basin-scale hydrological coherence and the LULUCF carbon accounting requirements, ensuring NRR compliance without sacrificing regional economic viability. By embedding multiple criteria for decision making within interoperable geospatial platforms, member states can transparently weigh habitat connectivity, socioeconomic risks, and multi-objective benefits, bridging the gap between ecological urgency and political feasibility (Vogt et al., 2007).

5. Conclusions

This study highlights the broader applicability of incorporating multiple classification systems into pressure-assessment approaches like the LUPLES concept. By demonstrating how land-use-based (CLC) and habitat-based (EUNIS) frameworks differently influence pressure quantification, it underscores the need for flexible model inputs that align with policy objectives (e.g., having WFD as reference) and management options. Integrating both classification types allows practitioners to derive complementary insights: CLC facilitates clear links between anthropogenic activities and physicochemical stressors, while EUNIS offers detailed ecological context for biodiversity and habitat-focused interventions. Linking pressure assessments with ecological status indicators is essential for achieving more accurate evaluations and designing effective restoration and management actions aimed at improving ecological integrity in accordance with the WFD. In this regard, the results obtained through the application of the LUPLES concept provide valuable insights for supporting integrated, evidence-based decision-making in wetland conservation and catchment management. Looking ahead, the Nature Restoration Regulation introduces an EU-wide ecosystem classification to unify restoration targets and reporting. Although crosswalks between CLC and EUNIS are not explicitly foreseen, developing them would help integrate existing datasets into the new framework and maintain the value of current monitoring systems. Using both classifications in spatially explicit modeling approaches remains important for capturing structural uncertainty and supporting more informed, context-specific restoration decisions.

Institutional Review Board Statement

The study was conducted in accordance with the Declaration of Helsinki. Ethical approval was waived for this study due to the Resolution of the Assembly of the Portuguese Republic No. 29/2017, articles 15 and 16.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the participants to publish this paper.

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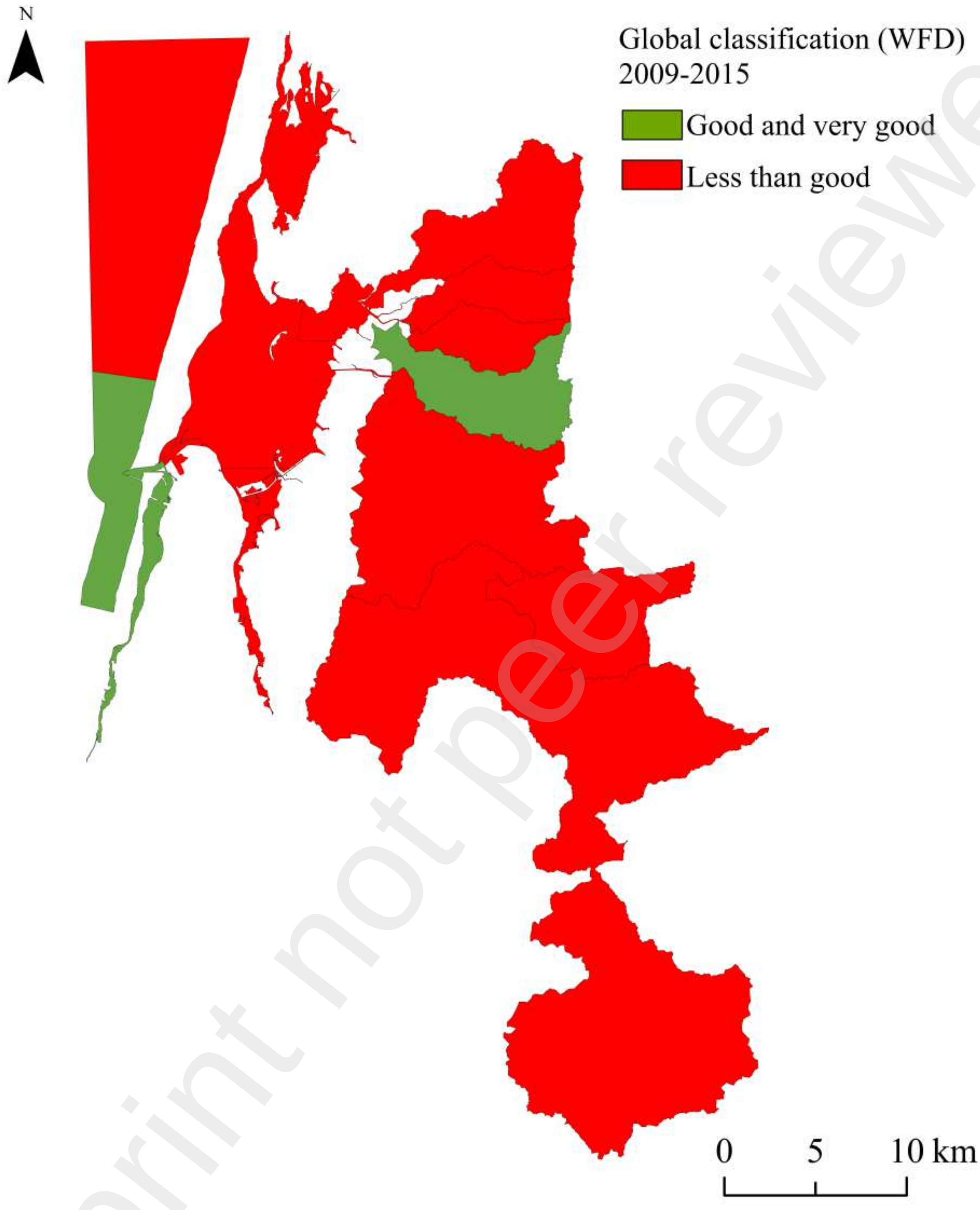
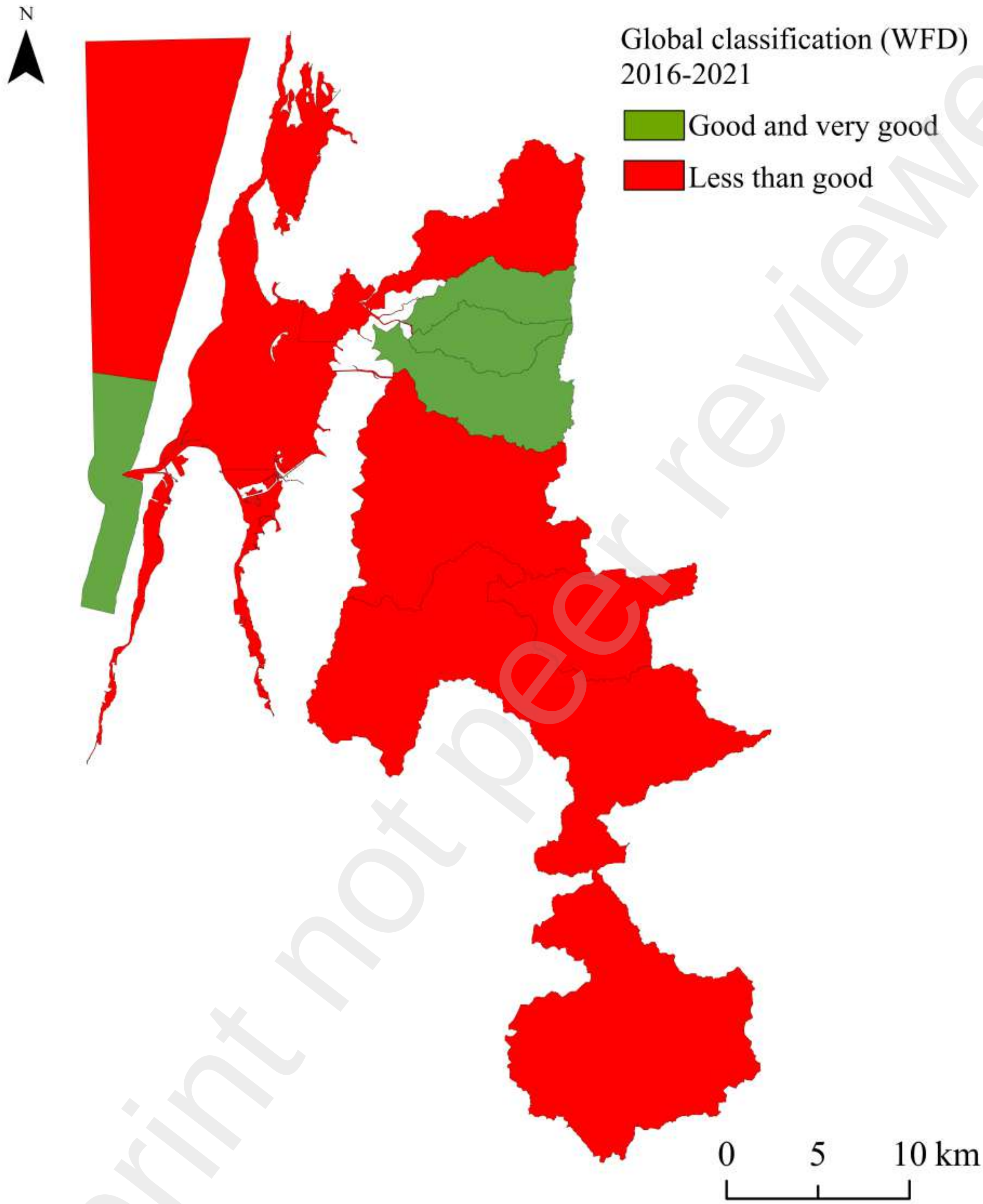


N
Global classification (WFD)
2009-2015
Good and very good
Less than good
0
5
10 km


N
Global classification (WFD)
2016-2021
Good and very good
Less than good
0 5 10 km

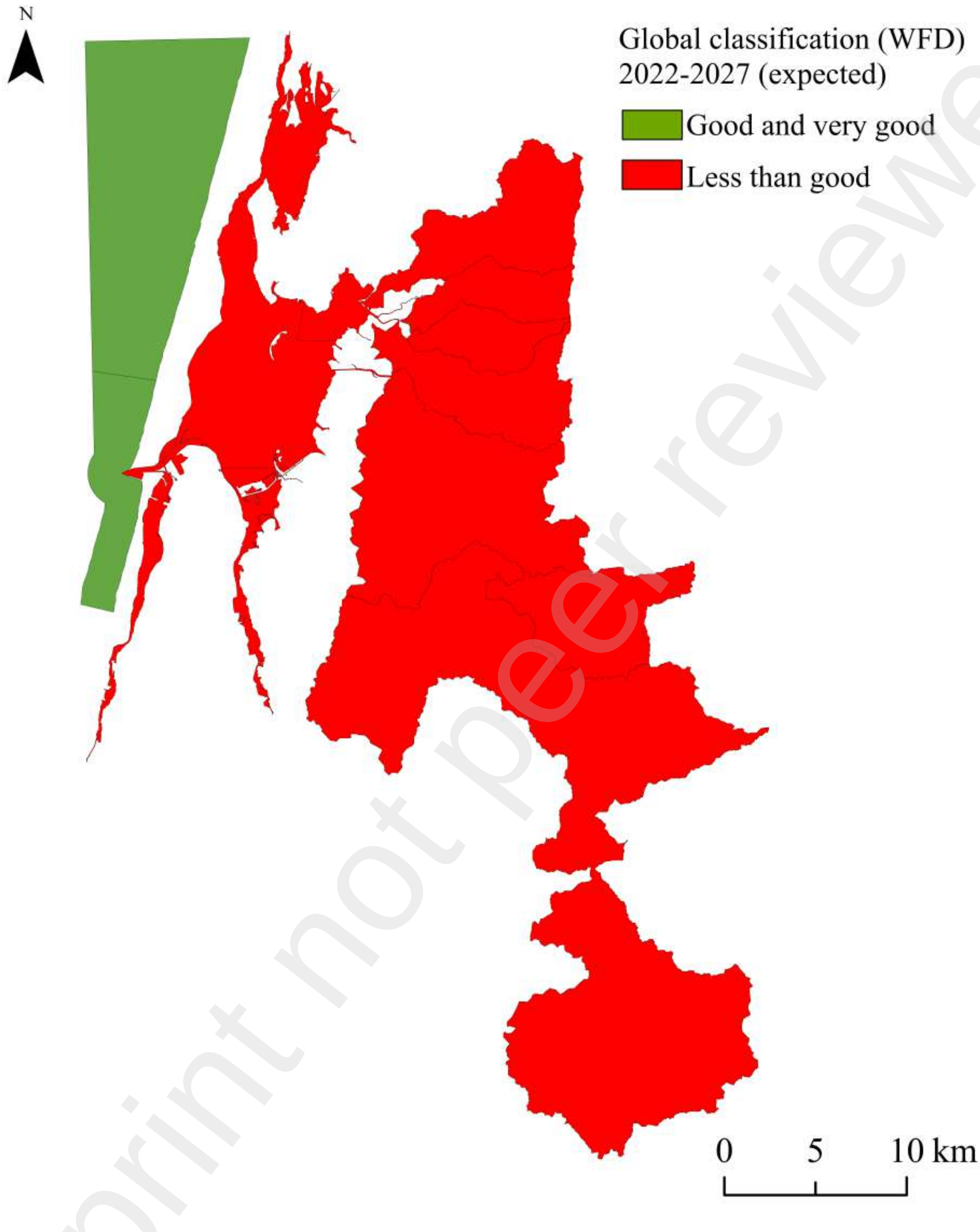

N
Global classification (WFD)
2022-2027 (expected)
Good and very good
Less than good
0
5
10 km

Figure 1: Ria de Aveiro Natura 2000 area location in Vouga River Basin, Portugal.

Figure 2: Classification of Ria de Aveiro Natura 2000 area considering level 2 of A) CLC 2018; and B) EUNIS 2021/2022.

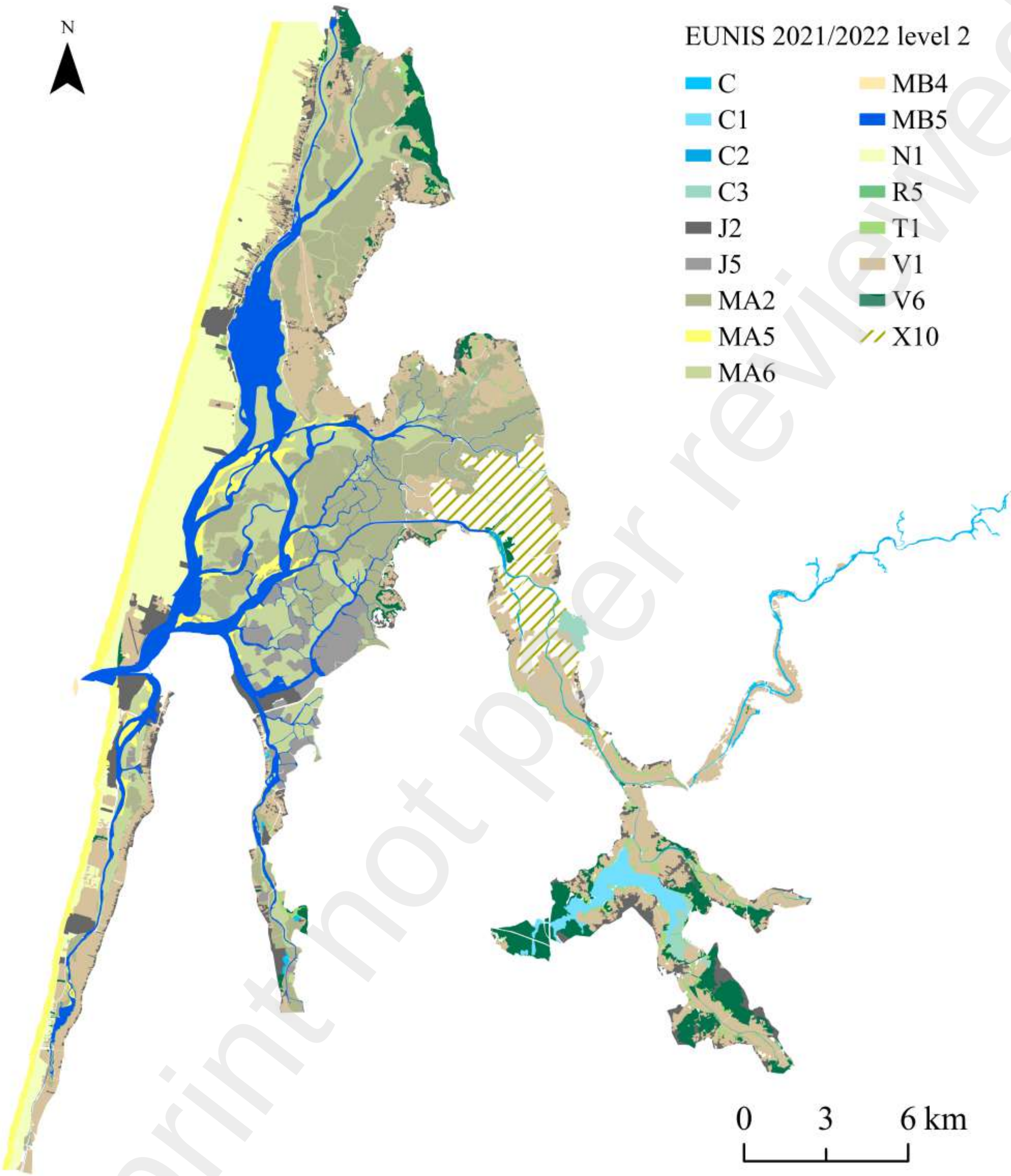
Figure 3: Status of the 14 water bodies in the Ria de Aveiro Natura 2000 area and their global status classification according to the Water Framework Directive in A) period 1 (2009-2015); b) period 2 (2016-2021); and C) expected for period 3 (2022-2027).

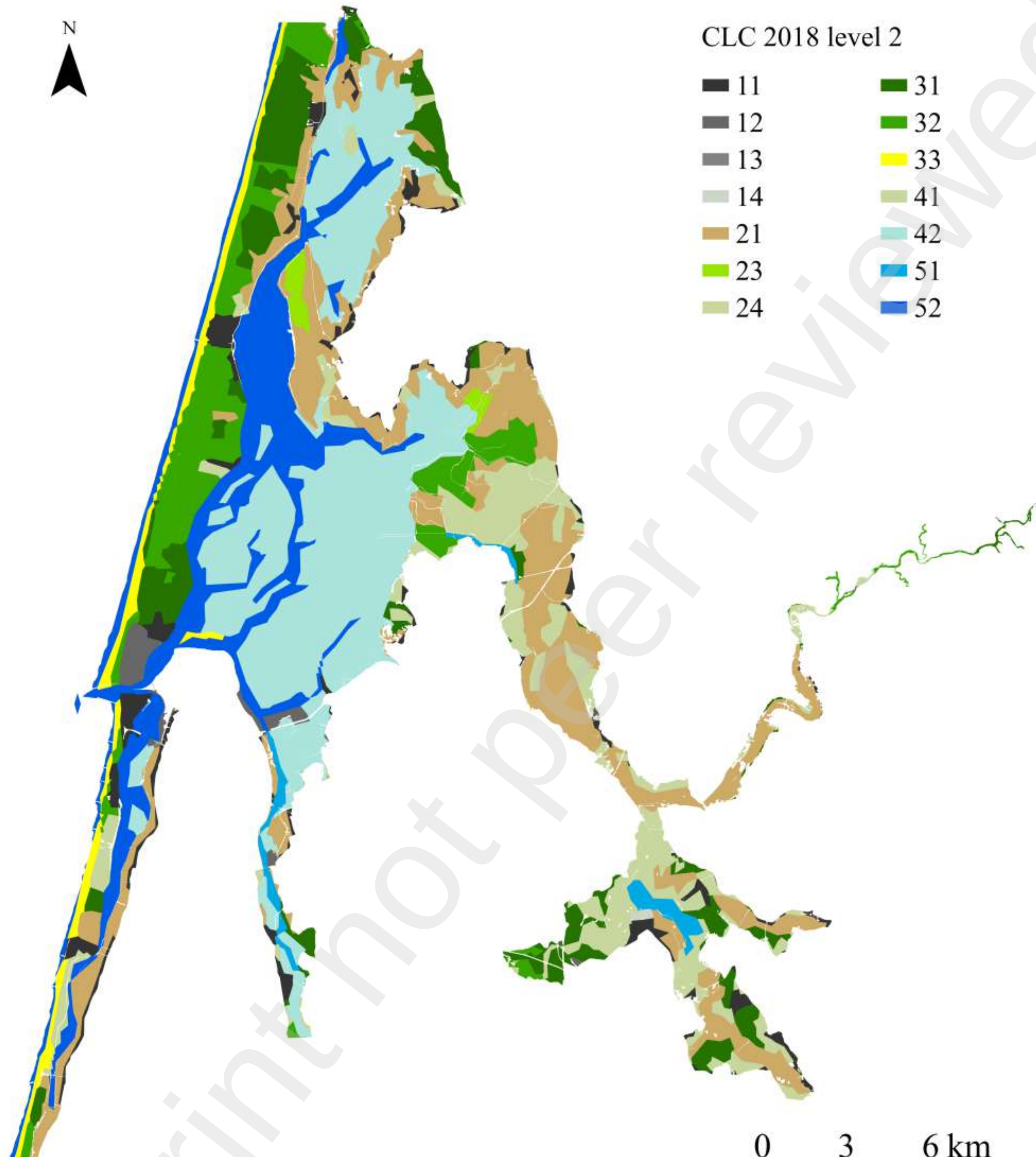
Figure 4: Groups used for the assessment of pressures A) using the CLC database as basemap; and B) using the EUNIS database as basemap.

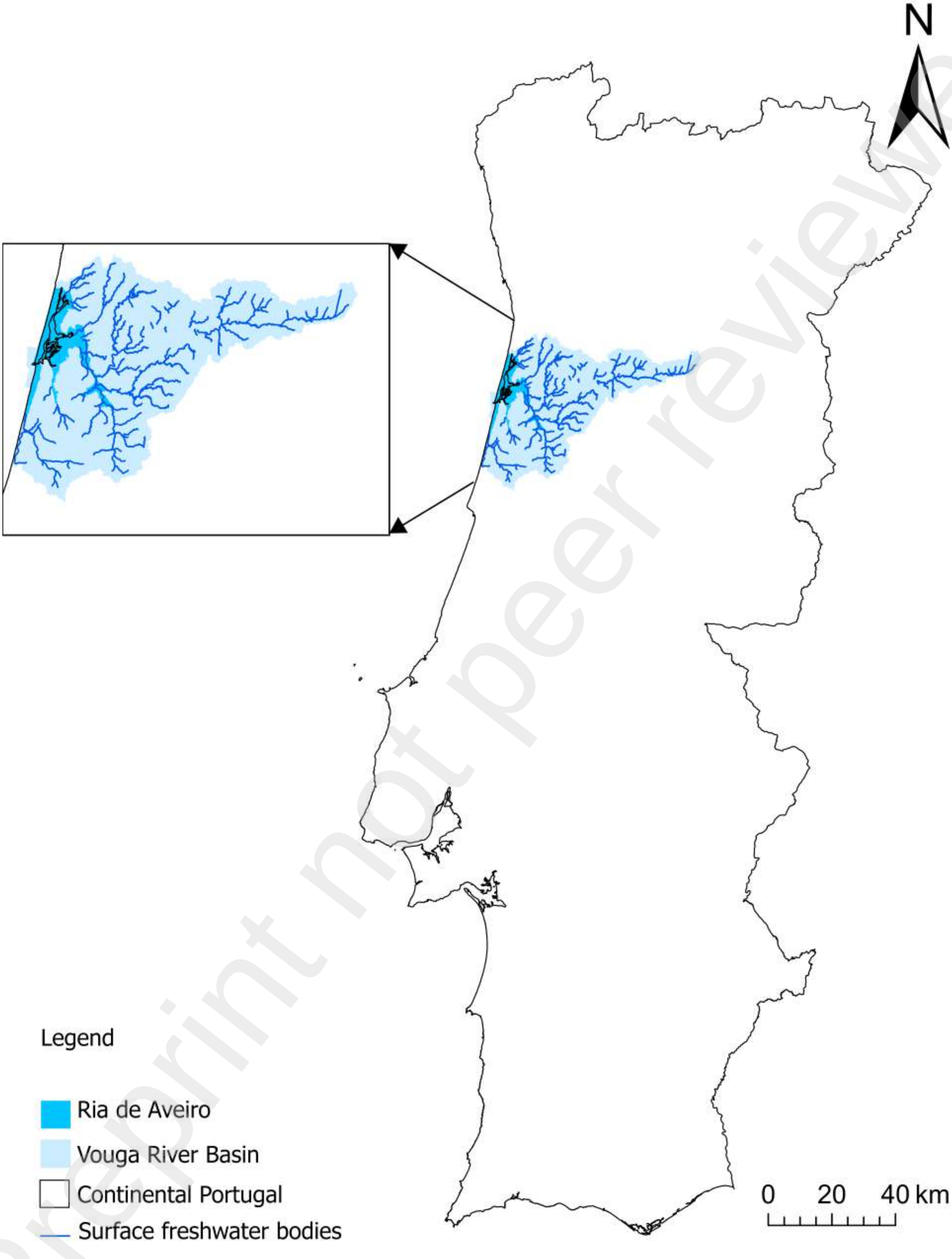
Figure 5: Distribution of experts (n= 13) per area of knowledge.

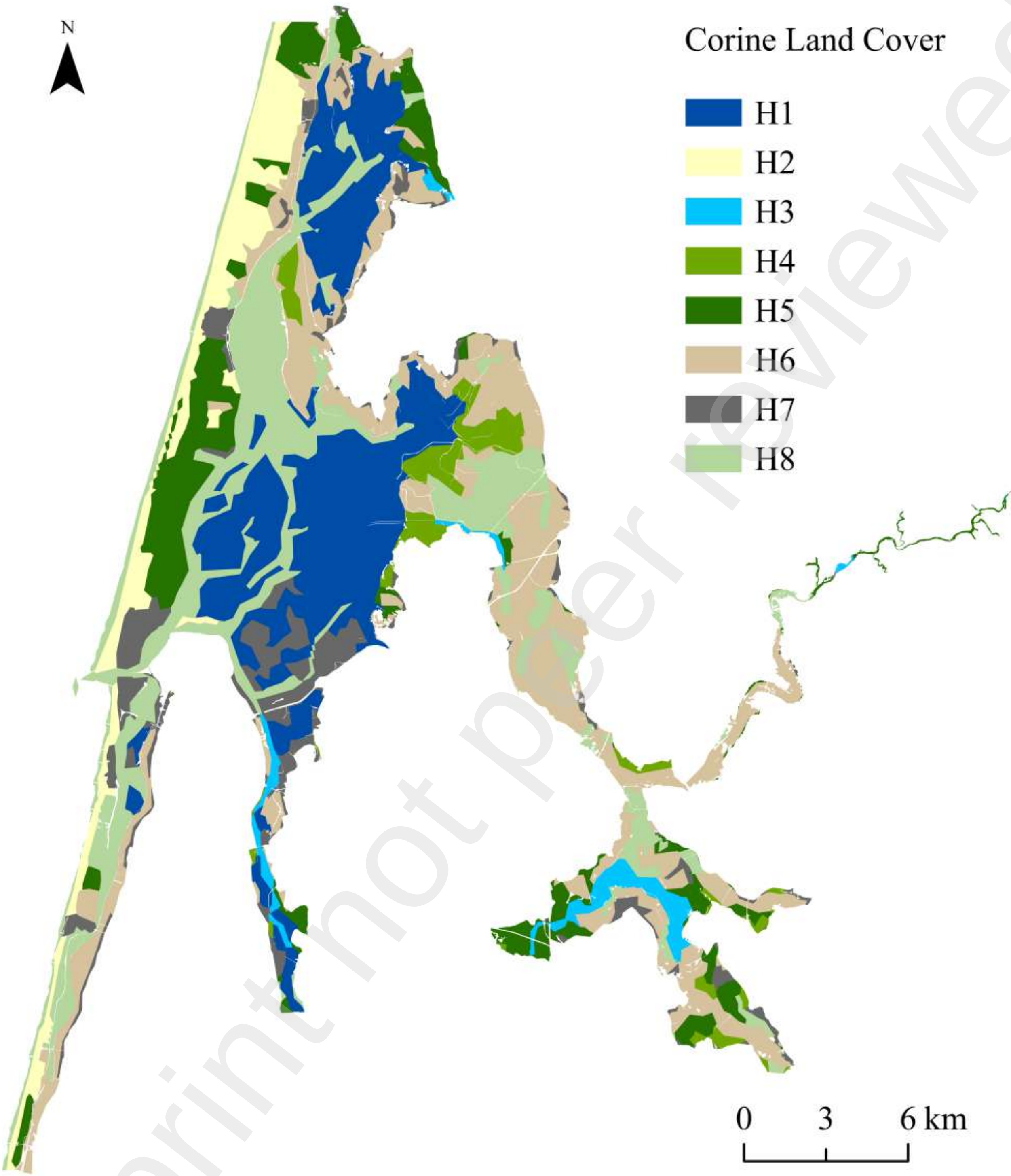
Figure 6: Weighting factors for pressure type as assessed for Ria de Aveiro Rede Natura 2000 area, using the CLC landscape groups: A) biological pressures; B) Chemical pressures; C) Connectivity pressures; .D)Energy pressures; and E) Energy pressures.

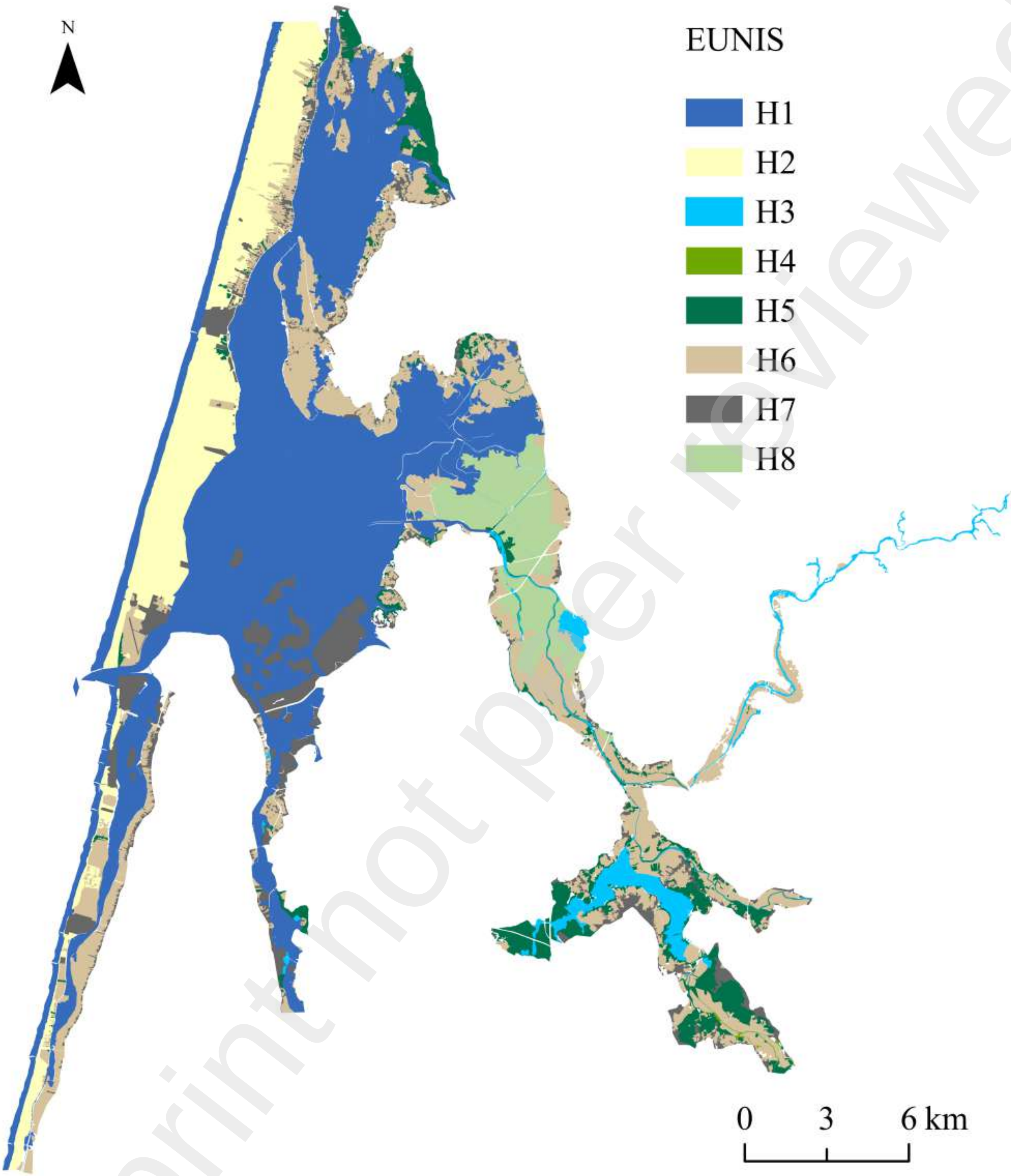
Figure 7: Weighting factors for pressure type as assessed for Ria de Aveiro Rede Natura 2000 area, using the EUNIS landscape groups: A) biological pressures; B) Chemical pressures; C) Connectivity pressures; .D)Energy pressures; and E) Energy pressures.


N
EUNIS 2021/2022 level 2
C
C1
C2
C3
J2
J5
MA2
MA5
MA6
MB4
MB5
N1
R5
T1
V1
V6
X10
0
3
6 km

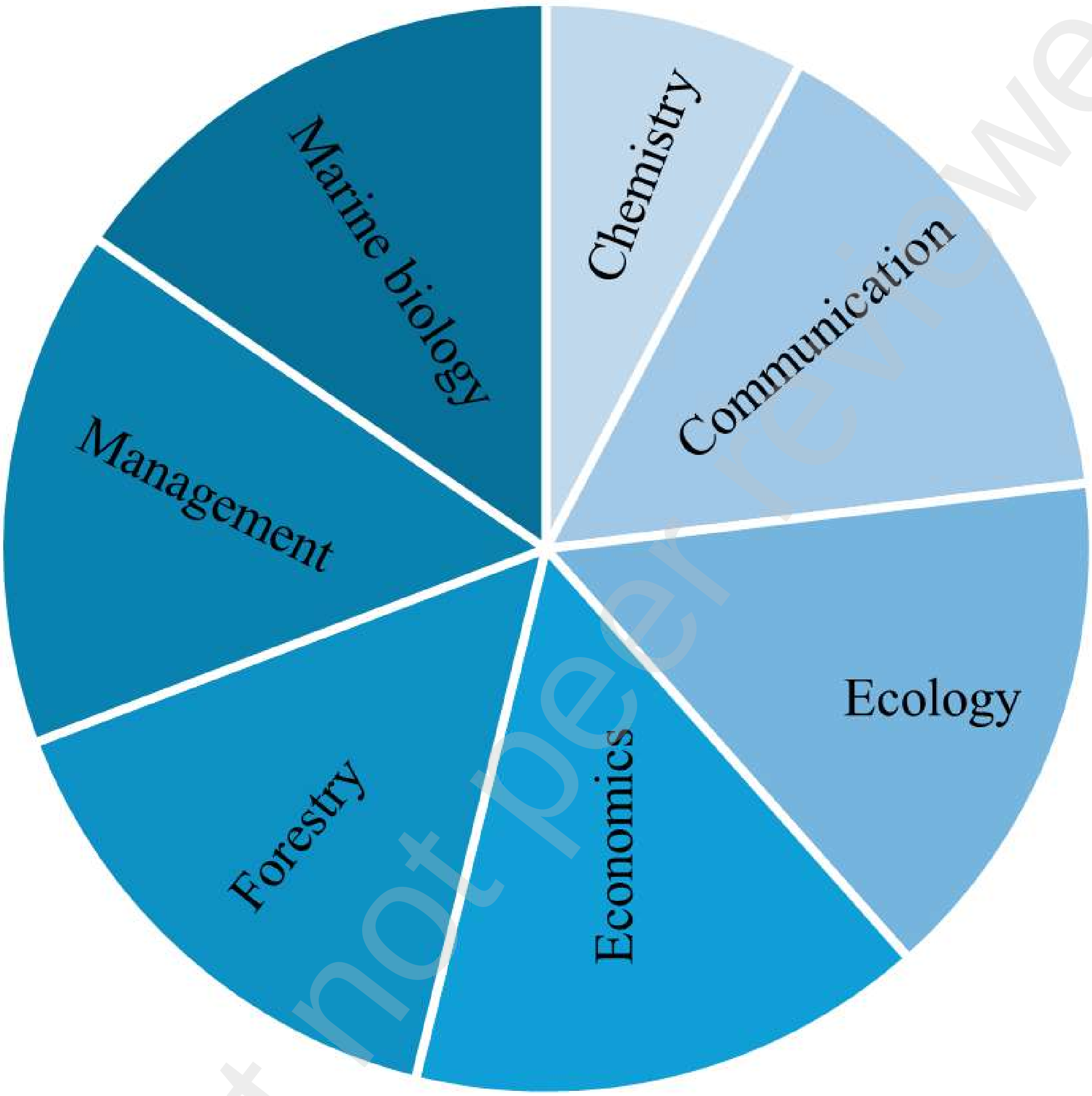

N
CLC 2018 level 2
11
12
13
14
21
23
24
31
32
33
41
42
51
52
0
3
6 km


N
Legend
Ria de Aveiro
Vouga River Basin
Continental Portugal
Surface freshwater bodies
0 20 40 km

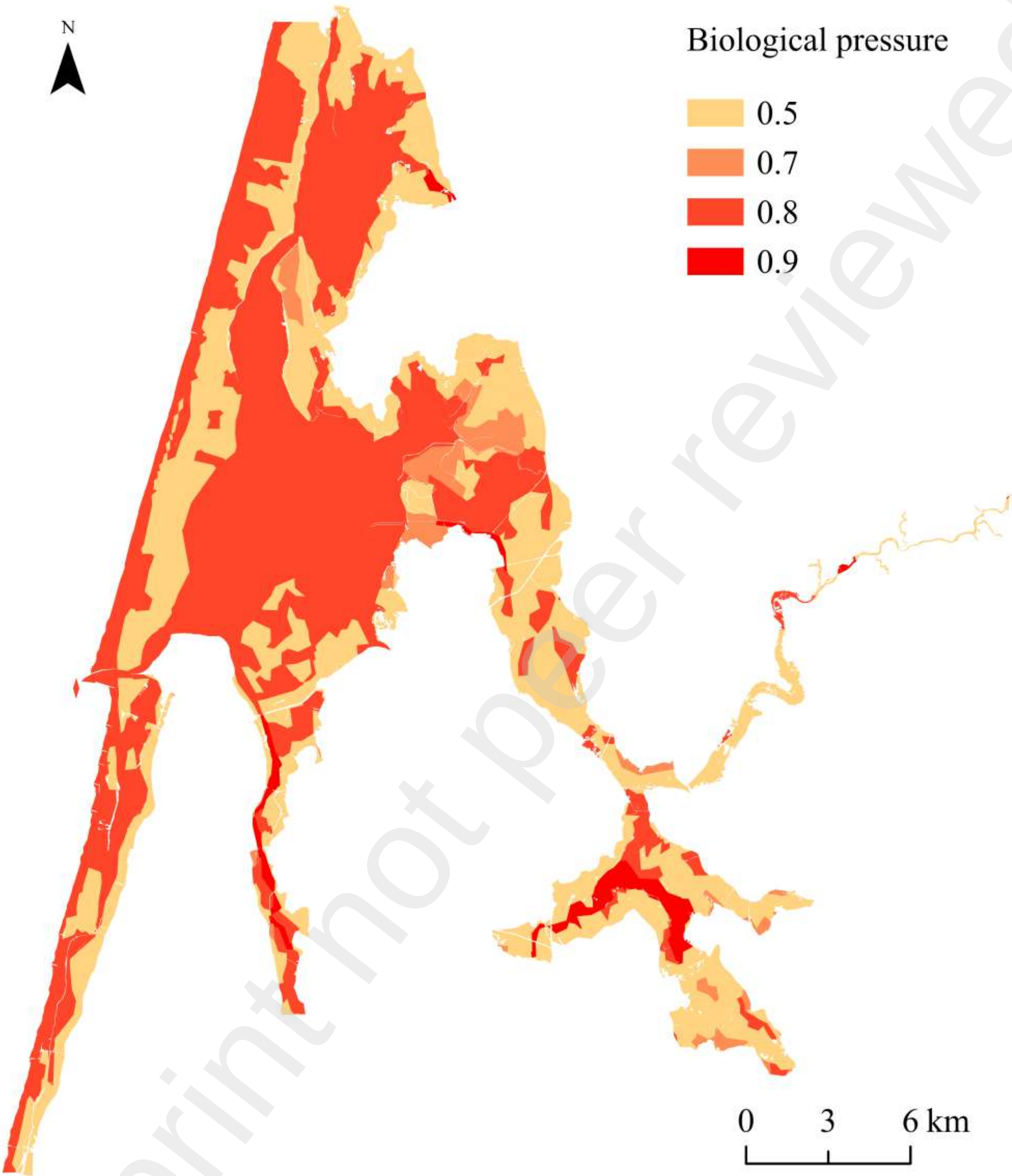

N
Corine Land Cover
H1
H2
H3
H4
H5
H6
H7
H8
0
3
6 km

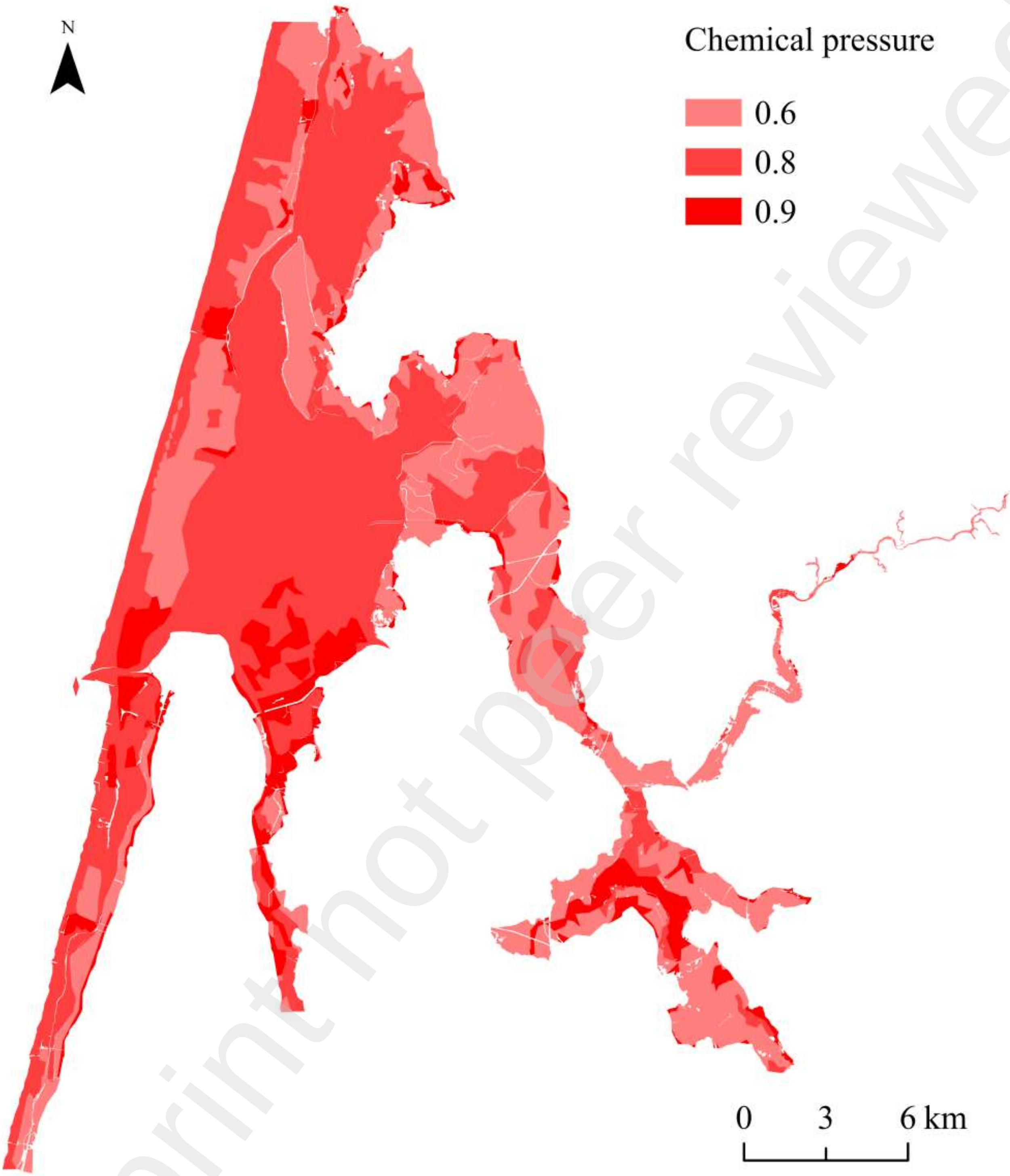


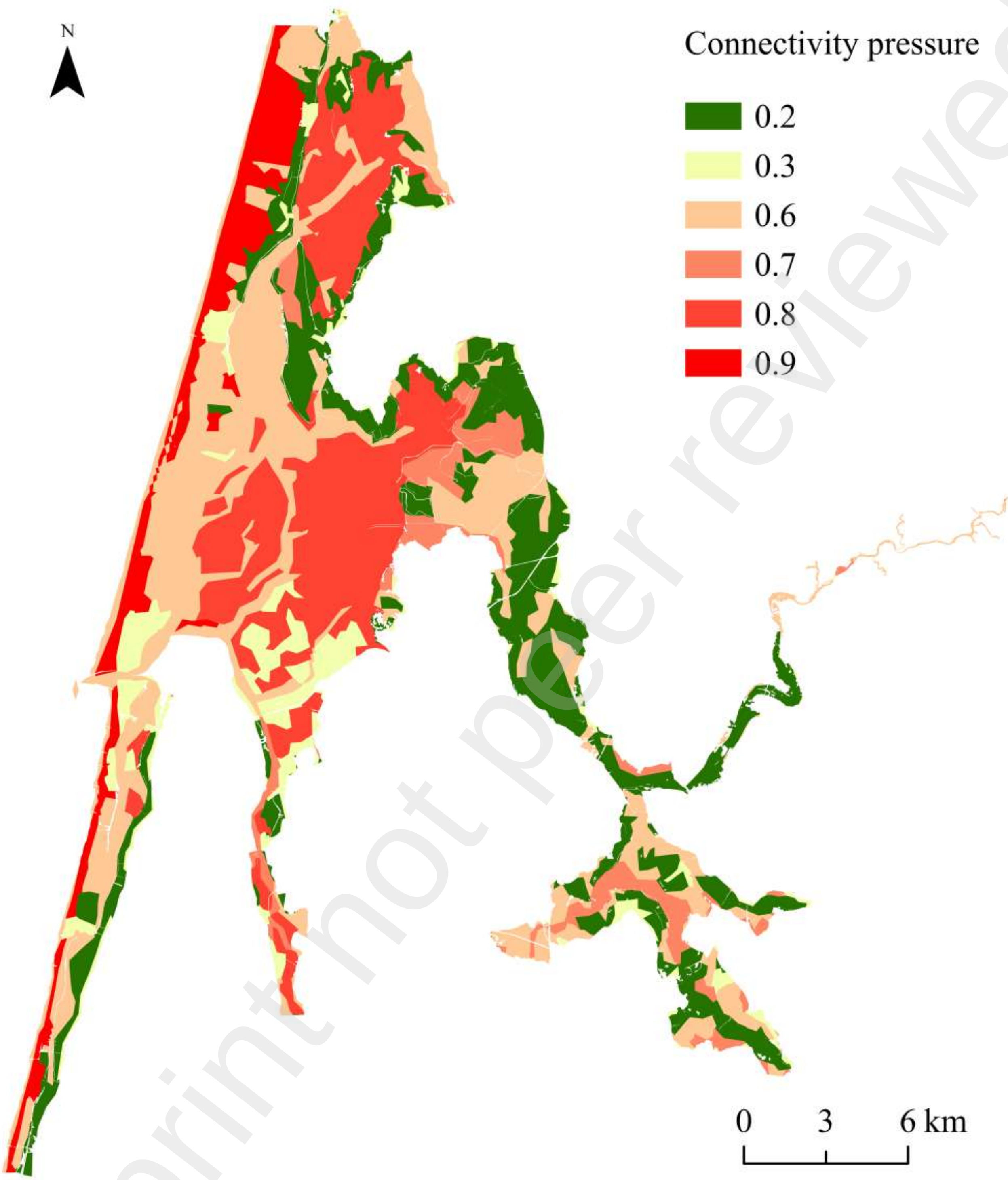
N
EUNIS
H1
H2
H3
H4
H5
H6
H7
H8
0
3
6 km

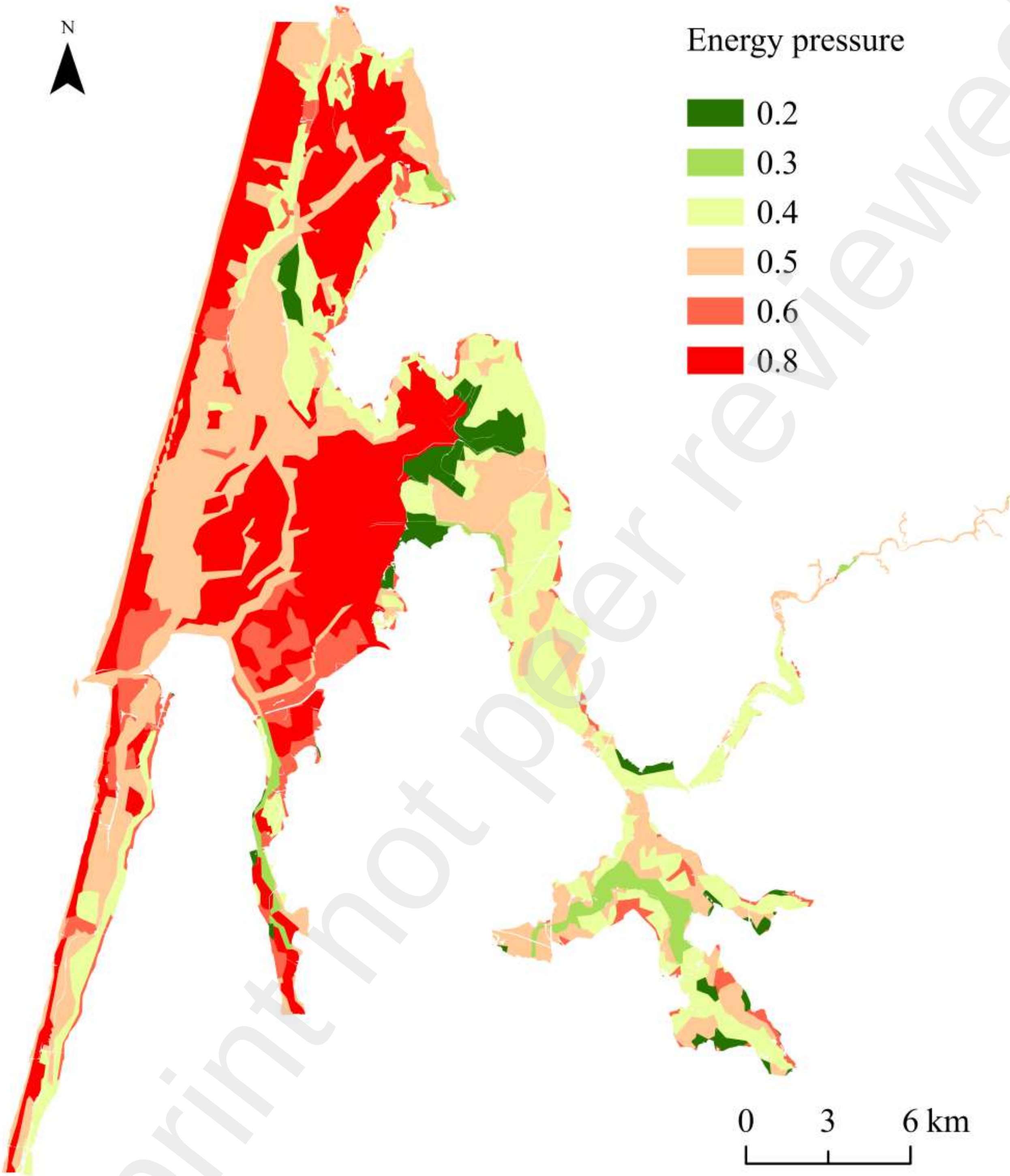


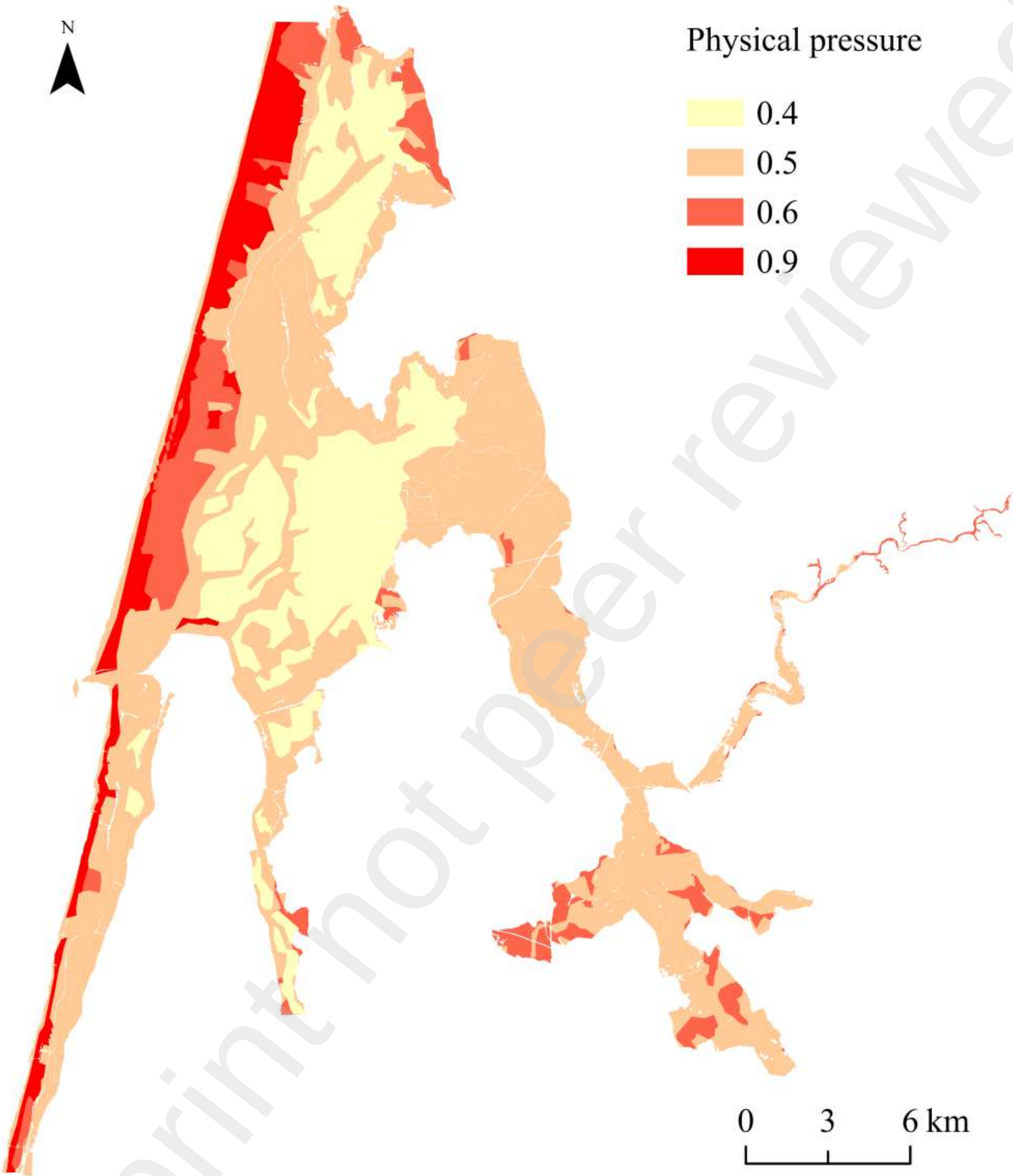
Chemistry
Communication
Ecology
Economics
Forestry
Management
Marine biology

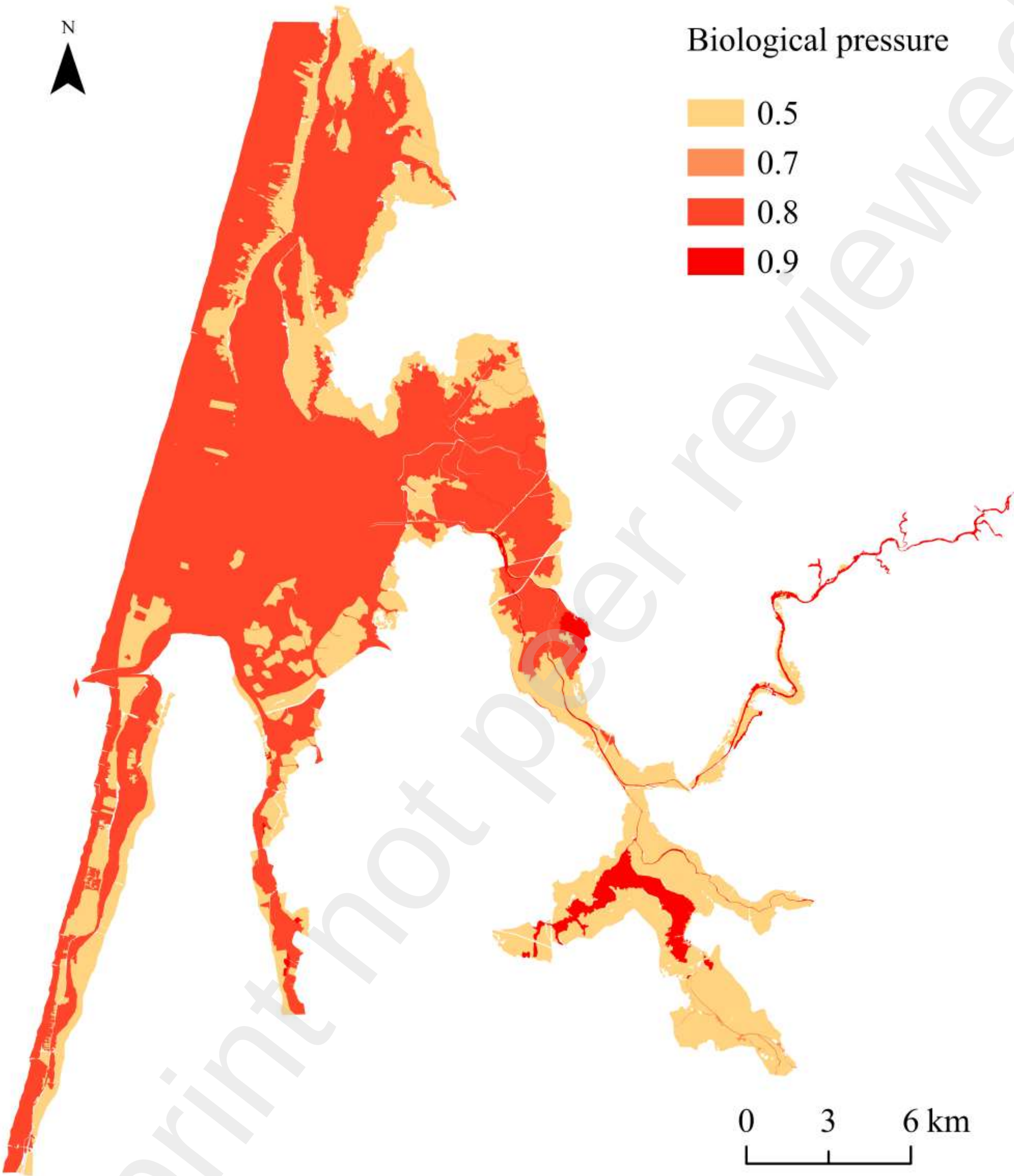

N
Biological pressure
0.5
0.7
0.8
0.9
0
3
6 km

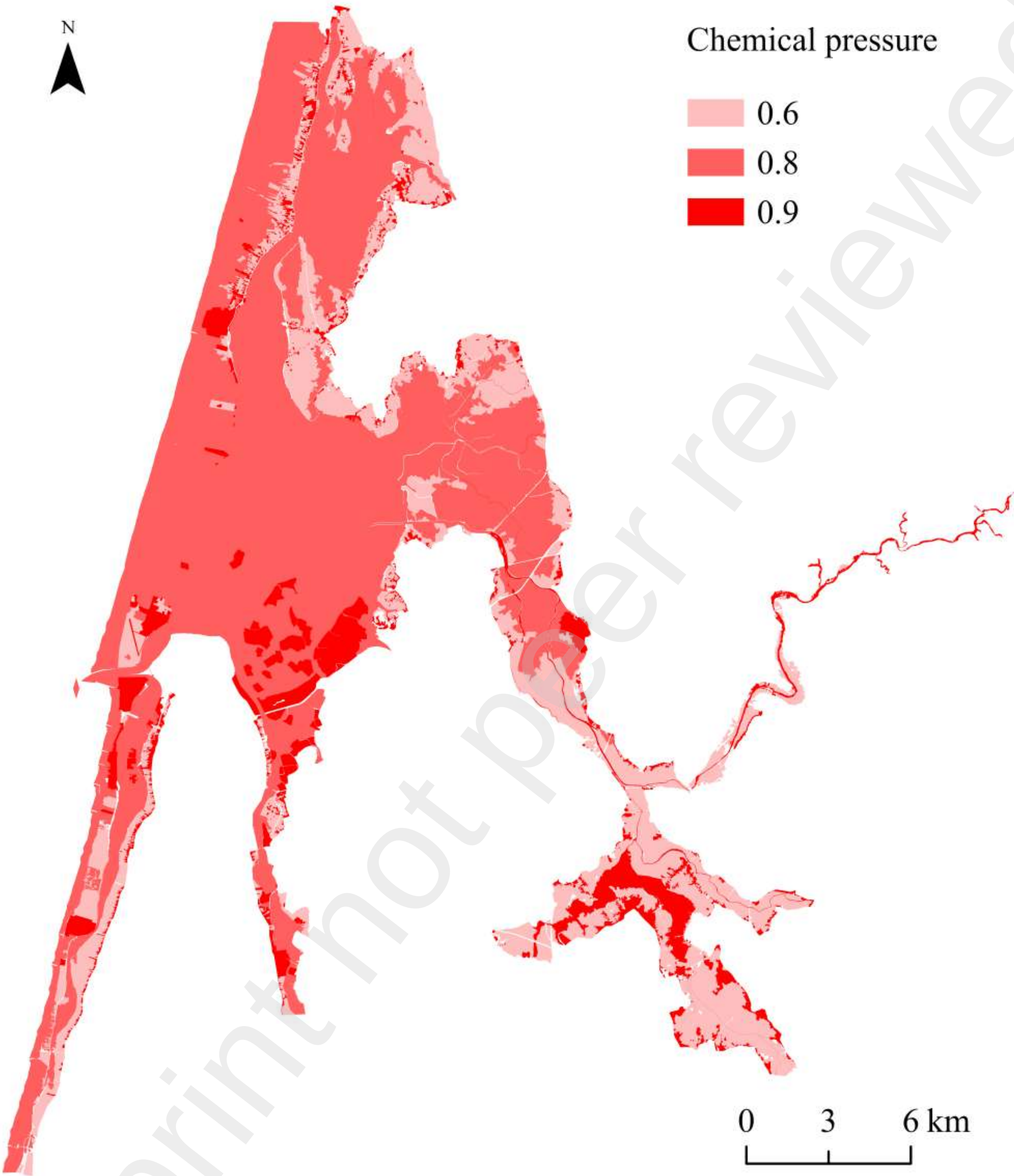

N
Chemical pressure
0.6
0.8
0.9
0
3
6 km

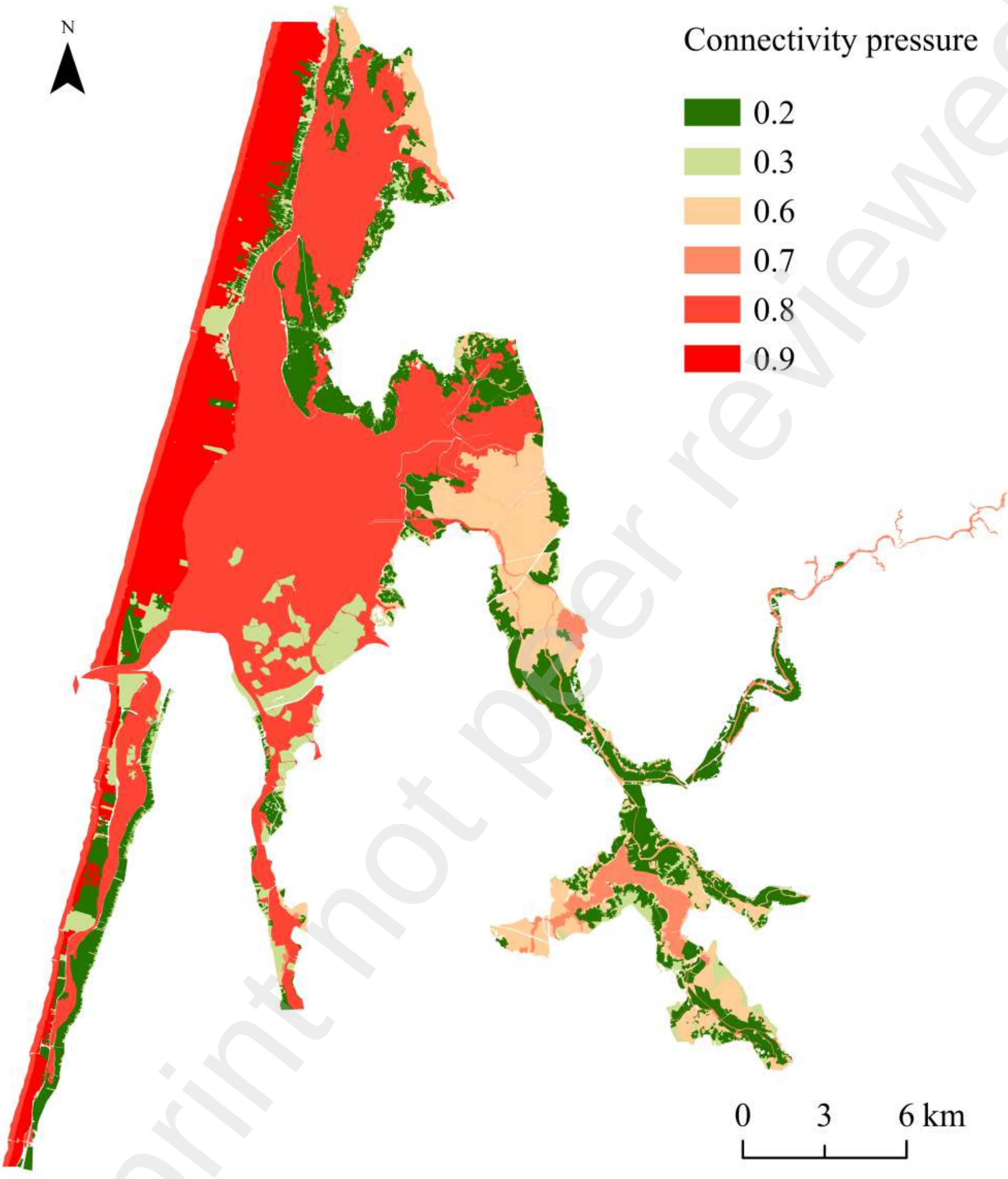

N
Connectivity pressure
0.2
0.3
0.6
0.7
0.8
0.9
0
3
6 km

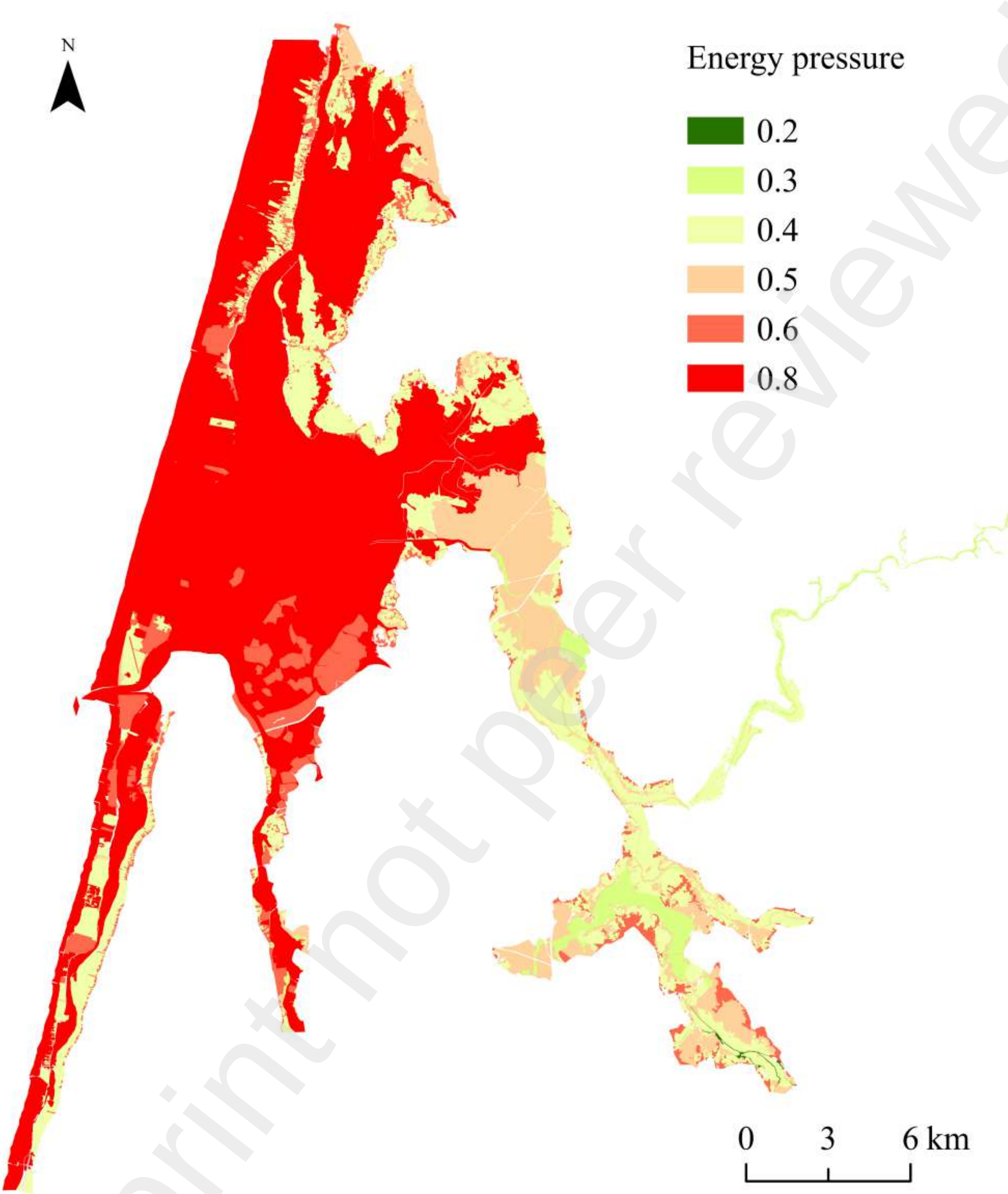

N
Energy pressure
0.2
0.3
0.4
0.5
0.6
0.8
0
3
6 km


N
Physical pressure
0.4
0.5
0.6
0.9
0
3
6 km

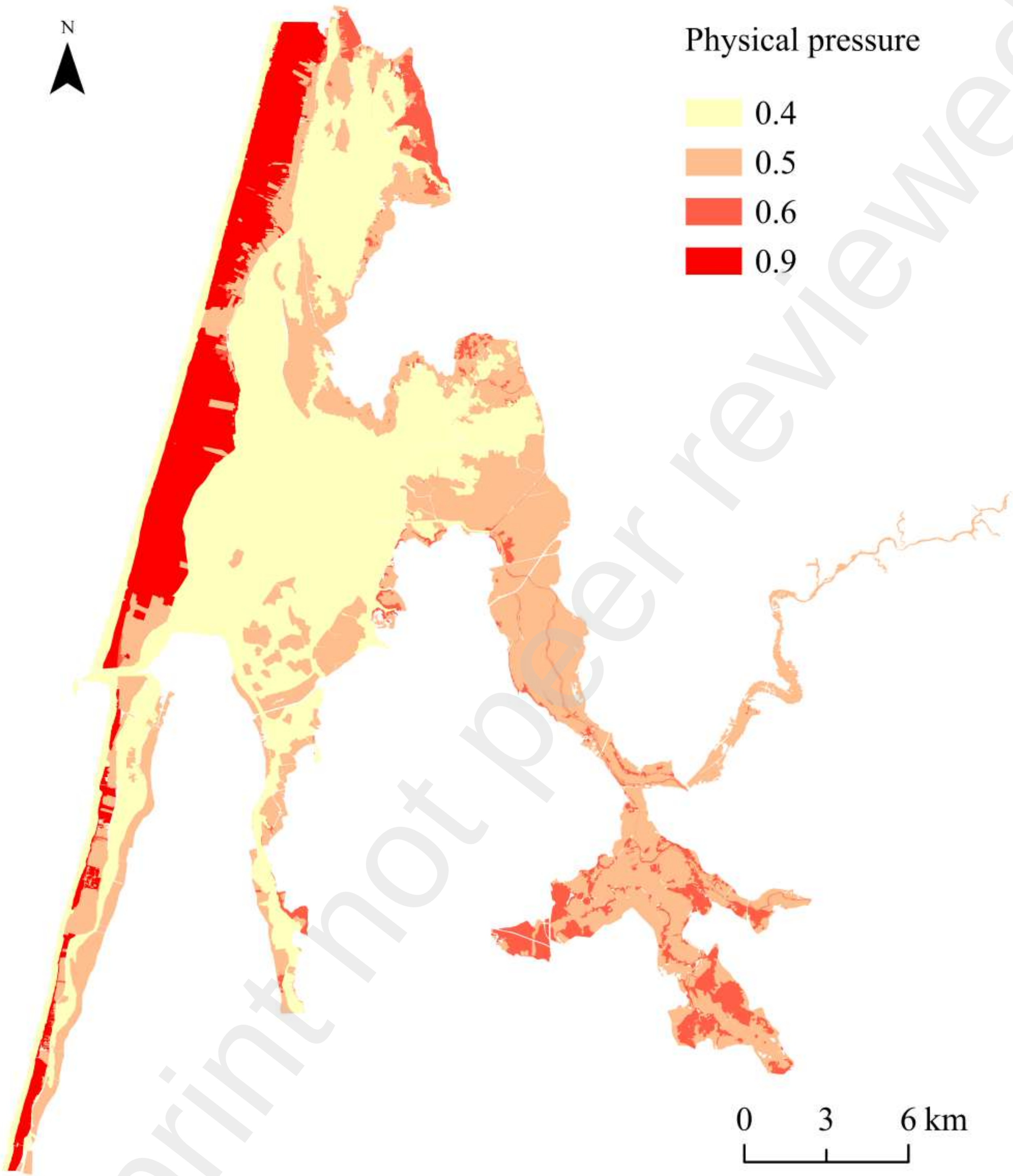

N
Biological pressure
0.5
0.7
0.8
0.9
0 3 6 km


N
Chemical pressure
0.6
0.8
0.9
0
3
6 km


N
Connectivity pressure
0.2
0.3
0.6
0.7
0.8
0.9
0
3
6 km



N
Energy pressure
0.2
0.3
0.4
0.5
0.6
0.8
0
3
6 km


N
Physical pressure
0.4
0.5
0.6
0.9
0
3
6 km